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Assessment of agricultural biodiversity through participatory approach

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Abstract

Agricultural biodiversity provides food, animal feed, fuel woods, shelter, medicine and cultural requirements and the aesthetic beauty for the life style of a particular community. Hence, knowledge on on-farm agricultural biodiversity is important in many aspects to determine the level of management required on biological resources for the better utilization and conservation for future use. Assessment of the agricultural biodiversity of three villages of Thanamalvila Divisional Secretariat, Mahaweva, Kahakurullanpellessa and Sooriyaara in Sri Lanka were carried out using participatory tools such as village transect walks, diversity fairs, four cell analysis and community biodiversity registers during 2012, 2013 and 2014. These participatory tools could be effectively used for the quick assessment of on-farm agricultural biodiversity in the selected three villages. Simpson's index for diversity (> 0.7) indicated that considerable species and varietal diversity exist within three villages. Cowpea and Yard-long bean had the highest varietal diversity. According to four cell analysis, Pinna mung, Kaha mung, Foxtail millets and Proso millets were grown in few households and in small land area and has categorized as a threatened group. It was recommended to increase the cultivation area of rare and threatened category of crops by introducing diversity blocks and further selection of adaptable varieties through mother and baby trials to increase the varietal diversity.

Key words: Agricultural biodiversity, Community biodiversity register, Diversity fair, Four cell analysis

Introduction

Agricultural biodiversity in farming systems is important in many ways. Sustainability of a cropping system mostly depends on crop diversity. Food and nutrition of human, animal feed, fiber, fuel, and other services that contribute to the livelihood of people including health and well-being are the security provided by the well preserved agricultural biodiversity. It conserves the habitats of many crops. According to Sthapit (2008), it is the outcome of thousands of years of observations, selection, exchange and breeding. The value of biodiversity is apparent in agriculture at all levels for meeting both short-term needs and achieving long-term sustainability.

Assessment of agricultural biodiversity in a particular target area prior to implementation of any participatory crop improvement activity is crucially important. In Sri Lankan context, on farm diversity of crops has been degraded rapidly within few decades due to introduction of new varieties, exotic hybrids and changing from old subsistence agriculture to modern irrigated cropping systems and urbanization and rapid development activities. Therefore, regaining of lost diversity and protection of existing diversity by encouraging on farm diversity conservation measures is important to develop sustainable agriculture with minimum risk (Millawithanachchi *et al*., 2012). Maintenance of crop diversity within on-farm conditions would enhance the conservation and sustainable utilization of genetic diversity of different crops and their varieties.

Various tools and techniques have been used to measure the extent of diversity. Transect walks, diversity fairs, four cell analysis, diversity blocks and community biodiversity registers are some information collection methods to estimate agricultural biodiversity, level of utilization and risk on it.

Transect walks could be effectively used to gather considerable amount of information on topography, natural resources available, crops and animals, constraints and requirements for improvements. Diversity fair has been found to be a simple and low cost approach for locating biodiversity. It helps to identify custodians of rare and unique crop genetic resources and local knowledge, and establish links for future studies (Sthapit *et al*., 2008).

Four cell analysis (FCA) is a quick method of participatory approach to identify most important biological assets that play a role in livelihoods of local people. This would facilitate a systematic analysis based on farmer's opinion on distribution of local crop diversity and helps to identify the common, unique and rare plant genetic resources. The results of the analysis could be used for the conservation plans, diversified livelihood options for further research activities (Sthapit *et al*., 2008).

Community Biodiversity Register (CBR) is a documentation of genetic resources of farming community including information of the custodians of them, passport data, agro ecology and traditional knowledge. This could be effectively used to create awareness among farming community on important species with respect to conservation, management and monitoring genetic erosion and account on new species entry (Subedi *et al*., 2006). Diversity block also has the additional advantage of raising public awareness. Further, it can produce planting materials of rare cultivars for exchange among farmers and to re-fill the community seed banks and also can consider as an *ex- situ* collection site (Tiwari *et al*., 2006).

Assessment of agricultural biodiversity and the level of agricultural biodiversity available for utilization, and conservation requirements for future use was studied during a research project conducted at three villages of Thanamalvila Divisional Secretariat namely Mahaweva, Kahakurullanpellessa and Sooriyaara in Sri Lanka.

Materials and methods

At the initial stage of the project, transect walks were carried out for each village separately with the participation of farmers of the village and other officials from different disciplines during the month of February 2012. Four distinguish areas representing different kinds of ecosystems within the same territory were considered while designing transect. Village water tanks (Weva), low land rice, upland *Chena* and house hold settlements were important locations along transect to gather information with maximum diversity. Fundamental information on soil conditions, water availability, present crop diversity, earlier grown crop, livestock, natural resources, constraints faced by the farmers and their requirements were investigated. A transect diagram was prepared with the gathered information.

