Farmers' Insight for Classification, Distribution and Genetic Erosion of Yams (*Dioscorea* spp.) Landraces from Southwest Ethiopia

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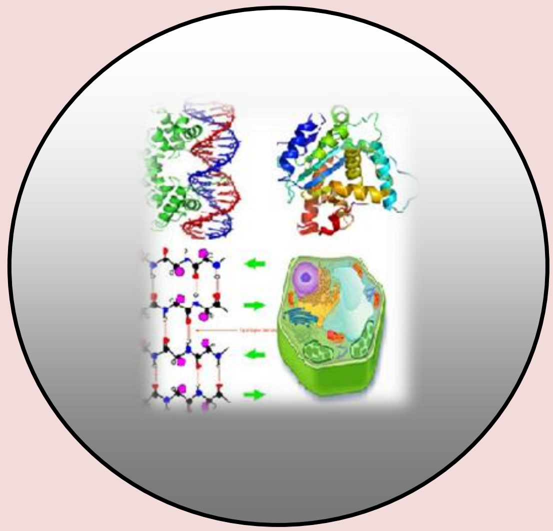

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RESEARCH PAPER

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Farmers' Insight for Classification, Distribution and Genetic Erosion of Yams (*Dioscorea* spp.) Landraces from Southwest Ethiopia

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ABSTRACT

Analysis of on farm diversity of plant genetic resources is fundamental for breeding and utilization. The study was conducted to assess farmers' insight for classification, distribution, quantify the rate of genetic erosion and identify major factor that causes ofgenetic erosion on yam in Southwest Ethiopia forstrategic conservation. A field survey was conducted on 240 households from seven districts of Jimma, Sheka and Bench maji zones from April to December 2015. Questionnaire was used to collect primary data from an average of 34farmers who are potentially rich sources of information on yam at district level. Additional data were collected through group discussions and key informant discussion. The results revealed, farmers' classification system of yam varied and depended on the domestication status, sex type, use value and type of maturity. The distribution of the landraces per district varied from 30 to 42 with a mean of 34.28. The lowest distribution was observed in Seka chekorsa and the highest in Kersa districts in the Jimma zone. At Kebele level, the number of landraces was varied from 6 to 21 with a mean of 10.90. The lowest diversity was observed in Gube muleta (Manna) and the highest in Boye kecema (Seka chekorsa) in the Jimma zone. The rate of genetic erosion at district and Kebele levels varied from 28.80% in Yeki to 57.93% in Kersa districts and 0% in Gubea muleta to 25% in Mehal sheko Kebeles with an average rate of 44.48% and 14.1%, respectively. Number of farmers growing landraces decreased drastically in all surveyed districts in the past decades. Low attention given to the crop (95%), drought at early stage (93%), porcupine attack (90%), shortage of farm land (74%), displacement of landraces by high value crops (72%), were the prominent factors for ending landrace cultivation. Moreover, farmers' preference for yield potential and cash crops subsequently reduced the chance of maintaining landraces.

Accordingly, in this study, the conceptual framework for analyzing farmers' classification system, spatial distribution of yam and factors that causes of genetic erosion was assessed in a systematic way for breeding and conservation.
Keywords: Conservation, Districts, Genetic Erosion, Households and Survey.

INTRODUCTION

Yams (*Dioscorea* spp.) constitute a diverse group of plant species widely distributed throughout the humid and semi-humid tropics (Alexander and Coursey, 1969; FAO, 2012). Most *Dioscorea* species exhibit considerable morphological variability both in the aerial and underground tuber (Scarcelli *et al.,* 2011).In yam study, combined analysis of morphological descriptors and farmers' knowledge have been widely used, to determine the relationships, classification and spatial distribution of the various species and landraces (Loko *et al*., 2013; Dansi *et al*., 2013a).Landraces are the result of selection from centuries by farmers and are a major source of genetic diversity in agriculture providing much of the genetic resources for plant breeding (Vavilov, 1951;Mashilo *et al*., 2015). However, study on landraces and their use by farmers are problematic in that the vernacular names used for landraces vary greatly and are not consistent (Demuyakor *et al*., 2013). Popular landraces can have several names even within the same district/Kebele and different landraces may have the same name (Mekbib, 2007). Thus, assessing the classification and spatial distribution of landraces in relation to vernacular names are imperative. Besides, determination of vernacular names of landraces with the phenotypic and genetic characterization with farmers' indigenous management system of their plant genetic resources is paramount importance (Mignouna *et al*., 2002; Siqueira *et al*., 2014).

In Ethiopia, there is large pool of yams that are broadly dispersed in major growing areas in composite cropping system with wide genetic base (Edward, 1991; Miege and Demessew, 1997; Hildebrand, 2003).Farmers have their own descriptor for classification and management of their landraces. Like other indigenous technical knowledge, folk taxonomy might have lake of consistency. Hence, uniformity of the naming system is the key issue for validation (Mekbib, 2007; Tamiru *et al.,* 2011). The existed local classification system is consistent to some extent with conventional botanical classification. As traditional farmers' numbering in the millions have turned away from their traditional landraces, the knowledge of how to maintain the selected landraces that performed well in particular habitats and conditions has fallen victim to even greater erosion than the landrace itself. While plant collectors have managed to save some of the abandoned genetic diversity, the knowledge that produced and maintained the diversity over many generations remains on site and has only rarely been recorded in connection with the collection of landrace for ex situ storage (Friis Hanse and Guarino, 1995; Loko *et al*., 2015). The erosion of indigenous knowledge which accompanies genetic erosion may be as damaging to the local community as the loss of the genetic material itself.

Currently, the indigenous yam genetic resources in Ethiopia are becoming seriously endangered owing to the high rate of genetic erosion resulted from natural calamities, displacement of yams by high value crops, changes in production systems and markets preferences(Hildebrand *et al*., 2002; Megersa, 2014). Further, the climate change and the availability of very limited funds for conservation have largely increased the genetic vulnerability of yam in the country. Moreover, limited attention has been given to assess the diversity and conservation of indigenous yam genetic resources and research is a rudimentary stage for identification, classification, description and evaluation of the available yam genetic resources for different utilization options. Besides, the causes and effects of the genetic erosion of plant genetic resources are poorly understood in Ethiopia (Megersa, 2014).As a result, some of yam genetic resources in Ethiopia are in danger of extinction, and unless urgent efforts are taken to characterization, evaluation and conservation, they may be lost even before they described and documented. In addition, the majority of yam genetic resource diversity found in the country, where documentation is scarce and risk of extinction is the highest and increasing. Further, genetic erosion of agricultural crops on farmers' fields receives less media attention even though, it is of far greater importance to the livelihood of millions of farmers, however, within the international community concerned with conservation and use of plant genetic resources, the causes and effects of the genetic erosion of agricultural crops and possible ways of limited such erosion have been heatedly discussed during the UNCED conference in 1992 (in the preamble to the Convention of Biological Diversity (UNCED, 1992) and in particular loss and threat to crop species has received much attention in recent years and there are often widely differing views on the issues involved. To address these constraints, genetic control through use of tolerant landrace are necessary (Yifru and Karl, 2006). Such landraces are expected to be found within the existing yam diversity in Ethiopia, which are yet to be studied. Moreover, the diversity of yam landraces maintained per districts and per households throughout agro-ecology and administrative zones has never been assessed and the rate of landrace loss at national and regional levels is still unknown. The name of the existing landraces hardly recognized; the ethno botanical, farmers' classification system and the spatial distribution of landraces per growing district by scientific research hardly assessed and it limits producers and researchers to access yam genetic resources in Ethiopia. Consequently, estimation of spatial distribution, diversity of yam, ethno botany and management of the existing diversity is crucial for conservation and sustainable utilization of yams in Ethiopia. Accordingly, the objectives of this study were: to assess farmers' classification system, estimate the rate of landrace loss (genetic erosion), analyze its spatial distribution and variation of yams across study districts and Kebeles and identify major factors that causes of genetic erosion in Southwest Ethiopia.

