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# Genetic Erosion of Enset (Ensete ventricosum Welw.Cheesman) in Wolaita Zone, Southern Ethiopia: A review

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**Abstract**
Ensete ventricosum (Welw.) Cheesman is a major food security crop in Southern Ethiopia, where it was originally domesticated. Genetic diversity within the species permits an organism to adapt to changes in environment and climate or to the presence of biotic and abiotic stresses. Only diversity can support social and economic systems to flourish that allow the poorest to meet their food and nutritional demands. The loss of variation in crops due to the modernization of agriculture has been described as genetic erosion. The current paper discusses the different views that exist on the concept of genetic erosion in enset crops. The different approaches in the recent literature to measure genetic erosion in enset crops are reviewed. According to the reviewed literature, the genetic diversity of enset in the study area is decreasing from time to time. The major genetic erosion cause mentioned by different researchers were lack of appropriate in-situ and ex-situ conservation, the diffusion of different modern varieties from crop improvement programs, the replacement of landraces by modern cultivars and etc. Therefore; collection of enset landraces which are at risk and on farm management, in-situ as well as ex-situ conservation is required.
**Keywords**: *Ensete ventricosum*, Genetic diversity, Genetic erosion, Wolaita

## Introduction

World population is expected to increase by 2.6 billion over the next 45 years, from 6.5 billion today to 9.1 billion in 2050. The world needs astonishing increase in food production to feed this population. Plant genetic resources constitute the foundation upon which agriculture and world food securities are based and the genetic diversity in the germplasm collections is critical to the world's fight against hunger. They are the raw material for breeding new plant varieties and are a reservoir of genetic diversity [1]

From the beginning of agriculture, farmers have domesticated hundreds of plant species and within them genetic variability has increased owing to migration, natural mutations and crosses, and unconscious or conscious selection. This gradual and continuous expansion of genetic diversity within crops went on for several millennia, until scientific principles and techniques influenced the development of agriculture [2]. The impact of humans upon biodiversity has gradually increased with growing technology, population, production and consumption rates.

Genetic diversity refers to variation in genes and genotypes between and within species. It is the sum of the variation contained in the genes of individual plants, animals and micro-organisms. Diversity within the species permits an organism to adapt to changes in environment and climate or to the presence of biotic and abiotic stresses. It is the diversity which allows sustainability. Only diversity can support social and economic systems to flourish that allow the poorest to meet their food and nutritional demands. Genetic variability within and between tree populations has been used as a tool to exploit their improvement potential. The genetic variability depends on the edaphic and climatic factors operating in a species [3]

It is not exactly clear when the term genetic erosion was first coined, but probably sometime in the 1960s it was first used to describe the process of the loss of genetic diversity in agriculture [4]. [5] define genetic erosion as follows: "Genetic erosion is the permanent reduction in richness (or evenness) of common local alleles, or the loss of combinations of alleles over time in a defined area." This is helpful, in that it draws attention on the aspect of local adaptation. However, it is not clear why a definition should specify reductions in either richness or evenness. Neutral or trivial changes could mask critical changes when summed over loci, genotypes, populations or species. A temporal indicator should reveal and be most sensitive to the changes of concern and not be swamped by relatively unimportant changes. For example, the loss of a few alleles at a highly polymorphic microsatellite locus is likely to be of trivial or no importance compared with the loss of disease resistance alleles. An additional problem lies in stressing combinations of alleles; in sexual species all multilocus genotypes are unique and ephemeral. Thus when a claim is made that some percentage of distinct clones or genotypes have been lost from a region or a species, this is not necessarily genetic erosion. The life of each genotype is finite in sexually reproduced species, although vegetative reproduction might prolong that life. A reduction in population size, and not increased recombination, is the primary agent of erosion. Thus an inclusive concept and definition of genetic erosion such as Maxted and Guarino's may be theoretically rigorous, but it does not readily lead to practical ways of monitoring the key issues of the phenomenon.

