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Community Based Approach to On-farm Conservation and Sustainable Use of Agricultural Biodiversity in Asia

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On-farm conservation is a process of the continuous cultivation and management of a diverse set of populations by farmers in the agro-ecosystem where a crop has evolved. The continued evolution and adaptation of a species/ cultivar, including adaptation to climate change, thus depend on continuous on farm management of local crop diversity. The paper discusses challenges of implementation of the on-farm conservation, despite significant support from the global scientific as well as civil society agencies, as the preferred method of conservation. Illustrating the insights obtained from three research case studies on crops and fruits of donor funded on-farm initiatives in Nepal and India and South East Asia, the paper aims to highlight the role and importance of community involvement for on-farm conservation of Plant Genetic Resources for Food and Agriculture (PGRFA). Community biodiversity management (CBM) emerged as an approach that is increasingly recognized as a process that contributes to on-farm conservation through the management of landscape, species and genetic diversity.

Key Words: Agricultural biodiversity, Community biodiversity management, Home garden, *In situ*/ On-farm conservation, Sustainable livelihoods, Tropical fruit species

Introduction

The Convention on Biological Diversity and International Treaty on Plant Genetic Resources for Food and Agriculture both acknowledge the importance of *in situ* and on-farm conservation of agricultural biodiversity (UNEP, 1992; FAO, 1998). On-farm (*in situ*) conservation of cultivated plants refers to management of landraces/cultivars and occasionally cultivated wild relatives (as in the case of fruit species like mango) in the very place where they developed their present-day characteristics (Altieri and Merrick, 1987; Brush, 1995; Frankel *et al.*, 1975; Sthapit and Rao, 2011 in press). On-farm conservation is a highly dynamic form of plant genetic resources (PGR) management, which allows the processes of both natural and human selection to continue to act in the production system. Farmer's ability to search for new diversity, selection of new traits and exchange of selected materials with friends and relatives is the processes that allow the genetic material to evolve and change over time. This conservation method is increasingly valued for evolving new adaptive diversity and therefore, enhances farmer's capacity to cope adversity resulting from the consequences of socio-economic and market forces and climate change.

In spite of these advantages, most agencies dealing with plant genetic resources conservation are facing the dilemma of implementing on-farm conservation of agricultural biodiversity in their national conservation programme as a functional strategy (Sthapit, Padulosi and Bhagmal, 2010). Most of globally implemented on-farm conservation projects are donor -funded with various objectives (Jarvis *et al*., 2004; CBDC, 1994). Global *In situ* Conservation Project launched in 1995 by Bioversity (then IPGRI) was aimed to understand the scientific basis of *in situ* and on-farm conservation of agricultural biodiversity, and to strengthen capacity of national partners for implementing on-farm conservation. The Community Biodiversity Development and Conservation Programme (CBDC) is another global initiative developed by governmental and non-governmental organizations (GOs and NGOs) involved in agricultural initiatives in Africa, Asia and Latin America, in cooperation with Northern partners to promote the objectives of CBD that

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includes *in situ* and on-farm conservation of globally important biodiversity (UNEP GEF, 1992). This initiative was focused–mainly through civil societies–to strengthen the ongoing work of farming communities in conserving and developing the agricultural biodiversity that is vital to their livelihood and food security (CBDC, 1994). Since then a number of specific case studies on *in situ* and on farm conservation of agricultural biodiversity were reported from China (Yongneng, 2006), European countries (Veteläinen *et al*., 2009), India (Bisht *et al*., 2006; Pandey *et al*.,2011), Italy (Negri, 2003), Ethiopia (Worede, 1997; Tsehaye *et al*., 2006), Mexico (Louette *et al*., 1997; Rice, 2007), Philippines (Carpenter, 2005), Thailand (Rerkasem and Rerkasem, 2002), Vietnam (Hue *et al*., 2003), but they are not clear as to how the role of farmers and their local institution on management of local crop diversity *in situ* can be consolidated. Economically emerging developing countries have seldom invested sufficient on this complementary plant genetic resources conservation approach to produce any tangible impacts. The major challenges faced by plant genetic resource conservation agencies to implement on-farm conservation are centered around i) lack of a clear understanding of the scientific basis of on-farm conservation of agricultural biodiversity and how it could be practically implemented on the ground, ii) difficulty in changing the mindset of current PGR institutional set up and staff to empower farmers and their rural institutions, iii) identifying priority region of diversity-rich regions/sites for on-farm conservation, iv) rationale for identifying the least cost conservation areas and policy trade-off between the locating diversity rich regions/sites and designating region for intensive modern agriculture, v) difficulties in identifying incentive mechanisms to support on-farm conservation of PGRFA, and vi) inadequate policy support for community based management of agricultural biodiversity as a *in situ* conservation strategy. What makes these challenges particularly complex is the fact that they are highly interlinked and dependent upon a mix of socio-cultural, economic and political factors, making on farm conservation not a purely technical intervention as it is the case in *ex situ* conservation methods but a much more complex endeavour (Ramanatha Rao, 2009; Ramanatha Rao and Sthapit, 2011 in press). This paper selected three case studies carried out in Asian region to illustrate the emerging method of consolidating role of farmer and rural institution in management of agricultural biodiversity on-farm.