Two diversity fairs were conducted at Mahaweva village with the participation of farmers from three villages for the quick assessment of diversity related to finger millet and associated crops in August 2011 and July 2012. Custodian farmers were identified based on the number of cultivars belongs to them and the amount of traditional knowledge they had with respect to rainfed farming. Four cell analysis (Sthapit *et al*., 2006), (Figure 1) was carried out to identify common, unique and rare plant genetic resources with the farmers participated for the diversity fair.

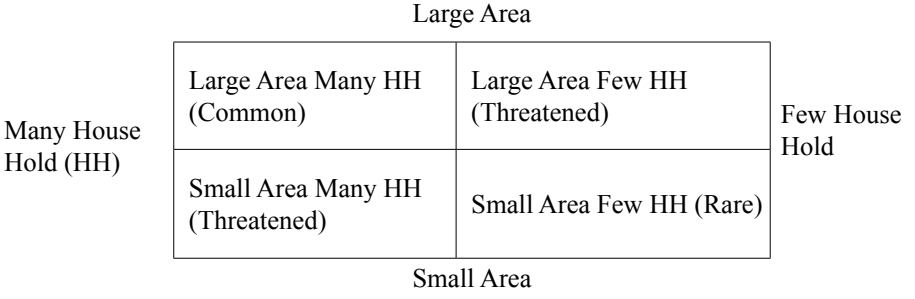

Figure 1. Diagram of four cell analysis

A format was developed for gathering information with three steps, including general information of three villages followed by data collection for community biodiversity register (CBR) including crop, vernacular name, scientific name, habitat and growth habit, area cultivated, present status, past information, specific characteristics, season of cultivation, traditional knowledge and their application. Prior to collecting data farmers were educated through training in small groups on CBR activities. Data collection was carried out as a group activity with the participation of officers, field assistants, farmer and the members of the farmer family of three villages Mahaweva, Sooriyaara and Kahakurullanpellessa during 2013 and 2014. Each crop and livestock were photographed for easy identification and completion of information.

Further, Simpson's Index (D), Simpson's diversity (1-D) and Simpson's Reciprocal Index 1 / D were calculated for both species level and variety level diversity of crops with respect to three villages. For biodiversity measurements, the Simpson's Diversity Index and Shannon Diversity Index are commonly used to measure the species richness, abundance and evenness at community level (Bioversity international, 2017).

The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i-1)}{N(N-1)}$$

where n_i = the total number of individual species/varieties

N = the total number all species/varieties

Results and discussion

Transect walk is a very quick assessment for locating crop and animal diversity, topography, natural resources available, constraints and requirements for improvements. The studied three villages were typical rain-fed dry zone villages, consisted with 3-4 minor irrigation tanks per each village within a cascade system. Water from each and every stream around the village were diverted to water collecting bodies such as village tanks or to Amuna aiming rice cultivation and to meet day today requirements. Forest of Udawalwe Natural Park surrounding these three villages was the major catchment for water streams. Most of the farmers still use slash and burn system of Chena cultivation in three villages. System of Chena cultivation has change due to the government prohibition on jungle clearing. Now the farmers are using same land for cultivation without giving adequate fallowing period. Continues cultivation of same land, no use of fertilizer with less land conservation methods had reduced the soil fertility. Weed problems also increased due to the accumulation of weed seed with continuous cultivation and ultimately reduced the yield potential of the land. Four different kinds of diversities observed related to the major categories of transects are shown in Table 1, 2 and 3. Considerable reduction in coarse grain cultivation has happened with the time, and the preference for vegetables and fruit crops has increased due to the demand and the income received from them. The identified major requirements were the improved irrigation and water harvesting facilities, good quality seeds and better adaptable varieties. Farmers need more water to cultivate vegetables and fruits than the crops grown in *Chena* cultivation.

