Community agro biodiversity conservation continuum: an integrated approach to achieve food and nutrition security

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Agrobiodiversity is a confluence of the past, present and future and both a tangible and intangible resource critical for both rural and urban food and nutrition security. Transformation in agricultural technologies, land and water use and urbanization has been largely responsible for its rapid erosion. *In-situ* conservation of crops and varieties within the context of communities is being increasingly recognized an important pathway for sustainable use of agrobiodiversity. The present article describes a C4 Approach that pay concurrent attention to conservation, cultivation, consumption and commerce of agrobiodiversity resources, conceptualized and operationalized by the M.S. Swaminathan Research Foundation in three agrobiodiversity hotspots of India. The C4 Approach consists of a series of village level interventions like establishment of gene-seed-grain banks, participatory conservation systems, participatory varietal selection, seed purification, promotion of farmer to farmer seed exchange, promotion of good agronomic and planting practices, use of small machinery for processing rice and millets at local level, product diversification and linking to markets for strengthening livelihoods as well as mainstreaming use of agrobiodiversity among urban consumers. Training and capacity development and institutionalization of the efforts through formation of grassroots institutions dovetailed with science-based interventions were important components aimed at sustaining the efforts.

Keywords: Agrobiodiversity, community partnership, conservation, consumption and commerce, cultivation, food and nutrition security.

Introduction

INDIA is one of the agrobiodiversity-rich countries of the world with over 160 crop species with hundreds of varieties, 325 crop wild relatives and around 1500 wild edible plant species and diverse domesticated diversity of animals and birds[1]. In stark contrast, the country is also having the largest undernourished children in the world[2] despite achieving high momentum in crop productivity enhancement, promoting cultivation of over 2300 high-yielding crop varieties, and being the first country in the world to develop hybrid cultivars like grain pearl millet and pigeon pea[1]. Agrobiodiversity has a critical role to play in dealing with the issue of under nutrition and hence dynamic conservation of agrobiodiversity needs to be placed high in the national development agenda for leveraging nutrition in agriculture and alleviating poverty and malnutrition.

The criticality of agrobiodiversity to meet the most important UN declared zero hunger challenge of '100% access to adequate food all year round' has now been recognized[3]. Kesavan and Swaminathan[4], and Nagarajan *et al.*[5] discussed the need for integrated nutrition management through nutrition sensitive agriculture and strengthening of family farms with emphasis on naturally bio-fortified plants and underutilized crops. In India, after the second global plan of action for plant genetic resources (PGRs) for food and agriculture and CBD decisions III/11, IV/6, V/5, VI/5, VII/3, VIII/23, IX/1, X/44 and XI/30 necessary policies and measures came in force to promote conservation and sustainable use of country's agrobiodiversity[6,7]. Some of the specific measures taken by India to motivate local communities and institutions engaged in agrobiodiversity management include establishment of two national level apex bodies – Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA) and National Biodiversity Authority with provisions like Genome Saviour Cash Award and National Gene Fund for sustainable management of PGRs, Registration for Farmers Varieties, and identification of agrobiodiversity hotspots.

Though these efforts have proven the strength and opportunities for India in the right direction, the attempts however have not led local community-centric on-farm conservation or sustainable utilization of agrobiodiversity as it could be for meeting the India-specific pertinent issues like the zero-hunger challenge.

The present article provides an overview of an integrated interventionist approach undertaken in three

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agrobiodiversity hotspots of peninsular India for a period of over two decades since 1992. Various field teams worked in the sites in promoting community-based participatory and integrated management approach for conservation of biodiversity, its sustainable utilization and poverty reduction. These interdisciplinary teams comprised of individuals drawn from the academic disciplines of botany, agriculture, sociology and economics. Selected knowledgeable individuals from the local communities also were part of the team, who contributed significantly in the research design implementation and monitoring. At different points in time, members from local communities were formally trained and involved under various categories to provide local perspectives and expertise in the projects undertaken. Some of such trained groups include: agro-biodiversity conservation crops (1997–2000), biodiversity management council (2000–2005), climate risk managers (CRM), community hunger fighters (CHF) and grass-root institutions (2005 to present). Such a trans-disciplinary action approach used the concept of 'socio-economic web' discussed by Lydia *et al.*[8] to focus on the three objectives of the Convention on Biological Diversity, viz. save, study and promote sustainable use of the 'orphan' crops and varieties, forest foods, and wild or semi-wild foods known to the tribal communities.

We briefly describe here an integrated strategy called 'C4 continuum' that pays concurrent attention to Conservation, Cultivation, Consumption and Commerce aspects of genetic resource management. Key lessons learned that are likely to contribute to issues of conservation and sustainable use of India's agro biodiversity in meeting current and emerging challenges like undernourishment, food security and sustainable agriculture in vulnerable locations of India have also been summarized.

The intervention locations

The intervention locations were Wayanad district in the Malabar region of Kerala, Koraput district in the Jeypore tracts of Odisha and Kolli hills in Namakkal district of Tamil Nadu. The selected sites also were in the category of backward locations identified by the Government of India and fall in 22 hotspots of agrobiodiversity listed by the PPVFRA[9]. The identified hotspots were reviewed in the light of richness of floristic diversity, endemism of flowering plants and the cultural, culinary and the curative diversities of the inhabitants.

Wayanad district of Kerala

Wayanad a steep mountainous plateau in the Western Ghats with vast forest cover, extensive rice fields and high concentration of tribal communities, is an agrobiodiversity and a poverty hotspot (for the tribal communities like Paniya, Adiya and Kattunaikka). The district is a site rich in biodiversity as evidenced by over 2100 flowering plants with 52 Red Data Species and 650 endemic plant species of Western Ghats[10]. It is one of the 150 economically most backward districts of India with a total of 173,529 BPL card holders. The tribal communities constitute 17.43% of the total population of the district, which is the highest share of Adivasi population (about 36%) of Kerala. The major communities that inhabit the district are Paniya (44.77%), Mullu Kuruma (17.51%), Kurichya (17.38%), Kattunaicka (9.93%), Adiya (7.10%) and Urali Kuruma (2.69%). Kurichya and Mullu Kuruma are traditionally agricultural communities, mostly involved in paddy cultivation. Paniya, Adiya, Kattunaikka, Kuruma and Kurichiya are the low income groups[11].

Koraput district of Odisha

Koraput district is one of the Globally Important Agricultural Heritage sites (GIAHs) identified by Food and Agriculture Organization (FAO) for maintaining unique tribal traditional agricultural practices, conservation and utilization of inherited traditional knowledge for local food security vis-à-vis cultural diversity[12]. It falls under 85 distress districts of India and is known for high incidence of poverty and malnutrition. PPVFRA identified the district as an agrobiodiversity hotspot[9]. Approximately 62 tribal communities are inhabitants of this region, constituting 50.6% of the total population of the district. Each tribe possesses its distinct identity in terms of social organization, culture and language. Striking parallels and close similarities between and among the tribes are quite conspicuous. The domain tribes of the district are Bhumia, Gadaba, Khond and Paroja, who are traditionally ingenious rice cultivators. The local economy is primarily driven by agriculture and collection of forest produce. The district has a population density of 156 per sq km. The region is one of the centres of origin and genetic diversity of Asian cultivated rice[13,14]. Rice being cultivated in four broad categories of land types such as *donger* – the hilly slopes used in the past for shifting cultivation; bunded or un-bunded upland fields called *dhepa*, irrigated or rainfed medium elevation land *Bhatta*, lowlands named *khala* and deep lowlands marshy plains called *jhola.* Different varieties of rice are cultivated in each of the land type, which are mainly for their importance to culinary and cultural purposes.

