SPATIO-TEMPORAL DYNAMICS OF CROP GENETIC DIVERSITY AND FARMERS' SELECTIONS *IN SITU*, ETHIOPIA

Awegechew Teshome (PhD)
Research Scientist and Project Leader

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EXECUTIVE SUMMARY

In this research report the dynamics changes in field size and fragmentation, farmers' selection criteria and sorghum landrace diversity, distribution and stability in the north Shewa and south Welo research area during eight intervening years between 1992/93 and 2000/2001 cropping seasons were examined. The research components included graduate research, training, gender and socioeconomic, landrace stability and landrace mapping across the agroecological gradients of five farming communities.

With support of the Institute of Biodiversity Conservation and Research (IBCR), IDRC, USC/Canada and IPGRI, 1992-93 research on "Factors maintaining sorghum landrace diversity in north Shewa and south Welo regions of Ethiopia" clearly demonstrated that: intraspecific variation closely accords with both folk and numerical taxonomies; as farmers increase their selection criteria, diversity at the field level increases to meet their diverse needs and requirements; sorghum farmers' varieties are variable in their levels of biological resistances to storage pests; farmers' knowledge of storability corresponds with laboratory estimates of resistance to rice weevil infestations; and both natural factors and farmers' selection criteria shape crop genetic diversity at the farm level.

A follow-up 2000/01 study, supported by IDRC, IBCR and Addis Ababa University, again investigated landrace diversity and distribution, field size and fragmentation, seed sourcing and the farmers' selection criteria and management practices. The specific goals were to measure the dynamics of temporal and spatial variations of sorghum farmers' varieties over the intervening eight years and to address questions about the stability over time of factors supporting the maintenance of the crop genetic diversity. The same farmers were interviewed both times. Substantial changes were found in farmers' selection criteria, field size fragmentation and farmer variety richness planted to each field. Mapping in 2000/01 shows "specialist" (niche specific) landraces restricted to certain microhabitats and "generalist" landraces widely grown across the agroecological gradients of the research area.

In all five farming communities, the field size planted to sorghum farmers' varieties has decreased significantly due to population growth, land redistribution policy, seasonal changes, and stagger cropping followed by interspecies crop displacement. Landrace richness increased significantly in two communities [Merewa **($Z=2.07$; $P<0.01$)** and Borkena (**$Z=5.34$; $P<0.0001$**)], but decreased significantly in three [Bati (**$Z=-1.61$; $P<0.05$**), Epheson (**$Z=-7.77$; $P<0.0001$**) and Hayk (**$Z=-1.76$; $P<0.03$**)]. Landrace evenness for most landraces decreased significantly. Farmers' selection criteria, which represent farmers' need from the crop genetic resources have increased significantly (**ten in '92/93 vs sixteen in 2000/2001 at $P<0.0001$**).

The gender and socioeconomic study has examined the role of women and men in seed selection, crop production, marketing agricultural produces and access to land in one hundred eighty households in south Welo. The average landholding for Male Headed Households (MHH) was 0.99ha and for Female Headed Household (FHH) was 0.64ha. Land preparation was observed to be the sole responsibility of male farmers. Every Male and female family members of each household carry out jointly and/or separately other agricultural activities including weeding, harvesting and livestock tending. The average parcel of land planted to sorghum landraces by MHH was 0.73ha while in the FHH was 0.55ha. Only men carry out seed selection on-farm while women are responsible for cleaning, drying, selecting, storing and fumigating at the household level until the next planting season.

As part of the capacity building effort two Ethiopian graduate students have earned their degrees through the technical guidance and financial support of this project. In addition, two graduate students (AAU), two field scientists (IBCR), three field technicians (IBCR), two extension agents (MOA), twenty enumerators (Gender and socio-economic) and eight farmer experts (participating farming communities) were trained on how to interview farmers and sample agrobiodiversity on-farm. Two M.Sc. theses are part of the final product of this research report. To date, including the project leader, a total of seven graduate students (4 in Ethiopia and three in Canada) have directly benefited to earn their graduate degrees from the IDRC supported project since 1995.

The graduate research examined the biophysical companionship between sorghum and six oil crops (Niger seed, Sesame, Linseed, Safflower, Sunflower and Ethiopian mustard) both at the field and household levels. 74% of the surveyed sorghum fields were intercropped at different levels of spatial compositions with different types of oil crops. The studied oil crops were planted with sorghum mainly as intercrops (55%) and border crops (20%). Sesame and Niger seed were the most frequently intercropped and border cropped oil crops in the 2000/2001 cropping season, respectively. Strong sorghum and oil crop association in meeting a variety of consumptive, cultural, spiritual and socioeconomic needs at the household level result in strong sorghum and oil crop companionship at the field level.

Biochemical experiments were conducted to measure the magnitude of sorghum variability and to correlate the isoenzyme evidence of variability to farmers' naming of sorghum landraces in north Shewa and south Welo study area. The research was also intended to compare previous numerical taxonomy work (Teshome, 1996 and Teshome et al., 1999) and work by graduate students from Addis Ababa University with enzymatic evidence of this study. Sorghum landraces showed significant groupings for the assayed enzymes when altitude (R=86.7%), locality(R=92.4%), and landrace (R=62%) as named by farmers, were used as grouping criteria. There was enzymatic evidence of correlation between farmers' naming system and the banding patterns interpretation of the assayed isozyme systems. Highly preferred landraces are widely adapted with interconnected meta-populations across the heterogeneous agricultural landscape of the study area.

The research findings will contribute directly to the sustainable conservation of the crop genetic resources and their use in heterogeneous, marginal and less-favored agricultural environments through favorable policy formulation, networking, community gene-banking and strengthening the complementarity between the *in situ* (on-farm) and *ex situ* (off-farm) conservation and sustainable use approaches.

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   The University of Ottawa

2. **Project Title**
   Spatio-Temporal Dynamics of Crop Genetic Diversity and Farmers' Selections *In Situ*, Ethiopia.

3. **Funding Agency**
   International Development Research Center of Canada (IDRC)

4. **IDRC Project and Contract Number**
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5. **Reporting Period**
   September 1, 2000 to December 31, 2001

6. **Project Leader**
   Dr. Awegechew Teshome, Biology Department, University of Ottawa

7. **Collaborators**
   - Professor Zemede Asfaw (AAU)
   - Professor Endashaw Bekele (AAU)
   - Dr. Abebe Demissie (IBCR)
   - Ms. Addis Tiruneh (IDR, AAU)
   - Professor Thor Arnason (University of Ottawa)
   - Professor Kenneth Torrance (Carleton University)
   - Dr. Danny Patterson (Carleton University)
   - Ato Mulat Geleta (Grad student, AAU)
   - Ato Medhane Asemelash (Grad student, AAU)
   - Ato Zewdu Yemenu (Farmer expert)
   - Ato Jemal Mohamed (Farmer expert)
   - Ato Abegar (Farmer expert)

8. **Collaborating Institutes**
   - Five farming Communities in north Shewa and south Welo regions
   - Addis Ababa University, Biology Department
   - Institute of Biodiversity Conservation and Research (IBCR)
   - University of Ottawa, Ottawa
   - Carleton University, Ottawa
   - Institute of Development Research (IDR), Addis Ababa University

2.0 THE RESEARCH AREA

The north Shewa and south Welo study area is in the central Highlands west of the great East African Rift Valley which bisects Ethiopia (Figure 1). It lies from 10'.10" to 11'.19" N, and 39'.38" to 40'.40" E, and the altitude range of the fields surveyed ranged from 1,200 to 2,400 meters above seas level. North Shewa and south Welo are the two most important sorghum growing regions of Ethiopia. Sorghum is an important component of the agricultural system of the regions and is grown by small farmers to meet a variety of needs.

