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Current Status of Arabica Coffee (Coffea Arabica .L Genetic Resource: Conservations, Constraints and Mitigation Strategies in Ethiopia

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ABSTRACT

We have reviewed on the current status of arabica coffee Coffea Arabica .L genetic resource: the conservations strategies used, constraints affecting coffee gene pool, and the mitigation strategies to be made in the future. Germplasm collection, have been followed since the commencement of the breeding program. In effect, outstanding achievements have been recorded in assembling of 6923 accessions, conservation of these germplasm in ex situ conservation of field gene bank by Jimma Agricultural research center and its sub centers; there is also a field genebank established and managed at Choche near Jimma by the Institute of Biodiversity Conservation with 5,196 randomly chosen accessions conserved. From 1996-2015, the collected accessions were reached around 6923 accessions. However, it was facing to genetic erosion as a result of: - Climate change (temperature rice), deforestation, crop replacement, disease and etc. Currently, about 5853 out of 6923 accessions are maintained under field condition and appropriate field management is under way. Example:- conversion of forest land to agricultural land for subsistence crops, fire wood and timber, settlement expansion, erosion, natural disturbance others share 35%, 17%, 12%, 12%, 3% and 4% respectively as deriving force for forest cover loss in Yayu coffee forest biosphere reserve and surrounding. The details of the conservations strategies used, constraints affecting coffee gene pool, and the mitigation strategies to be made in the future are discussed in this paper.

Keywords: *Coffee Coffea germplasm; conservations strategies; constraints affecting coffee mitigation strategies*

INTRODUCTION

Ethiopia is the origin of Coffee Arabica (*Coffea arabica L.*) and the largest producer of coffee in Africa and the largest fifth coffee Producer in the world (GAIN, 2014). Coffee is known to be one of the most important beverages in the world. It has a current estimated value of US$10 billion and is one of the most traded commodities second in value only to oil and a huge contributor of foreign exchange earnings for developing countries (Labouisse *et al.*, 2008). Coffee production is vital to Ethiopian economy and accounted for 19% of total Ethiopian export (Trading Economics, 2016). The annual coffee production in Ethiopia is with average yield of 6.34 quintal/ha (CSA, 2016). In 2014/15 Meher Season, the area allocated for coffee production was estimated to be 561,761.82 ha from which about 4,199,801.56 quintal was obtained with average yield of 7.48 quintal/ha. In 2015/16 production year Ethiopia produced an estimated 9.8 million bags that would rank the country as the third largest coffee producer in the world after Brazil and Vietnam, beating out Colombia (ICO, 2012) and the fifth major exporter of Arabica coffee, globally next to Brazil, Vietnam, Colombia and Indonesia and the highest producer of coffee in all of African country (Davis *et al.*, 2012). Currently it contributes about 30 present of the country’s foreign currency earnings. More than 15 million people directly or indirectly depend on coffee value chain for their income and employment. About 35% of the total production is consumed within the producing areas (Chauhan *et al.*, 2015) and in general, over 50% of the coffee produced is consumed within Ethiopia (Bart *et al.*, 2014).

Ethiopia is the homeland and center of genetic diversity of Arabica coffee (*Coffea arabica* L., Rubiaceae) (Vavilov 1951).The entire genetic diversity of indigenous (wild) Arabica coffee is confined mainly in the afromontane rain forest located in the west and east of Great Rift Valley (Taye and Jurgen, 2008). The scholars estimated that Ethiopia is home to an estimated of about 40,000 wild varieties of coffee. The crop is mainly produced in the Southern, South Western and Eastern parts of the country. The total area coverage of coffee in Ethiopia is estimated to be around 800,000 ha, of which about 95% is produced by 4 million small scale farmers (Berhanu *et al.*, 2015); whereas the estimated annual national production of coffee is about 419, 980.20 tons. Different research findings illustrate the importance of the Ethiopian coffee genetic materials in breeding programs for high productivity and disease resistance (Labouisse *et al.*, 2008). Ethiopian *C. arabica* accessions is used as parents for crossing with commercial varieties to obtain strong hybrid vigor, resulting in over 34% higher productivity of the F1 hybrids in full sun light (Bertrand *et al*., 2011).

