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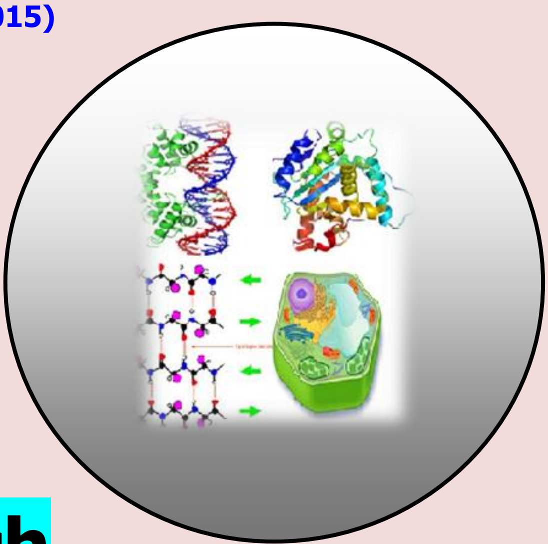

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RESEARCH PAPER

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Assessment of Genetic Erosion on Crop Genetic Resource Diversity in Ethiopia: An Implication for Conservation

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ABSTRACT

Ethiopia is the centre of origin and diversity of many important crop species. These diverse genetic resources are used, conserve and managed by farmers' by their indigenous knowledge to meet their livelihood needs. Presently, the indigenous crop genetic resources and farmers' indigenous knowledge are seriously endangered and exposed to the high rate of genetic erosion. Accordingly, assessment on Ethiopian genetic resource, estimates the rate of loss and identification of major factors that causes of genetic erosion are crucial for conservation and sustainable use. Presence of natural calamities, population pressure, market preferences, agricultural modernizations, urbanization, biotic factor and changing of cropping patterns due to climate change and environmental degradation are the main factors and largely affected the magnitude of the crop genetic diversity in the country. If this trend continues, the gene pool of crop genetic resources could be lost in the near future. Besides, conservation of crop genetic resource receives less attention and agricultural extension in the country has focused on the improved varieties to maximize yield. This is partly due to low attention to the value of indigenous crop genetic resources and the ambition to fill national gaps in food security. To increase diversity and conservation of crop genetic resources in the country, exchange of landraces (genetic enrichment) between farmers, districts and regions, training on the diversity, use, production and postharvest utilization on crops, collect different crop landraces from growing areas, characterize and use the combination of one or more strategies are vital to conservation and sustainable utilization of crop genetic resources in the country.
Keywords: Crop, Diversity, Genetic Resources, Genetic Erosion and Sustainable Utilization.

INTRODUCTION

Agriculture is the back bone of Ethiopia's economy. It contributes about 45% of gross domestic product (GDP), employs 85 % of the labor force, generates over 90 % of the foreign exchange earnings, and supplies the bulk of raw material for the industrial sector (FAO, 2004a; Anon, 2005). With the ever-growing population size, food and nutrition insecurity has become one of the biggest challenges in Ethiopia, while the country endowed with a rich crop diversity that can be valued to overcome hunger and poverty (Teshome, 2006). Currently, the growth rate in agricultural products is much less than population growth rate in Ethiopia (Awulachew *et al.,* 2010). For instance, during the period 1992-2004 annual average Ethiopian population growth rate was 2.7 %, while, the annual average growth rate for agriculture was 0.67% (MoFED, 2006). Rapid population growth in Ethiopia has brought about numerous changes in the traditional farming systems (Leulseged *et al.,* 2013). Dramatic changes were observed in farming systems and individual crops as well as peoples' lifestyles. That means actual and potential threats are progressing from different directions thereby affecting the sustainability of traditional farming systems. The changes are in the forms of replacement of local seed system by formal seed system, expansion of use of improved varieties, shifting from organic to inorganic fertilization of farms as crop residues became major animal feed and animal manure are becoming important sources of fuel by the farming communities (Anon, 2003). Despite changes in traditional farming system, low attention has been paid to conservation of crop genetic resources and documentation of farmers' indigenous knowledge. In this regard, very few studies have examined the significance of traditional farming system and the extensive use of improved varieties in modern agricultural system (FAO, 2004a; Anunda *et al.,* 2014). The current sustainability debates highlights this lack of knowledge and recommend that field studies of traditional system should be undertaken to fill the gap (Cromwell, 1996). In connection with the current displacement of landraces by improved varieties of crops, the claim that improved varieties of few crops feed the world should be critically reviewed (Zedan, 1995).