Kolli Hills of Tamil Nadu

Kolli Hills are a hill range covering an area of 280 sq. km constituting the southern-most edge of the Eastern Ghats of India. The hillock situated in Namakkal district of Tamil Nadu is about 1300 m from msl and inhabited by a single tribal community known as the Malayali. The word Malayali means people inhabiting hillocks. They are predominantly agriculturists, engaged in cultivation of a variety of food crops such as cereals, millets, pulses, oil seeds, fruits and vegetables. The community practices two types of agriculture – one that is irrigated mainly through natural springs and the other is rain-fed agriculture. Spring-irrigated terraced lands in the valley are known as *vayal*. In the valleys, only the rice crop is cultivated. The rain-fed land is further classified based on the land type and the method of ploughing. Land terraces that are moderately slopy and medium size are normally referred to as *mettankadu* (upland) and used for cultivating diverse types of millets. This type of land is referred as *uzhavukadu* (*uzuavu* = ploughing, *kadu* = land). The steep stony area is *karadu* (stony/rocky) or *kollakadu* or known as *kothukadu* where digging stick, locally known as *kothu* is used for turning over the soil. Traditionally, in uplands minor millets particularly finger millet, *puzhudicarnellu*, a local variety of rainfed rice and pulses are cultivated. If a farmer had four plots of upland, two or three were used for finger millet-based mixed cropping[15,16].

Integrated community conservation methods

Communities have a long tradition of being custodians of genetic wealth, particularly landraces, often carrying rare and valuable genes for traits such as resistance to biotic and abiotic stresses, adaptability and nutritional qualities. In recent decades, the rate of erosion of such rich biodiversity has been dramatic due to accelerated agricultural development calling for development of different strategies for *in-situ* on-farm conservation of agrobiodiversity[17]. Such strategies need to go beyond a mere conservationist or resource use approach. Conservation issues, cultivation knowledge, consumption awareness and commerce need to be integrated into one overarching strategy. The framework strategy of C4 continuum gains significance in this context for effective on-farm conservation and enhancement of crop genetic diversity, conservation of endangered plant species, study of diversity in crops like rice and millets, and capacity development of small holders and family farmers. Such a strategy envisages the involvement of multi-disciplinary experts including botanists, sociologists, gender experts, anthropologists, agricultural scientists, nutrition experts and biochemists working together closely with local communities to understand the issue of sustainable management of genetic resources.

The C4 continuum

The framework for community agrobiodiversity management was conceived by M. S. Swaminathan evolved into a practical approach for addressing the issue of agrobiodiversity conservation, its sustainable use, poverty reduction and under nutrition in the three locations[18]. It is a strategic framework known as C4 continuum and pays concurrent attention to conservation, cultivation, consumption and commerce within what is known as the community agrobiodiversity conservation continuum. Community-based biodiversity management incorporates approaches that address conservation and use within a livelihood and sustainable development setting. The methods were integrated within a strategic framework and a few action components evolved over time and implemented in partnership with local communities. In 1997, the C4 continuum activities in Kerala were brought under an exclusive institution called Community Agro-biodiversity Centre (CAbC) in Kalpetta, Wayanad district. In 2006, a similar kind of Centre, the Biju Patnaik Medicinal Plants Garden and Research Centre (BPMPGRC) was established in Koraput district in Odisha to coordinate and implement activities that had commenced in 1995. The works in Kolli Hills of Tamil Nadu were brought under the umbrella of Community Millet Biodiversity Programme in 1994. These centres emerged as the operational methods for community empowerment in mainstreaming biodiversity conservation in tribal/rural agricultural development.

The C4 continuum was designed as an appropriate strategy for incentivizing mechanisms that matched with community based agro-biodiversity management efforts, which revolve around the age-old traditional knowledge, practices and beliefs. In this continuum, equal importance is given to four streams of actions in sustainable biodiversity management – conservation, cultivation, consumption and commerce. Conservation activities included enhancement and sustainable use of biodiversity and comprises *in situ* on-farm and *ex-situ* conservation methods; Cultivation promoted low external input sustainable agriculture based on principles of organic farming, and the farming system with specific agricultural remedies for nutritional maladies, such as the cultivation of bio-fortified crops and crop–livestock integration; Consumption covered product diversification for linking with markets, provision and promotion of small machinery for processing and increasing consumption, nutritional surveys for identification of the major causes of chronic and hidden hunger and identifying activities for mainstreaming nutrition in agriculture programmes; Commerce activities meant for creating an economic stake in conservation through options in livelihood security and given greater attention to increase the net income of smallholder farmers.

The C4 continuum operated through five distinct components.

Village gene–seed–grain bank

Village field seed–gene banks were initiated in 2001 in four villages in Koraput and were the major vehicle to promote conservation of traditional rice varieties and ensure their continued cultivation. This was later expanded to 13 villages within the district. Seed materials, after characterization and evaluation by the farming communities, were stored in earthen or plastic containers in seed banks, which were constructed in a common place identified and earmarked by the villagers and managed by local communities. This is considered as an ideal place to store and promote farmer to farmer exchange of pure and quality seeds as well broaden the genetic base; ensuring seed security among the farming communities. In addition, farmers were encouraged to deposit their varieties of crops such as rice, small millets and grain legumes, with the medium-term storage facility Scaracia Mugonzza Community Gene Bank established during 1994 in MSSRF[19]. Each deposit was identified with an accession number and complete data on the accession generated over a period of time, with MSSRF acting as the trustee of deposited materials. Duplicate seed samples of every accession in CGB were also deposited at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi under a black box arrangement. The accessions are being periodically regenerated and serve as backup storage for village gene-seed-grain banks.

Nutrition garden

These gardens were meant for promoting household level consumption of the required nutritional food. The garden is an improved form of kitchen garden where round the year availability of essential nutrition is ensured at household level through access to vegetables and fruits, poultry, fish, mushroom and honey. These efforts were also integrated with activities to educate rural households about the importance and value of family farming and the need for production and consumption of diverse locally available foods. Equipping the small farm families with this awareness and seed materials of appropriate crops and breeds, as well as skills in horticulture methods helped partially to address the issue of nutrition.

Seed village

Seed village meant to explore the possibility of participatory enhancement and improved utilization of commercially potential native crop varieties. This is also to promote sustainable cultivation practices, particularly in case of food production at family farm and small holder farms' level. The activity is in operation in Wayanad district in about 10 villages with involvement of Kurichiya and Kuruma tribal communities for promotion of native rice cultivars. The operations of seed village include participatory varietal selection, yield improvement practices, seed and grain management practices, organic agricultural interventions and help for exploration of new markets.

Botanic garden

The community centres in both Wayanad and Koraput established a botanic garden in their premises to conserve those genetic resources that have recalcitrant seeds and make available seeds of the 'lost crops and species' of the region. The gardens apart from serving as a conservatory of diverse genetic resources that combines both wild like rare, endemic and threatened plants, and cultivated biodiversity, functions as a centre for education by attracting and serving a diverse group of stakeholders that range from student to teachers, general public to farmers and tourists to tribal community members.

Farmers' markets

Farmers' markets were introduced in Kolli hills and Wayanad in 2002 to promote the commerce aspects of small farmers' produce and to supply some of the essential farm inputs like microbial fertilizers and pesticides. Such markets are operated through a farmer collective approach and offer choices to both consumers and farmer producers to cultivate, sell and buy sustainably produced 'safe to eat' grains, fruits and vegetable produced and quality ensured farm supplies.