Currently coffee genetic resource is subjected to genetic erosion as a result of deforestation due to forest for investment, resettlement, fire wood, construction, replanting with improved varieties, expansion of land for food crops & others do advancing germplasm collections fear the extiniction of our coffee genetic resources. Considering the intensity of collection with in regions, large collections were made from Hararghe followed by Sidamo& Western Wollega & Gimbi areas. In Eastern Africa, the outbreak of the coffee berry disease in the 1970s and 1980s larger damage were caused. In Ethiopia the disease does not affect coffee production significantly, chiefly due to the availability of high genetic diversity which enabled to develop cultivars resistant to the disease in a very short time using materials from the wild coffee gene pool (Mesfin and Bayetta 1984). Hence, there is no doubt that it is essential to conserve and maintain the existed collected gene pool with wide genetic variability can safeguard coffee production from dangers posed by possible disease outbreaks and environmental stresses (Desalegn, 2017). The objective of this paper is to review on the current status of arabica coffee genetic resource: conservations, constraints affecting, and to give mitigation strategies to be made in the future.

Germplasm Collection and Conservation

The initial collection program launched includes both indigenous and exotic collections. However, since 1984, the introduction of arabica coffee varieties developed elsewhere in other countries had been discontinued because of the poor performance of these materials in the screening program under Ethiopian condition compared to the local materials *(*Fekadu *et al., 2008)*. The Indigenous coffee germplasm collection was started in 1970 under long term national coffee collection program. From (1966-2005), 5630 indigenous coffee accessions were collected, of which 1185 in national, 1041 in CBD resistant & 3404 in Regional programs (Table 1) below. Fekadu *et al.*, (2008) estimated that about 73% of the indigenous collections, large collections were made from Hararghe followed by Sidamo & Western Wollega &Gimbi areas.

Since the beginning of exotic coffee germplasm introduction program in 1967, a total of 190 exotc coffee accessions, consisting of 155 Internationally known Arabica varieties, 28 catimor hybrids & rust diffirentials, & 7 diploid species were introduced from various coffee growing countries such as Brazil, Costarica, Cuba, India, Tanzania & Portugual ((Fekadu, 2008). This scholar also indicated that only about 87% accessions were survived & adapted to the environmental condition of Jimma & Gera in Ethiopia. The rest had died & many had failed to acclimatize to local environments. Moreover, none of the introduced materials performed better than the locals, except a few local types such as Geisha & Catimor lines did well at lower altitudes of Bebeka & Tepi (Fekadu, 2008). In Ethiopia the Arabica coffee germplasm were collected from Hararghe (East and West hararghe), Jimma, Sidama, Wollega, Ilu Abbabora, Bale, South Omo, Kaffa, Shaka, Arsi, Gamogofa, Gedeo, Amaro, Guraghe, Gembella, Oromia special zone, South Wollo and Asosa as indicated in figure(1) below.

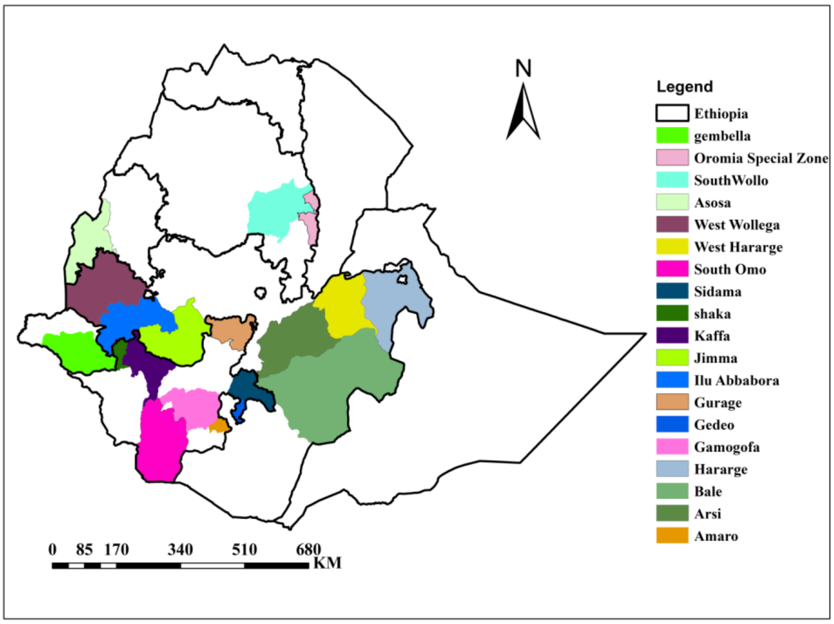

Figure1. *Agro-ecological zones Ethiopia showing a place of germplasm collected tiil now.*