2.1 Soil And Climatic Resources

The major soil types of the research area are Vertisols, Alfisols, and Inceptisols (Teshome, 1990). The topographic situation is the main differentiating factor determining the location of the major soil orders in the study area. Steep slopes over most of the area lead to a high land degradation risk due to water erosion.

Rainfall and temperatures vary greatly within the study area. The seasonality and variability of the bimodal rainfall regime of the research area dictate the cultivation, planting and harvesting activities (Teshome, 1990 and 1996; Dyer, Teshome and Torrance, 1992 and 1993). The unpredictability of rainfall for this primarily rain-fed agricultural system leads farmers to employ a range of strategies, including stagger planting and/or diversification of the cropping system, to minimize the chances of crop failure.

2.2 Agricultural Systems

The main crops of the research area include sorghum (*Sorghum bicolor*), maize (*Zea mays L.*), finger millet (*Eleusine coracana*), teff (*Eragrostis tef*), noog (*Guizotia abyssinica*), safflower (*Carthamus tinctorius*), linseed (*Linum usitatissimum*), sesame (*Sesamum indicum*), Ethiopian mustard (*Brassica carinata*), chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), field pea (*Pisum sativum*), and faba bean (*Vicia faba*).

The seed-farming complex is the most important agricultural system of the research area. This agricultural system is part of a highly developed, mixed agriculture in which livestock are used as a source of draft, transportation, and animal produce. All crops are grown from seeds that the farmer broadcasts over the prepared field and ploughs into the soil to facilitate germination and seedling emergence. Cereals, pulses and oil crops are the most important crops in the agricultural system.

In this rain-fed agricultural system, rainfall seasonality and variability are crucial in the farmers' decisions of when to plant the desired genotypes for a stable harvest. The decision of when to plant is a big gamble for the farmers. They usually begin planting early enough to take advantage of a long growing season and harvest before a damaging rainfall pattern sets in.

Farmers practice stagger cropping to avoid the risk of crop losses/failures, due to dry spells and unexpected prolonged drought, and will replant throughout the growing season if necessary. If the rains arrive late, quick-maturing varieties, which rely on the soil moisture reserve until harvest time, are planted.

Figure 1

The Research Area:
North Shewa and South Welo Region, Ethiopia

Tilling the soil, preparing the seedbed for crops, and fertilization create a favorable environment for those wild and weedy species that are adapted to take advantage of the newly created agricultural habitat. Farmers tolerate some of these wild and weedy species, but remove the undesirable ones that may inhibit the growth and reproduction of the crop plant.

Striga, armyworms, shootfly, aphids, stem borers and birds are among the agricultural pests that affect adversely the productivity of some sorghum varieties in the research area.

Most of the farmers, particularly those who own more marginal land, rotate sorghum with other crop species to renew the fertility of the land and to gain cash revenue from the sale of agricultural produce. The crop rotation practices involve temporal, spatial, and genetic components, as these practices are dependent on the crops' functional and structural requirements and the biophysical resource base on which the plants are growing. Teff, chickpea, beans, oil crops, and other non-cane crops are planted immediately after sorghum is harvested because farmers believe they renew the fertility of the land.

Before the harvest process begins, farmers walk around inside the fields of sorghum and select the sorghum heads that will be used as sources of seeds for the next planting season. The selected heads are taken home and hung under the roof of the house where there is enough smoke to kill any pests lodging inside the sorghum heads. After making sure the grain is dry and insect free, the sorghum heads are threshed and the seeds kept in small air-tight containers until required for planting.

Markets are the primary mode for seed exchange among households, villages and regions and break the physical barriers to genetic exchange created by rugged mountains and river valleys. The seeds obtained from farmer selection and exchange networks become part of the sources of the evolutionary processes of hybridization, gene flow, mutation, and recombination occurring in the field between the crops and their wild and weedy relatives.

During the harvesting, farmers fell each sorghum plant while the head is intact, they remove the head using a sickle, and collect the heads in baskets which once full are taken to the threshing ground located in the field. Depending upon the need and the decision of the farmer, threshing is done either in bulk mixture or each landrace is separated by its phenotypic appearance and is threshed separately. Livestock and human labor are used in threshing.

The harvest is taken home and stored. Depending on the amount of the harvest and the intended duration of storage, the grain is placed in air-tight underground pit storage or in above-ground container structures made of shrub sticks plastered with dung. Sacks, clay pots, calabash, and containers made of mud are also used as in-house storage. Weevils are the major storage pests damaging stored grains, including sorghum

While both women and men actively participate in agricultural activities, only men reportedly carry out the transportation of agricultural produce from the threshing ground to storage.

3.0 RESEARCH GOAL AND ORGANIZATION

There are four major components to this research report: Graduate research; training; gender and socioeconomic; landrace stability over eight intervening years between 1992/93 and 2000/01 cropping seasons; and landrace mapping across the agroecological gradients of the research area.

The overall goal of the research was to contribute to food security, agricultural sustainability and to the maintenance, conservation and use of genetic diversity in Ethiopia. The specific goal was to measure the dynamics of temporal and spatial variations of sorghum landraces and address questions about the stability over time of factors supporting the maintenance of crop genetic diversity *in situ* in Ethiopia.

3.1 Objectives

The specific objectives of the research were:

- To measure the spatio-temporal changes of sorghum landrace diversity in north Shewa and south Welo study site over eight intervening years between the 1992/93 and 2000/01 cropping seasons.
- To provide training to Ethiopian graduate students from the Biology Department of Addis Ababa University (AAU) and field scientists from the Institute of Biodiversity Conservation and Research (IBCR) in the sampling and analysis of agrobiodiversity field data.
- To gather gender disaggregated baseline socioeconomic information to look into the role of women and men farmers in the generation and maintenance of sorghum landrace diversity *in situ*.
- To map the distribution of sorghum landraces using GIS across the agroecological gradients of the study area.

4.0 RESEARCH OUTPUTS

4.1 Field Training

To facilitate the unbiased and representative collections of original field-based data, field training on how to interview farmers and sample agrobiodiversity *in situ* was provided at different stages of the field operations in the 2000/01 cropping season to the following people: two graduate students (AAU), two field scientists (IBCR), three field technicians (IBCR), two extension agents (MOA), twenty enumerators (Gender and socio-economic) and eight farmer experts (participating farming communities).

All the trainees as members of the project team were trained and given directions and insight towards working with farmers and in particular towards gaining their trust and confidence. This project has an agro-ecosystem approach to field data collections, analyses and interpretations on the basis of the strong conviction that agro-ecosystems are human created production systems and thus farmers are placed at the centre stage of the ongoing study. For this reason the field training focused primarily on how to approach and interview farmers to elicit as much original information on the dynamics of their time-tested experiential knowledge, farming practices, selection criteria and on the generation and maintenance of variable and adaptable crop genetic resources in their fields. Some of the highlights of the field training provided to the research team were given below:

- Random selections of farmers' fields with agro-ecological, cultural and socio-economic representations of the study area
- Gender and socio-economic data gathering at household level

- GPS (Global Positioning System) measurements of each field to map the distribution and continuity of crop genetic resources along the agro-ecological gradients of the study area
- Laying out transect lines in each farmer's fields
- Field measurements of genetic diversity, and
- Biophysical sampling of soil and plants for laboratory analyses at AAU and IBCR

Moreover, the research team was actively encouraged to make notes and observations during the actual field activities on:

- Genetic diversity indicators in different production systems of the study area
- Patterns of biophysical associations and companionships of both inter-and intra-specific crop genetic diversity at the field and household levels
- Slope, aspect, fertility levels and land degradation risk at the field level
- Soil and water conservation measures practised by each participating farmer to reduce land degradation risk *in situ*.