MATERIALS AND METHODS

Selection of study sites and farmers

A total of 22 Kebeles (Kebele is the least administrative hierarchy in Ethiopia) from seven districts of major yam growing areas of Jimma (Manna, Shebesombo, Dedo, Sekachekorsa and Kersa), Sheka (Yeki) and Bench-maji (Sheko) zones of Southwestern Ethiopia were assessed from April to December 2015.These areas were selected for study based on strong tradition in cultivating and domesticating various yam landraces with wide genetic base (Hildebrand, 2003; Demissew *et al*., 2003; Abebe *et al.*, 2013), high production potential and long history on production and management system of yam with farmers' traditional knowledge (Miege and Demissew, 1997). From each district, on average 34 farmers, 15 to 20 yam producers, 10 key informants and five DAs were sampled from different social groups for individual interviews, group and key informants' discussions.

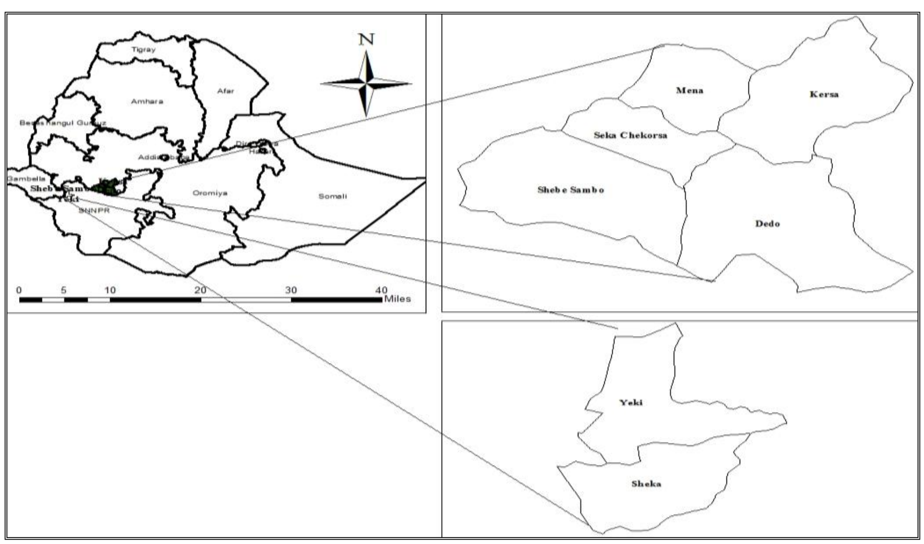


Figure 1. Districts of study area in Southwest Ethiopia.

The key informants were selected in order to conduct in depth interview and discussion. They were selected from household heads of both sexes and different age groups based on their availability, willingness and practical knowledge on yam in the areas. The local administrators and agricultural extension workers helped during identifying the names of the focus groups. Field visits (home gardens, cultivated fields) were conducted to perceive some of the species under cultivation. The household characteristics of the surveyed districts are presented in Table 1.

Table 1. Household characteristics of the surveyed districts.

Districts	No. of farmers	Religion			Sex		Mean age of farmers	Mean family size	Mean farm size(ha)
		Ortho	Mus	Eva	Male	Female			
Dedo	38.0	20.0	8.0	10.0	28.0	10.0	55.08	8.00	1.63
Kersa	42.0	22.0	13.0	7.0	30.0	12.0	47.83	6.19	0.86
Manna	35.0	9.0	22.0	4.0	28.0	7.0	47.46	6.08	1.47
Sekachekorsa	30.0	10.0	17.0	3.0	27.0	3.0	51.67	6.80	1.44
Shebesombo	31.0	19.0	7.0	5.0	23.0	8.0	52.35	6.90	1.40
Sheko	32.0	8.0	0.0	24.0	22.0	10.0	45.62	6.43	1.13
Yeki	32.0	15.0	2.0	15.0	24.0	8.0	50.11	6.80	1.51
Total	240.0	103.0	69.0	68.0	182.0	58.0	350.12	47.20	9.44
Mean	34.28	14.71	9.85	9.71	26.0	8.28	50.01	6.74	1.35

Ortho= Orthodox, Mus=Muslims, Eva= Evangelical Christian

Data collection

Data were collected from the different areas and institutions through the application of Participatory Research Appraisal (PRA) tools and techniques such as direct observation, individual interviews, key informants and focus group discussions using a well prepared questionnaire and checklists. Different households from each district were selected and interviews were conducted with the help of local translators. From each district, the selected farmers requested to bring samples of the yam landraces they produce or knew. Through discussion, some key information was recorded on each of the landraces identified. The information includes local vernacular names, adaptability, use value, time of plant and maturity of the landraces. Each landrace was properly evaluated based on, extent of the production, distribution, degree of consumption, perceived nutritional value, cultural importance, sex type, medicinal importance, market preferences, market value and contribution to household income. The distribution and extent of diversity of the landraces were assessed using the four cell sometimes called four squares analysis approach described by Loko *et al*. (2013) at district/Kebele level in the participatory way, to assess the abundance, distribution and extent of diversity of the identified landraces into four groups based on area apportioned to the landraces and the relative number of households cultivating it. These were landraces cultivated by many households on large areas; landraces cultivated by many households on small areas; landraces cultivated by few households on large areas and landraces cultivated by few households on small areas. Besides, reasons of explanation for each landrace by many or few households and on large or small areas were discussed and documented. Later on, the names of the landraces that have completely moved out from the areas were recorded and the causes of their abandonment are identified. It is the most important way to reduce further genetic erosion of yam in the areas. In addition, the distribution and association of factors that causes of genetic erosion at district/Kebele level were assessed through four cell analyses in the participatory way for conservation measure. For farmers' classification system, the identified yam landraces were assessed against domestication status, sex type, agronomic characteristics, use value, maturity and culinary traits of economic importance (Table 2) using participatory approach.

Additionally, data on indigenous knowledge and experiences of local farmers those considered to be more knowledgeable on the distribution, variability within the landraces and on genetic erosion at the landrace level were collected. Information such as change in cropping systems and reasons for change, adoption of improved technologies of yams, assessment of the yam seed supply systems, change with regard to the use of landraces, trends of yam cultivation in the area, availability of extension services on yam and farmers' perception about comparative advantages of landraces were assessed.
At individual, group and key informant levels, the discussions were free and open ended, without a time limit being set, following the method described by Dansi*et al*. (2013a). Information obtained from key informants are valuable to cross check and clear contradictory ideas on the existed yam diversity, farmers' classification system and distribution of yam throughout the study districts. Furthermore, data were collected from secondary sources like district agricultural offices, reports of extension and Institute of Biodiversity Conservation (IBC) at Jimma zone, to examine the extent of possible genetic erosion occurred in the last decades temporal comparison was used.

Table 2. Parameters used during participatory evaluation for classification of yam landraces in Southwest Ethiopia.