Enset *(Ensete ventricosum*) is perennial monocarpic crop, belonging to Kingdom: Plantae Order

Zingiberales and family Musaceae along with bananas. Musaceae is a family of (monocotyledonous) flowering plants. The family is native to the tropics of Africa and Asia consisting of 2 genera, *Musa* and *Ensete*, with about 50 species. They are grown mainly for their fruit, the banana, and for their fibers, manila and hemp, used for making rope. They are also grown as ornamental plants. enset (*Ensete ventricosum*) is Ethiopia's most important root crop, a traditional staple in the densely populated south and southwestern parts of Ethiopia [6].

Enset (*Ensete ventricosum*) is diploid with n=9 [7]. While species of Musa have different ploidy levels (diploid, triploid and tetraploid) with n=10, 11 or 14. Both Enset and Musa have a large underground corm, a bundle of leaf sheaths (pseudostem), and large, paddle-shaped leaves. The meristem region is located at the junction point of pseudostem and underground corm, near the soil surface. Although enset is thicker and larger than banana, often reaching up to 12 m in height and more than one meter in diameter, both enset and banana are herbaceous perennial monocarpic crops; they produce flowers only once at the end of their life cycle [8]

**Enset cultivation in Ethiopia**

There are several indigenous cultivated or semi-cultivated root and tuber crops in Ethiopia. Of the cultivated species 10 species are roots/tubers including *Ensete ventricosum, Coleus edullis, Colocasia esculents, Dioscorea spp., Coccinia abyssinica, etc.* Enset is endemic to Ethiopia and occurs throughout the country both cultivated and wild [9]. Enset domestication dates back to Neolithic time or even earlier [10] and its farming system is regarded as one of the few ancient and sustainable agricultural systems in Africa [11]

Enset is a multipurpose crop of which every part is thoroughly utilized, not only for food but also for several cultural applications and livestock feed. It is primary food item for more than 5,000,000 people in the growing areas of Ethiopia. Three or four *Enset* derived foods are popular (*Amicho*, *Kocho*, *Workey*, and *Bulla*) but the most common is *Kocho* [12 and 13] The plant is cut before flowering, the pseudostem and leaf midribs are scraped, the pulp is fermented for 10-15 days and finally steam-baked flat-bread is prepared. As many as 7 million people consume the low-protein *Enset* products as staple or co-staple foods, sometimes solely with Vitamin A foods but commonly without the needed protein supplement. Leaf, fiber and plant parts are used for food wrappers; cattle feed, ropes and house construction materials [14]. Being perennial, enset improves local climate and soil conditions [15].

In the Southern Nations Nationality and Peoples Regional state (SNNPR), the 1994 estimates show that 300,000 hectares of *Enset* is projected to yield almost 10 tons per hectare. *Enset* planting economy is one of the major activities of the agriculture in SNNPRs. The area contains over 80% of enset production of the country [12]. Inclusion of *Enset* production from Oromiya Region (Oromia) and the national root crop production would have placed estimated *Enset* and root crop production' at more than 1/4 of the total cereal and pulse production of Ethiopia. This would have created, on paper, a food surplus situation in Ethiopia that could endanger the food security of numerous communities, which are in fact food deficit areas [14].

**Enset cultivation in Wolaita**: 'the people of *enset* culture'

Wolaita Zone is one of the major parts of enset production area in the SNNPRs, Ethiopia. Wolaita administrative Zone is with an area of approximately 438,370 hectares, and an estimated population of 1,750,830. Geographically, Wolaita Zone is located between 7° 00' North latitude and 37° 45' East longitude at the edge of the East African Great Rift Valley. Inhabitants of the Wolaita Zone are primarily the Wolaita ethno-linguistic communities speaking the Omotic Wolaita language, *Wolaitato Donaa*. The Wolaita are predominantly agriculturalists, practicing mixed crop-livestock production and living in permanent settlements. Within their landholdings, community members maintain fruit orchards, nurseries, medicinal plants, vegetables, root and tuber crops, ornamentals, spices, as well as open areas for raising domestic animals [16]

The Wolaita are people whose agriculture is based on enset, locally known as *uutta*. The Wolaita is regarded as 'the enset people' or 'the people of *enset* culture' for the strong interlink that exist between *enset* cultivation and the local food and material culture of the people [17]. As indicated in Regional Statistical Abstract, the area coverage of enset production in the Zone is 5,400 hectare. The estimated annual production is 2, 032,656 quintal.

