THREATS, DRIVERS, AND CONSERVATION IMPERATIVE OF AGROBIODIVERSITY

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ABSTRACT

Agrobiodiversity underpins food, nutrition and livelihood security, ecosystem and environmental health, and climate change resilience but it is under threat of extinction. This paper highlights threats of agrobiodiversity, its drivers and conservation imperatives. Review shows prior to the green revolution, several crops and varieties were found in situ and on-farm but the number has declined since then. Extinctionis contributing to decline in crop productivity and resilience and consequently the long-term sustainability of human wellbeing. Extinctionis attributable to various natural and man-made factors. Various international and national level efforts are underway but not adequate to curb the loss. Therefore, further efforts are required to conserve and utilize agrobiodiversity, which will require concerted efforts in exploring agrobiodiversity, identifying drivers of loss and bolstering conservation efforts.This can be done through implementation of biodiversity-friendly legislations, actions and incentive mechanisms adhering to relevant global and national level policies, negotiations and conventions.

Keywords: Agrobiodiversity loss, drivers, in situ conservation, policy, sustainable use

INTRODUCTION

Biodiversity for food and agriculture or agrobiodiversity, a sub-set of biodiversity,[1] is the product of a continuous interaction of living things, land, technology and social systemsfor nearly 12,000 years (Partap and Sthapit 1998; Smale and Drucker, 2008). Throughout the history of mankind, a bounty of agrobiodiversity existed in nature,on-farm and *ex situ* condition. Worldwide, about 3,000 edible plant species are discovered, of which 30 crops account for 90% of plant-based calories and only three (rice, maize and wheat) fulfill two-thirds of food requirement (FAO, 2009a). Similarly, only 10

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species of cereal grains, legumes and oilseeds cover 80% of the world's cropland (Glover et al., 2007). Nearly 67% of global crop production (by mass) is directly consumed by humanand crops alone account for 55% of global calorie production and 40% of global plant protein production (Cassidy et al., 2013).

Agrobiodiversity is a vital element of human life and sustainability of mother earth since it underpins ecosystem functions, ecological health and human livelihoods (FAO, 2019). More specifically, it is considered to be the basis for sustainable food and nutrition security and human survival since human food, medicine, fiber, fuelwood and other resources come from agrobiodiversity (Brush, 2004; Frison et al., 2011). Extreme events such as droughts and floods push species to extinction (IPCC, 2007; Pascual et al., 2011) but rich on-farm biodiversity helps adapt to such climate change impacts (Frison et al., 2011) and reduce climate vulnerability and risks (Lobell et al., 2008; Galluzzi et al., 2011; Woods et al., 2015). For instance, planting different varieties at different times and the adoption of new varieties may decrease negative impact (Rosenzweig and Parry, 1994) and planting fast maturing and late maturing plant species can avoid short, irregular, uncertain and erratic rainfalls (Cavatassi et al., 2011).

Agrobiodiversity managed adopting eco-agricultural practices also underpin ecosystem and environmental health by generating positive co-benefits for production, biodiversity and local people (Scherr et al., 2008). Agrobiodiversity also enhances agroecosystem functioning when mixing of high yielding and pest resistance genotypes increases nutrient input and cycling (Jackson et al. 2007). Agricultural landscape provides us with various ecosystem services that support human and wildlife– provisioning (food, fiber, fuel), supporting (nutrient cycling, soil formation) and regulating services (climate, flooding, disease regulation, and water purification) (Pascual and Perrings, 2007). Despite their utmost importance to human being, various crops and varieties are rapidly eroding from their important habitats. A large number of genetic resources are on the verge of extinction while a large number of them have already extirpated from the agricultural system before their full utilization was made. The extinction is rapid, irreversible and irreplaceable in several cases due to various endogenous and exogenous factors including climate change (FAO, 2009b), which is leading to the erosion of important gene pools and associated knowledge (FAO, 1997). Global level efforts have been made to curb the loss but that has remained inadequate, further threatening the loss of agrobiodiversity and our livelihoods. Thus, concerted effort is required to protect agrobiodiversity for improving food security and resilience of agroecosystem. This paper discusses about agrobiodiversity loss, its drivers, current conservation efforts and future strategy to strengthen agrobiodiversity conservation efforts.