Variables	Parameters	Scoring
Domestication status	• Cultivated	0(cultivated)
	• Wild	1 (wild)
Sex type	• Male	0(Male)
	• Female	1(Female)
Agronomic	• Tolerance to drought	1(tolerant) – 0(susceptible)
	• Productivity	0 (low)-1(high)
	• Seeds production rate	0 (low)-1(high)
	• Adaptability of wider environment	0 (non adapted)-1(adapted)
	• Staking demanding	0 (low) 1(high)
	• Tolerance to weeds	0(susceptible) 1(resistant)
Use value	• For food	0 (no)-1(yes)
	• For medicine	0 (no)- 1(yes)
	• For market	0 (no)- 1(yes)
	• For food and medicine	0 (no)- 1(yes)
	• For food and market	0 (no) -1(yes)
	• For food, medicine and market	0 (no) -1(yes)
Maturity	• Early	0 (Early)
	• Medium	1 (Medium)
	• Late	2 (Late)

Data analysis
The collected data were analyzed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (Kebeles and districts) level using Statistical Analysis System (SAS) package (version 9.0 of SAS Institute Inc, 2000) and SPSS (1996) version 16 (Statistical Packages for Social Sciences).The rates of landraces loss (RLL) were calculated by using the formula described by Kombo *et al.* (2012) with some modification to assess the loss per study district and kebele level.

RLL = $\frac{(n-k)}{N}$ x100

Where n= number of landrace cultivated by few households on small areas within a district/kebele, k= number of newly introduced landraces in kebele/district and N= total number of landraces recorded in the district/Kebele level. To analyze the spatial distribution of the 38 identified yam landraces at districts and Kebele level, the principal component analysis tool was adopted by using Minitab statistical software (Minitab, 2010 version 16). Similarly, the degree of similarity and association between explored yam landraces and farmers identified causes of genetic erosion, the principal component analysis was also adopted based on likert scale method (Likert, 1932) (ranked 1-3, where, 1= factor that have low contribution to genetic erosion, 2= the causes that have medium contribution to genetic erosion and 3= the causes that have higher contribution to landrace erosion) and clustering of identified landraces computed by Minitab statistical software (Minitab, 2010 version 16) using the simple matching coefficient of similarity and a dendrogram was constructed with Un-weighted Pair group Method with Arithmetic average (UPGMA) to examine the relationships between identified landraces with factors of genetic erosion for conservation.

RESULTS AND DISCUSSION

Socio economic characteristics of surveyed farmers

The results of the present study indicated that, yam production is a male (75.83%) dominated activity. The high percentage of male farmers may be due to their access to farmland and their position as head of family. In this regard, similar study was conducted by Olweny *et al.* (2013) who concluded, farming is a male dominated profession. In all surveyed area, about 99% of the farmers were married; may be as a result of the belief of the areas that, married people are more accountable to control and manage farming. The mean age distribution of the farmers between districts revealed that the highest (55.08) age was recorded in Dedo and the lowest (45.62) age in Sheko. In this study, 42.91%, 28.75% and 28.33% of the farmers were found to be Orthodox, Muslim and Evangelical Christian, respectively. The educational background of the farmers showed, 102(42.5%) of them are illiterate with no formal education, 116 (48.33%) of the farmers had basic education (primary school level), whereas 22 farmers (9.17%) received secondary education. In each district, almost all farmers' have the same knowledge with regard to the name of landraces cultivated in their Kebele. This provides information for a good setting to access the diversity, distribution, management, classification, selection and evaluation of yam in traditional agriculture using naming landraces with a minimum influence of language polymorphism within the farmers. Morethan half of the surveyed producers (73.2%) had 8-25 years of experience in yam production and 26.8% had between 26 and 43 years of experience. In a cross tabulation in Table 1 it is shown that 82.5% of the farmers hold average farm size more than one hectare. Very few (17.5%) of the farmers in Kersa had 0.86 ha. Based on household family size, in all surveyed areas almost all the farmers had similar average household family size (Table 1).

Identification, naming and classification of landraces by farmers

In the present study, farmers distinguish each landrace from the other based on three main categories namely; landrace identification, naming of the landraces and classify them.

Identification of the landraces

Farmers used their own local descriptors for identification of the landraces (Table 4). Those descriptors are related to: morphological characteristics (vine color and length, twinge direction, tubercolor, shape and string on flesh tuber), agronomic characteristics (tolerant to drought, disease and pests, maturity time) and use value (food, medicine and market). Besides, farmers also use, tuber size, and tuber shape and tuber surface color for identification. The local farmers sometimes used the combinations of descriptors for identification traits. In most cases the descriptors that are related to the use value, culinary quality and agronomic characteristics came only after morphological characteristics (Brush *et al.*, 1981; Dansi *et al.*, 2013a).In the present study, 64%, 52% and 42% of the farmers mentioned descriptors for identification of landraces for tuber color, times of harvest and twing direction respectively.

Some descriptors (tuber flesh and surface color) were used for the identification of a limited number of landraces. For example, sharp and square vine with white tuber flesh, as descriptor was used specifically for landrace *badaye* to distinguish from the other landraces.

Table 3. The names and major attributes of yam landraces identified by farmers.

Name of landraces	Major attributes	Name of landraces	Major attributes
Afra	• White and red mixture flesh • Thorney tuber and vine • Used as food and medicine • Medium maturing type	Gurshume	• Deep purple flesh color • Used as a medicine • Late maturing type • Resistant to drought
Anchiro	• White tuber flesh color • More palatable and broad leaves • Early maturing and female	Hati-boye	• White tuber flesh color • More palatable and used as a food • Early maturing and female type
Badaye	• Early maturing type • White, purple and white purple flesh color • Thick/sharpand a squarevine	Karakachi	• Vigorous growth and large tuber • Thorns on vine and tuber • White yellowish tuber flesh • Wild type
Badenseye	• White and black mixture flesh type • Testy and female type	Kerta-boye	• Resistant to drought • Big tuber size • Medium maturing type
Baki-boye	• Thick vine • Used as food and medicine • Medium maturing type	Liyan	• White aerial bulbils flesh • Big tuber and testy • Used as food and medicine
Bambuche	• Long dark green leaves • Big tuber size • Female type	Mecha boye	• White tuber flesh color • More palatable and used as a food • Early maturing and female type
Banda	• Mixed black and white flesh • Used as a food and medicine	Offea	• Purple aerial bulbils flesh color • Small tuber and testy
Dapo	• White yellowish tuber flesh • Female type	Wadela boye	• Deep purple tuber flesh color • Used as a medicine
Bola boye	• Highly branched tuber • Big tuber size • Female type	Pada	• Early maturing type • White tuber flesh color • Tasty and female type
Bori-boye	• Large dark green leaves • Early maturing • White tuber flesh color	Sesa	• Wild type • Thorny on vine and tuber • White tuber flesh color

Naming of yam

In all study districts, famers' give separate vernacular name for each landrace they grew. The names are often descriptive and reflect the variations of landraces in places of geographical origin, morphology, agronomic and culinary characteristics. Most of the time, farmers' tie up the names of places in neighboring districts to the names of the landrace; for example, in this study, the name of landrace *pada* was originally collected from Daurozone of Southern region by Dedo farmers and had white flesh color, therefore, *pada* sometimes called *Dauro white* in Dedo district.

Moreover, the naming may also include the indication of physical entities. In other instances, farmers exactly used words to describe the specific morphological, agronomic and cooking quality attributes of the particular landraces (Magule *et al*., 2014). From all surveyed districts, a total of 38 farmers' namedyam landraces were identified and the attributes of each landraces are presented in Table 3.