Crop genetic resources constitute the building blocks of modern agricultural production to feed the growing of people currently we face (Mulualem, 2017). They form as the raw material from which new varieties have been systematically bred to meet the growing need for more food (FAO, 2004a). Besides, crop genetic resources are important sources of genes for crop improvement and resistance to major biotic and a biotic stress (Xiao *et al*., 1996). In many cases, small-scale farmers mainly depend on local genetic diversity to ensure sustainable production utilization and meet their livelihood needs. Loss of genetic choices as reflected by loss of traditional crop varieties diminishes farmers' capacities to cope with changes in pest and disease infection that leads to yield instability and loss (Teshome, 2006; UNEP, 2010). The use of variety mixtures, multiline, or different varieties in the same production environment, has been found to reduce disease incidence and increase productivity without the need for pesticides. Mixing crop species and/or varieties can delay the onset of diseases by reducing the spread of disease carrying spores, and by making environmental conditions less favorable to the spread of certain pathogens (Altieri, 2004). Most of known resistance to pests and pathogens in crops used in breeding programmes is derived from local varieties collected from farmers who traditional grow them in genetically diversity systems. Even so, the development of new cultivars grown as monocultures continues to be central to modern agriculture. Breeding programmes exist to develop new varieties and to replace varieties that have "lost" their resistance, but the maintenance cost of the current system is high (Jarvis *et al*., 2011). Traditional crop varietal diversity is an important aspect of farmers' strategies for resistance to diseases and pests. Increased diversity in farmers' fields, measured by the number (richness) and spatial distribution (evenness) of local and modern crop varieties was correlated with a decrease in damage levels as the intensity of pest and disease pressure increased. In addition, there was a consistent reduction in variance of damage levels as diversity increased.

Indigenous crop genetic resources are a fundamental to the growth of agricultural production and food security as well as to environmental conservation in Ethiopia (Teshome, 2006).

Equally imperative as genetic erosion of farmers' varieties is the loss of crop genetic resources in natural habitats due to the expansion of commercial agricultural production that are based on few improved varieties, changes in cropping system and markets preferences have highly affected the magnitude of crop genetic resource diversity in the country (FAO, 1996). In this regard, Worede (1997) indicated, genetic erosion of crops and their wild relatives are accelerating at a higher rates, due to of human intervention in Ethiopia. The recurrent drought in the past decades has eroded considerable amount of crop genetic resources in the country (Anunda *et al.,* 2014). Furthermore, less is known about the causes, effects and the degree of genetic erosion on local varieties of crop plant species or list of varieties/landraces lost in various parts of the country. Presently, the indigenous crop genetic resources of Ethiopia are becoming endangered owing to the high rate of genetic erosion resulting from biotic, a biotic and socioeconomic factor. Moreover, limited attention has been given to assess the diversity and conservation of indigenous crop genetic resources. As a result, some of indigenous crop genetic resources in Ethiopia are endangered, even they may be lost before they characterize and conserve (Mulualem, 2017). Loss of genetic diversity is detrimental to crop improvement programmes. To prevent this loss all stake holders in the country endeavoring to conserve and efficiently utilize the existed genetic resources. Besides, crop genetic resources and farmers' indigenous knowledge must be collect, characterized, evaluated, conserved and documented for present and future generation. Accordingly, this review was designed, to assess the rate of crop /landrace loss (genetic erosion) of crop genetic resources, methods used to estimate genetic erosion and diversity and identify major factors that causes of genetic erosion in Ethiopia.

Centers of Origin and Diversity of Crops

Centre of origin is defined as the primary centre of *in situ* diversity for a given crop and continued gene flow between crops and their wild relatives can occur (FAO, 1996). Centre of diversity is defined as geographical area where a wide genetic diversity is found for particular crops and related species (UNEP, 1992; Almekinders and Louwaars, 1999). This definition is, however, difficult to rely on. In some cases, different species of the same crop might have been domesticated in different places, for example, yams were domesticated in West Africa, Southeast Asia, and in tropical America (Harlan, 1976; Tamiru, 2006). Furthermore, since evolution outside the centers of origin has resulted in different genetic constitution of the materials, it can be argued that these materials originate from the farms, where they were further shaped and maintained by farmers (Mekbib, 2007). Currently, sophisticated methods of looking genetic diversity, such as isozyme and molecular analysis, it has become clear that most genetic diversity in a crop is not necessarily found in its centre of origin. In this regard, Ethiopia is an important center of domestication and genetic diversification centers of crop species and their wild relatives (Vavilov, 1951; Purseglove, 1968; Mooney, 1979; Zeven and de Wet, 1982; Hancock, 1992). Local cultivars/farmers' varieties of different major crops and wild relatives of some of the world's important crops are abundant in Ethiopia (Harlan, 1969).