Case Studies

Case 1: Strengthening Scientific Basis of In situ Conservation of Agricultural Biodiversity On-farm

Over the last decade, Bioversity International has worked with national, regional and local partners in eight countries (Burkina Faso, Ethiopia, Hungary, Mexico, Morocco, Nepal, Peru and Vietnam) on the maintenance and use of crop genetic diversity on farm, particularly that is found in traditional varieties (or landraces). The work involved investigating the extent and distribution of diversity in over 27 crops and exploring with farmers and rural communities the management practices used to maintain traditional varieties. The results of this collaboration have (i) provided tools to assess the amount and distribution of crop genetic diversity in production systems (ii) increased our understanding of when, where and how this diversity will be maintained, (iii) identified practices, communities and institutions that support maintenance and evolution of crop genetic diversity in production systems, and (iv) provided possible mechanisms for ensuring that the custodians of these systems and genetic materials will benefit from their actions. This international collaboration has provided significant contributions to the four elements of the Convention on Biological Diversity's Programme of Work on Agricultural Biodiversity: (i) assessment of diversity; (ii) adaptive management; (iii) capacity building; and (iv) mainstreaming (Jarvis and Hodgkin, 2008). The purpose was to strengthen the scientific basis, institutional linkages and policies that support the role of farmers in conservation and use of crop genetic diversity. Understanding the above mentioned questions provides the scientific knowledge needed not only to manage crop genetic resources on-farm, but also to develop options for better livelihoods and income that provide incentive for conservation efforts (Jarvis *et al*., 2004, 2007; Sthapit *et al*., 2007).

Through this partnership, countries worked together to collate datasets from biologically and culturally diverse sites from into a small number of globally applicable diversity indices to compare across farmer households and communities. Varietal data from 27 crop species from five continents were analysed to determine overall trends in crop varietal diversity on farm. Measurements of richness, evenness, and divergence showed that considerable crop genetic diversity continues to be maintained on farm, in the form of traditional crop varieties. Major staples

had higher richness and evenness than non-staple crops. Variety richness for clonal species was much higher than that of other breeding systems. Study suggested that diversity may be maintained as an insurance to meet future environmental changes or social and economic needs. Divergence estimates, measured as the proportion of community evenness displayed among farmers, underscore the importance of a large number of small farms adopting distinctly diverse varietal strategies as a major force that maintains crop genetic diversity on farm.

Studies on (i) on-farm diversity assessment, (ii) access to diversity and information, (iii) extent of use of available materials and information, and (iv) benefits obtained by the farmer or farming community from their use of local crop diversity, are necessary to identify the different ways of supporting farmers and farming communities in the maintenance of traditional varieties and crop genetic diversity within their production systems (Jarvis *et al*., 2010). The lessons learned from the study are into two key areas. First, any analysis within the four main areas (assessment, access, use and benefit) can, and most probably will, lead to a number of different community actions. Second, the decision to implement a particular community action, and therefore its success, will depend on farmers and the farming community having the knowledge and leadership capacity to evaluate the benefits that this action will have for them. This in turn emphasizes the importance of activities of strengthening and empowering local institutions so as to enable farmers to play a greater role in the management of their resources (Subedi *et al*., 2006; Sthapit *et al*., 2008ab; Smith, 2009). The consolidating role of farmer and community on management of agricultural biodiversity solely depends upon the experience and deeper understanding of community empowerment and its linkage with on-farm management of PGRFA.

When local institutions are weak, involving the community and community institution in the management of agricultural biodiversity is a challenge. This requires building of knowledge, skills and practices of farmers with social system and driven by local rules and institutions. Since the farmers and their social networks play a key role in maintaining dynamic process of evolution, selection and adaptation of useful diversity in the changing climate and other external forces (Subedi *et al.,* 2003), it is important to understand that on-farm conservation is a constantly changing complex system of relations between people, plants, animals, other organisms and the environment, continuously challenged by new problems (Brookfield, 2001). If dynamism of agricultural biodiversity constitutes of relations between people, plants, animals, other organisms and the environment, how can these relations be conserved *per se* for on-farm conservation and are there any social system/customs that support that? Often PGR agencies have difficulty to address this issue. Subedi *et al.* (2006) and Sthapit *et al.* (2008ab) used a participatory community based biodiversity management (CBM) as a method to realize the on-farm management of agricultural biodiversity.

CBM integrates knowledge and practices into social systems so that the process is dynamic and sustainable. The strategy strengthens the capacity of rural communities to make decisions on the conservation and use of biodiversity in order to secure access to and control over their resources (Subedi *et al*., 2006; 2007). Sthapit, Shrestha and Upadhayay (2006) described a number of steps of CBM method and a set of good practices that suit to the particular context. These include: i) understanding local biodiversity, social networks and institutions, ii) enhancing community awareness and capacity building of community institutions, iii) setting up of institutional working modalities, v) consolidating community roles in planning and implementation, iv) establishing a CBM Trust Fund (payment system for community conservation efforts), v) community monitoring and evaluation, and vii) social learning and scaling up for community collective action. The CBM strategy provides an overarching structure with practices (Sthapit *et al*., 2006; 2008ab; Subedi *et al*., 2007) that include a number of ways to contribute to the implementation of on-farm management. Some examples are:

- Diversity and seed fairs (Adhikari *et al*., 2006; Neuendorf, 1999);
- Community biodiversity register (Subedi *et al*., 2006);
- Diversity blocks, diversity kits (Sthapit *et al*., 2006) and participatory varietal selection (Joshi and Witcombe, 1996);
- Farmer and participatory plant breeding (Gyawali *et al*., 2006; Sthapit and Jarvis, 1999; Sthapit *et al*., 1996; Witcombe *et al*., 1996);
- Community seed banks, strengthening social seed networks and local seed business development (Shrestha *et al*., 2006; Subedi *et al*., 2003);
- Value addition of local crops and varieties, and

associated product chain development (Bhandari *et al*., 2006).