4.2 Graduate Research

The research has supported two graduate students to undertake research under the co-supervision of Dr. Awegechew Teshome, Dr. Zemede Asfaw, and Professor Endashaw Bekele. The students have benefited from the field guidance and supervision provided by Dr. Awegechew Teshome and Dr. Zemede Asfaw. The graduate research support is part of the human development aspect of the research, "Spatio-temporal dynamics of crop genetic diversity and farmers' selection *in situ*, Ethiopia". The research outputs of the graduate research are attached with this final report. Highlights of the two graduate research findings are summarized as follows.

4.2.1 Sorghum and Companion Oil Crops

Name of Graduate Student
Mulat Geleta

Research Title
Ethnobotanical study of edible oil crops as a companion of Sorghum landraces [*Sorghum bicolour* (L.) Moench] and biochemical genetic analysis of *in situ* and *ex situ* conserved Noog/Niger seed (*Guizotia abyssinica* Cass) from north Shewa and south Welo regions of Ethiopia. A copy of the MSc thesis is attached with this report.

Overall Goal
The overall goal of the research was to investigate the bio-physical associations of sorghum and oil crops in the field and their companionship at the household in meeting the dietary and economic needs of farming communities.

Objectives

- To generate information on farmers' selection criteria to maintain a range of intraspecific landraces of oil crops (Noog/Niger seed, Sesame, Safflower, Sunflower, Flax/Linseed and Brassica) to meet variable social, cultural, economic and ecological needs.

- To investigate the frequency of occurrences of farmers' fields planted to oil crops in association with Sorghum.
- To investigate genetic diversity of Noog/Niger seed (*Guizotia abyssinica*) and to determine its population structure.
- To determine the level of polymorphism and heterozygosity within and among populations of Noog/Niger seed.
- To describe the farming systems and agricultural practices of oil crops as companion crops of Sorghum.
- To identify advantages and disadvantages of intercropping oil crops and sorghum through comparing the relative performance of oil crops when grown alone and when intercropped with sorghum.

Research Output Summary

The research investigated the biophysical association and companionship of six oil crops with sorghum landraces at the field and household levels in six farming communities. Niger seed, safflower, Ethiopian mustard, Linseed, Sesame, and Sunflower were the six oil crop species studied for their companionship and association with sorghum landraces at the field and household levels.

Formal and informal interviews with both male and female farmers at the field and household levels were conducted to obtain original and time-tested experiential knowledge on the companionship and association of oil crops and sorghum landraces at field and household levels. Informal discussions were held at numerous villages to gather information on the actual companionship of oil crops and sorghum landraces in foods, medicines, cultural and spiritual practices at the respective household levels.

Over 700 sorghum fields in six farming communities were surveyed to measure the types of companionship and association of oil crops and sorghum observed in the 2000/01 cropping seasons. The ethno-botanical study and isozyme analyses revealed the significant levels of diversity existing among the six oil crops at the agro-morphological and enzyme levels, respectively.

It was observed that oil crops were planted as border crops or intercrops in the research area. Overall, 74.8% of the surveyed sorghum fields were intercropped with oil crops. Only 19% of the surveyed sorghum fields had oil crops as border crops. Niger seed and sesame were observed to be the most important oil crops of the research area with strongest companionship both at the field and household levels.

Sesame was the most frequently intercropped oil crop. Niger seed is the most frequently border cropped oil crop. Sunflower and linseed had the lowest companionship with sorghum at the field level. Compared with the other oil crops, Linseed was cultivated more as a sole crop than as a companion oil crop because it grows at higher latitudes where most of the oil crops and sorghum landraces do not grow and also due to its high susceptibility to the effects of shadow when intercropped with other crop species.

The strong association of sorghum landraces with oil crops is a reflection of their close companionship at the household level as farmers use oil crops to augment their diet, to enhance the palatability of sorghum, as sources of oil and protein for consumption with sorghum products, and to satisfy a variety of spiritual and cultural beliefs. Thus, a greater variety of uses mean more diversity and companionship of sorghum landraces and oil crops at both field and household levels. The research strongly recommends the establishment of a mechanism to strengthen the complementarity between the *ex situ* and *in situ* conservation approaches through the uses and conservation of oil and sorghum crop genetic resources at field, household and community levels. (Please refer to the attached copy of the thesis for further information on the association and companionship of oil crops and sorghum landraces at the field and household levels).

4.2.2 Isozyme Evidence Of Farmers' Naming Systems And Use Values Of Sorghum Landrace Diversity

Name of Researcher
Medhanie Assmelash

Research Title
Isozyme study for the assessment of continuity in the diversity of Sorghum [*Sorghum bicolour* (L.) Moench] landraces in relation to Farmers' naming system and use values in north Shewa and south Welo regions, Ethiopia.

Overall Goal
The overall goal of the research was to investigate the continuity of the different sorghum populations along agroecological gradients of the study area and relate the isozyme evidence to farmers' naming and use of the different sorghum landraces.

Objectives

- Study the diversity of *in situ* Sorghum landraces at the isozyme level using six selected enzyme systems
- Identify farming communities with high richness of sorghum landraces.
- Assess the presence of continuity/discontinuity in Sorghum landrace richness among the farming communities of the study area.
- Relate the isozyme frequency of each landrace with farmers' naming of the respective sorghum landrace.

Research Output Summary
The research was conducted to measure the magnitude of sorghum variability using biochemical analyses and to correlate the isozyme evidence of variability to farmers' naming of sorghum landraces in north Shewa and south Welo regions. The research was also intended to compare previous numerical taxonomy work (Teshome, 1996 and Teshome et al. 1999) and work by graduate students from Addis Ababa University with enzymatic evidence of this study.

For biochemical analyses, fresh samples of sorghum landraces from north Shewa and south Welo study sites were collected as named by the participating farmers and validated by Teshome (1996) and Teshome et al. (1999). Three enzyme systems were employed to assess the levels of variation among the collected sorghum landrace samples. Locality (farming community), altitudinal ranges and landrace (as named by the farmers) were used as grouping factors for the assayed enzymes.

It was observed that there was enzymatic evidence of correlation between farmers' naming system and the banding patterns interpretation of the assayed isozyme systems. The landraces showed significant different groupings for the assayed enzymes when altitude (R=86.7%), locality (R=92.4%), and landrace (R=62%) as named by farmers, were used as grouping criteria.

The five farming communities showed different groupings of genetic compositions of sorghum landraces. Farming communities with higher number of sorghum landraces showed better continuity in sorghum diversity at the biochemical level. Farming communities with few but adapted sorghum landraces also showed high diversity with poor continuity.

Sorghum landraces with restricted geographic coverage (i.e. localized landraces) were observed with low diversity. The enzymatic evidence clearly showed that highly preferred sorghum landraces showed both intermediate and high diversity indices. Zengada- a widely adapted sorghum landrace, and "Tinkish" (sorghum sweet stalk landraces) were observed with multiple morphotypes due to identical banding patterns for the assayed enzyme systems. Through time and spatial isolation, these subpopulations/morphotypes will evolve into distinct landraces. Landraces adapted to marginal agricultural habitats had higher levels of heterozygosity with better genetic bases for wider adaptation. (For further reading and information on isozyme evidence and farmers' naming systems of sorghum landraces, please refer to the attached copy of the graduate research report).