The following are the major results obtained through the operation of the C4 continuum.

Protection of farmers rights and biodiversity conservation

The legal and genetic literacy initiative undertaken in Wayanad, Koraput and Kolli hills reached out thousands of local community men and women, and hundreds of civil society organizations and elected members of the Panchayati Raj Institutions. A wide range of resource materials were prepared for dealing with concepts and issues related to on-farm conservation, seed storage, development and maintenance of farmers' varieties, farmers' rights, registration of farmers' varieties, benefit sharing, etc.[20]. The initial learning from such community management was fed as inputs into two important pieces of legislation of India that deal with sustainable management of India's biodiversity – the Protection of Plant Varieties and Farmers Rights Act 2001 and the Biodiversity Act 2002 (ref. 21).

The efforts under this initiative helped the tribal communities of the Jeypore tract to win the Equator Initiative Award in 2002 (ref. 22). Following this, Panchabati Grama Unnayan Samiti, a grass roots initiative (GRI) in Koraput, was selected for the Genome Saviour Award constituted by the Protection of Plant Varieties and Farmers' Rights Authority in 2007 and the Kurichya and Kuruma tribal communities of Wayanad, with the Second Plant Genome Savior Community Recognition and Award

Table 1. Intra-specific landraces of millets conserved by the Malayali Tribes in Kolli Hills

Crop	Landraces
Little millet (*Panicum sumatrense*)	Perumsamai, Vellaperumsamai, Kattavettisamai, Thirigulasamai, Sadansamai, Malliasamai, Karumsamai
Italian millet (*Setaria italica*)	Perunthinai, Palanthinai, Senthinai, Koranthinai, Mookkanthinai
Finger millet (*Eleusine coracana*)	Perungelvaragu, Arisikelvaragu, Karakelvaragu, Karumuliankelvaragu, Suruttaikelvaragu, Sundangi kelvaragu, Sattaikelvaragu
Kodo millet (*Paspalum scrobiculatum*)	Thirivaragu
Proso millet (*Panicum miliaceum*)	Panivaragu

Source: Ref. 34.

during 2008–2010. Subsequently in 2010–2013, the programme facilitated Koraput district and Kuttanad region receive the FAO's Globally Important Agricultural Heritage Systems (GIAHS) recognition for the ingenious and unique farming heritage of these regions[20].

Integrated conservation

The nearly two decades of work in the area of sustainable management of genetic diversity of crop plants helped in collection and conservation of hundreds of 'Farmers' varieties' and traditional germplasm of PGRs that include rice, roots and tubers, cucurbits and beans[22]. For instance, the CGB facility in Chennai preserves seed material of nearly 300 traditional cultivars of rice, CAbC in Wayanad has collected field level information of 400 traditional plant varieties, mostly cultivars and in some cases distinct species known for their various socio-economic values. Twenty varieties of yams were collected from five districts of Malabar and conserved in CAbC's Field Gene Bank[23]. Landraces of 140 rice, 19 finger millets, 2 little millets, 14 pulses, 1 maize variety and 1 pop-sorghum were conserved in the Koraput Centre[24]. In Kolli Hills, 21 landraces of 5 species of millets land races were collected from the custodian farmers (Table 1)[25,26]. The efforts integrate on-farm conservation and use by tribal and rural families at the household level, village and community level, at the local institutional level and backed up with the community gene bank in Chennai and also linked to the national gene bank in Delhi.

Conserving rice diversity

The Jeypore centre has primary level information about 400 varieties of rice that are being cultivated by the local communities. Explorations in parts of the Jeypore Tract carried out during 1995–1996 and 1998 resulted in collection of only 256 and 108 rice landraces respectively, which indicated the extent and severity of erosion[20]. About 123 landraces of rice were maintained in 3 clusters covering 25 villages for on-farm conservation and participatory varietal selection.

The Wayanad team recorded about 26 traditional rice varieties from the district[27]. Many of these varieties provide diverse kind of insurance against crop failure to the farmers. Extensive information on landrace/cultivar such as name of the donor providing the material, associated crops, soil colour and texture, land type, special characters, insect and pest incidence, habitat, status, etc. was gathered through field surveys/exploration along with collection and cataloguing of the landraces. Identification of rice diversity blocks using a cluster approach and assisting farmers in the selection of the best varieties based on traditional knowledge was one of the notable results of this initiative[28]. Farmers used characters such as weighted grain, tillering density, plant height, grain size and taste for selecting the varieties. Cooking quality, grain colour, aroma, calory content, feeling of stomach fullness, medicinal qualities, high fodder and grain yield are some of the main attributes that influence the choice of a variety among the traditional rice cultivators across the regions.

Conserving wild edibles

Over 200 species of wild edible plants are conserved in the botanical garden established as part of the community biodiversity programme in Wayanad. A study brought out detailed information on the status and utility aspects of 362 species of wild edibles[29]. The study identified 102 varieties of wild leafy greens, which have greater dietary importance and are a regular food supplement among the socio-cultural groups under study. Many edible greens are popular within the tribal and non-tribal people for their therapeutic properties. Certain greens also have significant ceremonial value and used in various community rituals. More than 25 wild plant species are known for their edible roots, tubers and rhizomes. Of these, 19 belong to the species *Dioscorea*. The study also revealed that there are 39 types of fish, 35 varieties of wild mushrooms, 5 species of crab and 5 types of honey that are consumed by the tribal communities of Wayanad district[29].

Conserving RET plants and medicinal plants

The botanic gardens in Wayanad and Koraput were evolved over a period of 10–15 years to become a significant

Table 2. Status of seed bank from 13 villages

Crop	Variety	Quantity (kg)	No. of house holds	Area (acre)	Amount saved (Rs)
Rice (upland, medium land and low land)	17	4551	175	123	77,367
Finger millet (upland)	9	225	72	45	4,500
Green gram (low land)	2	192	32	15	13,440
Total	28	4968	279	183	95,307

reserve for several floristic and PGR diversity that are of direct use to the local communities. The MSSRF's botanic garden in Wayanad conserved hundreds of conservation 'high value' wild plant diversity particularly rare, endemic and threatened (RET) plant species and medicinal plants[23]. Till date over 100,000 seedlings have been produced by multiplying more than 160 RET plant species and a total of 3750 seedlings of 40 endangered tree species were experimentally introduced to their natural habitats. Since the start of floristic study in 1999, the scientists associated with the garden have identified and published 15 new species[23].

Core groups and traditional knowledge documentation related to millets

Core group of 35 traditional millet farmers of men and women were motivated with the objectives to: ensure the sustainable supply of required seeds of local landraces; serve as a community based *ex situ* conservation facility and as a backup source; and enhance the access, availability, use and enhancement of locally adapted seeds of crops and their varieties, emerging as a Seed and Knowledge Exchange Network in the village managed by a group of tribal people in Kolli hills by institutionalizing community seed bank (CSB) as a common property resource. These core groups of farmers participated in periodical gathering and share knowledge about ethnotaxomy, culinary importance of millet landraces. This vital information is stored in the FRIS (Farmers Rights Information Service) database established by MSSRF[30]. The passport data of the landraces with farmer identity who had contributed materials were deposited along with the seed materials, in the Scarascia Mugnozza Community Gene Bank at MSSRF in Chennai with a duplicate of its accessions deposited at the NBPGR gene bank in New Delhi. With the participation of the custodian farmers[31] in 2012, in the framework of the IFAD NUS project farmers' knowledge on morphometric, yield, culinary, climate adaptation characters of 21 landraces had documented as community biodiversity register and deposited with the biodiversity management committee at Kolli Hills[32].