In Nepal, these community-driven practices empower farmers and community about the importance of local crop diversity and its maintenance for future crop improvement and two examples are cited below to illustrate this from the work done in Nepal during 1998-2005.

Participatory Landrace Enhancement

First, Gyawali *et al.* (2010) demonstrated how local diversity of *Jethobudho* rice can be made more competitive to so that farming community has incentive to continued cultivation of traditional cultivars and thereby supporting on-farm conservation. *Jethobudho* is an aromatic rice landrace of the Pokhara valley in middle hills of Nepal. Although local consumers are willing to pay a high price for its purchase, the landrace has a problem with quality variation. Decentralized participatory population improvement for specific market-identified traits was conducted on ''*Jethobudho*'' populations collected from farmers' fields in seven geographic regions of the valley in Nepal. The preferred post harvest quality traits, field tolerance to blast and lodging, and superior post harvest quality traits of *Jethobudho* were established by a consumer market survey. These traits were used for screening the materials. 338 sub-populations of *Jethobudho* were evaluated for yield, disease, lodging resistance, and post harvest quality traits. Six accessions with similar agronomic traits, field tolerance to blast and lodging, and superior post harvest quality traits, were bulked and evaluated on-farm using participatory variety selection (PVS). The enhanced *Jethobudho* accessions were also evaluated for aroma using simple sequence repeat (SSR) and found to have unique aromatic genetic constitution. Community based seed production groups were formed, linked to the Nepal District Self Seed Sufficiency Programme (DISSPRO), and were trained to produce basic seeds (truthfully labelled) of *Jethobudho*. The National Seed Board of Nepal released the enhanced landrace in the name of ''*Pokhareli Jethobudho''* in 2006, as the first bulk variety of traditional high quality aromatic rice improved through participatory plant breeding to be formally released in Nepal for general cultivation under the national seed certification scheme. Landrace improvement is shown as an important option for supporting programmes for *in situ* conservation of landraces on-farm. This example showcased evidence to policy makers how variability in local crop diversity can be capitalized to provide incentive for management diversity on-farm.

Community Seed Bank

Second example is from the high production potential area Indo-Gangetic plain of Bara district bordering to India. As part of a global on-farm crop conservation project in Nepal, community seed banks were established by the NGO Local Initiatives for Biodiversity, Research and Development (LIBIRD) and the Nepal Agriculture Research Council (Shrestha *et al*., 2006; Sthapit *et al*., 2007). The community seed bank in itself is managed by Agriculture Development Community Society (ADCS), a farmers' organization. The seed bank deals with a variety of local farmer's varieties. In addition, some rice varieties bred from traditional varieties with the technical assistance of LI-BIRD are included. In collaboration with partner organizations ADCS collects, regenerates, multiplies and promotes diversity on-farm. The diversity and knowledge gathered through different techniques, such as diversity fairs, biodiversity registration and diversity blocks, have improved farmers' access to seeds of preferred local varieties (Table 1). To refresh seeds maintained in the seed bank and meet local demands, seeds of the crop varieties are regenerated each year. The seed bank offers local people seeds of local origin as well as preferred improved varieties, and it empowers the community with respect to conservation, use and marketing. Farmers and farmers groups frequently visit the seed bank for technical input, facilitation of saving and credit schemes, business advice and funding for small scale businesses. This place is seen as the outlet of local varieties as they are increasingly difficult to access for farmers whereas modern varieties are easy to obtain from variety of sources such as Agrovets, Extension agencies, NGOs and research stations (Shrestha *et al*., 2006).

This strongly suggests that ADCS is becoming a key institution in the area. The most important lesson learned from the project is that most crop varieties of local origin are maintained by wealthier households. Poorer farmers use those varieties, but are unable to invest resources for the sake of conservation for future use. In this situation, the community seed bank can maintain and provide easy access of varieties preferred by small scale farmers, who often operate in marginal environments where local varieties are preferred. The amount of seed and varieties transactions of Table 1 illustrates that small holder farmers are 'drawing' locally adapted germplasm from CSB and multiplying them on their farm for further use. Thus, the easy access to needed seed provided by community seed banks is directly helps improve the food security of small

Table 1. Recipients of seed from CSB by socioeconomic categories

Year	Number of farmers of different socio-economic category				Number of	Seed Qty.
	Rich	Medium	Poor	Total	landraces	(Kg)
2007	3 (6)	20 (41)	26 (53)	49	23	61
2006	7 (11)	25 (39)	32 (50)	64	17	78
2005	17(20)	37 (42)	33 (38)	87	23	197
2004	6 (17)	14 (40)	15 (43)	35	13	69
2003	5 (12)	19 (48)	16 (40)	40	11	87

(Figures in parenthesis indicate the percentages, Source: Seed distribution records from community seed bank, Kachorwa)

scale farmers. ADCS has also established a diversity fund, which had been effective in raising the incomes of small scale farmers, including landless households. By accepting fund rules, those who borrow from the diversity fund agree to be responsible for the regeneration of one traditional variety. The fund thus strengthens small scale businesses and contributes to conservation of traditional varieties. Most of the diversity fund loan takers have been resource poor farmers or people from socially excluded and ethnic minorities (Table 1). Most importantly, community seed bank provides a local institutional platform to access local varieties and strengthen community capacity for monitoring local diversity. The detailed methodologies of such community based approaches were published (Sthapit, Shrestha and Upadhyaya, 2006; Sthapit *et al*., 2008ab). In the context of climate change adaptation, those practices can provide options that enhance the capacity of farming communities to adapt.