To facilitate the follow up over space and time of the dynamics of genetic diversity and farmers' selection, knowledge and farming practices, all the graduate field research activities were conducted in the study area where Teshome carried out his research in the 1992/93 cropping seasons. The researchers were part of the main project in the actual collection of field data and interviewing farmers *in situ.*

4.3 Gender and Socioeconomic

The gender and socio-economic data gathering was carried out as an integral part of the agroecosystem influencing the generation, maintenance, and sustainable use and conservation of crop genetic resources at the field and household levels. W/t Addis Tiruneh from the Institute of Development and Research (IDR-CERTWID/AAU) of Addis Ababa University, supervised the field data collections, analysed the data with the help of a consultant and interpreted and wrote the gender and socio-economic portion of this research report. The objectives of the gender and socio-economic activities of this project were:

- To identify women's and men's knowledge and activities related to the selection, conservation and sustainable uses of sorghum landraces in south Welo study area
- To take stock of the differential access to and the decision making process in the sustainable uses of sorghum landraces in south Welo study site.
- To gather gender disaggregated baseline socio-economic information to look into the structure and pattern of production for the crops where the landraces are dominant in south Welo study area.

4.3.1 Approaches, Methods and Output Summary

To achieve the above objectives, a feasibility study was conducted in the research area to forge collaboration with the Ministry of Agriculture (MoA) and administration offices; to recruit and train enumerators; and to introduce the gender and socio-economic team to participating farming communities and their leaders. As part of the feasibility study, informal interviews were conducted with women and men farmers using semi-structured questionnaires at randomly selected farming communities. This type of exercise has contributed tremendously in winning the acceptance of the research team by the participating farming communities. After the feasibility study, a questionnaire was prepared to facilitate the identification and documentation of traditional knowledge, practices and farming activities of women and men farmers in the selection, conservation and sustainable uses of crop genetic resources in north Shewa and south Welo region of Ethiopia. The questionnaire was prepared by IDR-CERTWID/AAU. A hard copy of the questionnaire was attached to the interim report and submitted to IDRC. A team consisting of the Gender specialist (IDR/AAU); Field scientists and technicians (IBCR); Graduate students (AAU); Extension agents (MoA); Farmer experts; and the Lead scientist tested the questionnaire in twenty households before it was put fully into use across the randomly selected farming communities of the research area. As a result of the test some minor changes were made to the questionnaire prior to it being officially employed to gather gender and socio-economic data in the randomly selected farming communities. Twenty enumerators out of fifty-nine applicants were selected using oral and written examinations to participate in the gathering of gender and socio-economic data in their own communities. A two-day training was given to the newly recruited enumerators on how to collect gender and socio-economic data using the pre-tested questionnaire at the household level. Extension agents, graduate students, field scientists and technicians, and farmer experts benefited from the training, in particular on how to approach and talk with farmers in their houses and collect original information.

Gender and socio-economic data were collected from two hundred female-headed (*de-jure*) and male-headed households where sorghum landraces were the predominant sources of livelihood security for the farming community. Household characteristics, family size by gender, differential ownership and access to resources by gender, decision-making processes, time-tested knowledge, and selection practices by gender, seed types and sources, crop grown, agricultural and non-agricultural labour inputs, and farm management were some of the major parameters employed to gather gender and socio-economic data at the household level.

In addition, focused group discussions involving men and women groups and in-depth interviews with key informant elderly women and men were conducted to facilitate documentation on the historical uses of sorghum landraces through time to supplement the gathered gender and socio-economic household data.

In total, including the pre-testing exercises, data from two hundred and twenty-two households were collected but only information gathered from one hundred eighty seven households was actually analysed, interpreted and reported.

The role of women and men in seed selection, sorghum landrace preferences, access to land, crop production and marketing of agricultural produces were examined for one hundred eighty seven households (127 male headed and 60 female headed). The average family size for Male Headed Household (MHH) was 6.11 and for the Female Headed Household (FHH) was 3.9 persons. The average landholding for MHH was 0.99ha and for FHH was 0.64ha.

Land preparation was observed the sole responsibility of men farmers. The average piece of land planted to sorghum landraces by MHH was 0.73ha while in the FHH was 0.55ha. Seed selection on-farm is carried out by men only while women are responsible for cleaning, drying, selecting and storing seed stocks at the household level until the coming planting season.

Sorghum landrace preference and ranking by household was different. For example different male and female led households ranked differently the six most popular sorghum landraces as shown in Table 1.

Table 1 Most Preferred Sorghum Landraces by Household

LANDRACE	MHH	FHH	TOTAL HOUSEHOLD
Cherekit	77	35	112
Gorad	71	17	88
Tenglay	56	15	71
Wofeaeybelash	38	13	51
Mokakie	39	11	50
Aehyo	26	15	41

In summary the study has identified gender-based agricultural activities carried out by women only, men only and jointly by family members composed of both female and male individuals. For detail further information on gender and socio-economic aspects of the sustainable conservation of sorghum landraces in south Welo, please refer to the attached separate report.

5.0 FARMERS' SELECTIONS, GENETIC DIVERSITY AND BIO-PHYSICAL MEASUREMENTS *IN SITU*

5.1 Purpose and Approach

The specific objective of this portion of the project activity was to measure the changes in farmers' selection criteria and sorghum landrace diversity that took place in the eight intervening years between 1992/93 and 2000/2001 cropping seasons at the field, community and landscape levels. Transect lines were placed 10 meters apart and the owner of each field was interviewed to identify and name each plant falling at 5 meter intervals along the placed transect line in his/her field. At least 200 plants were randomly sampled in one hectare of each farmer's field. Each farmer was asked the selection criteria he/she used to grow the different landraces on his/her field in the 2000/2001 cropping season. Measurements were specifically carried out on the distinct intraspecific sorghum landraces and their wild relatives grown and the number of selection criteria employed by each farmer to grow the number of intraspecific diversity in his/her respective field. A total of 360 farmers' fields were surveyed to gather information on farmers' selection criteria, field size, seed sources, companion crops, wild relatives and number of specific sorghum landraces planted in the 2000/2001 cropping season in the re-sampled fields.

These surveyed fields included the 300 farmers' fields studied by Awegechew Teshome in the 1992/93 cropping season. Observations on field size, fragmentation, connectivity, landrace type, and distribution, cropping patterns and biological companionship *in situ* were made. Particular observations were also made on biophysical companionship of sorghum with other inter-and intra-specific crop plants at each field. A research team composed of farmer experts, graduate student, field scientist and technicians, the project leader and the owner of the respective field collected a range of information related to the uses, conservation and management of crop genetic resources *in situ*. Statistical analyses and comparisons were conducted on the field-based data of 1992/93 and 2000/2001 cropping seasons.

5.2 Changes In Agrobiodiversity Factors (Field Size, Farmers' Selection Criteria And Landrace Diversity)

There are numerous interactive agro-ecosystem factors supporting the generation, maintenance, stability, conservation and uses of crop genetic diversity over space and time. Diversity factors are both biotic and abiotic in their category of classification. Farmers' selection criteria, seed supply systems, soil, climate, aspect, altitude, field size (fragmentation and connectivity) affect the types and diversity of the inter-and intra-specific crop genetic resources grown at field, community and landscape levels over different agricultural seasons. Farming practices such as plowing, weeding, intercropping, fallowing, seed exchange and marketing do also influence the generation, maintenance, diversification and stability of crop genetic resources over space and time. In this report the dynamic changes in field size and fragmentation, farmers' selection criteria and sorghum landrace distribution and stability in five farming communities of north Shewa and south Welo research area during eight intervening years between 1992/93 and 2000/01 cropping seasons were examined. Bati, Merewa Adere, Epheson, Hayk and Borkena were the five farming communities where the changes in agrobiodiversity factors during eight intervening years between the 1992/93 and 2000/2001 cropping seasons were measured, analyzed and compared.