Table 1. Transect diagram on soil, water, present crops, earlier grown crops, constraints and requirements of Sooriyaara

Criteria	Locations		
	Vijayapura - 02	**Vijayapura school road**	**Vijayapura - 16**
Soil	1.Low humic gley (Ash- Brown) 2. Reddish brown earths (uplands)	1.Reddish brown earths (uplands) 2. Sandy loams	1.Reddish brown earth (uplands)
Water	Kapati weva, Amuna 01, Mahaweva, wells	Palugasweva associated open wells, rain water harvesting tanks, bore wells	Open wells, rain water harvesting tanks, bore wells and surface runoff collecting tanks (Pathaha)
Present crops	Rice, Ladies fingers, Tomato, Water melon, Finger millet, Cowpea, Banana, Coconut, Spine guard	Banana, Mango, Rice, Cashew, Papaya, Pomegranate, Moringa , Cowpea, Maize, Finger millet	Maize, Bitter gourds, Cucumber, Banana, Pumpkin, Lime, Coconut, Moringa
Earlier grown crops	Rice , fallow lands for long time before that Finger millet, Proso millet, Fox tail millet, Kodo millet, and Chena vegetables	Sesame, Kodo millet, Proso millet, Fox tail millet, Finger millets	Sesame, Kodo millet, Proso millet, Fox tail millet, Finger millet, Maize and Cotton
Constraints	Salinity soils, low irrigation facilities	Water scarcity	Water scarcity
Requirements	Improved irrigation facilities	Increase the depth of Palugasweva Improvement of irrigation facilities and good quality seeds and better varieties	Improve water harvesting and irrigation facilities

Table 2. Transect diagram on soil, water, present crops, earlier grown crops, constraints and requirements of Kahakurullanpellessa

Criteria	Locations		
	Settlements around the temples	**Bambaragala area with HKT weva**	**Kahakurullanpellessa weva area**
Soil	Reddish brown earths, gravel soils (upper) brown soils and sandy soils (lower)	Sandy loams and clay soils	Reddish brown earths (uplands) and gravel soils. Low lands low humic gley soils
Water	Rain water harvesting from roof, surface runoff harvesting with Pathaha, tube wells and open wells and drinking water supply through tap line	HKT weva (115 ac paddy) Amuna 01, (07 ac of paddy) Amuna 02 (10ac of paddy), 4 agro wells	Kahakurullanpellassa weva open wells, rain water harvesting tanks, tube wells
Present crops	Groundnut, Cowpea, Finger millet, Sesame, Manioc, Banana, Coconut and upland Rice	Banana, upland Rice Cowpea, low land Rice, Tomato, Water melon, Pumpkin and Moringa	Rice, Coconut, Banana , Papaya, Mango, Chilli, Finger millet, Bitter gourd, Pumpkin, Water melon and Ela Batu
Earlier grown crops	Mung bean, Cowpea, Pumpkin, Ash pumpkin, Sesame, Ground nut, Proso millet, Fox tail millet, Finger millet	Proso millet, Foxtail millet, Finger millet and Mustard	Sesame, Kodo millet, Proso millet, Fox tail millet, Finger millet, Maize
Constraints	Cattle and wild animal damage, Water scarcity and change of rainfall pattern	Cattle and wild animal damage, Financial problems, Water scarcity	Water scarcity and wild animal damage
Requirements	Post harvesting technology, water pumps and rain water harvesting facility improvement	Good quality seeds, improved irrigation facilities and financial assistance during crop establishment	Good quality seeds, improved varieties, improved irrigation facilities and technical instructions related to agricultural practices

Table 3. Transect diagram on soil, water, present crops, earlier grown crops, constraints and requirements of Mahawewa

Criteria	Locations		
	Sinhalayagama	**Punchiweva**	**Mahaweva**
Soil	Reddish brown earths (uplands) and clay soil	1.Reddish brown earths (uplands) 2. Clay soil	1.Reddish brown earths (uplands) and clay soil
Water	Sinhalayagama weva (paddy 48 ac), drinking water facility for 80 families	Punchiweva (Paddy 10ac)	Mahaweva (paddy 180 ac), Open wells, rain water harvesting tanks, bore wells and surface runoff collecting tanks (Pathaha)
Present crops	Rice, Ela Batu, Tomato, Water melon, Finger millet, Cowpea, Banana, Coconut, Spine gourd,	Banana, Rice, Papaya, Chilli, Moringa , Cowpea, Maize, Finger millet Ela batu, Tomato, Water melon	Banana, Rice, Papaya, Moringa , Cowpea, Maize, Finger millet, Ela Batu
Crops earlier grown	Rice , Sesame, Groundnut, Finger millet, Proso millet, Fox tail millet, Kodo millet, and Chena vegetables	Sesame, Kodo millet, Proso millet, Fox tail millet, Finger millet	Sesame, Kodo millet, Proso millet, Fox tail millet, Finger millet, Groundnut maize, Rice
Constraints	Wild animal damage, water scarcity	Water scarcity	Water scarcity
Requirements	Improved irrigation facilities by rehabilitating old tanks	Rehabilitation of Punchiweva by strengthening the dam	Improve water harvesting and irrigation facilities, water pumps, and quality seeds

Crop diversity existing within the targeted area was prerequisite for the continuation of the research project. Diversity fair is a quick, simple and low cost approach for locating biodiversity. Sharing of local knowledge among participants, identification of rare and unique crop genetic resources, establish links for future studies and strengthening the seed flow network are the other benefits of diversity fairs. In the second diversity fair, participant exhibited better diversity in many crops. The highest crop diversity was recorded by vegetables followed by fruits. Cowpea also showed high varietal diversity.