Case 2: Home Gardens in Nepal

Home gardens are reported to be the oldest agro-ecosystem that provides a bridge between the social and the biological, linking cultivated species and natural ecosystems, combining and conserving species and genetic diversity. Home garden[1] is a traditional land use practice around a homestead where many annual and perennial plant species are planted and maintained by the members of the household (HH) intended primarily for HH consumption (Shrestha *et al*., 2002; Trinh *et al*., 2003). There is a wealth of literature that illustrates how home gardens[1] provide a niche where people keep those plants and animals that are precious to the household for religious, cultural, health, aesthetic, ecological and economic reasons (Eyzaguirre and Linares, 2004). They are often used as a place where farmers can experiment with, introduce and domesticate useful plants. Their structural composition, and species and varietal diversity are influenced by the socio-economic circumstances and cultural values of the users. Constant experimentation makes home gardens important reservoirs of germplasm-especially unique fruit trees and species associated with local food culture and preference (Gautam *et al*., 2008b). These gardens therefore are not only important sources of food and nutrition, but are also important for on-farm management of a wide range of plant genetic resources not found in larger agro-ecosystems (Agnihotri *et al*., 2004; Trinh *et al*., 2003). The dynamic nature and multiple uses of home gardens raise several research questions about the stability of this micro-ecosystem and its role as a viable conservation unit.

The Nepal home garden project was linked closely with the Bioversity International's global home garden project that was being implemented in five countries, namely Cuba, Venezuela, Guatemala, Ghana and Vietnam during 1998-2002. The methodologies developed under this project in understanding the dynamics and role of home garden were utilized in carrying out the Nepal project.

Systematic studies on Nepalese found that the compositions of home gardens were variable and species and varietal richness were high with variable distribution across home gardens (Shrestha *et al*., 2002; Sunwar *et al*., 2006 and Gautam *et al*., 2008). Although species diversity within community is large (172–342), 24 key species were identified for the study (Gautam *et al*., 2008). There was no fixed size of a home garden. Species richness was significantly higher in vegetable followed by fodder, fruits and spices. Within each trophic level, plant species that were frequently grown in home gardens in a relatively large area by many HHs were considered the key species that were locally important for the community. Broad leaf mustard, radish, hyacinth bean, garlic, yams, Biyee (*Solanum anguivi* L.), etc. were the common key species in winter season, whereas sponge gourd, pumpkin, bottle

1 There are many terms that describe these garden production systems, the term "home garden" is preferred as it highlight the close relationship between garden and the social group residing at home.

Table 2. Impact of home garden interventions on species richness in six districts in Hill (bold) and Tarai (normal) agro-ecological zones of Nepal

			Shannon weaver Indices† (H')		Simpson index (λ) ††	
District	Site	Altitude (m asl)	Before§	After§§	Before§	After§§
Ilam	Chaulachuli	173	3.81	3.95	0.97	0.98
	Larkhe	1717	3.70	3.34	0.97	0.98
	Sumbek	1413	3.53	3.74	0.96	0.97
Gulmi	Amarpur	1180	2.57	3.87	0.91	0.98
	Hardineta	1132	2.92	3.67	0.94	0.97
Rupendehi	KhadwaBangain	120	3.25	3.76	0.93	0.97
	Siktahan	115	2.53	3.85	0.91	0.98
Jhapa	Chakchaki	95	3.49	3.83	0.96	0.97
	Duwagadhi	116	3.78	4.10	0.97	0.98
Kailai	Godawari	679	3.17	3.47	0.95	0.96
Bardiya	Taratal	167	2.99	3.68	0.94	0.97

† Shannon-Weaver Indices (H'), and † † Simpson Indices (λ) or Dominance (Shannon and Weaver, 1949; Simpson, 1949).
§ Before (2002); §§ After (2011)

gourd, taro, cucumber, chillies, etc. were the key species in summer season. Within these key species, the amount of intra-specific diversity was relatively high compared with other plant species since it is an indication of farmers' diverse needs and preferences (Gautam *et al*., 2008; 2009). Monitoring of species richness over the years showed that richness has increased (Pudasaini *et al*., 2011) and spatial distribution (as measured by evenness, Simpson index) was also at par showing that the home gardens species diversity was not affected by market forces and most produces are consumed for family use (Table 2).

Success of home gardens has been measured as increase in species diversity (Table 2) as it is taken as proxy indicator for dietary diversity and the increase in options in functional categories from a nutritional perspective (Pudasaini *et al*., 2011 in press). The system provides a platform of exchange of locally important PGRFA and associated knowledge amongst farmers and in the process assists the farmer innovation at local scale. One of the important functions that home garden performs is to keep knowledge of crop and varieties and uses of diversity alive from generation to generation and serve a live school of biology for children from custodian elder farmers. However, this tradition is eroding fast and diversity and traditional knowledge on seed saving and propagation are also eroding fast.

Home gardens, though small in population size, offer not only refuge to crops that are no longer grown in larger agro-ecosystems, but also offer a method of conservation of many rare and unique components of biodiversity, which are then inherently decentralized and evolutionary. Many spices, vegetables, herbs and non-timber forest products, especially medicinal plants, are in this category. This provides an ideal setting to promote local-level innovation. Crops for family preference, traits for multiple harvests, use of multiple plant parts, perennial growth habits, unique to local food culture are some of criteria used by farmers in species/variety selection in home garden. The crop species, such as Pidar (*T. nudiflora* L.), Kundruk (*Coccinea grandis* L.) and Poi sag (*Basella alba* L.), are strongly linked culturally to indigenous ethnic groups in Tarai (Gautam *et al*., 2009). In this context, importance of home garden is well recognized to have bound between plant and human community.