Sustainable cultivation and consumption

With an objective of promoting cultivation, nearly 300 landraces and varieties from Jeypore and Wayanad were subjected to morphological and agronomic characterization using internationally standardized descriptor formats. Characterization for distinctness, uniformity and stability (DUS) using 62 descriptors prescribed in the DUS guidelines published by the Protection of Plant Varieties and Farmers' Rights Authority were carried out in farmer's field[33].

Promoting community seed–grain–gene banks

Participatory management strategies for managing the seed banks were evolved with the active involvement of community across the three sites. Currently there are a total of 13 gene-seed banks being operated in two community development blocks of Koraput district and have 28 varieties across three staple crops and controlled by 183 families (Table 2). Several of these have been in operation for almost a decade and helped communities reduce their dependence on bigger land owners[24]. Members of the management committee collect seed contribution from individual farmers, recorded them in register, issue a pass book during collection and identify the needy farmers with the help of Central Village Communities (CVC), who are involved in taking decision on quantity of seed to loan and interest rate. Once the crop is harvested, they check the quality of seeds and store them in the seed bank.

The seed banks now act as back up for provision of seeds of local landraces for members of the communities. In the past, farmers would borrow seeds from other wealthier farmers for resowing in case of crop loss arising due to early season drought or heavy rainfall or biotic stress like insect pests during the initial cropping season[24]. Seed banks provide an option for borrowing a replacement variety at a low rate of interest, thereby reducing dependency on larger landowners.

Some of the possible pathways by which seed banks (at the village level) can deal with providing seed support to farmers for reducing the impact of crop failure occurring during the cropping season due to various vulnerabilities.

Emergence of CSBs network

In Kolli Hills, as seeds of some of the identified varieties and landraces are in extreme shortage and as most of the varieties had got mixed with others under the traditional method of mixed farming, the self help groups (SHGs) formed by the core group of millet farmers were trained by the MSSRF in the production of quality seed and their safe storage in CSBs. The strategies for conservation of millets involved seed collection, multiplication, seed distribution, farmer to farmer exchange mediated through the seed storage banks. The establishment of such seed banks has been built upon traditional practice. MSSRF revitalized some of traditional seed storage practices like Thombais and Kuthirs under new social conditions[20]. Thombai is a traditional grain storage structure; size varies from small compartment within a house to a separate hut-like structure near the home. The general structure is located 2–3 inches above the ground level to avoid rat damage. Generally, there are two compartments inside and closed on all four sides with a small opening at the top. The roof materials were millet straw in earlier days and have slowly shifted towards tiles and asbestos and aluminium sheets. There are two types of ownership: individual single household; and kinship basis by more than one household and at the community level. Size of the granary directly correlates with the landholding categories. Women usually manage the granary and use plant-based materials as storage pest-repellent using dried leaves.

In addition, MSSRF facilitated the construction of new structures being done with the *Shram dhan* – manual labour wherever local Malayali community has limitation in accessing the support of associated communities such as Kuyavar (potter), Thappa Kuravan (bamboo craft workers), Ottan (stone worker) – who have special skills to make traditional implements of storages[34]. These revitalized and newly constructed seed banks are managed by the local communities established at the village or community level to facilitate seed availability on farm. Over the last decade, MSSRF facilitated the establishment of CSBs in 15 villages, located in 8 *nadus* (conglomeration of several geographically linked villages) have their own safe seed storage and institutional system for regular seed production, distribution and exchange (Table 3).

Seed purification

When the projects commenced in Jeypore during the early 2000, farmers had reported scarcity of pure seeds with regard to local landraces. Hence a strong component of capacity development of local communities in seed management was initiated[35]. Seed purification, viz. uniform and without mixtures, matured and well filled, healthy seeds of landraces was an important component adopted by different projects for enhancement of yield, and fulfill the criteria of the standards set by the PPVFRA.

Promoting home nutrition gardens

There were over 1600 home nutrition gardens, which have components like freshwater inland-fishery, backyard poultry and mushroom cultivation established in these three locations (Table 4).

Across the three sites more than 50% of households consumed all produce from the home gardens. A miniscule percentage of the households surveyed sold all their produce. In Jeypore about 47% of the households consumed the produce and sold the excess. In all the three sites, a significant percentage of households shared produce among their relatives, neighbours and friends, indicating the strong nature of social relations. Field surveys in Kolli Hills indicate vegetable consumption has increased on an average from four to seven kilograms after introduction of home gardens[36]. A significant number of households reported that they consumed more leafy vegetables, fruits, roots and tubers in their diets after the introduction of home gardens (Table 5), thereby increasing food and nutritional diversity. They also stated that the produce from the home gardens were free from chemical fertilizers.

Participatory quality seed production in millets

CSB facilitators are trained on the importance of weeding, thinning; identify the seed mixture, pest and disease infestation and post-harvest processing such as seed drying and safer storage. To promote millet production was broadening the genetic diversity used in the cultivation. Few hundreds of accessions of these three millets from the germplasm bank of ICRISAT, Hyderabad and improved cultivars developed under the national programme from the All India Small Millet Coordinated Research Programme, Bengaluru were accessed by MSSRF and repeatedly grew out for farmer participatory selection of varieties better than the local land races[26]. These experiments with improved varieties and local landraces were done in some of the seed banks. The participatory varietal selection (PVS) experiments resulted in identification of few varieties which have 20–30% higher yield than those varieties under cultivation.

Increasing yield through improving millet cultivation practices

The availability of quality seed substantially contributed to the promotion of millet cultivation. However, as compared to the alternatively possible crops (e.g. tapioca, pine apple, etc.) the millet yield and the income therefrom are poor. Productivity enhancement was hence an essential need to sustain the millets under competitive farming situation. Together with SHGs, MSSRF undertook different agronomic measures such as row planting, reduced seed rates, application of farm yard manure, and also intercropping millet with tapioca to increase the millet yield and net income from its cultivation. These initiatives could increase the yield by 39% in finger millet, 37% in

Table 3. Millet seeds transaction during the period between 2000 and 2014 in VMRCs

	Millet*				
Year	Little millet	Italian millet	Finger millet	Kodo millet	Proso millet
2000–2001	900	1089			
2001–2002	1389	987		24	
2002–2003	453	357	227		
2003–2004	508	435	240		
2004–2005	510				
2005–2006	95	279	172	43	27
2006–2007	7.5				
2007–2008	16.5				
2008–2009	56.5	18	112.8	0.5	0.5
2009–2010	306	55	519	20	11
2010–2011	298	150	232	10	10
2011–2012	176	63	246	5	7
2012–2013	197	81	270	10	15
2013–2014	432	353	562	15	35

*Quantity of seeds distributed in kilograms.

Table 4. Home gardens established in the three sites

Location	Structured home gardens	Unstructured home gardens	Total
Jeypore	85	302	387
Wayanad	125	663	788
Kolli Hills	342	129	471

Table 5. Increase in consumption of greens, roots, tubers and fruits (no. of HHs)

Consumption and diet	Jeypore	Wayanad	Kolli hills
More green leafy vegetable in diet	98	79	54
More roots and tubers in the diet	23	43	58
More fruits in the diet	37	65	13

Source: APM Detailed Survey 2013.

little millet and 30% in foxtail millet and the economic return per unit area[26]. This made convincing impact on farmers for increased cultivation of millets using improved practices.