Table 3. Continued

Name of landraces	Major attributes	Name of landraces	Major attributes
Chebesha	• Used as a food & more palatable • Early maturing and female • Low water holding content after boiling	Torebea	• Late maturing type • Used as food and medicine • Female type
Dakuy	• Deep red tuber flesh color • Big tuber size and used as medicine • Medium maturing type	Tsedeboye	• Black tuber flesh color • Big tuber size • Male type • Late maturing type
Dartho	• Purple and white purple flesh color • Resistant to drought • Female type	Woko	• White bulbils flesh color • Big tuber and testy • Early maturing type • Used as food and medicine
Doni	• Variegated tuber flesh color (white and red) • Early type • Used as a food	Washinea	• Large and black flesh yam • Thorns on tuber surface • Resistant to drought • Male type
Erkabea	• Outer deep purple and inner white flesh • Used as food and medicine	Wayera	• Vigorous growth and spiny vine • White flesh color • Female type
Feda	• White yellowish flesh color • Big tuber size • Female type	Welmeka	• Variegated bulbils flesh color (white and red) • Big tuber and testy
Geano boye	• Large and deep red tuber flesh • Used as a medicine • Male yam • Late maturing type	Zankur	• Deep purple flesh color • Used as a medicine • Resistant to drought • Male type
Gesa boye	• Variegated tuber flesh color (purple and white)	Zatemera	• Small dark green leaves • Resistant to drought
Goshitea	• Small leaves and high density • Late maturing • Female type	Zawera	• Outer surface of the tuber deep purple and inner white flesh • Big tuber and testy • Female type

Farmers yam classification system

In this study, farmers use folk classification systems in order to group their landraces into different categories such as, domestication status, sex type, use value and time of maturity to classify the landrace (Table 4). Based on domestication status, farmers distinguish their landraces by wild and cultivated. During in the key informants discussion and agricultural expert elicitation sessions, participants indicated that it is very unlikely to find wild yam in most study districts. However, wild yams only grow naturally in forest areas of Sheko (*karakachi*) and Manna districts (*sesa*) of Southwest Ethiopia.

Due to its dioecious in nature, yam landraces are grouped as 'female and male' is an interesting aspect of the local classification system. The two categories indicated that this grouping reflects more than mere differences in agro-morphological traits, consumption qualities and ecological adaptation (Tsegaye, 2002; Magule *et al*., 2014).Of the total 38 landraces identified, 9(23.68%) were classified as 'male', 16(42.11%) as 'female' and the remaining 13(34.21%) landrace had unclear sex designation, some farmers claiming them 'male' and others claiming them 'female'. Based on use value, farmers classified the landraces in two comprehensive use groups: food use and medicinal value. Although most landraces can be used as both for food and medicine, there are preferences for specific landrace among the societies for scrupulous purposes. In all districts, farmers planted the landraces primarily for food and others for medicinal uses.

Maturity yam is generally distinguishable by cessation of vegetative growth, yellowing of leaves, seed and flower development (Onwueme and Charles, 1994).Based on farmers' recognition, early maturing landraces mature within a short period (four to five months after plant) of time. Farmers' used these landraces to fill their seasonal food and economic gaps. Medium and late maturing landraces are mature 6-8 months and more than 8 months after plant, respectively. Selection based on maturity also varies within yam species. For example, *D. Cayenensis* matures within 280-350 days (9-11) after plant and *D. rotundata* matures within a range of 200-330 days (6-11) after plant (Onwueme and Charles, 1994). The time of maturity is the cause of variability of yield and highly dependent on the species (Mulualem, 2016).In this study, 18(47.37%), 11(28.95%) and 9(23.68%) landraces identified as early, medium and late maturing yam landraces, respectively. For the sake of times of harvest, both early and medium types have twice harvest while, for the late type harvest only once.

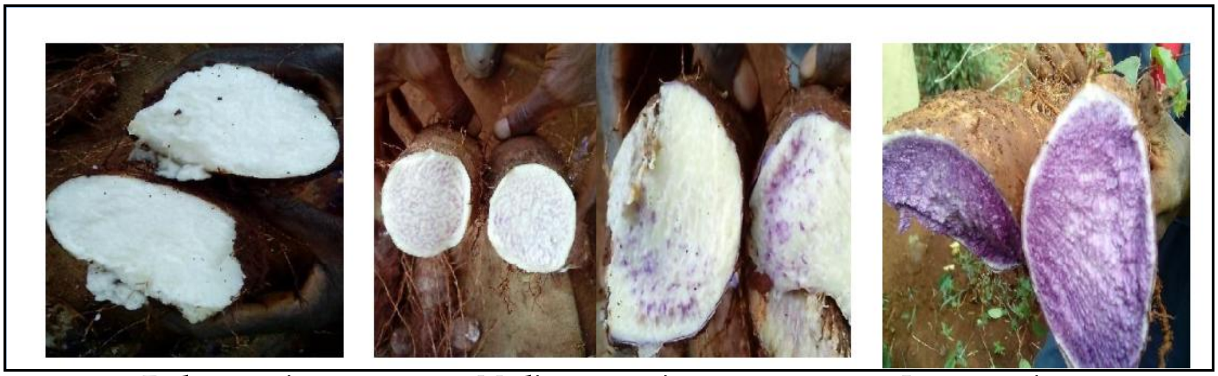
Table 4. Folk classification of yam landraces in Southwest Ethiopia.

Folk classification bases	Categories	Characteristics of landrace in each category	Landraces in each Category (%) (N =38)
Domestication status	Wild	Sexually reproduced; occurring naturally in forest areas;	2(5.26%)
	Cultivated	Vegetative propagated: it occurs in home garden under farmers' management condition	36(94.74%)
Sex type	Female	Early maturing, more tender, with edible storage tuber	16 (42.11%)
	Male	Late maturing, vigorous, drought tolerant, with medicinal tubers	9(23.68%)
	Un clear	Some of them are medium maturing yams used to fill seasonal food and economic gaps	13(34.21%)
Use-value of landrace	Food use	Mainly used for yam based foods	NA
	Medicine	Mainly used as medicine	NA
	Both	Mainly used as a food and medicine	NA
Maturity	Early	Mature within 4-5months	18(47.37%)
	Medium	Mature within 6-8months	11(28.95%)
	Late	Mature more than 8months	9(23.68%)

NA- Not available

Spatial distribution and diversity of yam at district level

The Principal Component Analysis (PCA) was adopted to assess the association and distribution of the identified landraces in the surveyed seven districts for conservation. The first two principal components scores 37.4% (PCA-1) and 57.5% (PCA-2) of the total variation are presented in (Figure 2).



Early maturing **Medium maturing** **Late maturing**

The distribution of 38 yam landraces resulted in partitioning of *chebsah, afra, banda, dakuy, woko* and *tsedeboy*, from other landraces, *mecha boye, gurshumea, bambuche, hati boye, bola boye, anchiro* and *zatemera* assigned them into the negative and positive direction of the first component, respectively. Being a negative or positive direction has nothing to do with values, it does show their association i.e. contribution to the distribution of respective districts (Figure.2). District such as Yeki showed higher score in the negative direction of the first components showing their strong association with early and the white flesh landraces of *badaye*. Attributes such as use value for food and medicine, yield and taste, was associated with *chebsha* and *woko* and *liyan*. Farmers described *woko* for its quality food and medicine. They also mentioned *woko* and *liyan* grows commonly in the lowland areas and had betteradaptation to moistures stress and produce bulbils after five to six months of planting. This result was supported by earlier study by Ketema (1997) who indicated, local cultivars of tef such as *gea-lamie, dabi, shewa-gimira, beten* and *bunign*, to be early maturing varieties(<85 days), and are widely used in areas that have a short growing period due to low moisture stressor high temperature.