It has been debated that the plot size and number of plants of key species in home gardens are so small that they cannot be considered an effective population size for conservation efforts (Brown, 2000). In reality, however, farmers have managed to maintain genetic diversity of cross-pollinated and self-pollinated crop varieties in home garden ecosystems by exchange of seed and knowledge as social practices. These seed exchange systems resemble the dynamics of a meta-population, where different farmer populations represent sub-populations; seed flow represents migration, and the rate of seed exchange determines extinction and colonization (Hastings and Hartison, 1994). A consideration of the populations of key species found in home gardens through the lens of meta-population theory can explain how, for example, farmers can maintain two to six distinct varieties of cross-pollinated sponge gourd in a community. Thus, from a conservation perspective, a single home garden may be insignificant, but a group of them can contribute significantly.

Home gardens seem devoted towards family well-being and nutrition but not necessarily oriented towards commercial production with the subsequent monoculture

of vegetable crops. Therefore, the size of home gardens in most countries are limited below 500m^2 and richness and evenness of diversity high is usually very high too (Gautam *et al*., 2008). Being small in size, home gardens have always been neglected by policy makers for research, development and conservation programmes as it is difficult to demonstrate large-scale economic impact from home garden interventions, and there are limited technological options to offer for semi domesticated, neglected and underutilized and lesser known minor crops. This suggests that government policies, linked to the millennium development goals (MDGs) and poverty reduction strategies, and research priorities need to re-examine home gardens in the context of their value towards family welfare in particular and society, in general. Suwal et al (2008) also found that home gardens are entry point to reach marginalized, socially excluded small holder farmers, especially women and children.

Case 3: Cultivated and Wild Tropical Fruit Diversity

Building upon previous two case studies, the Project," Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Tree Diversity : Promoting sustainable Livelihood, food security and ecosystem service" supported by Global Environment Facility (GEF)/UNEP and executed by Bioversity International together with ICAR, India, ICHORD, Indonesia, MARDI, Malaysia and DoA, Thailand. Tropical fruits are valued for their wide range of nutritional, health and commercial values that make them an important part of Asian culture.

The genetic diversity of tropical fruit trees in Asia is increasingly threatened – in the case of cultivated species by specialization of production systems in a few varieties and by land use changes, and in the case of wild relatives due to habitat loss and climate change. Its *ex situ* conservation is difficult because tropical fruit generally possess recalcitrant seeds that cannot be stored in conventional genebanks (Ramanatha Rao, 2009). *In situ*/on farm conservation is considered as viable low cost option, however, national partners face challenges to implement *in situ*/on farm conservation programmes from the current PGR institutions (Sthapit *et al*., 2010; Sthapit and Singh, 2010).

The project aims to improve the conservation and use of tropical fruit tree genetic diversity in Asia by strengthening the capacity of farmers, local communities and institutions to implement community-based management of local fruit tree diversity in home gardens and orchards, and to enhance the *in situ* conservation of their wild relatives in forests. These conservation goals are to be achieved by documenting the available diversity and related knowledge, identifying and promoting good practices, enhancing the livelihoods of farmers who conserve genetic resources of tropical fruit trees, and building local, national and regional capacity to provide assistance, monitoring and policy support.

The project focuses on two globally important tropical fruit species such as *Citrus* spp. and *Mangifera* spp. and two regionally important species *Garcinia* spp. and *Nephelium* spp. as well as their wild relatives. The four countries- India, Indonesia, Malaysia and Thailand-which are located in the centre of diversity of these species-, are participating in the project. Within four countries, a total of 22 sites and 36 communities and over 15,000 households are directly involved. The study sites are located from a wide range of the production systems as traditionally tropical fruits diversity are managed in a in natural forest, protected areas, buffer zones, home gardens, semi-commercial and commercial orchards.

In the context of cultivated fruit diversity, if topical fruit tree genetic resources (including landraces) are to be conserved on-farm, this should be the result of farmers' production activities directed to improve his/her livelihood. This means on-farm conservation efforts must be carried out within the framework of farmer's livelihood needs. The project is using community-based approach to strengthen capacity of farmers, local communities and institutions to improve conservation of tropical fruit tree genetic resources and sustainably use the genetic resources of target crops and their wild relatives.

Wild fruit genetic resources are increasingly becoming valuable for breeding, genomics and commercial fruit nurseries (*e.g.* rootstocks) programmes. Wild relatives of tropical fruit species may offer desirable traits that are not available in cultivated varieties, but "wilds" often also have traits that are highly undesirable. Advances in comparative genomics and marker-assisted breeding facilitate the inclusion of the valued traits from wild materials in plant breeding programs. As technologies advance, wild plant genetic resources will become even more valuable for future research developments (Volk and Richards, 2011).

To achieve *in situ* (on-farm) conservation, community biodiversity management (CBM) method is employed to empower farming communities to manage their

agricultural biodiversity collectively and intentionally, thereby seeking sustainability in conservation. The basic principle of the CBM method is legitimizing the role of locals on the following:

- building on local resources, skill, knowledge, practice, innovation & natural assets (local use of genetic diversity and blending new acquired knowledge and science),
- empowering community and local institutions for sustainable biodiversity management and better governance (social organizations),
- diversifying biodiversity based livelihood options by mobilizing social, human and natural assets (capitalizing sustainable livelihood assets),
- promoting good governance for biodiversity management and eco-friendly approaches, and
- providing a platform for social learning for collective actions (social learning institutions) to save and use agricultural biodiversity.

The methodology is designed in such a way that locals lead the process and make decision of management and use of agricultural biodiversity (Smith, 2009). Fig. 1 illustrates key steps of community-based management of agricultural biodiversity that employed in the conservation and sustainable use of tropical fruit tree diversity.