THEORETICAL FRAMEWORK

THREATS TO AGROBIODIVERSITY

Genetic erosion is a“loss of genetic diversity between and within populations of the same species over time, or reduction of the genetic base of a species” (Jarvis et al., 2000). In other words, it is the loss of species, varieties and alleles which affect species richness (Nabhan, 2007).The genetic erosion continues unabated worldwide. A wholesale loss of plant genetic resources, also known as “genetic wipe-out”, is also a continuous process and it is rampant worldwide (Harlan, 1975; Wilkes, 1993; Chhetri and Chaudhary 2011). International Centre for Agricultural Research in the Dry Areas (ICARDA) warns about two decades ago that, up to 60,000 (about 25% of the world’s total) plant species would be lost by the year 2025 if the trend continued (ICARDA, 1999).

Prior to the Green Revolution, some 30,000 landraces of rice were grown in India, but now 50 modern varieties predominate the rice growing environments (Hardon, 1996). In China, nearly 10,000 wheat varieties were believed to be grown in 1894, but the number reduced to only around 1,000 by the 1970s. The United States had lost over 90% of the local cultivars of cabbages, maize, and peas grown the past century toward the end of 20th century (FAO, 1996). Similarly, in Nepal about 50 % of local crop landraces or traits and 40% of total agrobiodiversity (crops, forage, livestock, aquatic agricultural genetic resources, insects and microbial genetic resources) are believed to be lost and many remained threatened mainly due to replacement by modern varieties, less use of local races in breeding and non-profit agricultural business (Upadhyay and Joshi 2003; Joshi et al., 2020).Chaudhary et al., 2004 have mapped varietal loss and genetic erosion of rice varieties in Bara district of Nepal using a few case studies and they revealed several social, economic and ecological drivers of varietal replacement. Sherchandet al., 1998 documented currently existing, threatened and lost varieties of rice, finger millet, sponge gourd, cucumber, taro, pigeon pea in Bara district, which is summarized in Table 1. Some introduced agricultural crops are invasive species that are spread beyond their planned range thus displacing native species and affecting ecosystem functioning (Mooney et al. 2005). According to Paini et al. 2016, Nepal is the third most affected country by plant invasion in agricultural system.

Table 1. Number of existing and lost landraces (LR) reported in different villages of Bara, Nepal

No.	Village	Existing cultivated LRs	Lost LRs
1	Amarpatti	5	9
2	Bachanpurwa	14	12
3	Bariyarpur	13	5
4	Chhatapipara	6	8
5	Dumarwana	6	6
6	Inarwasira	4	13
7	Jitpur	10	6
8	Kachorwa	24	2
9	Kolvi	4	5
10	Lipanimal	3	10
11	Mahendra Adarsh	6	4
12	Matiarwa	2	17
13	Parsurampur	2	14
14	Prastoka	2	21
15	Sapahi	11	7
16	Sinhasani	7	6

Source: Sherchand et al.,1998; Chaudhary et al., 2004

DRIVERS OF AGROBIODIVERSITY LOSS

Agricultural system, along with the refugia of agrobiodiversity, is continuously evolving as a result of natural selection and human selection, either deliberate or unintended, of desired crops and varieties (IPGRI, 1997; FAO, 2009). Some examples are given in Table 2 and further discussed below.

Natural drivers

Natural selection is affected by macro and micro environmental factors of the growing areas and surrounding. Climate variability and change have various effects on species through altering hydrological cycles, high temperature and variation in the length of growing season and increased frequency of extreme weather (Reilly and Schimmelpfenning, 1999). Scientists have pointed out climate change and variability as an increasing threat to agricultural yields and food security (Lobell et al., 2011).

Anthropogenic drivers

Various manmade activities also cause negative effect on agriculture. Modern techniques in agriculture exacerbates climate change when greenhouse gases are released by chemicals used in field, land clearing and other practices (Smith et al., 2007).A recent study done by Aryal et al. (2017) documented five anthropogenic drivers of crop diversity losses (Figure 1). The leading cause of loss of crop genetic resources was found to be the availability of the improved and hybrid seeds (77%) followed by seasonal migration of the human force (56%). Human decisions on crop and variety selection are influenced by land ecology, environmental factor, sociocultural and economic factors, market institutions and government policies (IPGRI, 1997; Gauchan et al., 2003; Chaudhary et al., 2004; Rana et al., 2007).