**Approaches to Study Genetic Erosion**

Several approaches have been employed to estimate the degree of genetic erosion that a particular taxon faces in a certain region over a given time. Methods usually rely on either the analysis of molecular data [18] and allozyme analysis [19] or comparison between the number of species/cultivars still in use by farmers at present time to those found in previous studies [20] or using the genetic assessment model presented by [21] or using a checklist of risk factors [22]. The most widely used figures in estimating genetic erosion are two. The first approach is a comparison of the number of landraces or botanical varieties found in an area during collection missions at two different times [20] and [23]. A possible problem with this approach is that a more intensive survey might yield more landraces, and it may be difficult to copy the approach of the original collection mission.

 

A second approach is interviewing farmers about landraces formerly grown in the area [24] and [25].

According to literature, genetic erosion can be quantified on three different methods. These are:

a) Genetic erosion as an absolute loss of a crop, variety or allele [24] and [25]. The use of an absolute loss as evidence of genetic erosion ignores the dynamic nature of a farming system and population genetic processes. This approach only looks at what has been lost, and not at what has replaced this lost material.
b) Genetic erosion as a reduction in richness [26] and [27]. A reduction in richness is a better indicator for genetic erosion, as it does recognize the dynamics in the system. A reduction in richness is always accompanied by an absolute loss, but an absolute loss does not necessarily imply a reduction in richness, as a loss may be compensated for by novel diversity. A drawback in the use of richness as a criterion for genetic erosion is that very rare varieties or alleles contribute as much to the diversity as the most common varieties or alleles, and therefore richness might only poorly reflect increased levels of uniformity in agriculture. Also, the level of richness found depends to a large extent on the intensity of the investigation.
c) Genetic erosion as a reduction in evenness [26] and [27]. Genetic erosion as a reduction in evenness originates from the diversity indices used in vegetation ecology and population genetics. Diversity is measured using the frequencies of alleles within a group of genotypes or using the production areas of landraces, cultivars or crop species in a region. Diversity levels are lowered due to increasing dominance of a single or small number of crop species, genotypes or alleles, even though alleles or varieties are not necessarily lost. Using evenness, rare varieties or rare alleles contribute little to the diversity. The risks of losing alleles or varieties are higher when distributions are much skewed. Using evenness as a measure for genetic erosion offers the opportunity to take action before a reduced diversity results in an absolute loss and reduced richness. Considerable overlap between these three views on genetic erosion exists, and most studies use a combination of the different approaches. The use of the concept of genetic erosion is not limited to the field of crop diversity [29]. Genetic erosion equates genetic impoverishment and this concept is also applied to conservation ecology and animal husbandry, as the genetic impoverishment of a species or a population. Genetic erosion in ex situ collections may occur due to the loss of accessions or loss of alleles as a result of regeneration and storage practices [30].

**Farmers' Enset *(Ensete ventricosum)* varieties in Wolaita Zone**

*Enset* cultivation is the centre of the cropping system in which the entire farming system is based and the crop is the major food security and livelihood source in the Wolaita community [31]. Different enset (*Enset ventricosum*) vernaculars/clones are identified by the farmers in the study area and have their own names that are uniformly spread across the study zone. Enset clones are very diverse in the area ranging from 2 to more than 50 clones. Each farmer possessed various number of enset varieties in his farm. Farmers give vernacular names for each clone. They differentiated one from the other phenotypically by looking the color (as dark green, light green, brown, light brown, red, pinkish, etc.) of petiole, mid-rib, leaf sheath, angle of leaf orientation, size and color of leaves and circumference & length of pseudostem (as tall, medium, short, very short, etc.). Almost all the farmers in the area produce many enset clones in mixtures that are used for different purposes [15, 32 and 33].