The project builds capacity of frontline staff and local institutions (self-help group, CBOs, women groups etc) why studies on (i) on-farm diversity assessment, (ii) access to diversity and information, (iii) extent of use of available materials and information, and (iv) benefits obtained by the farmer or farming community from their use of local crop diversity, are necessary to identify the different ways to support farmers and farming communities in the maintenance of crop genetic diversity within their production systems. Using participatory research method and creating platform of farmer and research sharing and learning, farmer and local institutions build local capacity to assess on-farm diversity, identify elite materials and improve access of useful diversity and make community action plans for deriving benefits from their conservation efforts of fruit tree diversity.

On-farm Diversity Assessment

A participatory four cell analysis method was used to assess preliminary amount and distribution of citrus, mango, rambutan and mangosteen species diversity in 36 communities from India, Indonesia, Malaysia and Thailand (Sthapit *et al*., 2006). Baseline measurements of richness

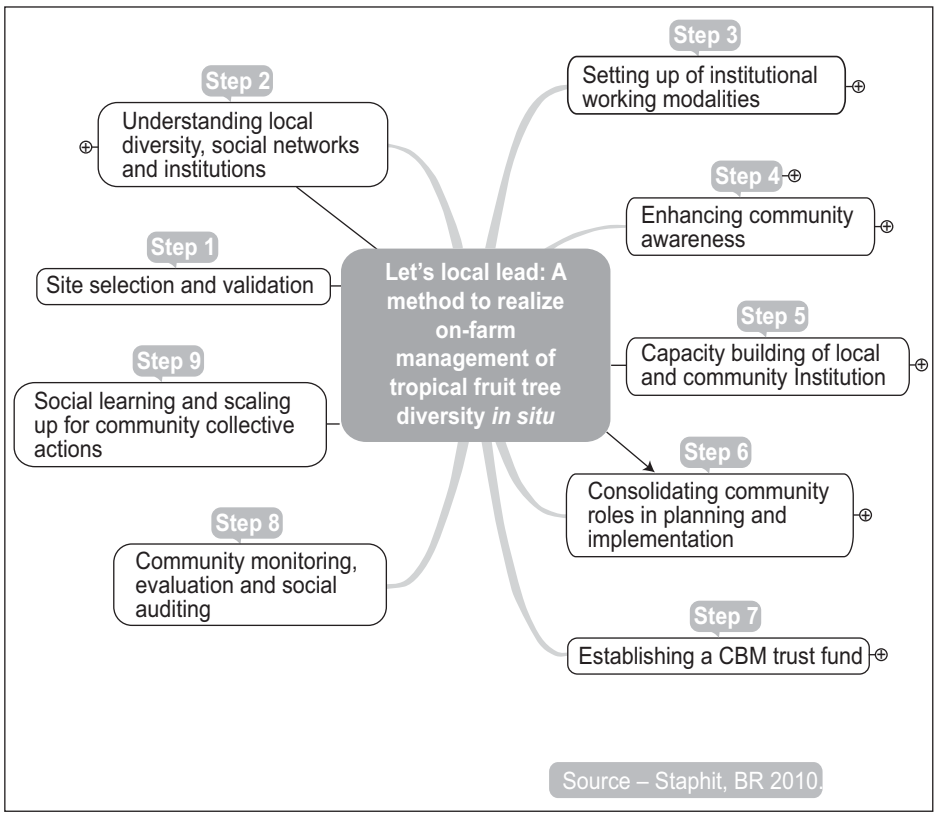

Table 3. Community richness of target fruit tree diversity (as measured by names using FCA method)

Site	Community	Total fruit HH#	*Mangifera* diversity	*Citrus* diversity	*Garcinia* diversity
Amravati	Bargaon	150	7	8	0
	Jarud	1301	6	6	0
	Nagziri	20	2	5	0
Chittor	Bangarupalyam	245	23	5	0
	Polakala	900	21	3	0
	Talupulapalli	160	25	4	0
Malihabad	Gopramau	475	14	2	0
	Kasmandi Kalam	285	40	2	0
	Mohammed Nagar Talukedari	225	11	2	0
	Sarsanda	230	8	2	0
Pusa	Dhobgama	250	20	3	0
	Jagdishpur	60	27	3	0
	Mahmada	160	26	6	0
	Murliyachak	55	13	3	0
Sirsi	Gonsar	251	47	6	3
	Koligar	320	27	6	3
	Kulibeedu	220	17	7	5
	Kumta	374	22	2	2
Total	18	5681	2-47*	5-8	2-5

*Besides, a large amount of seedling variability was observed and is being documented.

and evenness showed that considerable fruit tree diversity continues to be maintained on-farm in orchards, home gardens and natural ecosystems. Table 3 shows on-farm diversity of mango, citrus and Garcinia in India and are being maintained for various purposes.

Information generated by these focus group discussions (FGD) are used to have deeper understanding of the local context and analyze both natural, human and social assets in developing a set of livelihood action plans that farming community believe priorities intervention. This process - though looks to be a pragmatic approach - aims to enhance knowledge and skills of farming communities and local institutions on key issues of maintenance of local crop diversity and potential threats of not addressing those issues at the local platform so that the local communities are empowered in making decision related to their own genetic resources. In this iterative process of knowledge sharing of traditional and scientific multi-disciplinary and multi-sectoral professionals, a common heuristic understanding of agricultural biodiversity is assessed at the community level and facilitates the process of choosing appropriate intervention. Such process is graphically illustrated in Fig. 2. The choice of interventions that support on-farm management of local crop diversity may vary with the context and interest of farmers and therefore, we need local institution that provide a platform for actors and farmers to discuss, debate and identify key practices that help the process to be continued so evolutionary process of on-farm and *in situ* conservation are continued or at least does not intervene the process. This requires deeper understanding evolutionary ecology, population genetics and social science.