Wild populations of Arabica coffee in are genetically diverse, and probably possess desirable traits that can be used to improve the cultivated varieties of *C. arabica* worldwide (Aerts *et al*., 2013; Tesfaye *et al*., 2013). At least within Ethiopia, active selection and hybridization activities with wild coffee individuals in recent decades have led to numerous landraces or farmers' varieties as reviewed by (Labouisse *et al*., 2008). The importance of the Ethiopian wild coffee populations can be expected to increase in the future as breeders attempt to address the threats of the combination of global environmental change and a higher demand for food (Foley *et al*., 2011). Conservation of the genetic diversity of *C. arabica* in Ethiopian rainforests is therefore of major importance, but the conservation of wild gene pools of cultivated species generally remains an often undervalued challenge for conservation biologists (Honnay *et al*., 2012).

Table1. *Summary of indigenous and exotic collections*

Type of collection	Year of collection	No of accessions				Total
		Indigenous collection			Exotic collection	
		Oromia(54)	SNNP(28)	Other regions(10)		
National collection (different regions)	1966, 1970-2004	622	424	139		1185
CBD resistant selection program	1973-75,1980-87	721	320	38		1041
Regional collection	1994-2005	2748	609	9		3404
Sub-total		4091	1353	186		5630
Exotic collections	1967-84				190	190
Total		4091	1353	186	190	5820

Figures in parenthesis indicate the number of woredas where the collections were made.

Source. *Fekadu Tefera 2008*

Coffee Germplasm Conservation & Maintenance

A tota of 6717 coffee accessions are conserved in Jimma Agricultural Research Center & its Sub-centers i.e 6717 coffee germplasm collected and maintained at Research sites (Taye, 2013). Till now about 6923 indigenous and exotic coffee accessions are collected and conserved at field gene bank. There are two ways of conserving wild genetic resources: In situ (nature reserves) and ex situ (zoos and gene banks) (Allen and Allen 2013). Both are needed.

Ex-Situ Conservation

Ex situ conservation is a technique of conservation of biological diversity outside its natural habitats, targeting all levels of biodiversity such as genetic, species, and ecosystems (Antofie, 2011; Allen and Allen 2013). In general, *ex situ* conservation is applied as an additional measure to supplement *in situ* conservation, which refers to conservation of biological diversity in its natural habitats. In some cases, *ex situ* management will be central to a conservation strategy and in others it will be of secondary importance (Reid *et al.*, 2013).

And this technique is particularly appropriate for the conservation of crops and their wild relatives. Ethiopia has a unique genetic diversity of cultivated, semi-wild and wild Arabica varieties with different types of disease resistance environmental adaptations and quality characteristics for future breeding coffee varieties opportunity that are adapted to the changed climate (Bongase, 2017). Changes in temperature and frequency of rains are associated positively and significantly with a higher probability to implement at least one adaptation strategy to climate change (Zuluaga *et al.*, 2015). Proven approaches were built on existing indigenous practices and knowledge to maximize benefits of climate change adaptation (Dinesh and Vermeulen, 2016). As climate change becomes increasingly severe, an assessment of coffee producers' ability and willingness to adapt would be especially valuable to those hoping to create adaptation strategies and policies (Rahman, *et al.*, 2016). The objective of ex situ conservation is to maintain the accessions without change in the genetic constitution. And it is aimed at minimizing the possibility of mutation, selection, random genetic drift or contamination.

Field Gene Banks

One of the main strategies for the long-term conservation of genetic resources of crop plants is the maintenance of collections in field gene banks. These facilities allow ease of access by plant breeders, researchers and other users (van Hintum *et al.*, 2000). Even though considerable progress has been made in assembling and conserving these genetic resources till now, many of the germplasm collections were faced to major problems of maintenance and organization. Conserving in the areas of origin has advantages over conserving at Ex-situ field gene bank. That is because local landraces have better adaptation in their areas of origin. For example, conservation of Hararghe coffee 2002 at Melko (field gene bank) and Mechara (areas of origin) is shown in Figure(2), below.