Over View of Crop Genetic Resources in Ethiopia

There are 270,000 known plant species. Of these, about 7000 or more are being cultivated and/or used by humans for food at one time or another (FAO 1996a; Sadhan and Dipak, 2016). Of these, 30 crops provide 95% of calories in the human diet and three crops (wheat, maize and rice) supply more than half (56% of calories) (Zedan, 1995). Besides, seven crops, sorghum, millet, potatoes, sweet potatoes, soybeans and sugar (cane/beet) bring the total to 75% of the energy intake (FAO, 1996). According to Prescott-Allen and Prescott-Allen (1990) indicated that, 103 species of plants contribute 90% of the world plant food supply. Unique accessions estimated to be one or two million only. It is estimated that currently some 30% of know threatened species are maintained in living collections, while, 2% of threatened species are included in recovery and restoration programmes and 34,000 plant species are classified as globally threatened with extinction (Global strategy for Plant Conservation, IUCN).

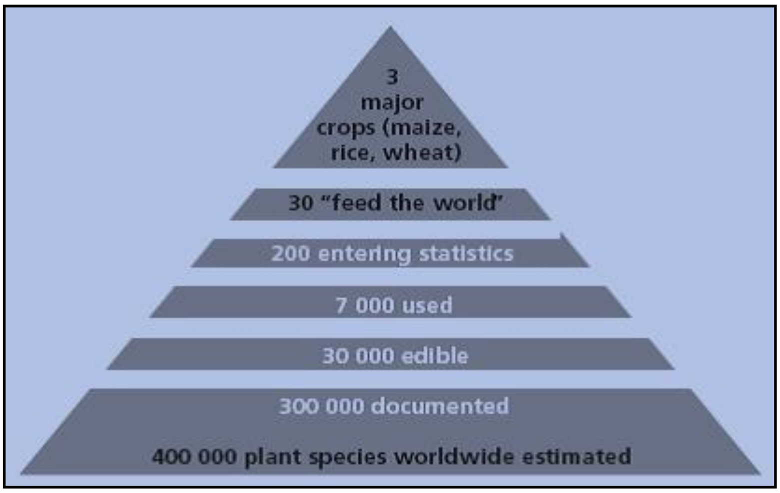

Figure 1. Use of crop species diversity in agriculture, source FAO, 1996.

The Ethiopian region is characterized by diverse agro-ecology, which account for the huge diversity of biological resources that exist in the country (Mekbib, 2007). These biological resources are the enormous genetic diversity of the various crop plants grown in the country. For many crop species, Ethiopia is considered to be the centre of origin and diversity, for example, *Eragrostis tef* (tef), *Coffea arabica* (buna), *Guizotia abyssinica* (nuge),*Rhamnus prinoides* (geeshoo), *Ensete ventricosum* (enset), Yam (*Dioscorea abyssinica*) and *Catha edulis* (chat) are distributed over a wide range of agro-ecological areas in the country (Vavilov, 1951; Harlan, 1969; Worede, 1991). These diverse genetic resources are used and managed in various ways by farmers' communities. The indigenous plant species, their wild relatives and weedy species which form the basis of Ethiopia's crop genetic resources are highly prized for their potential value as sources of important variations for crop improvement programs (Mulualem, and Bekeko, 2014). The most important domesticated crop plant species in Ethiopia are: sorghum, barley, teff, chickpeas, and coffee, largely represented in the country as the landraces and wild relatives that are uniquely adapted and genetically diverse forms (Kebebew, 1997). The genetic diversity found in Ethiopian wild crop relatives have been used worldwide for develop new resistant crop varieties and addressing acute yield constraints currently we faced. For example, Zerzara sorghums from Ethiopia have provided resistant to downy mildew in many inbred lines and widely used in the United States and Mexico resulted in a gain to productivity of millions tons per year. Probably the absolute monetary benefit is greater than the sum needed to conserve all sorghum diversity in perpetuity (Mekbib, 2007).

Table 1. Major crop types and total number of collections.

Crop type	Total no. of collected and donated accession	Percent (%)	No. of accessions collected by PGRC/E	Percent (%)	% of total no. of accessions
Cereals	28849.0	73.1	8219.0	56.4	28.0
Oilseed	4490.0	11.4	2355.0	16.2	52.0
Legumes	4170.0	10.6	2890.0	19.8	69.0
Spices	749.0	1.9	520.0	3.6	69.0
Coffee	702.0	1.7	140.0	0.9	20.0
Medicinal	62.0	0.1	61.0	0.4	98.0
Others	452.0	1.2	397.0	2.7	88.0
Total	39474.0	100.0	14582.0	100.0	

Source: PGRIE (1991)

Much of this crop diversity is found in farmers' fields that, aided by nature, have played a central role in the creation, maintenance, and use of these invaluable resources (Mark van *et al.*, 2009). Peasant farmers' in Ethiopia translate their deep understanding and use of different wild crop relatives, or the general biology of their surroundings from farming systems that are best adapted to their own circumstances.