According to four cell analysis based on the crop samples received during the diversity fair, Cowpea, Groundnut, Sesame, Maize and Finger millet (*Galmora Kurakkan* and *Kiri Kurakkan*) were identified as common group of crops grown in large area by large number of households. Mung bean was categorized as a rare group with respected to the studied area since it was retracted to small areas with many farmers. *Pinna* mung, *Kaha* mung, foxtail millet, *Proso* millet were considered as endangered since these were grown by few household in small areas. Kodo millet and horse gram varieties were not found within the experimental area. According to Rana *et al*. (2005) FCA mainly used for, classification of varieties according to population structure, identification of common and rare alleles for conservation, understanding of socioeconomic reasons and use value, and a decision making tool for on-farm conservation. According to the information gathered based on transect walk and diversity fair (Table 4) sesame, finger millet, proso millet, fox tail millet, kodo millet, chena vegetables were the crops mostly grown in the area in early days. Area of course grains have reduced due to low yield potential and high postharvest processing technologies. Vegetables and fruits cultivation has increased due to higher income generation. Four custodian farmers were identified during the diversity fair and they possessed more than ten types of germplasm related to finger millets, legumes and other millets. It was suggested to improve the diversity of rare, endangered and extinct varieties by re-introduction of germplasm through diversity blocks (varietal displays maintained at farmer level), community seed banks and improving the small scale post harvest processing units to increase the proper utilization of crops.

CBR activity was a new approach for documentation of biodiversity in Sri Lanka. Community Biodiversity Registers were made with respect to three villages with the participation of farming families and the knowledgeable people of the villages. Forty three farming families of three villages, 15 of Kahakurullanpellessa, 16 of Mahaweva, 12 of Sooriyaara were participated. According to the recorded data one hundred twenty two plant and herb species were found within the studied farming community which included 153 different crop varieties (Table 5). The highest richness of crop species was found in Mahaweva village and the highest number of crop varieties recorded by the individual farmer was 63 and followed by 56 and 50 by the other two successors of the same village. Radar chart indicated that number of crop species recorded by Kahakurullanpellessa village was lower compared to Mahaweva, and it was higher than Soriyaara.

Table 4. Local name, number of samples of different crops exhibited in the diversity fair at Mahaweva in 2012.

Crop	Local name	Number of samples	Crop	Local name	Number of samples
Cowpea	Black (Kalu kawpi)	3	Vegetables		
	Brown (Dumburu kawpi)	2	Wing bean	Dambala (two types)	6
	Dhawala	3	Yard long bean	Bonchi mee	4
	Red (Rathu)	14		Thissa mee	1
	Kadala	18		Polong mee	2
	White (Sudu)	16		Kootu leema	2
	Rata leema	5		Diga leema	1
Finger millet	Kiri kurakkan	8	Pumpkin		7
	Galmora	8	Amaranths	Green & red	4
	Introduced selections by project (seven)	28	Bottle gourds	Labu	1
Sesame	White	13	Hen Wetakolu	Two types (Diya wetakolu)	3
	Black	5	Brinjal	Wambatu	3
Sorghum		1	Ela Batu	Ela Batu	5
Proso millet	Meneri (two types)	3	Moringa	Murunga	2
Rice	Niwdu	3	Ladies fingers	Bandakka	4
	Red (Rathu kekulu)	5	Tomato	Takkali	1
	White (Sudu kekulu)	10	Bitter gourds	Kariwila	3
	Samba	1	Spinach	Niwithi	2
	Suwandel	1	Radish	Raabu	1
	Rice	3	Asamodagam	Asamodagam	4

Table 4(continued). Local name, number of samples of different crops exhibited in the diversity fair at Mahaweva in 2012.