Access to Diversity

Cultivated tropical and sub-tropical fruit tree species have generally been selected to suit the environment in which it is cultivated or selected naturally to satisfy the particular needs of its growers and users; such as colour, flavour and taste. Farmers have several good reasons for maintaining and using diverse traditional fruit tree diversity in home gardens or orchards for their own welfare and benefit. Deeper understanding of farmers and consumers preference and making available to farmers is essential for choosing options of interventions (Fig. 2). These options vary with the specific context. We have found six broad context of management of tropical fruit diversity in Asia. First those regions, where local fruit diversity and associated traditional knowledge, do not exist should be

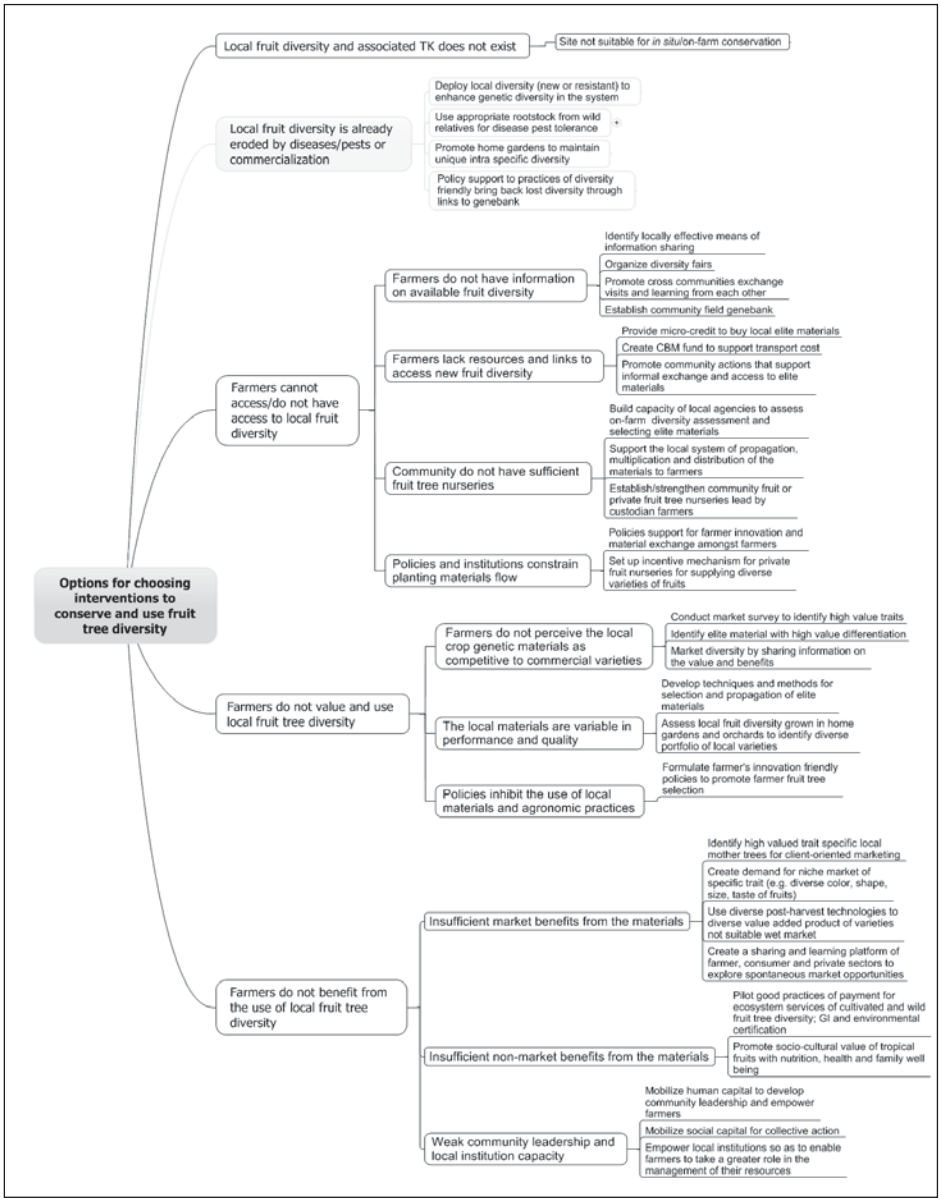

Fig. 2: Options of interventions for conservation and sustainable use of fruit tree diversity led by the local institution

selected for on-farm*/in situ* conservation. Second, the context where local fruit diversity is already eroded by commercialization of monoculture production system and thereby rapid decline of diseases/pests, for example, decline of Nagpur mandarin orchards in Amravati. Third, the context where farmers cannot access or do not have access to local fruit diversity. On-farm diversity assessment in the project sites identified a wide of range of unique and commercially high value traits. Knowledge and information on such valuable genetic materials are limited to few custodian farmers and are under threat to genetic erosion because of increasing deployment of youth in non-agriculture enterprises and pushing a single option to farmer by aggressive extension messages. Figure 2 illustrates number of options available for such context specific problems. Fourth, the context where farmers do not value and use local fruit tree diversity. This context is great threat and barrier to conservation of fruit tree diversity so it is essential to demonstrate that useful elite materials can be selected from the local fruit diversity and use diversity for marketing so that the value of specific traits are appreciated by community. Finally, the context in which farmers do not benefit from use of local fruit diversity and production, there are serious threats of replacing traditional fruit orchards by commercial commodity crops. In Nai Tao, Nong Sri Chan communities

of Southern Thailand, east java of Indonesia, and Kota Belud and Yen communities of Malaysia, farmers are not getting benefits from cultivation of native high value fruits as the monetary benefits from industrial crops such as rubber, oil palm and cassava are much higher because of government subsidies. In these areas a strong local institution is required to mobilize social, human and natural capitals for creating monetary and non-monetary benefits to the community. The project identified a total of 33 good practices that can be piloted as set of interventions to suit these situations. Jarvis *et al.* (2011) has also documented a number of such interventions in recent publication.