In Ethiopia the main cereal staples include durum wheat, bread wheat, barley, *tef*, finger millet, maize and sorghum grown in varying proportions according to soils, altitude and the prevailing climatic and market conditions during planting seasons. Cereal production comprises about 82 % of the total cultivated land area, and pulse a further 12 % (FAO, 2004a). The continued interaction of cultivated crop plants with their wild crop relatives under diverse ecological, social, and economic conditions has made the country one of the most heterogeneous areas of the world in terms of genetic diversity of farmers' varieties. For instance, crops that were originally domesticated outside of the East African highlands exhibit extreme secondary diversification in Ethiopia (Vavilov, 1951; Harlan, 1969). According to Harlan (1969), sorghum, finger millet, okra, castor bean, and sesame could be of Ethiopian origin. Numerous useful genetic variations of global significance have evolved at the local farm and farming community in the country. These diverse genetic resources are used and managed in various ways by communities.

Today Ethiopia's biological wealth is being depleted at an ever-increasing rate and this will adversely affect the livelihood security of people in the country.

Threats to Crop Genetic Resources

Genetic Erosion

Genetic erosion is defined as the loss of variability from crop populations in diversity centers, i.e. areas of domestication and secondary diversification (Brush, 1999; Loko *et al.,* 2015). It implies that the normal addition and disappearance of genetic variability in a population is altered, so that, the net change in diversity is negative (Tsegaye and Berg, 2007). According to Guarino (1998) genetic erosion as a permanent reduction in richness or evenness of common localized genes or alleles or the loss of combination of alleles over time in a defined area. Genetic diversity is always dynamic, according to the report on the State of the World's Plant Genetic Resources (FAO, 1996), summarizing country reports, suggests that "recent losses of diversity have been large, and that the process of 'erosion' continues". The report further explained that, about 10,000 varieties of wheat, which were in use in China in 1949, only 1,000 remained in 1970. Besides, in United States of America, 95 % of cabbage, 91 % of maize, 94 % of pea, 86 % of apple and 81 % of tomato varieties of last century have been lost (Arunachalam, 1998). From this report, clearly understand that the trend of genetic erosion is worrisome (Mark van *et al*., 2009). Nevertheless, monitoring genetic erosion of crop species/varieties at any scale requires understanding of the concepts and causes of genetic erosion in a particular crop (Friis-Hansen, 1999; Ford-Lloyd, 2006).

In Ethiopia, the local crop genetic diversity acutely endangered for high rate of genetic erosion, due to natural calamities, population pressure, market preferences, agricultural modernizations, urbanization, high pest and disease pressures and changing of cropping patterns due to climate change and environmental degradation have largely affected the magnitude of the crop genetic diversity in the country (Hildebrand *et al*., 2002; Megersa, 2014). If this trend continues, the gene pool of crop genetic resources could be lost with in short time. Moreover, on farm genetic resource conservation receives less attention and agricultural extension in the country has focused on the improved varieties to maximize yield (Yifru and Karl, 2006). For many decades the government agricultural policy did not adequately address the role and contribution of indigenous crop genetic resources could play (Tamiru, 2006; Tsegaye and Berg, 2007). This is partly due to low attention to the value of indigenous crop genetic resources and partly because of the ambition to fill national gaps in food security (Mulualem, 2017).

Besides, information on traditional farming system on crop genetic resources in Ethiopia is scanty (Teshome, 2006). The rate of genetic erosion of crops and their wild relatives is accelerating at an alarming rate due to human interventions (Sadhan and Dipak, 2016). The frequent drought in the past decades has eroded considerable amount of biodiversity in the country. In addition, the causes, effects and the degree of genetic erosion on local landraces or list of varieties/species lost in various parts of the country are unknown. Furthermore, the causes and effects of the genetic erosion of crop genetic resources are poorly understood in Ethiopia (Megersa, 2014).