5.3 Field Size Changes (1992/93 vs. 2000/2001 Cropping Seasons)

The agricultural fields in the north Shewa and south Welo region, like any fields in a traditional farming system, are the production units where a variety of crops are grown over different cropping seasons to meet the varied needs of the farming communities. These fields provide heterogeneous edaphic, altitude, topographic and climatic resources which create natural selection pressures in the generation, maintenance, diversification of a range of crop genetic resources over time. The farmers, in the study area do not have either the external inputs or scientific backing to homogenize the heterogeneity of their fields, and use instead the multiple microhabitats to grow a variety of crops. Over generations they have learned how to meet their varied needs and how to reduce the risk of crop failures in a range of cropping calendars. Part of this strategy is the recognized need to maintain and use on a sustainable basis a broad genetic base across variable growing seasons and niche-rich agricultural fields. Thus, the size, heterogeneity, distance, location, altitude, aspect and fertility of each agricultural field, generate the natural selection pressures along with farmers' decision processes in determining the population size and levels of diversity of any crop plant grown in a particular space and agricultural season.

In all the five farming communities the land size planted to sorghum crop in the 1992/93 compared to the 2000/01 cropping season has decreased drastically (Figures 2 & 3). Almost over 50% of the landholdings in each of the five farming communities (Borkena – 66%; Bati – 65%; Epheson – 64%;

Hayk – 54%; and Merewa Adere – 47%) have shown a reduction in their field sizes planted to sorghum crop as compared to the acreage of 1992/93 cropping season. Population increase, recent government land partition and repartition policy, dry spells followed by stagger cropping, and inter-species displacement of sorghum contributed to the fragmentation and shrinkage of agricultural lands planted to sorghum landraces. The partitioning and reapportioning process has created numerous interconnected fragmented fields that are owned by numerous farmers facilitating the creation of metapopulation of landraces adapted to the various niches of the agricultural landscape of the study area. Besides, the physical fragmentation of farmers' fields may facilitate the biological fragmentation of sorghum landraces to evolve into new populations through patch occupancy, temporal and spatial isolation. In adjacently interconnected farmers' fields planted closely to related taxa through biotic and abiotic agents there may be an exchange of genetic traits that may boost the adaptability of cultivated crops to the dynamics of the biophysical processes and disease and pest infestations.

The bimodal relationship between diversity and field size is still valid (Teshome, 1996 and Teshome et al., 1999). Generally as the field size increases diversity increases due to the availability of heterogeneous niches in larger fields to meet the agro-climatic requirements of diverse intraspecific crops. But also smaller fields, particularly closely located to homesteads do show diverse intraspecific diversity due to the conscious creation of heterogeneous niches by the farmers using household refuses and family labour to accommodate the diverse requirements of diverse intraspecific crops. The intraspecific crops are adapted to the diverse niches and are used to meet the varied needs of the farmer, including income generation, food security and agricultural sustainability. Most farmers do have smaller fields due to the recent land redistribution policy, which forced them to derive their livelihood security by growing diverse inter- and intra-specific crop genetic resources by creating heterogeneous niches on their limited field size. More young families join the farming profession contributing to further fragmentation of the already small family landholdings. Hunger for land is widespread. Landless farmers and other farmers who do not have enough land to support their family have encroached adjacent and steep slopes land exacerbating the risk of irreversible land degradation processes.

The intermittent occurrences of dry spells also force the farmers to practice stagger cropping that may result in the displacement of sorghum by other quick maturing crop species such as teff and chickpea. Apparently teff has become the single most important threat to sorghum due to its quick maturing attributes, as it grows on soil moisture residual at the end of the rainy season and is ready for harvest before a destructive rain sets in. Teff is also a cash crop with more commercial value on the market than sorghum. Thus, farmers are attracted to cultivate teff over a larger area than sorghum for its high monetary value and quick maturing attributes, contributing to further shrinkage of fields planted to sorghum landraces.

Figures 2 & 3

Field Size Changes in Bati, Borkena, Epheson, Hayk and Merewa Adere Farming Communities (1992/93 and 2000/01 Cropping seasons)

5.4 Landrace Stability

Over 360 fields representing 5 farming communities from north Shewa and south Welo research area were re-surveyed to measure changes in richness (representativeness) and evenness (equitability) of sorghum landraces at the field, community and landscape levels over the intervening eight years of 1992/93 and 2000/01 cropping seasons. Sorghum plants at 5m intervals along transect lines spaced 10m apart over the whole of each field were identified by the farmers. Sorghum landrace diversity for this research is defined as the number of distinct sorghum plant populations grown on a field, as named by the farmers. The naming of crop plants by farmers has consistently been found to approximate the standard scientific approaches (Berlin et al, 1973; Quiros et al, 1990; Teshome, 1996 and Teshome et al 1999).

As stated in the field methodology, along a transect line of 5 meter intervals each farmer identified crop plants growing in his/her field. A total of 200 plants/ha were identified and named by each farmer grown in his/her field. At the landscape level over 80,000 individual sorghum plants were identified to measure the changes of landrace richness over the eight intervening years between the 1992/93 and 2000/01 cropping seasons.

Landrace richness, distribution, and its relationship to field size and farmers' selection criteria across the five farming communities have shown substantial changes. The total number of agro-morphologically distinct sorghum landraces measured in the 2000/01 cropping season at the landscape level was sixty-eight, up by eight as compared to the number of landraces measured in the 1992/93 cropping season.

The distribution of these landraces in each of the farming communities has shown tremendous changes. Table 5 shows landrace representations restricted in each of the five farming communities of north Shewa and south Welo study site. Borkena (n=14) and Hayk (n=2) farming communities have registered respectively the highest and the lowest number of sorghum landrace representations in the 2000/01 cropping season. The number of agro-morphologically distinct sorghum landraces in a field is influenced by a number of interrelated factors including community size, agricultural habitat heterogeneity, seed sources and exchange mechanisms. Landrace richness is highest when a farming community is large enough with heterogeneous agricultural fields and diverse seed sources, as in Borkena farming community.

The ranges of distinct numbers of sorghum landraces planted per field in 1992/93 and 2000/01 cropping seasons were -24 and 34, respectively. The relationship between sorghum landrace diversity and field size is still bimodal, (Teshome, 1996 and Teshome et al, 1999), in which both small and large heterogeneous agricultural fields support diverse sorghum landraces. The total number of distinct sorghum landraces measured in the 2000/2001 cropping season at the landscape level was sixty-eight, up by eight as compared to the number of landraces measured in the 1992/93 cropping season. Teshome (1996) did not, however, measure eight of the sixty landraces in the 1992/93 cropping season. Some farmers were observed to grow over thirty different sorghum landraces per field in the 2000/01 cropping season, as opposed to twenty-four landraces in the 1992/93 cropping calendar. Figures 4 and 5 show the landrace changes observed among the five farming communities in the intervening eight years between the 1992/93 and 2000/01 cropping seasons.

Reasons given by the farmers for the changes of sorghum landrace diversity included seed source, land fragmentation, seasonal changes, and cropping patterns of both interspecies and inraspecies.