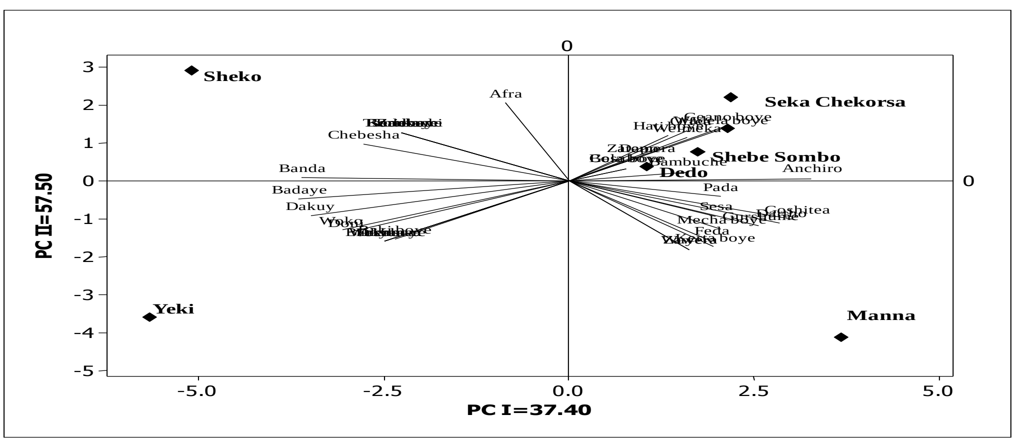


Figure 2. The spatial distribution of 38 landraces in seven districts.

In the positive and negative direction of the first component covers 71.5% of the total distribution of the landraces that adapted to Dedo, Shebesombo, Kersa, Manna and Seka chekorsa districts of Jimma zone (Figure.2). Landraces distributed in this axis indicated high association with low and mid altitudes, earliness, different tuber flesh color, and have double harvest. Most of the landraces are used as food, high market value and resistant to disease and pests. This result is in agreement with the findings of Gizachew (2000) and Addis (2005) who indicated that landraces *nobo, mezya* and *henewa* are tolerant to enset bacterial wilt and mealy bug and adapted variable environments.

The spatial distribution of landraces indicated specific interactions between landraces and their areas of collection. *Pada, anchiro, bambuchea, sesa* and *bola boye* were the landraces with stable for variable environments, as the points for these landraces were close to the origin of the biplot. On the other hand, landraces *liyan, badensey, erkabea, baki boye, washinea, badaye* and *woko* had adapted specific environments especially Sheko and Yekidistricts of Southern Ethiopia (Figure 2). This result is in line with the report of Hildebrand *et al.* (2002) who confirmed four *Dioscorea* species which were found in Sheko district. Besides, Miege and Demessew (1997) reported eleven *Dioscorea* species, both wild and cultivated in Ethiopia.

Spatial distribution and diversity of yam at kebele level

At Kebele level, the number of landraces varied from 6 to 21 with an average of 10.90. The lowest diversity was observed in Gubemuleta (Manna) and the highest in Ankaso (Kersa chekorsa) in Jimma zone of Oromia region (Table 5). Principal component analysis was adopted to understand the distribution of landraces at Kebele level. It is evident from previous descriptions that changes were observed for certain landraces when analyzed individually. Figure 3, reveals, the distribution of landraces and their distant positions from their area of collection in the biplot. Most of the landraces distributed from the origin. The first principal component had a variation value (Eigen value) of 6.2643 and explained the 39.2% of difference among the total landrace distribution. The coefficients listed under PC1 showed the relation of the landraces distribution. The landraces *afra, badaye, badenseye, baki boye, banda, bori-boye* and *chebsha* etc. are limited distribution on six Kebeles (Figure3). On the contrary, the negative coefficients expressed the more dispersed landraces in different Kebeles. The 2nd principal component consisted of variance values (Eigen value) greater than 2.7168and accounted 17.0% of the difference among the total landrace distribution at Kebele level. Together, two principal components represented 56.20% of the total variability among the total landrace distribution. Thus, most of the data structure can be captured in some underlying variations. The remaining principal components account 43.80% of the variability. Based on the above results, it is possible to predict the extinction of the existing landraces in Southwest Ethiopia. Yam landraces grew in few districts and distributed in small areas exposed to erosion unless urgent control measure are applied.

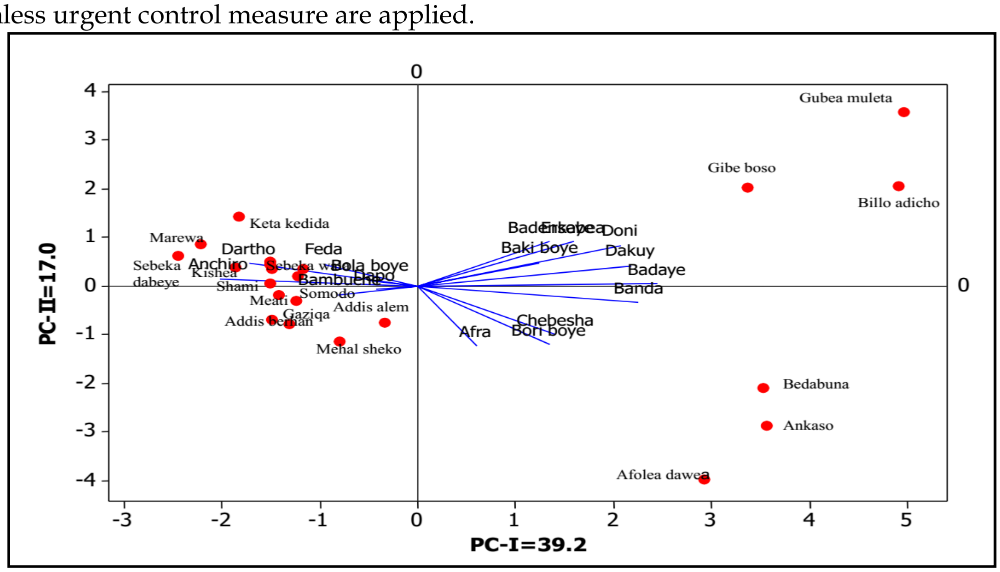


Figure 3. The spatial distribution of 38 landraces at 22 Kebele.

Distribution and rates of genetic erosion

In the present study, the reasons for abandoning landraces identified throughout the Kebeles and district were diverse and varied from one Kebele to another. At district level, the rate of genetic erosion varied from 28.80% in Yeki to 57.93% in Kersa with a mean rate of 44.48% (Table 5).

Genetic erosion is a complex process and several factors that involved either directly or indirectly on existed landraces (Mulualem, 2016). Some of these factors are related to socio-economic factors in general, while others are related to biotic and a biotic factor (Brush and Meng, 1998).

The common, unique and rare/endangered landraces or species of yam at Kebele and district level was identified through four cell analyses. The results also revealed that, only a few landraces (2.5) on average per Kebele were cultivated by many households and on large areas. According to the producers, these landraces were found to have good agronomic (high productivity, high multiplication rate, etc.), utilization and culinary characteristics and therefore their production are economically profitable (Table 5).Landraces cultivated by many households but on small areas (3.9) on average per Kebele had exceptional culinary characteristics (good taste, good quality for medicine) but presenting a lot of weaknesses (Dansi*et al,* 2013b).

Table 5. Distribution, extent of analysis and the rate of landrace loss in the study districts and Kebeles.