Introducing drudgery-free grain processing technology

One of the important reasons for decreased interest in millets cultivation and use was the high drudgery associated with its processing. All millets except finger millet have a very hard seed coat requiring high abrasive force to remove the rice from the seed coat. This decortication process has been done by a very tedious physical process using mortar and pestle. This is almost exclusively done by women. No machinery suited to these millets was available to reduce this drudgery. Therefore, the introduction of small mechanical milling facility in the area by MSSRF signalled a major change in the outlook of women and substantially contributed to revival of interest in finger millet cultivation and consumption. Currently pulverizers and de-hulling mills are managed by community institutions in nine settlements. A collaborative project with UASD and McGill University, Canada, supported by CIFSRF-IDRC, has yielded a development of new prototype machinery for processing little millet with processing recovery efficiency[37] of 90–95%. Further research is in progress to extend this technology to customize to other small millets. Another important spin off from the mechanization of millet processing was the local interest, particularly from women, in building value chain of millets and using such facilities for local processing and reintroduction in the food systems.

Creating an economic stake in conservation

Commerce with local landraces of rice

Three varieties of rice Kalajeera, Machhakanta and Haladichudi were promoted for large scale cultivation in Koraput. An area of 302 ha was brought under three rice varieties involving 721 farmers from 25 operational villages. For promotion of Kalajeera rice, a producer company called Kalinga Kalajeera Dhan Utpadak Samabaya

Ltd is being promoted with 13 Central Village Committees (CVC) and 30 SHGs. The value of the rice was Rs 1200/ql before this farmer producer company was in place, whereas the rice was procured from individual farmers at Rs 1700/ql and processed rice was sold at Rs 4000/ql. About 900 ql processed rice was sold within the state during 2012–2013. Kalajeera paddy (120 tonnes) was branded, packaged and marketed by the society or samabay. Storage facilities at village level reduced the distress sale (2013–2014). Out of 30 SHGs, 11 women SHGs were formed into entrepreneur groups for preparation and sale of rice value added products. Each group is earning on an average Rs 3000 to 5000 as net income from four value added rice products per month.

The team in Wayanad mobilized 105 households from 10 villages of the district to serve as custodian farmers of 8–10 traditional rice varieties. Seed purification of 10 selected varieties was carried out in partnership with knowledgeable farmers from these households. The area under traditional varieties has now expanded from the initial 41 acres to over 100 acres in these villages and the price farmers get for seeds increased from around Rs 14/kg to Rs 35–40/kg. The aromatic rice varieties Jeerakasala and Gandakasala fetch Rs 50/kg.

Commerce with millets

Value chain building required specialized training on value-added product development, maintaining product consistent product quality, packaging, labelling and marketing. The selected members of SHGs were trained on value addition at the Rural Home Science Colleges under Avinashilingam University, Coimbatore and also the Agricultural Universities at Bengaluru and Dharwad[38–40]. This training planned and supported by the MSSRF has empowered the village women for the first time in production of all value-added items like malt, rava and readymade mixes of millets. Some of these value-added products with good commercial potential were identified through market studies and put in the production line through collective work of the SHGs. Different SHGs are encouraged to specialize in the production of different value-added products. During the early stages of production of these value-added products and marketing, assistance of MSSRF was extended for further training on product quality, packaging, labelling, marketing and account keeping. Currently, three villages are engaged in millet value addition activities. There are various steps involved in the millet market chain (Figure 1).

Establishing a market for value added millets products

While farmers have experience in marketing the primary produce, they lacked capacity in marketing value-added products. Therefore, MSSRF was required to continuously assist the SHGs in marketing the products in urban areas. This was done through a combination of approaches such as promotion campaigns, awareness raising and policy lobbying. Slowly members of SHGs with marketing skills were identified and promoted to undertake product marketing with local retail outlets. They were also helped to establish a retail outlet for all products in Kolli Hills under the banner of Kolli Hills Agro Biodiversity Conservers' Federation (KHABCoFED)[41,42].

Over the last few years, millet products branded under 'Kolli Hills Natural Products' are available in department stores in Chennai and few other towns in Tamil Nadu. To increase awareness on the nutritional quality of millets and its derived products, MSSRF and SHGs are promoting millet products through exhibitions at local events and annual temple festivals. In addition, MSSRF is advocating the use of millets in the Integrated Child Development Programme (ICDS) and distribution of millets in the Public Distribution System (PDS), in areas where millets are largely grown and available at favourable prices.

The most popular and largely sold millet products are readymade mixes, milled rice of little millet and Italian millet, finger millet malt. The net profitability from these products is five to ten times higher than that from the production and marketing of grains (Table 6). Since 2001, millet producers of KHABCoFED have sold 9 metric tonnes of whole grain, 23.3 metric tonnes of little millet rava and flour, 7.4 metric tonnes of value-added products of total value of 15.2 lakhs.

Establishing community institutions for promotion of millets

In 2009, a farmer collective named KHABCoFED was formed in the Kolli hills for managing nutritious and underutilized species of millets. The activities of the federation involve a holistic value chain approach from 'farm to fork', addressing highly interconnected aspects of conservation, cultivation, consumption and marketing of local produce. The federation manages a portfolio of 21 diverse landraces of millets belonging to different species (finger millet, little millet, proso millet and kodo millet), cultivated under different cropping systems and through a wise blend of traditional and modern practices.

The KHABCoFED initiative successfully created the 'Kolli Hills Natural Foods' brand, which is currently marketing 11 types of products. The millet supply chain consists of conservers, farmers, members involved in procurement, value addition through processing and conversion into products and market promoters. The federation is currently composed of 109 different groups having a membership of 985 men and 526 women. It has built an asset of agricultural machineries and value addition units

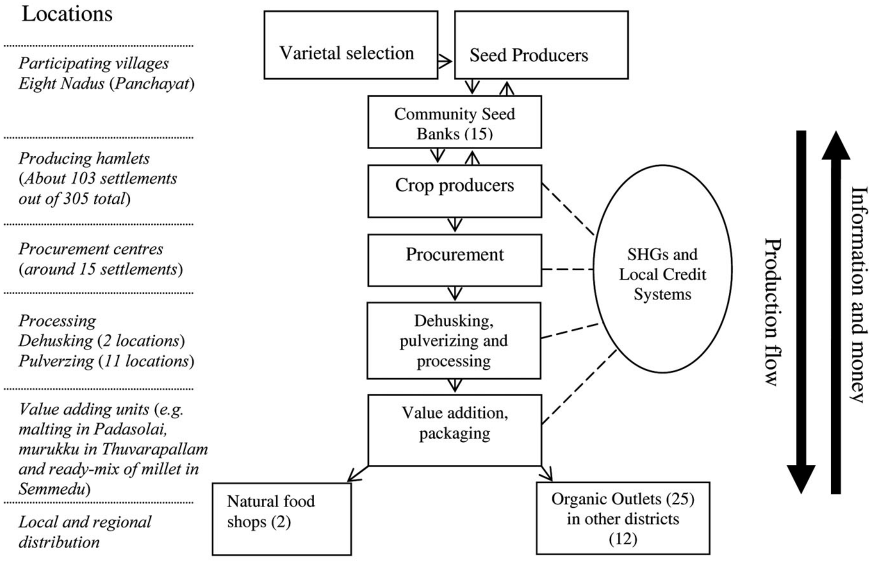

Figure 1. Schematic representation of the market chain for minor millets.