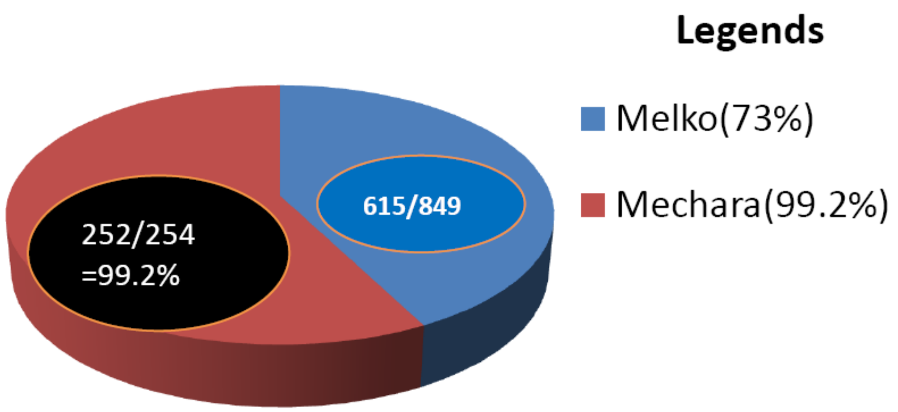

Figure2. *Consevation Haraghe coffee at Melko(field gene bank) vs Mechara (areas of origin)*

In Situ Conservation

In situ conservation is defined as conservation of ecosystems and natural habitats, the maintenance of viable populations of the species in their natural surroundings and, in the case of the cultivated species, in the surroundings where they have developed their distinctive properties. In situ conservation can be done in farmers' fields, in pasture lands, and in protected areas. *In situ* conservation of genetic resources is acknowledged as being complementary to *ex situ* conservation and its implementation in Ethiopia has long been considered as a national urgency (Labouisse and Kotecha, 2008). For example, some of the natural habitats or wild habitats are very risky when compared to relatively safe captive environment (Kasso and

Balakrishnan, 2013). One of the key threats to in situ populations of coffee is deforestation caused by human population pressures leading to conversion of land to agriculture. It is critical that before a substantial proportion of coffee gene pools are lost to deforestation, in situ conservation of their forest ecosystems need to be achieved (Krishnan, 2013).

Germplasm Maintenance

The age of coffee germplasm maintenance at JARK was as old as coffee collection programs itself. At Jimma- Melko & Gera coffee maintenance/conservation activity was started with national &CBD selection programs, whereas in other sites, the collection & maintenance/conservation activity was affected after re-designing of breeding program as <local landrace development program>in 1994. From 1966-2005, about 5746 accessions (including some possible duplicates) have been maintained in seven Ex-situ sites (Fekadu, 2008). Currently from 1996-2015, the collected accessions were reached around 6923 accessions. However, it was facing to genetic erosion as a result of: - Climate change (temperature rice), deforestation, crop replacement, disease and etc.

Current Growing Status Of Coffee Collection At JARC And Its Sub-Centers

Currently, about 5853 out of 6923 accessions are maintained under field condition and appropriate field management is under way. However, these coffee accessions are suffering from adaptation problem, disease and climatic factors. For instance the Arabica coffee collected from Dawro, Gamogofa & Wenbera, field established at Gera sub-center is highly infected by CBD & shows poor growth performance. Over all the national collection program, CBD resistant, local landrace collection and exotic Arabica coffee genetic collection and survival status was summarized as indicated in the following table(2). In addition to ex situ conservation by JARC, there is also a field genebank established and managed at Choche near Jimma by the Institute of Biodiversity Conservation (IBC) with 5,196 randomly chosen accessions conserved (Labouisse and Kotecha, 2008).