The Wolaita hold a great repository of enset landrace diversity in their homegardens. The Wolaita agricultural systems maintain a greater level of enset intra-specific diversity than any other crop species. It is maintained in homegarden (*darkuwa*) ring in poly-varietal perennial plantations without any crop-rotations and land-fallowing. A study done by [34] indicated that there are 55 morphologically diverse enset clones known by Wolaita People (Table 1). However; two years later review done by [6], at the then Areka Research Station showed that there were 77 *enset* accessions in Wolaita administrative regions.

**Table 1. 54 Common enset landrace's identified by in Wolaita**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Achaka | Badadia | Chichia | Gishera | Kekeruwa | Matia | Separa | Tagacha |
| Adnona | Banga | Chorore | Godaria | Kuania | Mazia | Shalakumia | Tenna |
| Afamma | Benuwa | Dalulia | Gonwassa | Kuchia | Mochia | Shamaruwa | Tuzuma |
| Aginia | Budaro | Doko | Guniashia | Lembuwa | Nakaka | Silkantia | Wanadia |
| Alagena | Bukunia | Fara | Halla | Lochingia | Peluwa | Sirarea | Zinkia |
| Argama | Bundwa | Gefetanuwa | Hawsakuwa | Mahia | Pena | Siskela | Ankogena |
| Arkia | Catania | Genesa | Kabaria | Masmasa | Sanka | Suitia | |

[34]

After eight years later the same study done by the Areka Agriculutural Reseach Center (AARC), 2012 indicated that from the overall landraces that are known to the Wolaita farming communities only 35 are represented in the national *ex situ* enset collection of AARC (Table 2). This showed that 42 landraces of enset is either genetically eroded or not recorded very well. Different researchers result indicated that there is a decreasing trend in maintaining landrace enset diversity in Wolaita. Some of the landrace genotypes have been rare; many more are not cultivated anymore.

 

**Table 2: Enset landrace names known to the Wolaita community,maintained in ex situ collections at Areka**

| | | | | |
|---|---|---|---|---|
| Adinona | 8. Botya | 15. Fenku | 22. Kembata | 29. Mochie |
| Agina | 9. Bulua | 16. Gefetenewa | 23. Kikiro | 30. Osogurzo |
| Akacha | 10. Chamia | 17. Gemorcha | 24. Kualia | 31. Pokuwa |
| Ankogena | 11. Dirbuwa | 18. Gena | 25. Kucharkie | 32. Posha |
| Ankuwa | 12. Dokozuwa | 19. Genesa | 26. Locha | 33. Shedodinya |
| Banga | 13. Ersha | 20. Gezetiya | 27. Mattie | 34. Shemeroy |
| Bedadia | 14. Eslamia | 21. Ginawa | 28. Messa | 35. Tuzuma |

Recent research result by [33] indicated that 67 different vernacular names of enset landrace were under cultivation. From these 31 landraces in lowland and 52 landraces in each of the highland and midland agro-ecologies, 22 of which were shared across the 3 agro-ecologies. In general, many landraces are identified by vernacular names, showed a narrow and unique pattern of distribution, whereas 39 (41%) landraces known to the Wolaita community were commonly reported at least by 3 of the 5 *kebeles* [35].

Different previous studies showed that the genetic diversity of enset was decreasing from time to time. This may be due to farmers give priority for some selected clones; genetic erosion or limited researcher's sample size. Generally different researchers result combined together identified and named a total of 95 *enset* landrace vernacular names known to the Wolaita farming communities [15,16, 33 and 35] (Table 3).