Table 6. Cost : benefit analysis of production and marketing of value-added millet products

Millet products	Production costs (INR/100 kg)	Total return (INR/100 kg)	Net return (INR/100 kg)	Profit as % of costs	Labour days for production 1 tonne produce
Little millet rava (Samai)	4,300	7,000	2,700	63	100
Italian millet rava (Thinai)	4,300	7,000	2,700	63	100
Little millet flour (Samai)	4,500	7,400	2,900	64	150
Italian millet flour (Thinai)	4,500	7,400	2,900	64	150
Finger millet flour	2,222	3,333	1,111	50	40
Finger millet malt (ragi malt)	5,600	9,000	3,400	61	400
Thinai payasa mix	7,600	12,000	4,400	58	300
Thinai laddu	13,340	23,345	10,005	75	300
Samai bajji mix	7,600	12,000	4,400	58	300
Samai uppuma mix	7,200	12,800	5,600	78	300
Samai rava dosa mix	7,600	12,000	4,400	58	300

along with a procurement centre whose value is estimated at 9,229,913 INR. Over a period of 12 years (2001–2015), the cultivation, procurement, value addition, diversification and sale of products have generated a gross income of 2,620,452 INR (Table 7).

Millets, policy environment and further task

It is encouraging to note that the current Food Security Bill in India has made provisions for the inclusion of millets in the Noon Meal Programme and PDSs. Millets are gaining a new role as healthy food among rural and urban high income user groups, although mostly through niche markets. In spite of these successes, further work is still needed for the refinement of equipment to allow dehulling, polishing and milling of some of those species having smallest grain size (such as little millet, proso millet, kodo millet). Enhanced networking among NGOs, CBOs, private and public sectors has become imperative to scale up successful methods and approaches beyond projects sites. Further innovative practices developed in the process of networking CSBs and network, recognition of custodian farmers and their enhanced role in the cultivation, processing, marketing of the underutilized and neglected nutri-millets will have potential for larger replication in similar agro ecologies.

Need for integrated community agrobiodiversity management

In India agriculture is the backbone of the livelihood security system for 700 million men, women and children. Although agriculture contributes only 17% to GDP, but accounts for 57% workforce employment, about 600 million people directly or indirectly depend on agriculture for their livelihoods. Further, out of the net cultivated area of about 141 million ha, about 85 million ha (–60%) fall under dryland/rainfed zone. Since India is a

Table 7. Quantity of different forms of millets marketed during 2001–2015

Year	Whole grain (kg)	Little and Italian millet rava and flour (kg)	Value added products (kg)	Gross returns (Rs)
2001–2002	9000	1200		62,000
2002–2003		2662		70,068
2003–2004		1365		25,524
2004–2005		3138		71,500
2005–2006		2255	1110	116,098
2006–2007		1062	240	50,598
2007–2008		1770	414.45	73,694
2008–2009		2672	831	129,639
2009–2010		1465	1061	125,853
2010–2011		681	984	132,893
2011–2012		1373	1119.75	242,422
2012–2013		3658	1660.2	420,054
2013–2014		5486.5	1497.85	549,908
2014–2015 (December)		5227.5	1405.35	550,201
Total	9000	34015	10323.6	2,620,452

primary centre of diversity of rice, conserving and widening its agro-biodiversity base with genes for drought, flood, salinity and submergence tolerance would be extremely prudent[43]. Importantly, rice occupies a prominent position in Indian culture, spirituality, traditions and customs. Thus, rational conservation, appropriate cultivation and proper utilization is essential to meet the future demands of an increasing population.

The present interventions attempted in the dynamic conservation of a diverse range of ‘functional agro-biodiversity’[44] in agricultural landscapes and common property lands that are managed by often the resource poor farmers and tribal communities. The biodiversity which provides distinct variability in crops and breeds, and habitats with a range of ecosystem services is critical for the food and nutrition security of the local communities.

Food and nutrition security through conservation of agrobiodiversity

Several locally cultivated food crops and wildly available species offer much to the calorific, protein and micronutrient needs of human health during chronic food shortages in many of the poor households of these three locations. It was also noticed that many of the species of yams and aroids are able to withstand severe drought and remain as reserve food beneath the soil for longer periods of time. Assistance, however, needs to be extended to local communities to establish farm gene banks for the diverse food plants and crop varieties. Developing nutrition gardens and new seed materials to cope with the changing needs in the light of climate change was an important activity of the intervention. The intervention helped us to understand that many of the small holder farms and family farms in remote hilly and coastal locations still have traditionally conserved varieties that are highly nutritious and are sources of valuable genes which confer tolerance to drought, floods, and the increased salinity of soils. The baseline information on this category diversity should be utilized for prioritizing species and varieties for studying their potential for using them as pre breeding materials in crop improvement programmes for achieving the twin objectives of nutrition and resilience.

However, unfortunately the rapid loss of functional agro-biodiversity from fragmented farms is the major challenge in keeping the sustainability of small-scale farming. There must be concerted efforts in curtailing the severe loss of diversity from small and family farms and initiate sustainable agriculture as the major pathway for achieving food and nutrition security for the country. Unless, there are effective efforts, it would be difficult for India to achieve the zero hunger challenges and the global target of conservation of up to 70% genetic diversity of crops and other major socio-economically valuable plant species *in situ* by 2020. The management efforts should be taken into consideration sustainable agriculture as the mainstream portfolio in food production through integration of community-conserved biodiversity and agricultural landscapes. Saving vanishing ‘orphan crops’ like millets, tubers, and grain legumes that are rich in micronutrients is crucial in this context in terms of providing nutrition conveniently and at low cost to the poor.

The core objective of such kind of a programme should be ‘Community Biodiversity Management’ with a focus on the critical genetic resources such as food crops, particularly famers’ varieties of rice, roots and tubers, and pulses; neglected and underutilized plants; non wood forest produce; domesticated animal breeds and aquatic diversity of micro-nutrient value, as they are vital sources for not only the food and nutrition point of view, but on the livelihood sustenance to the poor as well.

Enhancing climate resilience through agrobiodiversity conservation

It is an accepted fact that change in land use from traditional to modern methods, has increased food and agricultural production but contributed to emission of more greenhouse gases (GHGs)[43]. Most of the climate-related studies with reference to biodiversity predict intensification of pests and disease attack, increased soil moisture evaporation and lower yields of crops, livestock and fisheries and, reduce diversity of species. Therefore, every ecosystem, species and variety matters to arm ourselves to counteract the deleterious effect of climate change.

Climate change has underlined the need for increasing our efforts in the area of agro-biodiversity conservation. Agrobiodiversity enables the development of plant varieties with novel genetic combinations, which will be required to meet the challenges arising from adverse alterations in temperature, precipitation and, sea level as well as more frequent drought and floods. Hence, strengthening *in-situ* conservation and *ex-situ* preservation by both farm and tribal families and professionals are important[45]. The need for widening the food basket by including underutilized or 'lost' crops gains importance in this context. There is an increasing need in the changing conditions, scientists and local farming communities to work collectively to become an integral part of the conservation continuum.

On-farm erosion of genetic diversity of crops, breeds and strains are reported as exceptionally high in the biodiversity and hunger hotspots and predicted to continue at much faster pace in the future[46]. As an adaptation option, *in-situ* on-farm conservation of traditional crops and breeds that cope with wide agro-climatic and agro ecological conditions is seen as a reliable tool. Conservation of diversity on-farm and *in situ* as well as in forests and protected areas is likely to back up food and agricultural security options of the future.

Traditional land use is now considered as a sustainable pathway for reducing GHG emissions from agricultural landscapes. In addition, such practices also increase the habitat value by restoring wild vegetation for carbon sequestration. Reduction of chemical fertilizers through use of alternate methods like INM and IPM results in minimizing pollution and thereby contributes to health of communities dependent on it is absolutely necessary especially in the biodiversity hotspots. Promoting ecologically sound agricultural practices, therefore gains importance[43].