Table2. *Summary of indigenous and exotic collections from 1996-2015/16 by JARC*

Type of Collection	Year of Collection	No of Collected Accession (Original)	No. of Alive Accession	Number of Lost Accession (%)	Remark
National	1966-1990	1633	1431	12.37	Indigenous collection
CBD Resistant selection program	1973-1987	868	825	4.95	
Local Landrace Collection program	1994-2015	4232	3519	16.85	
Exotic Coffee Collection	1968-1984	190	78	58.95	Exotic collection
Total		**6923**	**5853**	15.46	

Source. *Jarc inventory 2014-2015*

Constraints Related to Genetic Erosion

The broad range of genetic diversity existing in Ethiopia, particularly the wild genepools, is presently subject to serious genetic erosion and irreversible losses. This is due to the interaction of several factors and is progressing at an alarming rate. Currently in Oromia & SNNP regions due to deforestation of forest for investment, resettlement, fire wood, construction, replanting with improved varieties, development in Agriculture or expansion of land use for food crops, replacement of forest coffee by Chat & others are advancing germplasm collection fearing the extinction of our coffee genetic resources.

Climate Change

Coffee is the world's most important tropical export crop but recent studies predict severe climate change impacts on Coffee Arabica production (Craparo *et al.*, 2015). According to Killeen and Harper (2016) coffee production areas has been changing because suitable areas become too warm or prone to periodic drought

(Killeen and Harper, 2016). Most suitable area becomes unsuitable because of climate variation (Dekens and Bagamb, 2014). The climate variations affect coffee industry from production to export (Dekens and Bagamb, 2014). Davis (2012) stated that the profoundly negative trend for the future distribution of indigenous Arabica coffee would be 65% reduction in the number of bio climatically suitable localities, and at worst (scenarios of almost 100% reduction, by the year 2080 under the influence of accelerated global climate change). The unpredictable rains will make coffee to flower at various times throughout the year, making the farmers to harvest small quantities continuously (Jassogne *et al.*, 2013). This change will affect the crop physiology especially during the flowering and fruit filling stage (Jassogne et al., 2013).

Climate Change (Temperature Rice)

Climate change can is affecting the world cultivation (Esser, 2015). In East Africa, coffee production is likely to be severely affected by climate change (Dinesh *et al.*, 2015). According to Storm (2016) about 33% out of total national exports; In Ethiopia, temperature has risen by 1.3 ^{o}C and predicted rise of 3.1 ^{o}C by 2060, 5.0 by 2090. And major shifting in coffee growing areas is expected (Storm, 2016). These imply that climate change is threatening coffee crops in virtually every major coffee producing region of the world.

Deforestation

Deforestation is land use change from forest covered to other non-forest land use, whereby the primary forest is disturbed and altered structurally and in species composition and no more resembles the character of forest (Dereje, 2014).The main contributing factor to tropical deforestation is mainly due to conversion of forests into agricultural land FAO (2010). Ethiopia is the only place where wild populations of coffee Arabica still existing. The forest cover change is regarded as conversions from forest covered to other non- forest types, while forest disturbance is relatively defined as a discrete event occurring over short time period disturbing the structure of forest ecosystem (Verbessel *et al.*, 2012). The rising population pressure and accelerated deforestation rate mainly for agriculture are impacting the rich biodiversity of the region (Wakjira, 2010). Many studies (Getahun *et al.*, 2013; Wakjira 2010) indicated that human activity is critically threatening the stability of the forest ecosystems in the in Jimma zone of South-western Ethiopia also showed socio-economic and biophysical factors as of control deforestation, indicating more deforestation in remote location Getahun *et al.*, (2013).

Concerning changes in forest cover, FAO estimated that Ethiopia lost an average of 141,000 hectares of forest per year between 1990 and 2000 with an average annual deforestation rate of 0.97%. Between 2005 and 2010, the rate of forest change increased by 1.11 % per annum. In total, between 1990 and 2005, Ethiopia lost 14.0% of its forest cover, or around 2,114,000 hectares (FAO 2010). Measuring the total rate of habitat conversion (defined as change in forest area plus change in woodland area minus net plantation expansion) for the 1990-2005 intervals, FAO also estimated that Ethiopia lost 3.6% of its forest and woodland habitat (Dereje, 2014).