District	Kebele	TNL	SH	DH	DET				NIL	RLL%
					ML	MS	FL	FS		
Dedo	Afoleadawea	14.0	2	12	3	4	2	4	1	21.42
	Billoadicho	13.0	3	10	4	5	2	2	0	15.38
	Keta kedida	11.0	2	9	4	3	1	2	1	9.09
	Total	**38.0**	**7**	**31**	**11**	**12**	**5**	**8**	**2**	**45.89**
Kersa	Ankaso	21.0	9	12	5	7	3	5	1	19.04
	Beda buna	12.0	2	10	4	4	2	2	0	16.67
	Marewa	9.0	2	7	2	4	1	2	0	22.22
	Total	**42**	**13**	**29**	**11**	**15**	**6**	**9**	**1**	**57.93**
Manna	Bilida	9.0	2	7	2	4	1	2	0	2.22
	Gubea muleta	6.0	1	5	1	3	0	1	1	0.00
	Meati	10.0	1	9	3	4	1	2	0	20.00
	Somodo	10.0	3	7	2	4	1	2	1	10.00
	Total	**35**	**7**	**28**	**8**	**15**	**3**	**7**	**2**	**32.22**
Seka chekorsa	Boye kecema	17.0	5	12	3	6	4	4	0	23.52
	Gibe boso	6.0	2	4	1	3	1	1	0	16.67
	Sheni qoche	7.0	3	4	3	2	1	1	0	14.28
	Total	**30**	**10**	**20**	**7**	**11**	**6**	**6**	**0**	**54.47**
Shebe sombo	Kishea	9.0	2	7	2	3	1	2	1	11.11
	Sebeka dabeye	14.0	4	10	3	5	2	3	1	14.28
	Sebeka wala	8.0	2	6	1	4	1	1	0	12.50
	Total	**31**	**8**	**23**	**6**	**12**	**4**	**6**	**2**	**37.89**
Sheko	Gaziqa	9.0	2	7	1	3	2	2	1	11.11
	Mehal sheko	12.0	2	10	3	5	1	3	0	25.00
	Shami	11.0	2	9	2	3	1	3	1	18.08
	Total	**32**	**6**	**26**	**6**	**11**	**4**	**8**	**2**	**54.19**
Yeki	Addis alem	13.0	1	12	3	5	1	2	1	7.69
	Addis berhan	9.0	2	7	2	3	1	2	1	11.11
	Selamber	10.0	2	8	2	3	2	2	1	10.00
	Total	**32**	**5**	**27**	**7**	**11**	**4**	**6**	**3**	**28.80**
Mean		**10.9**	**2.5**	**8.4**	**2.5**	**3.9**	**1.4**	**2.3**	**0.5**	**14.1**

They had low productivity, high staking demand, poor postharvest storage and post maturity conservation in the mounds, high susceptibility to poor soils fertility, low multiplication rate, etc. making their production economically unprofitable some landraces (1.4) on average per Kebele were cultivated by few households on large areas. According to the farmers, these landraces had good agronomic and culinary qualities but presenting some particularity: difficulty to harvest, soil selectivity and long dormancy. Finally, some landraces (2.3) on average per Kebele were cultivated by a few households and on small areas indicating that, landraces had high growth performance and were threatened or being disappeared (Table 5). This result was also supported by Loko *et al*. (2013) who reported that yam cultivars produced by few households and distributed on small areas considered as threatened last generally only five years and most often, effectively disappear after this period from the villages where they identified. If this trend continues, the indigenous yam diversity and knowledge could be lost in the near future (Hammer and Laghetti, 2005).

TNL= Total number of landraces; SH= Single harvest landraces; DH= Double harvest landraces; DET= Distribution and extent; RLL=Rate of landraces loss; NIL= Newly introduced landraces; ML=Many households and large area; MS = Many households and small area; FL= Few households and large area; FS = Few households and small area.

In line with this, Diehi (1982), Manyong and Nokea (2003) and Ashiedu and Alieu (2010) predicted a future decline yam production based on socio economic and agronomic consideration. For example, according to Hildebrand *et al*. (2002), who described five farmers' landraces namely, *erkabea*, *don-babu*, *don-bai,chebesha* and *kuchi-kundi* to be threatened in Sheko district. In the present survey, except *erkabea* and *chebesha*, three landraces were lost and not described by farmers in the same district. Moreover, changes in production systems, market preferences, environmental hazards and the availability of very limited funds for conservation activities have reduced the diversity of yams genetic resources in the country (Dansi *et al*., 2010; Sesay *et al*., 2013).

From the 22 Kebeles assessed, the rate of genetic erosion (loss of landraces diversity) varied from 0% in Gubea muleta to 25% in Mehal sheko with an average rate of 14.1% (Table 5). The zero rate of diversity loss recorded in Gubea muleta is not an indication of a better preserver, but rather a maximum threshold of landraces abandonment reached. Similar results were obtained on yam (Dansi *et al*., 2010) and cassava (Kombo *et al*., 2012).

Causes of genetic erosion

Farmers' named landraces had decreased cultivation areas or which entirely disappeared and were no longer cultivated by farmers in the study areas. For example, in the present survey, farmers verbally reported some vernacular names of landraces that were no longer found in their districts/Kebeles and thought to be lost. Some other landraces had undergone notable reductions during recent years (Brush, 2004; Mark, van de *et al*., 2009). This result is consistent with the report of Megersa, (2014) and Tsegaye, and Berg, (2007) who reported the decline the production of farmers named barley and wheat genotypes in North and East Shewa zone of Oromiya region. The loss of diversity on yam in study districts of Southwest Ethiopia could be attributed to several reasons.

Based on the result, low attention given to the value of the crop is one of the main factors that caused genetic erosion and it accounts 95% of the total farmers (Table 6). Although, the most frequently reported about 95% of the cause of crop genetic erosion is dilution of the crop by improved technologies, in this study, it accounts 72% of the total farmers replace the yam field by coffee, chat, turmeric and maize. In all study districts, farmers' confirmed, young people today have less interest to yams 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.

In addition, more productive maize varieties have been and are being introduced by agricultural extension workers, who also encourage intensive cultivation practices and contend area and labor force from yam production during main planting time (February and early March). These times correspond to the ideal period for field preparation and collection of stake to support plant for maize and yam, during which maize and stake yams compete directly for labor.

Changes of farming system are 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 all surveyed districts, 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. 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, 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 yam landraces by modern varieties in many fields.

The other most important cause of genetic erosion was the occurrence of drought at early stages of the crop and it accounted93.0% of the total farmers (Table 6). Most of the interviewed farmers indicated, yam planting was done in October and November, and during this period moisture stress was happen at emergence and subsequent months, thus, the plant became stunted and finally die. Porcupine (90.0%) and mole rat (60.0%) attacks were the other prominent factors contributing more to genetic erosion of yams. Some landraces used as medicine are less preferred by porcupine and mole rats. This might be due to medicinal yams had high polyphenols or tannin like compound and not favorite by wild animals. In this regard, Arunachalam (1999) who reported, natural disaster such as floods, drought and wild animal attacks are more contributing to genetic erosion. Shortage of farm land (74.0%) and labor (23.0%) were also another factors mentioned by farmers as causes of genetic erosion. According to the farmers', high population pressure and urban expansion in different districts are cause land shortages.

Table 6. Factor that causes of genetic erosion of yam in Southwest Ethiopia.