We recognize the immense importance of agro-biodiversity and sustainable management of agro-ecosystems services as an effective adaptation method for farming communities to climate change. It is inevitable to generate much scientifically credible information on the essential services, particularly related to the provisional and regulating services of traditionally managed agro-ecosystems like paddy fields, millet fields and coffee groves.

Creating new knowledge through integrated study in agrobiodiversity

Unfortunately, in India scientifically generated evidences about the agro-ecosystem functions and importance and value of genetic diversity of crop plants, are awfully inadequate. Many varieties of millets, yams, aroids, small roots and tubers, cucurbits, bananas, leafy vegetables, minor citrus fruits, bread fruit and the largest tropical fruit like jack still slip out from any serious crop improvement programmes. Study of the food biodiversity available in small holder farms or in uncultivated fields need to get adequate attention to avoid the traditionally cultivated or conserved species that are historically contributed to the food and nutritional needs become orphans.

There are also many gaps in the existing research, starting from gender insensitive documentation of traditional knowledge to failure in identifying the innovations and ingenious practices of local communities. It is high time to promote trans-disciplinary research by involving scientists like social scientists, gender experts, anthropologists, agricultural scientists, nutrition experts and biochemists with local community men and women to produce new evidences that help to take better decisions for the sustainable management of agrobiodiversity. However, this requires the team to acquire specialized skills and expertise to study plant groups such as 'Orphan Foods', Wild Foods, and Crop Wild Relatives.

The research in this area should address the gaps outlined here and integrate procedures/strategies/actions required for facilitating access and benefit sharing (ABS) with effective participation of local community knowledge holders and through documentation of the intellectual contributions of the communities. The team engaged in the agrobiodiversity science should be continuously working to build and reinforcing their core competency in community biodiversity management. It is required to introduce more research fellowships that help attracting young talents to undertake research studies in these three mandated research areas.

Conclusion

The interventions undertaken in the three agrobiodiversity hotspots brought out explicitly that food and nutrition security, particularly of those people who are vulnerable depends upon a wide range of food genetic diversity cultivated or found in the wild/semi wild-habitats. The availability and consumption of agrobiodiversity enables the local communities in varied ecological regions to prevent the micronutrient deficiencies, which is prevalent amongst them.

So, it is important the nutrition-sensitive and conservation-oriented agriculture projects should aim at revitalization of proven traditional cultivation efforts that can lead in creating multiple benefits. The plan of actions in such projects should be visible at four levels of actions, viz. Category 1 – activities where sustainable and equitable utilization of agrobiodiversity for overcoming micronutrient malnutrition and achieving the zero hunger challenge, Category 2 – activities where agrobiodiversity conservation directly benefit farmers to mitigating, and adapting with climate vulnerabilities, Category 3 – activities that increases awareness on value of agrobiodiversity and thus benefiting agrobiodiversity itself, especially its rare and threatened group of species and varieties, Category 4 – activities related to access to biodiversity that benefit the local communities who possess unique knowledge about various uses of genetic resources. Some of the possible positive outcomes of such projects would be (i) saving the vanishing crop diversity in the agro-biodiversity hotspots; (ii) promotion of household level food production, self-consumption and thereby improved nutrition to the family members; and (iii) spreading literacy on nutrition and sustainable diets that are safe, healthy and produced through environmentally safe and climate smart methods.

Interventions under these four categories of action in agrobiodiversity conservation need to be implemented in all the 22 agrobiodiversity hotspots of India and it can help India to address the UN declared 2030 Zero Hunger Challenges and the CBD initiated 2020 Aichi Biodiversity Targets 13 and 14, which advocate the contracting parties to maintain and safeguard the ecosystems that provide essential services and genetic diversity of cultivated plants including the wild relatives, other socio-economically and culturally valuable species with minimum genetic erosion.

1. Policy Paper for Conservation: Management and use of Agrobiodiversity, National Academy of Agricultural Sciences, India, April 1998.
2. Future of India the winning leap. PricewaterhouseCoopers Private Limited, India, 2014; http://www.pwc.in/en_in/in/assets/pdfs/future-of-india/future-of-india-the-winning-leap.pdf
3. Swaminathan, M. S., Zero hunger (editorial). *Science*, 2014, **345**(6196), 491.
4. Kesavan, P. C. and Swaminathan, M. S., 2014 International Year of Family Farming: a boost to evergreen revolution. *Curr. Sci.*, 2014, **107**(12), 1970–1974.
5. Nagarajan, S., Bhavani, R. V. and Swaminathan, M. S., Operationalizing the concept of farming system for nutrition through the promotion of nutrition-sensitive agriculture. *Curr. Sci.*, 2014, **107**(6), 959–964.
6. Nayar, M. P., Singh, A. K. and Nair, K. N., *Agrobiodiversity hotspots in India – Conservation and Benefit Sharing*, Protection of Plant Varieties and Farmers' Rights Authority, New Delhi, 2009, vol. 1, pp. 2–3.
7. Goyal, A. K. and Sujatha, A. (eds), India's Fourth National Report to the convention on Biological Diversity, Ministry of Environment and Forests, New Delhi, 2009; http://www.moef.nic.in/sites/default/files/India_Fourth_National_Report-FINAL_2.p
8. Lydia, B., Isabelle, K., Parameswaran, P., Suma, T. R. and Padmanabhan, M., The social-ecological web: a bridging concept for trans-disciplinary research. *Curr. Sci.*, 2014, **107**(4), 572–579.
9. Annual Report: Protection of Plant Varieties and Farmers Right Authority, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, 2008–2009; http://www.plantauthority.gov.in/pdf/AnnualReport_08-09esum.pdf
10. Ratheesh, K. N., Floristic Study of Wayanad District giving special emphasis to Rare and Threatened Plants, Dept of Botany, University of Calicut, Kerala, 2002.
11. Suma, T. R., Customary vs state laws of land governance: Adivasi joint family farmers seek policy support: The case of Kurichya joint families in Wayanad, Southern India, M.S. Swaminathan Research Foundation. International Land Coalition Secretariat at IFAD, Rome, November 2014.
12. Koohafkan, P. and Altieri, M. A., *Globally Important Agriculture Heritage Systems – A Legacy for the Future*, Food and Agriculture Organisation of the United Nations, Rome, 2011, p. 41.
13. Ramiah, K. and Ghose, R. L. M., Origin and distribution of cultivated plants of South Asia Rice. *Indian J. Gen. Plant Breed*, 1951, **11**, 7–13.
14. Oka, H. I. and Chang, W. T., Rice varieties intermediate between wild and cultivated forms and the origin of Japanico type. *Bot. Bull. Acad. Sinica*, 1962, **3**, 109–131.
15. Vedavalli, L., Case study: Kolli Hills, Tamil Nadu. In *Gender Dimensions in Biodiversity Management* (ed. Swaminathan, M. S.), New Delhi, Konark Publishers, 1998, pp. 107–122.
16. Vedavalli, L., *Landed Property Inheritance and Loss of Crop Diversity: A Genealogical Study among Malayalar of Kolli Hills*, MSSRF, Chennai, 2004.
17. Kumar, A. N., Gopi, G. and Parameshwaran, P., Genetic erosion and degradation of ecosystem services of wetland rice fields: a case study from Western Ghats, India. In *Agriculture, Biodiversity and Markets – Livelihoods and Agro-Ecology in Comparative Perspective* (eds Stewart Lockie and David Carpenter), Earthscan, Washington, DC, USA, 2010, pp. 137–153.
18. Swaminathan, M. S., *From Green to Evergreen Revolution*, *Indian Agriculture: Performance and Challenges*, Academic Foundation, New Delhi, 2010, p. 410.
19. Geetha Rani, M. and Swaminathan, M. S., Biodiversity in India: Heritage and Management. In *Gender Dimensions in Biodiversity Management* (ed. Swaminathan, M. S.), Konark Publishers, New Delhi, 1998, pp. 4–22.
20. Annual Reports, M.S. Swaminathan Research Foundation, Chennai, 1992–2014.
21. Parameshwaran, P., Farmers Rights to Seeds: Issues in the Indian Law. *Econ. Pol. Weekly*, 2014, **2**, 16–18.
22. Kumar, A. N., Nambi, A. V., Nampoothiri, K. U. K., Geetha Rani, M. and King, E. D. I. O., *MSSRF Biodiversity Programme: Handsight and Forethought*, M.S. Swaminathan Research Foundation, Chennai, November, 2010.
23. Community Agrobiodiversity Centre Report – 20 years, Wayanad, Kerala, 2011, pp. 13–15.
24. Mishra, S. and Chaudhury, S. S., Landraces of rice: traditional and participatory conservation systems in Jeypore tract of Orissa. In *Genetic Resources of Rice in India*, Today & Tomorrow's Printers and Publishers, New Delhi, 2010, Ch. 17, pp. 557–585.
25. King, E. D. I. O. and Bala Ravi, S., Making on-farm conservation a self-sustainable practice: An Indian perspective. In *Onfarm Conservation of Neglected and Underutilized Species. Status, Trends and Novel Approaches to Cope with Climate Change* (eds Padulosi, S., Bergamini, N. and Lawrence, T.), Proceedings of an International Conference, Bioversity International, Frankfurt, Rome, 2011, pp. 14–16.
26. King, E. D. I. O., Bala Ravi, S. and Padulosi, S., Creating economic stake for conserving the diversity of small millets in Kolli Hills, India. In *Community Biodiversity Management: Promoting Resilience and the conservation of Plant Genetic Resources* (eds Simon, W. *et al.*), Earthscan, Routledge, 2013.