Example:- conversion of forest land to agricultural land for subsistence crops, fire wood and timber, settlement expansion, erosion, natural disturbance others share 35%, 17%, 12%, 12%, 3% and 4% respectively as deriving force for forest cover loss in Yayu coffee forest biosphere reserve and surrounding area figure (3). The first and most series underlying factor for forest cover loss in this site is high population pressure in need of more arable land to produce subsistence food crops. In south-west Ethiopia, approximately 38% of the highland plateau was covered by 1,158,000 hectares of closed high forest at the beginning of the 1970s, and, by 1997, only 556,700 hectares were left making a loss of 52% in less than 30 years (Labouisse and Kotecha, 2008). This causes local and landless farmer to be pushed in to marginal and forest edges and convert forest land to farmland.

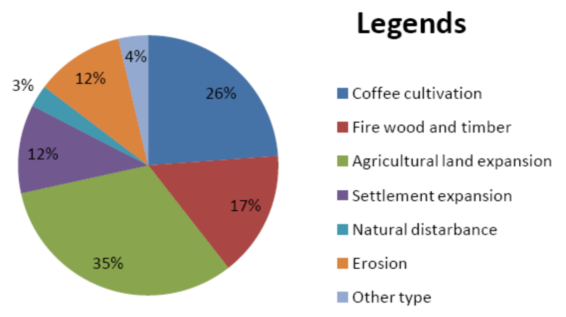

Figure3. *Proximate causes of forest cover loss in Yayu coffee forest biosphere reserve and surrounding areas*

Source: *Dereje, 2014*

Figure4. *Deforestation by new settlers in the south-western Ethiopia near Teppi.*

Source. *Labouisse and Kotecha, 2008.*

Chat Expansion On The Farming System

The expansion of chat plant in Ethiopia has been increasing radically. It was investigated that the total area of chat plant some thirty years back was 3000ha, 3500ha and 6997ha in 1954, 1957 and 1961 respectively (Amare and Krikorian ,1973). According to CSA the total area of land under chat cultivation in the year 1998 was estimated at 78,570 ha in 2008 increased to 163,227ha and then 204,648 ha in 2011 and in 2015 it reached 248,964 ha (Binalfew, 2017). Shift coffee to khat jimma zone (Dube *et al.*, 2014).

Diseases

Ethiopia, as the center of origin for *Coffea arabica*, hosts a large diversity of germplasm and is native to southwestern Ethiopia growing as understory of the rainforests that harbor huge floral and faunal diversities. Besides drastic reduction in the forest cover and low average yield, the crop is attacked by several diseases among which coffee berry disease, coffee wilt disease and coffee leaf rust caused by Colletotrichum kahawae, Gibberella xylarioides and Hemileia vastatrix, respectively, are the major fungal diseases contributing to reduced yield in the country (Chala *et al.*, 2010; Sihen, 2017).

Coffee Berry Disease (CBD)

Arabia coffee in Ethiopia is attacked by numerous diseases that reduce its production and productivity significantly. Coffee berry disease (CBD) is the top major disease of coffee in Ethiopia, which attack mainly the green berries of coffee. CBD was first observed in Ethiopia in 1971 (Mulinge, 1973). Since then it spreads and found in all coffee producing areas in which it has been favored by favorable environmental conditions. According to Kumlachew *et al.* (2016) survey reports the CBD disease incidence ranged between 10 and 80% in Borena, 40–100% in Gedeo and East Hararghe, 10–90% in Illubabor, 30–90% in Jimma and Sidama, and 30–80% in West Wollega . Higher CBD incidence was recorded in East Hararghe (71%) and Gedeo (65%); and Jimma (59%). This disease kills the berries of coffee and it limits the source of planting material to establish new plant tree for next generation.

Coffee Wilt Disease (CWD)

Historically, coffee wilt disease (CWD) on C. arabica was first observed in Ethiopia (Keffa province) by Stewart (1957). Van der Graaff and Pieters (1978) reported that this pathogen caused a typical vascular wilt disease and was the main factor of coffee tree death in Ethiopia. In Hararge coffee wilt disease or tracheomycosis destroyed coffee trees (Labouisse and Kotecha, 2008). Coffee wilt diseases are more prevalent in plantation and garden coffee than forest and semi-forest coffee (Sihen *et al.*, 2012). Coffee wilt is a vascular disease whose symptoms progress from inward curling and wilting of leaves to dieback and death of affected trees. Symptoms may suddenly occur all over the stem, but usually, they start on a single or a few primary branches on one side of the stem and progress laterally until all branches are affected. Symptoms on trees with multi stems first appear on a single stem and progress laterally until all stems are affected. The disease kills its host at all ages and within a short period (Musoli et al., 2008).