Causes	Dedo (38)	Kersa (42)	Manna (35)	Seka chekorsa (30)	Shebe sombo (31)	Sheko (32)	Yeki (32)	Total
Low attention to the crop	11.0	20.0	18.0	17.0	16.0	8.0	5.0	95.0
Drought at early season	31.0	3.0	7.0	2.0	9.0	18.0	23.0	93.0
Porcupine attack	17.0	7.0	5.0	25.0	13.0	15.0	8.0	90.0
Need more management	4.0	20.0	14.0	10.0	6.0	8.0	20.0	82.0
Shortage of farm land	8.0	17.0	13.0	4.0	2.0	8.0	22.0	74.0
Replaced by high value crop	16.0	4.0	7.0	2.0	2.0	17.0	24.0	72.0
Attacked by mole rat	0.0	14.0	3.0	10.0	18.0	7.0	8.0	60.0
Shortage of stake	11.0	0.0	13.0	10.0	12.0	1.0	2.0	49.0
Labor shortage	5.0	0.0	0.0	3.0	2.0	13.0	0.0	23.0
Low market value	0.0	2.0	2.0	0.0	0.0	0.0	0.0	4.0
Low soil fertility	0.0	2.0	0.0	1.0	0.0	0.0	0.0	3.0
Lack of extension service	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Total	103.0	89.0	83.0	84.0	80.0	95.0	112.0	646.0

Figures in parenthesis refer to number of farmers surveyed in each district. Source: own survey result, 2015; Sum greater than 100 is due to double counting.

Table 7. Rank of landraces given by farmers to genetic erosion in study districts.

Landraces	A	B	C	D	E	F	G	H	I	J	K	L
Afra	3.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0
Anchiro	2.0	2.0	1.0	1.0	2.0	2.0	1.0	3.0	2.0	1.0	1.0	1.0
Badaye	2.0	2.0	2.0	1.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	1.0
Badenseye	2.0	2.0	3.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0
Baki boye	3.0	2.0	2.0	2.0	1.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0
Bambuche	3.0	3.0	2.0	2.0	2.0	2.0	1.0	3.0	2.0	2.0	1.0	2.0
Banda	3.0	2.0	2.0	1.0	2.0	1.0	1.0	2.0	2.0	1.0	1.0	2.0
Bola boye	2.0	3.0	1.0	1.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0
Bori boye	2.0	2.0	3.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	2.0
Chebesha	2.0	3.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	2.0	1.0
Dakuy	3.0	2.0	2.0	1.0	2.0	2.0	1.0	2.0	2.0	1.0	2.0	1.0
Dapo	2.0	3.0	2.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	2.0	1.0
Dartho	2.0	1.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Doni	2.0	3.0	2.0	2.0	3.0	2.0	1.0	2.0	1.0	1.0	2.0	1.0
Erkabea	3.0	2.0	2.0	3.0	3.0	2.0	2.0	3.0	1.0	2.0	3.0	2.0
Feda	2.0	2.0	3.0	2.0	3.0	2.0	1.0	1.0	1.0	2.0	2.0	2.0
Geano boye	2.0	1.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	1.0	2.0	1.0
Gesa boye	3.0	2.0	2.0	2.0	2.0	3.0	2.0	1.0	2.0	2.0	1.0	1.0
Goshitea	1.0	2.0	1.0	1.0	2.0	2.0	2.0	3.0	2.0	1.0	1.0	1.0
Gurshume	2.0	2.0	3.0	2.0	2.0	3.0	1.0	2.0	2.0	3.0	1.0	1.0
Hati boye	2.0	1.0	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	1.0
Karakachi	2.0	2.0	1.0	2.0	2.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0
Kerta boye	2.0	1.0	2.0	2.0	3.0	2.0	2.0	2.0	1.0	2.0	1.0	2.0
Liyan	3.0	2.0	3.0	2.0	2.0	1.0	2.0	2.0	2.0	3.0	1.0	2.0
Mecha boye	2.0	2.0	2.0	1.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
Offea	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	1.0	1.0
Pada	2.0	3.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0
Sesa	2.0	2.0	3.0	2.0	2.0	1.0	2.0	2.0	1.0	3.0	2.0	2.0
Torebea	2.0	3.0	2.0	2.0	1.0	2.0	2.0	3.0	2.0	3.0	2.0	2.0
Tsedeboye	2.0	3.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	1.0	2.0
Wadela boye	3.0	2.0	2.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	1.0	2.0
Woko	2.0	3.0	2.0	1.0	2.0	2.0	1.0	2.0	3.0	2.0	2.0	2.0
Washinea	2.0	1.0	2.0	2.0	3.0	2.0	2.0	2.0	3.0	2.0	1.0	1.0
Wayera	2.0	3.0	2.0	2.0	3.0	2.0	1.0	2.0	1.0	2.0	2.0	1.0
Welmeka	3.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0
Zankur	2.0	2.0	3.0	2.0	3.0	2.0	1.0	3.0	2.0	2.0	3.0	1.0
Zatemera	2.0	1.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	3.0	2.0	3.0
Zawera	2.0	2.0	2.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0	2.0	2.0

1=low cause, 2=Medium cause and 3= Higher cause for landrace erosion

A= Low attention to the crop, B= Drought at early stage, C= Porcupine attack, D= Need more management, E= Shortage of farm land, F= Replaced by high value crop, G= Attacked by mole rat, H=Shortage of stake, I= Labor shortage, J= Low market value, K= Low soil fertility and L= Lack of extension service.

In this study, the clustering approach was adopted to examine the relationships between explored yam landraces based on the degree and similarity of the 12 farmers identified factors of genetic erosion by using likert scale method (Likert, 1932). The degree of yam landraces react with different factors of genetic erosionis presented in Table 7. The results revealed the clustering of landraces classified into six distinct groups with different sizes. A dendrogram summarize the similarity among 38 yam landraces is given in Figure 4. The clustering pattern showed that the amount of landraces in each cluster varied from one in cluster VI to eighteen in cluster II. Cluster II, consisted the maximum number and accounted 47.36%) % of the total landraces. Landraces in this cluster were mainly identified by 80.07% of similarity.

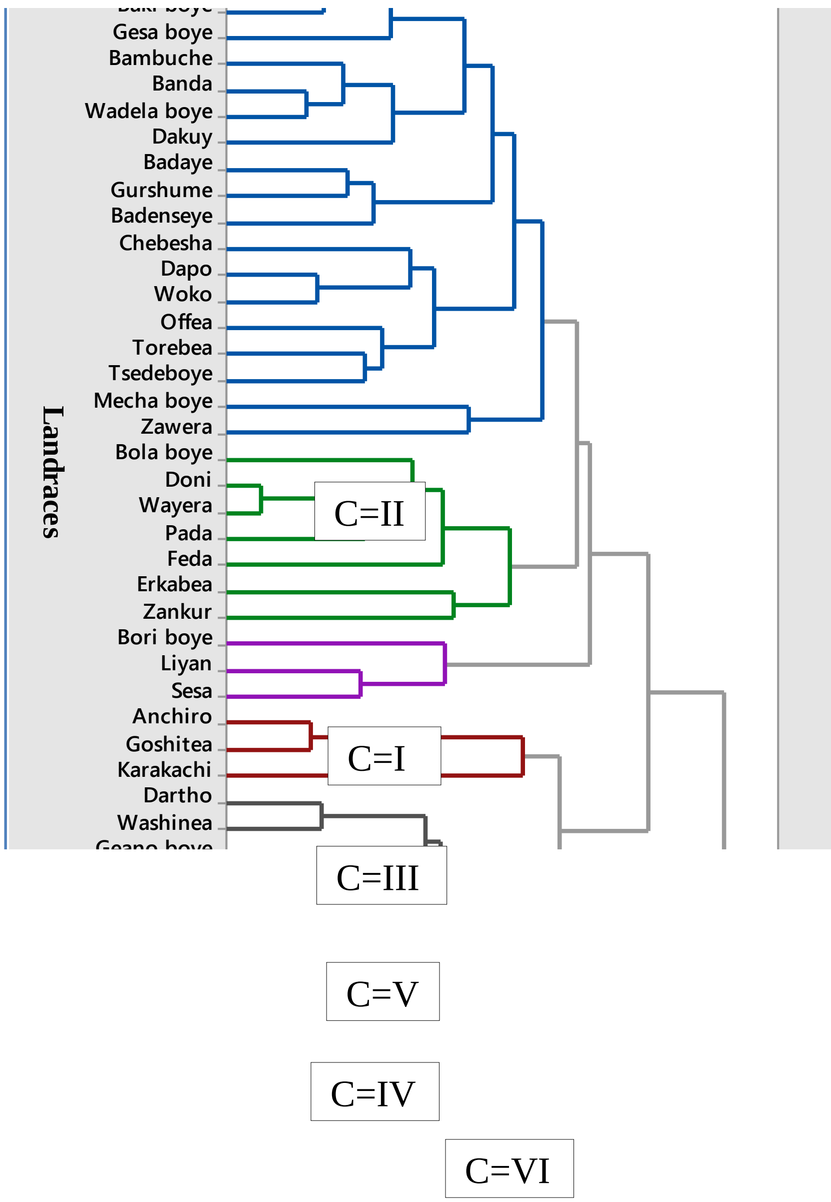


Figure 4. UPGMA based clustering of 38 yam landraces based on 12 farmers' identified causes of genetic erosion.