Crop	Local name	Number of samples	Crop	Local name	Number of samples
Groundnut	Red	3	Fruits		
	White	1	Passion fruit	Wel dodam	1
	Thissa	2	Mango	Amba	3
Maize	Two types Local varieties (Waga irngu) & exotic hybrids)	22	Guava	Peera	1
Mung bean	Waga mung	9	Papaya	Gaslabu	2
	Pinna mung	3	Anoda	Weli anoda	1
Fox tail millet	Four type	3		Lawalu	1
Condiments	Chilli	4	Saur orange	Ambul dodam	1
	Tamarind	2	Sweet orange	Peni dodam	1
				Piti kekiri	1

According to Madhusudan *et al*. (2008), most widely used diversity indices that combine richness and evenness are the Shannon Weaver (Shannon and Weaver, 1963) and Simpson (Simpson, 1949) indices. Simpson Index of Diversity (1-D) was more than 0.7 for three villages indicated that all three villages are having higher species and varietal diversity. When considering the individual crops, cowpea recorded the highest varietal diversity with 8 different varieties which included both farmer grown varieties and Department of Agriculture recommended varieties. Second highest diversity was recorded by Yard long bean with six varieties. Compared to Sooriyaara, the other two villages were rich in crop varietal diversity due to high extent of Chena cultivation, better availability of water resources, soil type and comparatively older settlements. Kindt *et al*. (2001) described that, based on Simpson and other indices for richness calculations average species diversity varied according to farm to farm in four African counties including Western Kenya, out of them rich diversity was found with Kenyan farms. Based on the survey results further development activities will be planted in those counties.

It was identified that availability and extent of early grown crop varieties such as Foxtail millet, Proso millet and traditional famer grown vegetables has been reduced to a lower extent. Drastic genetic changes were observed by the farmers in their traditional maize and pumpkin cultivars due to out-crossing with imported hybrid varieties. Farmers explained that, they have experienced a reduction of inherent taste, aroma, and the pest and diseases tolerance levels of their traditional varieties due to changing of varietal characters with time.

Table 5. Summary of crops based on species and variety level in CBR of three villages

Crops	Mahaweva		Kahakurullanpellessa		Sooriyaara	
	Species (no.)	Varieties (no.)	Species (no.)	Varieties (no.)	Species (no.)	Varieties (no.)
Fruits	18	36	20	24	12	16
Other Field Crops	12	28	10	19	10	17
Trees	21		17		9	
Vegetables	19	35	12	14	11	11
Leafy vegetables	9	10	6	6	5	5
Culinary/Medicine	16	16	8	8	8	8
Yams	5	5	5	5	2	2
Total (N)	100	130	78	76	57	59

Table 6. Simpson's index, Simpson's diversity index and Simpson reciprocal index for species and variety level diversity in three villages

Index	Mahaweva		Kahakurullanpellessa		Sooriyaara	
	Species	Varieties	Species	Varieties	Species	Varieties
$\sum n(n-1)$	1532	3556	980	1182	482	700
N(N-1)	9900	16770	6006	5700	3192	3422
Simpson's index (D)	0.155	0.212	0.163	0.207	0.151	0.206
Simpson's diversity index (1- D)	0.845	0.788	0.837	0.793	0.849	0.795
Simpson's reciprocal index 1/D	6.462	4.716	6.129	4.822	6.622	4.889

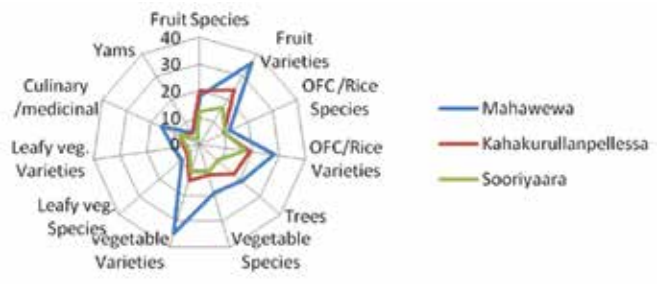

Figure 3. Radar chart representing crop diversity with respect to three villages of CBR activity

Conclusion

Village transect walks, diversity fairs, four cell analysis and CBR activities could be used for quick assessment of crop biodiversity in the selected sites. Reduction in coarse grains cultivation was observed. Yet a rich diversity of crops was observed within three villages having 123 crop species. Considerable amount of varietal diversity was recorded in fruit crops, field crops and vegetables. According to Simpson's index of diversity three villages has shown high diversity with respect varieties and species. The crops that are found in the rare category need to be increase with better awareness programs such as diversity blocks and strengthening of seed availability through seed flow. Diversity within Cowpea germpalsm was selected for enhancement of germplasm availability. *Kiri Kurakkan* and *Galmora Kurakkan* were selected for further evaluations in diversity blocks for yield and adaptability.

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