In past the world has invested lot to collect and conserve for future use by plant breeder rather than developing mechanism to make germplasm accessible to poor and needy people. Sthapit and Ramanatha Rao (2009) argued that the benefit of such rich diversity can be capitalized by simple grassroots breeding method[1]. It could be carried out by community-based organizations and private/community nurseries at a local level who can implement the activities on a large scale in order to maximize the benefits from locally available useful diversity. The project realizes that there is immediate urgency to demonstrate the value of local fruit diversity by identifying high value traits, and improve access to farming community by rapid selection, characterization and multiplication efforts from the extant diversity.

Access to seed or planting material diversity requires people having adequate land (natural capital), income (financial capital) or connections (social capital) to purchase or barter for the varieties they need (Sperling *et al*., 2008). There may be pressure from both formal extension services and community peers against obtaining and using planting materials of local varieties. Often, value of locally available local fruit tree diversity is not known to all community and potential markets because of lack of information sharing mechanisms. In India, Indonesia and Malaysia, fruit diversity fairs were organized at regular intervals for locating new diversity and promoting exchanging of planting materials. On farm management of agricultural biodiversity (e.g. seed/planting materials) can be conceptualized as open, dynamic and decentralized genetic systems since they are the crop populations that farmers manage, and which result from farmers' seed selection practices, the flows of seed among them, and farmers' production and utilization strategies (Bellon, 2010). Interventions like traditional mango eating feast, diversity fairs, cross communities' exchange visits etc can assist to break such social barriers. In addition, organizing such events by local institutions in participation of research institutions provide platform for farmers and researchers to locate unique and useful diversity and arrange/negotiate/transact the materials on preferred terms.

This process might improve access of germplasm. Participatory techniques such diversity fair followed by four-cell analysis researchers have identified 10 clones of *Citrus grandis*, 8 clones of *Mangifera indica,* 2 clones of *Nephelium* spp. (*lappaceum* and *ramboutan-ake*) and 2 clones of *Garcinia atroviridis* and *G. forbesii* from all four countries that have favourable traits, such as quality traits. These selected varieties are propagated by the community and sold/distributed for further promotion and conservation.

Use

The use of the traditional fruit diversity by farmers might often be increased (i) if there were more information on the characteristics (eco-physiological, adaptive, quality traits) or uses of these materials, (ii) if the materials themselves were enhanced, or (iii) if the agronomic management of the materials were improved. Farmers may perceive that traditional fruit varieties are not competitive with other options because of a lack of characterization and evaluation information on the varieties, or because of a lack of information on appropriate management methods. Four cell analysis in the community with key FGD groups helps to disseminate information as default manner. Unique and high value traits can be characterized, evaluated and made available to larger impact groups by small investment. The relevance of such work in on-farm management of fruit orchards and home gardens is great as there is lack of fruit breeding work in these neglected perennial crops and time required to produce outputs is long and expensive. To date Indian researchers have identified unique and high value traits of farmer's managed fruit trees in orchards and home gardens. This includes 10 elite materials of mango, 2 pummelo and 1 *Garcina indica* for further multiplication and use by the community. At least 5 elite materials are already characterized and submitted for official registration

1 Grassroots breeding (GB) is defined as a simple step in the plant breeding process which enhances the capacity of grassroots institutions and farmers to assess existing diversity, select niche-specific plant material, multiply and produce sufficient quality seed and distribute it within the community (Sthapit and Ramanatha Rao, 2009).

in the name of farmers at NBPGR and PPV &FRA. Identified clones are being multiplied with farmers to provide direct benefits to the impact groups as the part of community action plans to provide incentive mechanism for conservation of valuable diversity. Community based organizations (CBOs) like farmer organizations, women groups or self-help groups are established or strengthened in all 36 communities for the implementation of local action plans. Research has shown that improving markets and quality of indigenous fruit and products would be a major driver for increased investment by the private sector in the production and commercialization of indigenous fruit trees.

Conclusions

It is important to note that on-farm conservation *per se* is not a panacea. It is neither recommended as a universal practice nor a feasible method in all circumstances. It has a place and a time, as on-farm conservation can be transient and subject to change over time and that provides the major link with *ex situ* conservation. Sustainable on-farm conservation is possible only when farmers, communities, and national institutions perceive benefits in terms of social, economic and environmental services. Once we understand that the farmer management of local crop diversity is a primarily livelihoods option for rural communities, and then cost of on-farm conservation is much cheaper than *ex situ*. In the process of farming, farmers not only derive social, economic and environmental benefits from local genetic resources but also the evolutionary potential of these genetic resources. In order to ensure that communities have platform for social learning and local organizations are equipped to make decision about the management of on-farm local crop diversity, government agencies and donors must collaborate directly with them about their specific requirement and let the local lead to save agricultural biodiversity. CBM is therefore ensure that communities have the knowledge and skills and appropriate decision making capacity to manage the agricultural biodiversity to cope any adversity situation and opportunities.

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