Figures 4 & 5

Landrace Richness Changes
in Bati, Borkena, Epheson, Hayk and Merewa Adere Farming Communities
(1992/93 and 2000/01 Cropping seasons)

5.5 Changes In Farmers' Selection Criteria

Farmers' selection criteria represent a range of complementary socioeconomic, cultural, agronomic, ecological, biological, dietary and nutritional needs each farmer derives from a range of crop genetic resources planted in his/her agricultural fields during variable cropping seasons. Farmers in north Shewa and south Welo research area have been observed both in the 1992/93 and 2000/01 cropping seasons growing a range of both intra- and interspecific crop plants in their fields. This is because a single landrace does not possess all the necessary attributes to meet the requirements of the individual farmer and, hence, all farmers plant/grow more than two landraces with their companion crops and use the range of selection criteria, appropriate to their household requirements, when deciding which landrace to grow.

The study on "Factors maintaining sorghum landrace diversity in north Shewa and south Welo regions of Ethiopia (Teshome, 1996 and Teshome et al., 1999) demonstrated that as farmers increase their selection criteria, diversity at the field level increases. This finding is still observed to be valid in the 2000/01 cropping season. The range of selection criteria in 1992/93 cropping season was ten and in 2000/01 the range has increased from ten to over twenty. Table 2 shows the list of selection criteria observed in 1992/93 and 2000/01 cropping seasons. Seed experimentation and multiplication was one of the new selection criteria that were recorded in the 2000/2001 cropping season. The inclusion of seed multiplication as a criterion serves as a strong indicator of scarcity of seed supply and the need for self-reliance in producing one's seed requirement in his/her field. Multiplied seeds are not only a source of planting materials but also a source of cash by selling the seeds in the local market. Farmers set aside a portion of their parcels of land to experiment the viability, adaptation and performance of newly exchanged seed materials.

The number of selection criteria has increased significantly in all the five farming communities. Figures 6 and 7 show the changes in Farmers' selection criteria in the five farming communities of the research area during the intervening eight years between the 1992/93 and 2000/01 cropping seasons. The dynamics of Farmers' selection criteria is influenced by a number of factors including seed sources, seasonality, market, seed and information exchange mechanisms and the heterogeneity of the agricultural fields on which the diverse genotypes are grown seasonally.

In the 1992/93 cropping season the number of selection criteria applied to individual landrace ranged from one to six, while the number of selection criteria used per field ranged from two to ten. In the 2000/01 cropping season the number of selection criteria applied to individual landrace ranged from two to eight, while the number of selection criteria used per field ranged from two to over sixteen. Farmers in north Shewa and south Welo employ a range of selection criteria to maintain a range of intra-specific sorghum landraces to meet their varied social, cultural, economic and ecological needs. In risk-prone situations the farmers are aware that growing a range of sorghum landraces in a field increases the security of obtaining a satisfactory harvest.

When farmers select for one agronomic value, they also select simultaneously for other attributes. For example, if a landrace is selected primarily for its yield, then the farmer also looks for associated important features including large heads, larger seeds, more seeds, better seed set, ease of threshing, and quick maturation before destructive rains set in. Such a conscious selection conducted by the farmer increases the statistical chances of survival and perpetuation of a given genotype in the field. For example, a landrace selected for its milling quality or for making beer survives in the field only if disadvantages it may have in terms of susceptibility to negative natural selection factors are balanced by the human selection factors, including the activities of transplanting and the use of back up seeds for planting during poor crop performance. The survival of such a landrace in heterogeneous agricultural habitats is heavily dependent on farmers' selection pressure and manipulations. Thus, the selection criteria associated with each landrace could be used to identify what is useful to the farmers and to identify valuable characters in the sorghum landraces germplasm for the development of adaptable new varieties.

Table 2 Summary of Farmers' Selection Criteria at the landscape level in north Shewa and south Welo study area

1992/93 CROPPING SEASON	2000/01 CROPPING SEASON
Grain yield	Grain Yield
Biological Yield	Biological Yield
Insect/Pest resistance	Insect/Pest resistance
Market value	Market value
Beverages	Beverages
Milling quality	Milling quality
Maturity level	Maturity level
Drought resistance	Drought resistance
Threshability	Threshability
Bird Resistance	Bird Resistance
	Fresh green consumption
	Sweet stalk
	Nutritional value
	Popping quality
	Livestock feed
	Biomass production for fuel and construction
	Buffer Crop against bird attack & invading pests
	Maternity meal
	Adaptation to marginal soils
	Seed experimentation & multiplication

Figures 6 & 7

Farmers' Selection Criteria Changes
In Bati, Borkena, Epheson, Hayk and Merewa Adere Farming Communities
(1992/93 and 2000/01 Cropping Seasons)

Table 3

Statistical Significances Of Field Size, Landrace Richness And Selection Criteria Changes In Bati, Borkena, Epheson, Hayk And Merew Adere Farming Communities Over Eight Intervening Years Between 1992/93 And 2000/01 Cropping Seasons

6.0 THE SEED SOURCES

Over fourteen types of seed sources have been documented at the landscape level in the 2000/01 cropping season. To help understand the seed supply system of the research area, each farmer was asked *in situ* the sources of the seed materials he/she was using to grow the standing crop populations in the cropping season. Out of the fourteen seed sources, Self, Market, and a combination of Market and Self, and Self and GEF (Global Environment Fund) were the first four most important seed sources used by the farmers at the landscape level in the 2000/01 cropping season. Table 4 shows the 14 seed sources, along with their explanations, in each of the five farming communities and at the landscape level.

Self-seed sourcing involves the actual selection of seed stock from the standing crops of last harvest and its maintenance under household conditions until the planting season by the farmer himself/herself. Farmers do practice exchange of one crop seed material with another one to plant the crop that they think is adaptable and profitable. Exchange can also be conducted if the farmer does not have the type, quantity and quality of the seed material he/she would like to plant in his/her field. Exchange of seed materials of both interspecies and intraspecific are practiced to test deliberately the performance and adaptability of newly acquired crop population. Seed materials are given as gifts among closely related farming communities of the research area. Financially stable farmers may purchase desired seed stock in the local markets when they do not have the seed materials at home. Farmers who planted seed stock mixtures obtained from the local markets have reported the appearances of unexpected sorghum and at times unintended landraces and wild-relatives. Thus, markets do not only serve as sources of seed materials but also as one of the mechanisms of differentiation and intraspecifications when purchased seed materials are planted in farmers' fields at different agro-ecological niches.

The Ethiopian Gene bank (IBCR) through its Global Environment Fund (GEF) project had distributed some sorghum landrace seed materials to some participating farmers of the study area. The seed distribution was not a hand out, rather the farmers were required to pay back the same type, quality, and quantity of seed stock at the end of the harvest season. The involvement of the government through the IBCR/GEF project in seed distribution indicates its interest in the conservation and uses of traditional genetic resources, such as the primary research crop of this project, i.e. sorghum landraces.

Combinations of seed sources are used by different farmers to augment the seed materials available first in type, then quantity, quality and diversity. The sequences of the seed sources indicate the primary, secondary, and tertiary sources of availability for seeding during the planting season. For example, the combination of seed sources of Self, Market and Gift indicates that the farmers had their own seed materials harvested from their own field, but, to diversify the seed in type, quality and quantity, they got additional seeds from the market as a secondary source and as a gift from tertiary sources. The order of the seed sources is dynamic and varies according to the season as decided by the farmer. The following is the description of the most important seed sources in the 2000/01cropping season in each of the five communities:

6.1 Bati

Self and Market were the two most significant types of seed sources for most of the farmers in Bati farming community. The Bati farming community employed seven types and combinations of types of seed sources of variable order and importance in the planting season. Over 70.27% and 16.22% of the farmers reported Self and Market, respectively, as the two most important seed sources in the 2000/01 planting season. Given the vulnerability of the farming community to drought and dry spells, the reliance of most farmers on household seed supply (Self) as the primary seed source is remarkable.