Coffee Leaf Rust

According to Arega *et al.* (2009) in all investigated forest coffee areas coffee leaf rust

(CLR) was prevalent to a high extent (around 96 %). Coffee leaf rust assessment were made again in 2007 and 2008 in three southwestern Ethiopian montane coffee forest populations revealed its presence in all fields assessed differing in magnitude with time (season) and location of the forest coffees (Chala *et al*., 2010)**.**

MITIGATION STRATEGIES

The available coffee genetic diversity before the advance of deforestation, the identification and protection of more in-situ conservation site and systematic collection that cover all coffee growing areas of Ethiopia should continue. In situ conservation where coffee biodiversity is expected to be rich should be encouraged and characterized. Moreover, effective germplasm conservation strategy measures are crucial opportunity to overcome the problem encountered. Both *ex situ* conservation and in situ conservation need to be used the national conservation strategies of the country though *ex situ* conservation is applied as an additional measure to supplement *in situ* conservation, which refers to conservation of biological diversity in its natural habitats. In some cases, *ex situ* management will be central to a conservation strategy and in others it will be of secondary importance (Reid *et al.,* 2013). E*x situ* conservation(field gene bank) can also do have dual purpose, that is in addition maintenance of coffee Arabica germplasm it also encourage the coffee to adapt outside it origin when it is conserved at field gene bank.

Coffee genetic resources are under threat of extinction in the wild. In existing ex situ field genebanks the threat of genetic erosion is very high. Before it is too late, a complete evaluation of existing germplasm should be undertaken, based on which a comprehensive conservation strategy should be developed that includes both in situ and ex situ conservations and addresses the need for duplication of germplasm in multiple locations. An undertaking like this will involve the participation of all major coffee origin and producing countries and national and international organizations with the ultimate goal of developing policies for germplasm exchange, property rights and benefit-sharing. Conservation of the germplasm though not large enough to represent the available diversity, would also serve as an immediate source of breeding material in the future breeding program. However, it is vital to strengthen the national coffee germplasm collection program to ensure sustainability of the program.

SUMMARY AND CONCLUSION

Ethiopia is the origin of Coffee Arabica and the largest producer of coffee in Africa and the largest fifth coffee Producer in the world. The scholars estimated that Ethiopia is home to an estimated of about 40,000 wild varieties of coffee. Currently coffee genetic resource is subjected to genetic erosion as a result of deforestation due to forest for investment, resettlement, fire wood, construction, replanting with improved varieties, expansion of land for food crops & others do advancing germplasm collections fear the extiniction of our coffee genetic resources. Wild populations of Arabica coffee in are genetically diverse, and probably possess desirable traits that can be used to improve the cultivated varieties of *C. arabica* worldwide.

The importance of the Ethiopian wild coffee populations can be expected to increase in the future as breeders attempt to address the threats of the combination of global environmental change and a higher demand for food. Conservation of the genetic diversity of *C. arabica* in Ethiopian rainforests is therefore of major importance, but the conservation of wild gene pools of cultivated species generally remains an often undervalued challenge for conservation biologists.

There are two ways of conserving wild genetic resources: In situ (nature reserves) and ex situ conservation. Both are needed; *ex situ* conservation is applied as an additional measure to supplement *in situ* conservation, which refers to conservation of biological diversity in its natural habitats. In some cases, *ex situ* management will be central to a conservation strategy and in others it will be of secondary importance

Currently from 1996-2015, the collected accessions were reached around 6923 accessions. However, it was facing to genetic erosion as a result of: - Climate change (temperature rice), deforestation, crop replacement, disease and etc. Currently, about 5853 out of 6923 accessions are maintained under field condition and appropriate field management is under way. In addition to ex situ conservation by JARC, there is also a field genebank established and managed at Choche near Jimma by the Institute of Biodiversity

Conservation (IBC) with 5,196 randomly chosen accessions conserved (Labouisse and Kotecha, 2008).

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