Factors that causes of crop genetic erosion

In the current situation, different farmers named crops that had cease cultivation areas or which entirely disappeared and were no longer cultivated by farmers in many growing areas. Some other species had undergone notable reductions during the decades (Anunda et. al., 2014). Crop genetic erosion is a complex process and several factors that involved either directly or indirectly on existed crop landraces (Mark van *et al*., 2009). Some of these factors are related to socio-economic factors in general, while others are related to biotic and a biotic factor (Loko *et al.,* 2015). Agenda 21 of the Rio declaration on environment and development states that, 'the current decline in biodiversity is largely the result of human activity and represents a serious threat to human development' (Sadhan and Dipak, 2016). Generally, habitat loss or modification, over-exploitation, introduction of exotic species, disturbance, disease and limited distributions are quoted as factors currently endangering biodiversity (Muchiru, 1985; WCWC, 1992). Threats endangering the genetic diversity of cultivated plants could be seen from global environmental change and international economic pressure to crop specific problems. In view of this, fragmentation of farm holdings, allowing farmers to maintain landraces in at least one field; increasing cultivation of marginal land, where landraces tend to have an advantage over modern varieties; economic isolation, creating market distortions which give landraces a competitive advantage; and cultural values and preferences for diversity are important factors in preserving crop diversity. Any process that counter-balances this situation could cause genetic erosion of crops (Brush, 1993). Similarly farmers' local knowledge of crops associated crop diversity lost as the result of such causes (Kebebew, 1997).

Ethiopia has economically important plant resources and rich wild gene pools of cultivated species. It is acknowledged that these are an important source of genetic variation for the plant breeding of commercial crops. The Ethiopian crop wild relatives are increasingly threatened by genetic erosion and extinction mainly due to habitat fragmentation and over-exploitation. Currently, farmers and their systems of production face new challenges from genetic erosion, ecological degradation, and pressures to produce more from the land. The most crucial factors for genetic erosion in the country include displacement of farmers' varieties by new, genetically uniform crop cultivars, changes and development in agriculture or land use, destruction of habitats and ecosystems, and drought (Worede, 1997). Moreover, the famine that persisted in some parts of Ethiopia has forced farmers to consume their own seed in order to survive or to sell the seed as a food commodity. This often resulted in massive displacement of native seed stock (mostly sorghum, wheat, and maize) by exotic seeds provided by relief agencies in the form of food grains in the country. The extent to which the displacement of farmers' varieties by exotic /improved materials occurs has not yet been fully studied. This would also vary between regions and crops.

For example, in Southwest region of Ethiopia, farmers' named landraces that had decreased cultivation areas or which entirely disappeared and were no longer cultivated by farmers in the study areas. According to the survey report of Mulualem, (2017), in Southwest Ethiopia, farmers verbally reported some local names of crop landraces that were no longer found in their districts/regions and thought to be lost. Some other crop landraces had undergone notable reductions during recent years (Megersa, 2014). The loss of diversity on crop in Ethiopia could be attributed to several reasons. Based on overall assessment, low attention to the value of the crop is one of the main factors that caused genetic erosion.

Although, the most frequently report, dilution of the crop by improved technologies, and replace the crop by coffee, chat, turmeric and maize are the cause of crop genetic erosion in the country. The result also confirmed, young people today have less interest to root and tuber crops as compared to grains. Elder farmers' allege that maize varieties with shorter maturation time had been introduced in the past 30 years, making maize harvested twice within a year (Teshome, 2006). In addition, more productive maize varieties have been and are being introduced by agricultural extension workers, who also encourage intensive cultivation practices and compete area and labor force from root and tuber crops production. For example, the main planting time in Ethiopia is at onset of rainy season, it requires field preparation in February and early March, and planting during the small rains in March. These times correspond to the ideal period for preparing the fields of stake rows to yam, during which maize and stake yams compete directly for labor.

Changes from tuber crops to cereals based farming system is also another cause of genetic erosion. Agricultural extension workers in different districts are more knowledgeable and enthusiastic about grains, especially maize, and less familiar to root and tuber crops (Hildebrand *et al*., 2002). Furthermore, many people from northern Ethiopia had settled in most areas of Southwest Ethiopia, often achieving majority status over the indigenous people. Having grown grains in their former region, most northerners despise root and tube crops and eat them only when absolutely necessary (Mulualem, 2017). Thus, root and tuber crops have come to be regarded as low status relative to the grains sown by extension workers and new comers. In addition, in some farming community in Ethiopia, cultivation of cereal crops considered as modernization of living standards. In this regards, similar findings are reported by Zimmerer (1992), Kiambi (1998), Charles and Weiss (1999) and FAO (1999) who described farmers preferences to maintain their desires in satisfying different foods and income generating in time, in addition to socio-cultural value that farmers preserve (Loko *et al.,* 2015). In some cases, however, farmers express some contrary needs and make different choices, due to other factors of economic or market importance. Furthermore, due to the superior qualities of modern varieties (especially higher yields and higher prices), farmers are increasingly replacing local crop landraces by modern varieties in many fields (Tsegaye and Berg, 2007).