**Table 3 Enset landrace names known to the Wolaita community**

| **Vernacular names** | **Vernacular names** | **Vernacular names** | **Vernacular names** |
|---|---|---|---|
| Achaka | Hoiya | Falakiya | Dirbuwa |
| Adinona | Kabaria | Fara | Dokozuwa |
| Aduwa | Kambata | Fenku | Dokuwa |
| Afamma | Kambata-maziya | Gassa | Erasha |
| Agino | Kataniya | Gefetanuwa | Eslammia |
| Ala-genna | Kekeruwa | Genaowo | Sanka |
| Anko-genna | Koltua | Genessa | Sassa |
| Ankuwa | Kuania | Genna | Separa |
| Argama | Kucha-arkiya | Gezetiya | Shalakumiya |
| Arkiya | Kuchia | Gishera | Shamaruwa |
| Badadia | Lalukiya | Godariya | Tuffa |
| Bala | Lembuwa | Gomorcha | Tuzuma |
| Banga | Locha | Gonwassa | Wanadiyia |
| Benuwa | Lochingia | Guniashia | Woisha |
| Bora | Mahia | Halla | Zinkiya |
| Boroda-wanadiyia | Masa-maziya | Hawsakuwa | Dalulia |
| Bota-arkiya | Masmasa | Shedodiniya | Dawro-arkiya |
| Botya | Matiya | Shuchafe-godariya | Pokuwa |
| Budaro | Maziya | Shuchafiya | Posha |
| Bukinia | Messa | Silqantiya | Tenna |
| Buluwa | Mochiya | Siraria | Chorore |
| Bundiya | Nakaka | Siskela | Pena |
| Chemia | Oso-gurzo | Sorgiya | Tagacha |
| Chichia | Peluwa | Suitia | |

Table 3 showed that though there were large numbers (95) of landraces of enset was identified in the study area only 35 landraces that were known to the Wolaita farming communities are conserved in the national *ex situ enset* collection of Areka Agricultural Research Center. This showed that Populations of enset landraces, particularly threatened endemic species, have sharply declined as a result of habitat degradation, fragmentation and overexploitation. Small populations face the risks of extinction due to demographic, environmental and genetic stochasticity [36].

**The major causes of Genetic Erosion**

The broad range of genetic diversity existing in different parts of the world, mainly of land races and wild gene pools is presently subject to serious genetic erosion. This loss involves the interaction of several factors, and is now progressing at an alarming rate. The most crucial factors are [1].

The diffusion of modern varieties from crop improvement programs**:** The operative variable in this hypothesis is the decrease in area devoted to indigenous crop varieties as modern ones are adopted. One footing of the genetic erosion hypothesis is that modern varieties are spatially competitive with indigenous ones. In preceding paragraphs, this paper has argued that the heterogeneity of farming systems in centers of diversity limits the diffusion of modern varieties and maintains production spaces for indigenous varieties. Nevertheless, modern varieties have diffused into centers of diversity and caused declines in area devoted to indigenous varieties. A second footing of genetic erosion is that declining area reduces diversity. The genetic erosion hypothesis takes a simple and direct approach to this relationship smaller area in traditional crops reduces diversity [37]. However, as long as some areas continue to be planted in indigenous varieties, the relationship between area and diversity is complicated by the population structure of landraces and by the role of conscious (artificial) selection [38]

By replacement by introduced elite germplasm: The replacement of landraces with modern cultivars is a gradual process, and the length of the transition period will vary much between crops and regions. In developed countries like North America and many European countries for many crops landraces have become absent and only modern cultivars are grown by farmers while in developing countries like Ethiopia, the replacement of landraces is currently in progress. The first cultivar introduced in an area will not immediately displace landraces, and therefore it is likely that the total diversity will initially show an increase, especially if the introduced cultivar is of a foreign origin. In the early stages, the contribution of the cultivars to the total diversity will be minor, while in the latter stages the landrace contribution will become small. For studying trends in diversity during the process of replacement of landraces with cultivars, the total diversity at a certain time period should be taken into account. A possible modernization bottleneck due to the replacement of landraces by cultivars would be reflected in a higher diversity of the landraces before the introduction of cultivars when compared to the diversity of the cultivars after the replacement with the landraces is completed. Studies that compare groups of landraces with sets of cultivars mostly show a reduction in both richness and evenness of alleles [39 and 40]. In cases where contemporary landraces and cultivars are compared for their diversity [41], the diversity differences found might be more a reflection of the stage of development of agriculture than of possible genetic erosion, as the contribution of cultivars to the total diversity will increase as the replacement of landraces by cultivars advances.