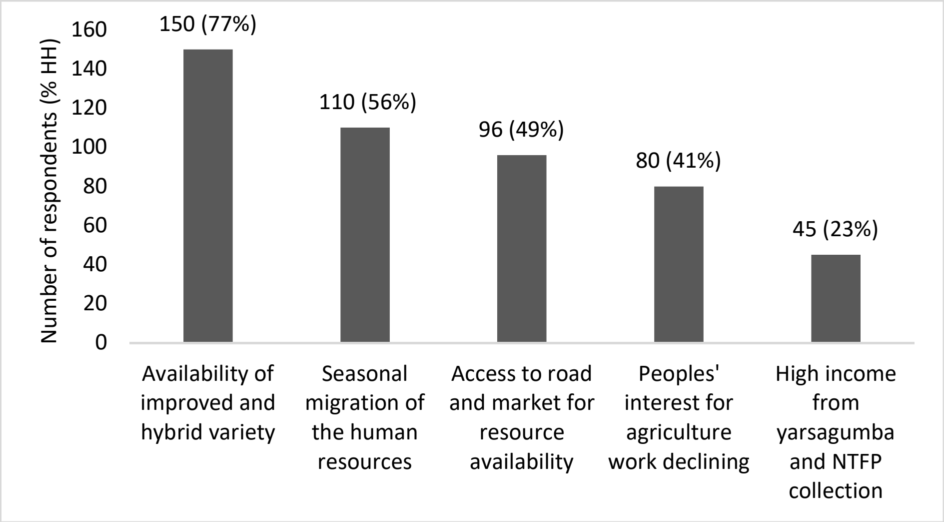

Figure 1: Drivers of agrobiodiversity loss (Adapted fromAryal et al., 2017)

Table 2. Examples of natural and anthropogenic drivers of agrobiodiversity loss and genetic erosion

Type of driver	Drivers of change	Nature of loss and extinctions	Reference
Natural	Natural selection	Biotic and abiotic stress tolerant species survive, and others go extinct	Sthapit et al. 2015; Solankey et al. 2015
	Land use change	Habitat for species is disturbed and turned out to be unsuitable The traditional agricultural land has been brought under cash crops Population growth and land fragmentation	Aryal et al. 2017; Jose and Padmanabhan, 2016; Upreti and Upreti, 2002; Maikhuri et al., 2001
	Climate change and disaster	Increase temperature, drought, diseases and pests result in the loss of poorly adapted crop species and cultivars	

Anthropo-genic	Change in food choice, preferences	Local landraces replaced by modern varieties due to introduction of new varieties, alteration of food choice	Agnihotri and Palni, 2007; Rana et al., 2007; Aryal et al., 2017
	Market demand and value chain	Except a few well-known local varieties, others are not preferred by consumers due to lack of promotional activities Change in cropping pattern due to comparative economic advantage Access to road and market leading to easy availability of the fast foods and resulting in the loss of traditional crops Value chain of uniform and modern crops and varieties results in the loss of traditional diverse crops	Aryal et al., 2017; Nautiyal et al.. 2008; Gauchan et al., 2019
	Gene manipulation through breeding and non-breeding approaches	Gene manipulation introduces new genes at the cost of certain old genes, so the old one is lost Poor recognition of informal seed exchange and farmers network	Poudel et al., 2015; Hodgkin et al., 2006
	Human response to climate change and disasters	Local landraces replaced by modern varieties due to drying up of pond Farmers' perceptions on climate change risks on cereal crops	Katwalet al., 2015
	Seasonal and or out migration	Seasonal migration of the human resources to city areas and abroad Peoples' interest on agriculture work is declining	Aryal et al., 2017; Nautiyal et al., 2008
	Lack of transfer of traditional Knowledge	No systematic documentation of ethnomedicinal uses of traditional landraces, leading to poor knowledge transfer Younger generation is unaware of the distinct properties of the landrace diversity	Aryal et al., 2018; Nautiyal et al., 2008

AGROBIODIVERSITY CONSERVATION STRATEGIES ADOPTED WORLDWIDE

Agrobiodiversity conservation efforts have been made by government organizations and their allies worldwide for centuries. Farmers are also making intended and unintended efforts to conserve, manage and utilize agrobiodiversity. The effort has been further accentuated following the call to action of the Convention on Biological Diversity (CBD, 1992) for halting the current loss of plant and crop diversity while contributing to poverty reduction and sustainable development. Agrobiodiversity conservation strategies broadly include *exsitu* and *insitu* (Maxted et al., 1997; UNCED, 1992) and its promotion can be done, *inter alia*, by establishing living collection and germplasm banks and introducing varieties of species to agroecosystem (Long et al., 2003).Nepal has adopted four strategies (namely *ex situ*, *in situ*, on farm and breeding) separately for management of six components of agrobiodiversity (crop, forage, livestock, aquatic agricultural genetic resources, insect, and microbe) as summarized by Joshi and Upadhya(2019) and Joshi et al. (2020).