6.2 Borkena

Eight types and combinations of types of seed sources were recorded in the Borkena farming community in the 2000/01 planting season. Self (61.24%), Self + GEF (17.83%), Market (7%) and Market + Self (5.43%) were the first, second, third and fourth important seed sources for the planting season in the farming community. The highly diversified seed sources contribute to the generation and maintenance of the richest sorghum intraspecific diversity grown in this farming community. Borkena farming community has the richest sorghum landrace diversity in the research area. The highest level of sorghum landrace diversity in this farming community could be attributed to the influence of the dominant seed source, primarily, self.

6.3 Epheson

Market and Market combinations of types of seed sources dominate in the Epheson farming community. Nine types and combinations of types of seed sources were recorded in the community for the 2000/01 planting season. Market (46.43%), Self (19.64%), and Market + Self (17.86%) were, respectively, the primary, secondary and tertiary seed sources reported by most of the farmers for the planting season in the farming community. Most of the landraces grown in this farming community are market oriented as a result of the influences exerted by the dominant seed source, i.e., Market.

6.4 Hayk

Eight types and combinations of types of seed sources were documented in this highland farming community for the 2000/01 planting season. Self (42.5%), Exchange (20%), Market + Self (12.5%) and Market (10.%) were, respectively, the first, second, third and fourth important seed sources reported by most farmers for the planting season. The farming landscape supports a number of legume grain and temperate crops and thus farmers use these grains to obtain sorghum seeds through exchange within and between farming communities.

6.5 Merewa Adere

Six types and combinations of types of seed sources were documented in this rain shadow but with clay rich Vertisols farming community. Self (48.39%), Market + Self (19.35%), and Market (12.9%) were, respectively, the first, second, and third important seed types and combinations of types of seed sources for most farmers in Merewa Adere farming community. It is also remarkable to observe that close 50% of the seed in this rain shadow farming community is derived from self seed source type.

6.6 All farming Communities (Landscape)

In all the five farming communities at the landscape level fourteen types and combinations of types of seed sources with variable degrees of importance were reportedly used in the 2000/01 planting season. Self (50.51%), Market (16.72%), Market + Self (9.89%) and Self + GEF (8.19%) were, respectively, the first, second, third, and fourth important seed sources for the season at the landscape level encompassing all of the five farming communities.

Although farmers have an appreciation for mixtures obtained from a variety of seed sources, the selection of landrace mixtures is conducted according to the desires of individual cultivators. Farmers are interested in individual landrace type, and consequently, selection, exchange and maintenance of sorghum for seed is done at a landrace level rather than as bulk mixtures. Markets are the primary mode for seed exchange among households, villages and regions and break the physical barriers to genetic exchange created by rugged mountains and river valleys. The seeds obtained from farmer selection and exchange networks become not only the sources of important agronomic traits but also contribute to the evolutionary processes of hybridization, gene flow, mutation, and recombination occurring in the field between crops and their wild and weedy relatives.

Figures 8 & 9

Seed Sources
in Bati, Borkena, Epheson, Hayk and Merewa Adere Farming Communities
(2000/01 Cropping Season)

Table 4 Summary of seed sources in Bati, Borkena, Epheson, Hayk and Merewa Adere farming communities of north Shewa and south Welo research area

SEED SOURCE TYPE	EXPLANATIONS	OBSERVATIONS AT LANDSCAPE LEVEL
GEF (Global Environment Facility)	A bilateral project is being implemented by IBCR in distribution, multiplications and diffusions of certain threatened landraces on farmers' fields. What GEF does is to distribute seed materials to certain farmers who do not have adequate seeds to plant their fields, and retrieve the same quality and quantity of seeds from the farmers at the end of the harvest season. By doing this the farmers will have their own seeds and farmers who do not have seeds in the next growing season will get the chance to borrow from the project for further diffusion.	Only 2.38% of the farmers reported using GEF seed materials as sole seed source in the planting season. Over 85.7% of these farmers were from Borkena farming community, where GEF is highly active in its field operations.
SELF (S)	Before the harvesting begins, farmers select the sorghum heads that will be used as sources of seeds for the next planting season. The heads selected for seed are taken home and hung under the roof of the house where there is enough smoke to kill potential pests lodging inside the sorghum head. After making sure that the grain is dry and insect free, the sorghum head is threshed and the seeds are kept in small airtight containers until they required for planting. This is what is involved in self- seed sources.	Over 50.3% of the farmers in the research area reported to use household seeds (self) as the sole seed source for planting purposes. Over 53.4% of these farmers were from the Borkena farming community alone.
Gift + Market (G+M)	Donated seeds are the primary sources of seeding augmented by seeds purchased and/bartered in the market.	Only 1.02% of the farmers reported using Gift + Market combination as seed source for the planting season. Over 66.67% of these farmers were from Epheson farming community.
Exchange (E)	Farmers traditionally exchange within and among communities grain, seed and any useful plant part, to obtain what they do not have by giving what they have in surplus, or not in demand, at a particular growing season. In this case those farmers who do not have adequate seed of sorghum landraces exchange with other farmers who do have surplus of sorghum seed material. The exchange is mutually benefiting both parties without incurring any cash payment.	2.7% of the farmers in the research area employed exchange as a sole seed source to plant their fields; close to 90% of farmers who used exchange as sole seed source were from the Hayk farming communities.
Market (M)	Farmers who do not have the seed but with financial means go to the market and buy the seed stock they need for a particular field and growing season using their cash. The cash may be obtained through the sale of other surplus grain and/or livestock	16.67% of the farmers in the five farming communities reported to use the market as sole source of seed materials. Over 53% of these farmers were from the Epheson farming community alone.
Gift + Market + Self (G+M+S)	Gift, Market and Self are the primary, secondary and tertiary sources of seeds, respectively, used by farmers to meet the type, quantity and quality of seed materials needed to plant sorghum in the growing season.	Only 0.68% of the farmers in the study area reported Gift + Market + Self as seed source in the planting season. All of these farmers using this order of seed source were from the Bati farming community.

Self + Exchange + Market (S+E+M)	Household seeds are the primary source of planting materials augmented by seeds obtained from exchange and market as secondary and tertiary sources.	1.7% of the farmers in all the five farming communities reported S+E+M combination as seed source during the planting season. 60% of these farmers were from the Epheson farming community.
Self + Exchange + Market + GEF (S+E+M+GEF)	Household seeds are the primary sources of planting materials augmented by seeds obtained from exchange, market and GEF as secondary, tertiary and quaternary sources of seeds to complete the actual seeding activities in the planting season.	Only 0.68% of the participating farmers reported using S+E+M+GEF combination seed source during the planting season. All of these farmers were from the Borkena farming communities.
GIFT (G)	Seed materials are donated to a family member, close relatives and friends free of charge and with no expectation of seeds being received or given back.. The main purpose of donated seeds is either because the recipients do not have the desired seed material for that particular season or they would like to experiment with seed stock for its adaptability and profitability.	No farmer in all the five farming communities was reported using gift as a sole seed source during the planting season.
Self + GEF (S+GEF)	Threatened seeds from GEF for multiplication and diffusion purposes augmented the household seed materials.	Over 8.16% of the farmers reported a combination of self + GEF as seed source in the planting season. Over 95.83% of these farmers were from Borkena farming community.
Exchange + Market (E+M)	The larger proportion of the seed materials was obtained through exchange to which seeds bought from the market were added to for adequate and diversified seeding.	Only 1.7% of the participating farmers reported using Exchange + Market combination as seed sources during the planting season. 60% of these farmers were from the Hayk farming community.
Exchange + Self (E+S)	The larger proportion of the seed materials was obtained through exchange to which household seeds were added to make a diversified and complete seeding.	Over 2.38% of the farmers across the five farming communities reported using Exchange + Self combination as a seed source in the planting season. Over 57.14% of these farmers were from the Merewa Adere farming community.
Market + Self (M+S)	The primary source of seed is the market, augmented by the seed material saved at the household.	Over 9.86% of the farmers in the study area reported using M+S combination as seed source for the planting season. Over 34.48% of them were from Epheson alone.
Self + Gift (S+G)	The seed materials saved at the household are augmented by donated seeds to meet the seed requirements of the farmer in the planting season	A mere 0.68% of the farmers in all of the five farming communities reported Self + Gift combination as a seed source in the planting season. All of these farmers were from Merewa (50%) and Epheson (50%) farming communities.