Enset diseases: Enset diseases such as those caused by viruses and bacteria were identified as one of factors that lead to genetic erosion of the crop. The Rue of 'Halla' at Areka was lowering most likely associated with a virus infection. At the same site, the Rue of 'Nekakia' was much higher suggesting a lower level of virus infection and/or clonal variation in sensitivity to such an infection. Although bacterial wilt diseases caused by the bacteria *Xanthomonas campestris* pv *musacearum* were not observed in the yield potential trial, during the survey work it has been observed as the most serious disease of enset. Fungal leaf spot diseases are also common in enset-growing regions. Root lesion nematodes *(Pratylenchusgoodeyi)* and root knot nematodes *(Meloidogyne*sp.) are commonly found and are apparently widely distributed [42]. Mammals such as porcupines, molerats, and wild pigs attack enset plants in the field [16].

Abundant habitat fragmentation and destruction of the crops and their wild relatives: Genetic diversity is lost in much the same manner as species become extinct. Habitat loss and habitat fragmentation can reduce the size of plant populations. If the habitat and not just the plants are removed (such as in land conversion), and there is no subsequent regeneration from seedbanks or previously collected seeds, then loss of genetic diversity can occur immediately, assuming that there is some diversity in the removed plants that is not contained elsewhere. The link between habitat fragmentation and loss of genetic diversity has been well established, both theoretically and empirically, particularly in forest tree species [43].

Other factors: population growth, urbanization, developmental pressures on the land resources, deforestation; changes in land use patterns, natural disasters,; drought due to the el ni˜ no phenomenon and flooding; social disruptions or wars pose a constant threat of genetic wipeout of such promising diversity; overexploitation; the introduction of invasive alien species; global warming and a high degree of pollution, these all can contribute to the speed of genetic erosion [1, 38 and 44].

**Conclusion**

Many researches showed that the Wolaita people is among the enset growing zones where landrace diversity and enset culture was reported to be vulnerable to the recent socio-economic and ecological changes occurring in the area. Even though enset production plays major economic and social roles in the study area, it is not included widely in extension package. Little attention was given to research and extension services. Moreover, substantial research and development has not been carried out in the enset growing areas of the wolaita zone in order to maintain the genetic resources of enset on on-farm conservation. The major factors that have contributed to the loss of genetic resource in the study area include: introduction of exotic species, habitat destruction, land use change, population pressure, selection by farmers and climate change. Moreover; there had less government attention with regard to conservation of root crops in the study area. The causes and effects of the genetic erosion of plant genetic resources are poorly understood in the area. At present, increasing crop yield through improved technology led to the loss of genetic resources of land races. On-farm genetic resource conservation received less attention and agricultural extension in the zone has focused on the improved varieties. Furthermore; there is inadequate documentation of indigenous knowledge and the biological and agronomic characteristics of enset crops in the study area. The conservation and utilization of indigenous crop species largely depends on the motivation of farmers. As a result, *enset*, the indigenous crop that historically was used for food security is now lost or have become under-utilized.

Genetic Erosion leads to genetic uniformity which leaves a species vulnerable to new environmental and biotic challenges and causes heavy damage to the society. Knowing the causes of genetic erosion is equally important for devising conservation measures. Likewise, identifying local crop varieties and associated wild relatives that are lost or are on the verge of extinction, play crucial role in designing and implementation of conservation policies. Research on enset crop genetic resource management is indispensable for wise use of crop by research and seed producers for further improvement and conservation.

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