In situ conservation

In situ conservation means conserving diversity in the setting where it developed (UNCED, 1992). CBD (1992) defines "In-situ conservation' as the “conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties”. It, along with on-farm conservation, is “the continuous cultivation and management of a diverse set of populations by farmers in the agroecosystems where a crop has evolved” (Bellon et al., 1997). Various *in situ* conservation methods have been adopted by different countries as summarized in Table 3. On-farm conservation encourages farmers to continue selection and management of local crop populations (Brush 1999). On-farm conservation has focused on *de facto* conservation in centers of origin (Qualset et al., 1997; Brush, 1991), but exceptionally valuable varieties are found outside their centers of origin (Vavilov, 1951). Resource-poor farmers in marginal environments often maintain large amounts of agrobiodiversity (Maxted et al., 2002; Wood and Lenne, 1997; Bellon, 1996).

Ex-situ conservation

Ex-situ conservation is about conserving diversity outside of natural habitats (UNCED, 1992) including genebank storage (seed and field), in-vitro storage, pollen storage, and DNA storage (Maxted et al., 1997). In globe, 4,362,100 accessions of Plant Genetic Resources for Food and Agriculture (PGRFA) are maintained of which Nepal contributes about 23,600 accessions of plant genetic resources conserved in more than 12 countries (Joshi et al., 2016). *Ex situ* conservation is also the source of re-introduction and restoration of genetic diversity (van de Wouw et al., 2009) but the *ex situ* sites are not immune to genetic erosion which is mainly the result of the loss of accessions and alleles due to poor regeneration and storage practices (Parzies et al., 2000). The target 8 of Global Strategy of Plant Conservation (GSPC) 2010-2020 reveals at least 75% of the threatened plant species are in *ex situ* conservation and around 20% are available for restoration.

Table 3. Examples of in situ, ex-situ and on-farm conservation methods have been adopted by different countries

Conservation strategy	Growing condition (Habitat)	Examples of conservation methods	Characteristics
In situ	Wild habitat	Crop wild relatives Wild edible plants Uncultivated plants	Plants and animals available for food and agriculture that support human economy, livelihoods and wellbeing.
	On-farm	Farmers' field	Local landraces grown by farmers for generations, so co-evolved with natural, social, cultural, economic and environmental change
		Diversity block	A number of crop varieties found in local communities growing in a single plot for demonstration, multiplication, regeneration and awareness
		Community seed bank	Community-initiated seed conservation and distribution mechanism where seeds are stored in a locally constructed house
		Field genebank	Often biennial and perennial crops are grown in field to conserve them
		Participatory Crop Improvement (PCI)	A number of varieties are given to farmers to grow and choose the best from (also called basket of choice)
		Participatory Plant Breeding (PPB)	Crossing made between local germplasm and modern variety to retain desired traits from both
		Value chain and Market Development	Value addition, value chain and market development of underutilized and traditional crop biodiversity

Ex situ	Genebank & preservation centers	National genebank& International genebank	Genebanks equipped with high voltage cold storage where germplasms can be preserved for hundreds of years depending on the level of low temperature maintained
		Seed vault	Natural seed storage in perennial snow-covered polar region (permafrost), which are duplicate samples or spare copies of germplasms stored in genebanks
	Other *ex situ* sites outside genebanks	Botanical garden	A large number of flowering and non-flowering plants are grown for recreation purpose
		Parks	Protected areas from where people collect their wild food
		Research stations	Several local landraces are planted in research stations for research and development

GOING FORWARD – CALL FOR ACTION

Although several agrobiodiversity conservation strategie have been developed and practiced by farming communities, public and private organizations, the current efforts are not adequate. A complete picture of the total agricultural diversity worldwide is not knownhitherto. Information for wild relatives and wild edibles is even scarcer. It is thus important to further explore agrobiodiversity in different habitats along with social, cultural, economic and ecological information associated with them. Location-specific drivers of agrobiodiversity loss need to be identified for developing strategies tailoring to local needs and priorities.