Furthermore, occurrence of drought at early stages of the crop is considered as a cause of genetic erosion (Sadhan and Dipak, 2016). In Ethiopia, some crops especially, root and tuber crops planting are done in October and November, and during this period moisture stress found to occur at emergence and subsequent months, thus, the plants became stunt and finally die. Wild animals (porcupine and mole rat) attacks are also the other prominent factors contributing more to genetic erosion of crop genetic resources. Some crop that used as medicine is less preferred by porcupine and mole rats. This might be due to medicinal crops had high polyphenols or tannin like compound and not favorite by wild animals. Arunachalam (1999) who reported, natural disaster such as floods, drought and wild animal attack are more contributing to genetic erosion. Shortage of farm land and labour are also another factors as causes of genetic erosion (Anunda *et al.,* 2014). High population pressure and city expansion in different areas are the main factor to cause land shortage leads to genetic erosion. In this regard, Cebolla *et al*. (2007) who reported city expansion is the main causes of genetic erosion in city of Valencia. Besides, the high rate of urban migration, especially younger people, has reduced the labor force, resulting in the abandonment of landraces requiring high amounts of labor. This finding also similar with the result of Charles and Weiss (1999) and Zimmerer (1992) who described land and labor shortage are the main causes of genetic erosion in many crops. Changing climatic conditions resulted in development of new diseases and pests and the loss of adaptation of some formerly high yielding crop landraces, forcing farmers to shift to new and better adapted landraces (Sadhan and Dipak, 2016). Decline soil fertility, as a result of frequent cultivation of the land without furrowing was evident and some landraces have therefore been abandoned due to low productivity.

In this regard, Worede (1997) who reported that the Ethiopian crop genetic resources are increasingly threatened by genetic erosion and extinction mainly due to habitat fragmentation and over exploitation of natural resources. In some crops, for example in yams and tomato staking is one of the most common agronomic practices in crop production and high contribution to genetic erosion. This is highly associated with high cost of the stake at critical time planting.
High market preference is also another factor for contribution of genetic erosion (Loko *et al.,* 2015). In eastern part of the country, farmers replace coffee orchards by *Catha edulis* (chat), due to high market preference, for example, one kilo gram of coffee bean about 150 Ethiopian Birr, while, one kilo gram of *Catha edulis* estimated about 4000-5000 Ethiopian Birr (Personal observation). In addition, some local experts consider root and tuber crops as a less valuable crop and low yielding ones leads to genetic erosion. Similar study was conducted by Tsegaye and Berg (2007) who reported in tetraploid wheat, that farmers' varieties have not been part of the agricultural extension package in Ethiopia. Inadequate attention has been given to the improvement of farmers' varieties as they have often been regarded as low yielding. Besides, some socio economic parameters such as, the age of the households and years of experience in crops production, the size of the family of the household, the size of the farm and labor supply give the impression to affect the farmers' decision making in the number of crop landraces to maintain (Anunda *et al.,* 2014). According to Mulualem, (2017) who reported, about 98.7% of the farmers recognized decreasing the trend of crops diversity in Southwest Ethiopia. In line with this, recollection of one elder farmer in Sheko district gives a more specific picture of decline in household yam production. During his childhood and adolescence (40 years ago), each household had a field of yams containing 15-25 rows of stakes. Such a field would have 260-350 individual plants with multiple harvests per season, would have yielded approximately 100 family evening meals with leftovers for breakfast. Today, in the same district most farmers plant 1-4 rows of stake yams across a narrower area (Hildebrand *et al*., 2002). This result is similar with the work done by Megersa (2014) who reported that the tendency of barley genetic resources in North Shewa zone of Oromia National Regional State region deteriorated through decades without any measure. The cause of genetic erosion is varying and depends up on the type of the crop and their growing agro-ecologies (Mark van *et al.,* 2009). Thus, estimate the diversity and quantify the rate of genetic erosion is vital for conservation of crop genetic resources.

Estimation of Crop Genetic Diversity and Erosion

Estimates of crop genetic erosion is a key factor to develop conservation strategy and sustainable utilization of crop genetic resources. Basically there are different methods that used to estimate the diversity and quantify the rates of crop genetic erosion.