Conversely, landraces in this cluster have low contribution to drought and wild animal attacks particularly of porcupine and mole rat. Cluster I had seven (18.42%) of the total and landraces grouped in this cluster had 73.49% similarity and high contribution to most of the causes of genetic erosion identified by farmers. Cluster III and V had had three entries (7.89%) from each, all of them had medium contribution to most of the causes of erosion on yams. Similarly, cluster IV and VI had seven landraces (18.42%). Landraces in these clusters had 70.32% and 40.20% similarity, respectively and high contribution to drought, shortage of farm land, management and mole rat attack.

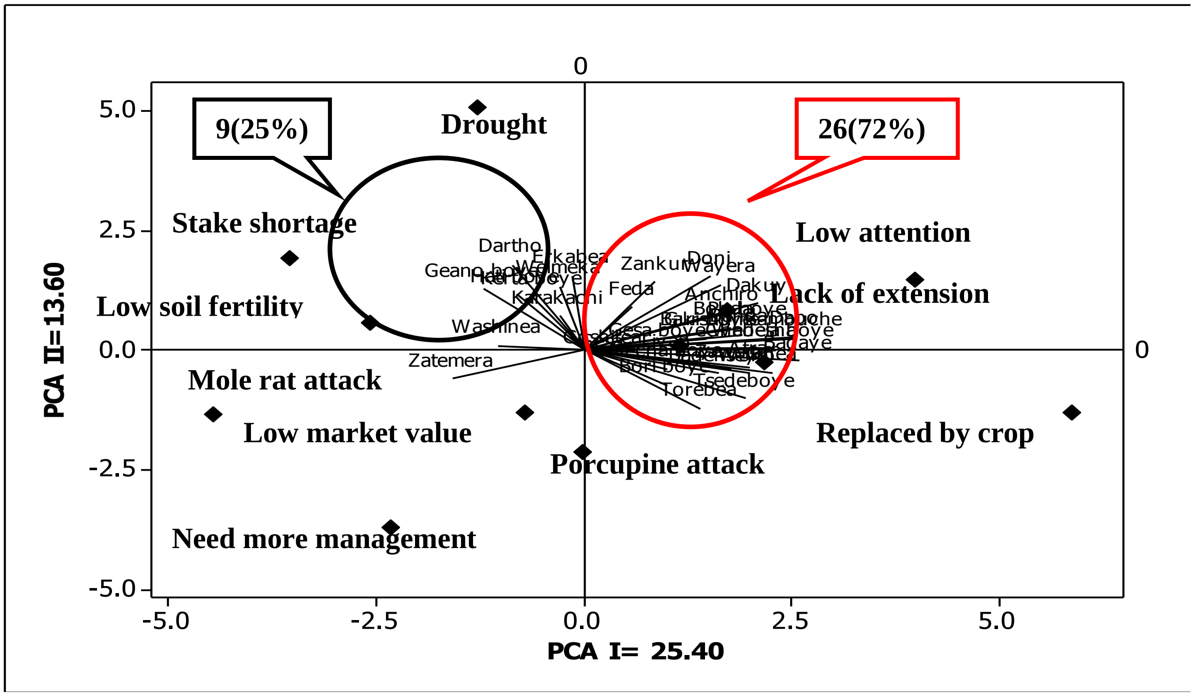


Figure 5. The association of 38 yam landraces and 12 causes of genetic erosion in the study areas.

The results obtained from bi-plot principal component analysis evidently showed, genetic erosion is an important constraint in yam production in Ethiopia. The first two principal components contributed 25.40% (PCA-I) of the total variation and the second component contributed 13.60% (PCA-II) showed a clear interaction between yam landraces and causes of genetic erosion (Figure 5). In the positive direction of the first component, attributes such as low attention given to the crop, porcupine attack, presence of drought at early stage of the crop, replaced the yam field by high value crops (chat and coffee) and availability of low extension services contributed more and are the most important sources of genetic erosion of yam in Southwest Ethiopia. About 72.0 % of the identified landraces were eroded by these factors. Therefore, by improve the extension service and awareness creation to farmers has high possibility to conserve 72% of yam genetic resources in Southwest Ethiopia. While, stake shortage and poor soil fertility showed higher score in the negative direction of the first component.

Furthermore, the bi-plot principal component also clearly indicated the relationships among yam landraces and resistant to the factors that cause genetic erosion. In this study, landraces *torebea, baki boye, badaye* and *tsede-boye* were quite similar in terms of resistance early drought and porcupine attack. Landraces, *gesa- boye, goshitea, gurshume, hati boye, karakachi, kerta boye, liyan, mecha boye, offea, pada* and *sesa* were found to have stable resistance to most of the factors of genetic erosion, as the points where close to the origin of the bi-plot. On the other hand, landraces *zatemera*, *washinea* and *geano boye* are sensitive to management, poor soil fertility and stake demand. Thus, the knowledge of genetic erosion and interaction with the landraces are significantly important to apply conservation measure.

Conservation of yam genetic resources

The present study, clearly flagged out the factors that determine the place of yam landraces in the production system and the interest that farmers have in them. These factors are important to develop sustainable conservation strategies (Jianzhang and Kun, 2012).Yam production system in Southwest Ethiopia, conservation through use approach needs to be sustained with a number of strategic actions such as i) collection of yam genetic resources, ii) morphological and genetic characterization of these resources, iii) promotion of yam diversity with emphasis on production locations where the diversity is high and iv) training and capacity building, particularly on cultivation and post harvest practices(personal discussion with farmers). Besides, establishment of a core collection of yam genetic resources at regional level in major growing areas are paramount importance. Although yam is vegetative propagated, it cannot only rely on farmers to maintain all the diversity that might be available particularly when the diversity is unknown.Furthermore, the analysis on the extent and distribution of the genetic diversity in a species, and of the way in which its structure is an essential prerequisite to determine what to conserve, and where and how to conserve it.

CONCLUSION

Farmers in the study area have substantial traditional awareness on yams. Due to the past research neglect, farmers are commonly the bases of information on yams in southwest Ethiopia. Subsequently, the analysis of indigenous knowledge, farmers' perception in designing conservation and improvement programs are critical to solve the identified problems in the study areas. Farmers' classification systems are mainly based on very specific needs, preferences and socio-cultural aspects; thus, research in cooperation with farmers becomes necessary for breeding and conservation. In this study, the major causes of genetic erosion and its distribution on yam was identified, thus, training to farmers, diversity fair, diversity block, genetic enrichment/diversity kits across districts and Kebeles are crucial for sustainable utilization of yam genetic resources in Ethiopia.

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