It is important to integrate different conservation approaches. Article 9 of the Convention on Biological Diversity (CBD) emphasizes the complementarity of *ex situ* and *in situ* conservation of species through facilitating exchange of plant genetic resources between farmers and genebanks (Thormann et al. 2006). So, a multi-disciplinary conservation strategy that integrates *insitu* and *exsitu* management processes is necessary wherever appropriate (Conway 2007; Byers et al., 2013; Schwartz et al., 2017), which necessitates an adaptive management processes and a strong collaboration at all levels of conservation action including planning, implementation, monitoring and assessment (Schwartz et al., 2017).This will also require engagement of multiple actors with different complementary skills. Community seed banks and community field genebank have been developed to bridge gap between genebank and farmers. They play the role of facilitator and a platform for knowledge exchange (Chaudhary, 2013). Generally, *ex situ* conservation for plant breeding involves collection, classification, evaluation and utilization of agrobiodiversity and community seed banks support genebanks in collecting, regenerating, and exchanging genetic materials (Vernooy, 2018; Joshi et al., 2018).

From a sustainable food system perspective, the diversity held in gene banks or *in situ* and on farm do not support and promote optimum conservation without their sustainable use in food and nutrition security and livelihood of the increasing global population. For instance, *ex situ* facilities represent tip of the ice bergs as gene banks have largely focused on conservation of major staple crops, while non-staple crops represent only 2% of materials stored and crop wild relatives are also poorly represented (Dulloet al., 2019). Furthermore, even diversity held in *ex situ* facilities can face genetic erosion due to inadequate management practices as a result of insufficient support, lack of duly trained staff and frequently overwhelmed and underfunded conservation programs. Value chain development of underutilized nutrient dense food crops can directly improve the livelihoods and nutrition security of poor farmers in marginal environments by increasing yields, managing marginal lands and improving income of the households (Gauchanet al., 2019).

Further policy gap analysis needs to be done to examine policy incentives and barriers and suggest formulation and revision of policies based on the identified gaps. It is also important to build strong network with global communities working on agrobiodiversity conservation in order to exchange knowledge, human resource and financial resources for sustainable management and utilization of agrobiodiversity. Using local crop varieties for future breeding can also curb genetic erosion asit can help retain useful genes from rare varieties. For this, participatory approaches such as participatory plant breeding and participatory crop improvement can be applied to develop locally acceptable and future climate-smart varieties. In addition, future smart crops, including neglected and underutilized species, need to be promoted to meet the future demand of nutritious and climate resilient crops so that people can be fed sustainably for several generations from now.

The Convention on Biological Diversity (CBD), Nagoya Protocol and International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) are important international instruments guiding conservation and use of agricultural biodiversity. However, current international attention to biodiversity focuses mainly on conservation of “globally-important” forest and wildlife biodiversity with less attention given to importance of agrobiodiversity to food security and livelihoods of the poor, and the vulnerable communities (Gauchanet al., 2017). This has resulted in loss of agrobiodiversity. There are various economic, non-economic and indirect incentives that influence conservation and sustainable use of agrobiodiversity (Gauchan et al., 2005; 2016). The major gaps and challenges to be addressed include the formulation and implementation of biodiversity friendly legislative framework, action plans and incentive mechanisms (royalty, subsidy, value addition, property rights, benefit sharing, rewards, recognition etc.) supporting conservation, sustainable use and their integration in national development programs (Gauchanet al., 2017). However, experiences of incentive schemes for conservation and agri-environmental schemes indicate that incentives need to be carefully designed in order to avoid pitfalls and achieve the desired outcomes (Attwood et al., 2017).

CONCLUSIONS

Agrobiodiversity is important for food and nutrition security and climate change resilience of farming communities worldwide. Its conservation and proper utilization are thus necessary in order to sustain human live on earth. However, we have already lost precious agrobiodiversity from different households, farms and agroecosystems and extinction of remaining ones continues unabated. Various natural and man-made factors are attributable to extinction of agrobiodiversity. So, the ongoing loss of agrobiodiversity from farmers' fields or on-farm is of concern to global community. Proper strategies to promote agrobiodiversity are crucial in the future to cope with risks presented by climate change and non-climatic factors. Various strategies, *in situ, ex situ,* and on-farm, are adopted by farming communities, practitioners, NGOs and governments to conserve and promote valuable agrobiodiversity but the current efforts and strategies are not adequate to curb the ongoing loss of agrobiodiversity. It calls for national and global level efforts to conserve agrobiodiversity and harness its benefits now and in the long run. Therefore, breeding techniques combined with market-led approaches supported by national and international level policies are necessary to conserve valuable agrobiodiversity and increase its utilization for improving farmers' benefits, satisfying consumers' needs, and helping cope with changing social, economic, environment and climatic conditions in the long run.

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