Simpson's diversity index

Simpson's diversity index is used to compute to estimate diversity of landraces (evenness and richness) in all the districts. Simpson's index (K) mainly measures the probability that two individuals randomly selected from a single belong to the same category (Simpson, 1949) and hence, as K increases, the diversity decreases. Therefore, it transformed as 1-K with values ranging from 0 to 1. The index was computed for all districts using the function:

$$(1\text{-}k) = \sum (n/N)^2 = \sum (n(n-1)/(N(N-1))$$

Where (1-k) = Simpson's diversity index

N= the total number of households assessed in each district

n= the number of households where a landraces was found.

Shannon diversity index (*H'*)

The Shannon diversity index (*H'*) is considered to assess the diversity of landraces by using the number and evenness of the landraces. The index is defined as:

$$H' = -\sum_{i=1}^{S} pi \, ln \, pi$$

Where S= the number of landraces, p=the proportion of landraces i relative to the total number of landraces (S/N) and ln=logarithm to base e.

The Shannon weaver index values (*H'*) can range from 0 to ~ 4.6 using the natural log (versus $\log_{10}$). A value near 0 indicated that every species in the sample are the same. Conversely, a value near 4.6 indicated the numbers of individuals are evenly distributed between the species (Hennink and Zevan, 1991). Although, Shannon's index takes in to account evenness of the abundance of landraces, evenness can be calculated separately as a measure of the observed diversity to the maximum diversity.

Pielou's evenness index (E)

It is important to calculate the evenness of the landraces (Pielou, 1966). It is defined by the function:

E=*H'*/lns

Where, H' is Shannon diversity index and S referring to the number of landraces described in each district/area (Vikrant and Pawan, 2014).

High evenness resulting from all landraces having equal abundance is normally is equated with high diversity (Magurran, 1988). Differentiation of diversity estimates how different and similar habitats in terms of diversity of category under consideration.

Sorenson's similarity index

The index is used to compute based on the presence and or absence of landraces to estimate landrace similarity between pairs of districts as follow:

Sorenson's Similarity index = $\frac{2S}{(Sa+Sb)}$

Where, *S*= the number of landraces common to both districts, *S*a= the number of landraces in district A and *S*b= the number of landraces in district B.

Four cell Analysis

It is important to identify common, unique and rare landraces in a given area/district, type of intervention for conservation and document the reason why crops are found in a dynamic state. Four cell analysis mainly depend on the number of farmers who cultivate a given crop/variety and the area coverage of a given crop /variety.

To assess the rate of genetic erosion occurred in the last decades temporal comparison was used. This was done by re-sampling and through indigenous knowledge surveys as described by Guarino (1999). For example in Ethiopia, re-sampling of the existed crop landraces of *Triticum dicoccon*, *Triticum turgidum* and *Triticum durum* was done in three areas namely Harar Zuriya, Tulo and Chiro districts in eastern Ethiopia in 2001/2002 and 2002/ 2003 main cropping seasons and compared with germplasm accessions collected by IBCR from the same areas at different times in the past and conserved ex situ. For locating the sites, where previous collections were made, to undertake re-sampling information on the passport data from earlier years of collection was used. Among others, the passport data of IBCR contains information on collection site like administrative region, district name, altitude, latitude, and longitude of collecting site including the distance from the nearby town. For re-sampled areas, genetic erosion (GE) was calculated as GE=100% - GI (Genetic integrity) (Hammer *et al*. 1996). This approach is possible because collecting missions have been carried out in 2001/2002 and 2002/2003 covering the same areas, and following the same procedures of IBCR germplasm collection method. Furthermore, the rates of crop genetic erosion (CGE) per districts can be calculated using the formula:

CGE = [(n-k)/N]/ 100

Where n = number of landrace cultivated by few households on small areas, k = number of newly introduced cultivars and N = total number of cultivars recorded in the district.

The other method of estimate crop genetic erosion is Ordinary Kriging method it is based on the spatial autocorrelation between closed sites (Bio *et al.* 2002). This method takes into account the spatial structure in the data from sample districts to generate point estimates for un-sampled sites. Kriging provides not only predictions of crop genetic erosion, but also the prediction errors or kriging variances at each prediction location (Bilgili, 2013). The spatial auto-correlation is quantified through a function called a semi-variogram (Arslan, 2012; Meng *et al.* 2013) can be computed from:

$$\gamma(h) = 1/2n \sum_{i=1}^{n} (Z(x_i) - Z\,x_i + h))^2$$

Where, $Z(xi)$, in this study, is the cultivar diversity (number of cultivar to be inventorized) in the district i, $Z(xi + h)$ is the cultivar diversity of other districts separate from xi by a discrete distance h; n represents the number of pairs of observations separated by h, and γ (h) is the estimate or "experimental" semi-variance value for all pairs at a lag distance h. Semi-variances will be calculated for each possible pair of sampling districts, and the mean values of semi-variances will plot for increasing distance intervals (h) to produce the experimental semi variogram. The semi variogram is representing as a graph and reveals the underlying spatial pattern of variables, having more similar values when they are spatially closer. The spatial prediction of cultivar/landrace diversity mainly based on the geographical information (latitude, longitude) of the tested districts. The above estimates are important for maintenance of PGR. Conservation of crop genetic resources is essential to broaden the diversity of crops and related products, improve food crops in terms of yield, quality, adaptability to different environmental conditions and resistance to pests and diseases, build reserves of breeding materials, of native and exotic species that have nutritional or industrial potential, economically help nations to increase productivity and sustainability of their agriculture and restore and conserve the environment.

Conservation of crop genetic resources in Ethiopia

In Ethiopia, farmers' are the primary creators, users and conservers of crop genetic resources on farm (Teshome *et al*. 2007). If availability of local market remains stringent, smallholder farmers will continue shifting from labour intensive landraces to more easy to grow landraces. This trend is common for all crops, because farmers are guided by local consumer's preference, and more importantly farmer's knowledge of cultivation techniques is basically related to their knowledge of the crop. The sustainable use and conservation of Ethiopian crop genetic resource, the strategy fulfill the following criteria: (i) the conserved genetic resource must be contribute to the national food security program of the country. (ii) the conserved genetic resource must have high integrity with social, religious and culture of the society (iii) the genetic resources must have high commercial/export value.

In this review, clearly identified the main factors that determine the place of crop genetic resources in the production systems and interest that farmer have in them. These factors are important to develop a sustainable conservation strategy (Brush and Meng, 1998). Crop production system in Ethiopia, conservation through use approach needs to be sustained with a number of strategic actions such as i) collection of crop genetic resources, ii) morphological and genetic characterization of these resources, iii) promotion of crop diversity with emphasis on production locations, where the diversity is high, iv) training and capacity building, particularly on cultivation, management and post harvest practices (personal observation). Besides, establishment of a core collection of crop genetic resources is of paramount importance. It is highly depends up on the reproductive nature of the crop. For example, root and tuber crops are mainly propagated by vegetative, it cannot only rely on farmers to maintain all the diversity that might be available particularly when this diversity is unknown. That is why in addition to landrace collection activity the morphological and genetic characterization of crop genetic resources should be carried out.

Based on the overall assessment, the main causes of crop genetic erosion in Ethiopia were identified. Consequently, the associations between the causes and the landraces based on Socio-economic factor of the house hold, morphological, biochemical, molecular traits and farmers' indigenous knowledge have marvelous impact to build up conservation plan, genetic enhancement and efficiently utilization of the crop. Another strategic action includes promotion of crop diversity with emphasis on production areas have valuable impact.

In many cases, in developing countries in general, in Ethiopia in particular, results revealed that research centres are not the best keepers of crop genetic resources particularly vegetative propagated crops which need to be maintained as live collection. In this regards, conservation of crop genetic resource should be promoted at on farm level is crucial. This could be supplemented with training and capacity building particularly on cultivation, uses and post harvest utilization techniques. Develop training with radio and plasma programs also helps to expand the awareness, the knowledge and practical skills of farmers in order to improve crop production in Ethiopia. Furthermore, description of the extent and distribution of the different aspects of genetic diversity in a species, and of the way in which its structure is an essential prerequisite to determining what to conserve, and where and how to conserve it.

CONCLUSIONS

Ethiopia is considered to be the centre of origin and diversity of many crop species. These local crop genetic diversity is managed by farmers' indigenous knowledge to meet their livelihood needs. Currently, the Ethiopian crop genetic resources are exposed to severe threat of disappearance (genetic erosion) mainly due to low attention given to the value of the crop, drought at early stage, wild animal attack, shortage of farm land, displacement of crop/variety by high value crops. Erosion of crop genetic resources is not simply the replacement of a diversity of crops with one or a few modern varieties/ cash crop, but involves the loss of farmers' indigenous knowledge of and ability to manage their own crop genetic resources. The degree to which diffusion of modern varieties results in genetic erosion depends on the strength and quality of local crop genetic resource management and the comparative ability to satisfy the farmers' household requirements of local landraces vis a vis the modern varieties introduced. Its causes are varying from one area to another, even one country to another. Therefore, urgent intervention such as, training to farmers, diversity fair, diversity block, genetic enrichment/diversity kits across districts/ regions and countries are required to develop conservation strategy to maintain and enhance the existing diversity and documentation of farmers' indigenous knowledge for use by present and future generation.

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