27. Smitha, K. P. and Anitha, K., Seed villages: granary of traditional rice varieties, Case study: Seed Village Story, 2014; https://www.mssrfcabc.res.in/assets/publication/case-studies/seed-village-story.pdf
28. Arunachalam, V., Participatory plant breeding and knowledge management for strengthening rural livelihoods, M.S. Swaminathan Research Foundation, Chennai, 2007.
29. Narayanan, N. M. K., Swapna, M. P. and Kumar, A. N., Gender dimensions of wild food management in Wayanad, Kerala, Community Agrobiodiversity Centre and Utara Devi Resource Centre for Gender and Development, M.S. Swaminathan Research Foundation, 2004.
30. Rengalakshmi, R. *et al*., *Role of Rural and Tribal Women in Agrobiodiversity Conservation: An Indian Case Study*, FAO–MSSRF, 2002.
31. Bhuwon, S. T., Hugo, L. and Ramanath, R., Custodian farmers of agricultural biodiversity: selected profiles from South and South East Asia. In Proceedings of the Workshop on Custodian Farmers of Agricultural Biodiversity, Bioversity International, New Delhi, India, 11–12 February 2013.
32. Padulosi, S. N., Bergamini, S. and Lawrence, T. (eds), On farm conservation of neglected and underutilized species: trends and novel approaches to cope with climate change. Proceedings of an International Conference, Bioversity International, Frankfurt, Rome, 2011.
33. Geetha Rani, M., Management of agrobiodiversity conservation, facilitated access and benefit sharing: experience of M S Swaminathan Research Foundation. In *Agrobiodiversity Hotspots – Access and Benefit Sharing* (ed. Kannaiyan, S.), Narosa Publishing House, New Delhi, 2009, p. 2.
34. King, E. D. I. O., Nambi, V. A. and Nagarajan, L., Integrated approaches in small millets conservation: a case from Kolli Hills, India. In Proceeding of the International Symposium on Underutilized Plant Species for Food, Nutrition, Income and Sustainable Development (eds Jaenike, H. *et al.*), Acta Horticulturae (ISHS), Arusha, Tanzania, 2009, pp. 79–84.
35. Arunachalam, V., Panda, A. K., Thomas, A., Shanthi, G., Sathya, C. K. and Nambi, V. A., Knowledge and impact of participation: technical analysis of a knowledge survey, M.S. Swaminathan Research Foundation, Chennai, 2008.
36. Siddick, A., Gopi, G., Mishra, C. S., King, E. D. I. O. and Goddard, E., Home gardens and fish ponds for nourishment and empowerment, IDRC Stories of Change, Wren Media, 2014.
37. Dolli, S. S. *et al.*, Drudgery reducing interventions in millet cultivation and their impact. In International Workshop on Promoting Small Millets for Improved Rural Economy and Food Security, UAS, Dharwad, India, 8–9 February 2013.
38. Yenagi, N. B., Handigol, J. A., Bala Ravi, S., Bhag Mal and Padulosi, S., Nutritional and technological advancements in the promotion of ethnic and novel foods using the genetic diversity of minor millets in India. *Indian J. Plant Genet. Resour*., 2010, **23**(1), 82–86.
39. Vijayalakshmi, D., Geetha, K., Gowda, J., Bala Ravi, S., Padulosi, S. and Bhag Mal, Empowerment of women farmers through value addition on minor millets. Genetic resources: A case study in Karnataka. *Indian J. Plant Genet. Resour.*, 2010, **23**(1), 132–135.
40. Bergamini, N., Padulosi, S., Bala Ravi, S. and Yenagi, N., Minor millets in India: a neglected crop goes mainstream. In *Diversifying Food and Diets using Agricultural Biodiversity to Improve Nutrition and Health* (eds Fanzo, J. *et al.*), Issues in Agricultural Biodiversity Series, Earthscan, Routledge, 2013, pp. 313–325.
41. Assis, A. L., Sofia, Z., Temesgen, D., Uttam, K., King, E. D. I. O., Swain, S. and Ramesh, V., Global Study on CBM and Empowerment – India Exchange Report, Wageningen University and Research Centre/Centre for Development Innovation, Wageningen, The Netherlands, 2010.
42. King, E. D. I. O., Resilience, the empowerment of tribal peoples' and access to markets, in the context of community biodiversity management in Kolli Hills, India. In the Symposium 19. Community resilience: strategies for empowerment in agro biodiversity management and adaptation. In 4th International Ecosummit, Ecological Sustainability Restoring the Planets Ecosystem Services, Columbus, Ohio, USA, 2012; http://www.ecosummit2012.org/symposia-deboef.html
43. Swaminathan, M. S. and Kesavan, P. C., Agricultural research in an era of climate change. *Agric. Res.*, 2012, **1**(1), 3–11.
44. Bianchi, F. J. J. A., Mikos, V., Brussaard, L., Delbaere, B. and Pulleman, M. M., Opportunities and limitations for functional agrobiodiversity in the European context. *Environ. Sci. Pol.*, 2013, **1164**(27), 223–231.
45. Swaminathan, M. S., Gene banks for a warming planet (editorial). *Science*, 2009, **325**(6196), 531; www.science magazinedigital.org
46. Balakrishna, P., Biodiversity conservation and Impact assessment. *Curr. Sci.*, 1999, **76**(2), 129–131.

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