7.0 LANDRACE MAPPING

Three-dimensional measurements of altitude, longitude, and latitude from each field using GPS (Global Positioning System) devices were taken to help map the distribution of crop genetic resources across the research area. Farmers' selection criteria, field size, seed source, wild relatives encountered, companion crops planted and number of intraspecific sorghum landraces grown in the season were documented along with the GPS measurements of each field.

Figure 10 and Table 5 show the distribution of the sixty-eight sorghum landraces across the agro-ecological gradient of the five farming communities. Five out of the sixty-eight sorghum landraces (*Necho tinkish, Keyo tinkish, Jiru, Gorad and* Aehyo) are represented in all the five farming communities. Three of the five sorghum landraces (*Jiru, Gorad* and *Aehyo*) are grown for dry grain production while the remainder sorghum landraces (*Keyo tinkish* and *Necho tinkish*) are grown for sweet stalk consumption. Eleven, seven, seventeen and twenty-eight sorghum landraces were recorded respectively in four, three, two and one farming communities. The sixty-eight sorghum landraces are represented at different levels in the five farming communities. Forty-four sorghum landraces are grown in Borkena farming community. Twenty-three and sixteen sorghum landraces are grown in Bati and Hayk farming communities, respectively. Bati and Hayk, respectively, represent the lowest and highest farmers' fields altitudinal measurements in the whole research area. In the neighboring farming communities of Epheson and Merewa Adere thirty-five and thirty-two sorghum landraces are respectively cultivated.

The twenty-eight landraces recorded as occurring in one community have different levels of representations among each of the five farming communities. Fourteen landraces (*Worebabo, Tuba, Subahan, Serege, Nchiro, Meltae, Megale, Jofa*, *Dowye, Dekussie, Aso, Amelsi, Ajaebe*, and *Abdoke*) are restricted landraces grown only in the Borkena farming community. Six landraces (*Aba-erie, Bakelo, Borshe, Humera, Kume* and *Rayo*) are another group of restricted landraces which are grown in Bati farming community. In the Epheson five sorghum landrces (*Zetere, Afeso, Gomzazie, Gebsitu,* and *Gedalit*) are restricted and grown by the farming community. Only two sorghum landraces (*Buskie* and *Aehyo-Jamuye*) are restricted and cultivated in the highland Hayk farming community. There is only one sorghum landrace (*Atsebayush*) restricted and grown in the Merewa Adere farming community. There are a number of contributing factors to the number of restricted sorghum landraces in each farming community, including ethnic grouping and association, market proximity, elevation gradients, soil types and levels of agricultural habitat heterogeneity.

Figure 10

Regional Distribution Of Sorghum Landraces Among The Five Farming Communities Of Bati, Borkena, Epheson, Hayk And Merewa Adere.

Table 5

Landrace Distribution Among The Five Farming Communities Of North Shewa And South Welo Research Area

LANDRACE	BATI	BORKENA	EPHESON	HAYK	MEREWA ADERE	REGIONAL DISTRIBUTION
Necho*	1	1	1	1	1	**5**
Keyo*	1	1	1	1	1	**5**
Jiru	1	1	1	1	1	**5**
Gorad	1	1	1	1	1	**5**
Aehyo	1	1	1	1	1	**5**
Zengada	0	1	1	1	1	**4**
Yikersolate	1	1	1	0	1	**4**
Wofaeybelash	1	1	1	0	1	**4**
Tenglay	1	1	1	0	1	**4**
Mokake	1	1	1	0	1	**4**
Mognayakish*	0	1	1	1	1	**4**
Merabete	1	1	1	0	1	**4**
Kilo**	1	1	1	0	1	**4**
Goronjo	1	1	1	0	1	**4**
Ganseber	0	1	1	1	1	**4**
Cherekit	1	1	1	0	1	**4**
Yikermindaye	0	1	1	0	1	**3**
Wotetbegunche	0	1	0	1	1	**3**
Wogere	0	1	1	0	1	**3**
Watigela	0	1	1	0	1	**3**
Mote*	0	1	0	1	1	**3**
Gubete	0	1	0	1	1	**3**
Yifate*	0	0	1	0	0	**2**
Yegenfo-ehel	0	1	1	0	0	**2**
Wuncho	0	0	1	0	1	**2**
Wanesie	0	1	0	1	0	**2**
Sedecho*	0	0	1	0	1	**2**
Mogayfere	0	0	1	0	1	**2**
Malie*	0	1	0	1	0	**2**
Keteto	0	0	1	0	1	**2**
Jibo*	0	1	0	1	0	**2**
Jemaw	0	0	1	0	1	**2**
Jamuye	1	1	0	0	0	**2**
Ismael	1	1	0	0	0	**2**
Gigrete	1	1	0	0	0	**2**

Dobe	0	0	1	0	1	**2**
Delgom	0	0	1	0	1	**2**
Chomogo	0	0	1	0	1	**2**
Betenie*	1	1	0	0	0	**2**
Basohe	0	0	1	0	1	**2**
Zetere	0	0	1	0	0	**1**
Worebabo*	0	1	0	0	0	**1**
Tuba	0	1	0	0	0	**1**
Subahan	0	1	0	0	0	**1**
Sererge*	0	1	0	0	0	**1**
Rayo	1	0	0	0	0	**1**
Nchiro	0	1	0	0	0	**1**
Meltie	0	1	0	0	0	**1**
Megale	0	1	0	0	0	**1**
Kume	1	0	0	0	0	**1**
Jofa*	0	1	0	0	0	**1**
Humera	1	0	0	0	0	**1**
Gomzazie	0	0	1	0	0	**1**
Gedalit	0	0	1	0	0	**1**
Gebsitu	0	0	1	0	0	**1**
Dowye	0	1	0	0	0	**1**
Dekussie*	0	1	0	0	0	**1**
Buskie	0	0	0	1	0	**1**
Borshe	1	0	0	0	0	**1**
Bakelo	1	0	0	0	0	**1**
Atsebayush	0	0	0	0	1	**1**
Aso*	0	1	0	0	0	**1**
Amelsi*	0	1	0	0	0	**1**
Ajaebe	0	1	0	0	0	**1**
Afeso	0	0	1	0	0	**1**
Aehyo-Jamuye	0	0	0	1	0	**1**
Abdoke	0	1	0	0	0	**1**
Aba-erie	1	0	0	0	0	**1**
TOTAL	**23**	**44**	**35**	**16**	**32**	**68**

*   Sweet stalk ("tinkish")
**   Sorghum wild-relatives
0   Absence of the indicated landrace in the community/communities
1   Presence of the indicated landrace in the community/communities

8.0 CATEGORY OF LANDRACE USES

Farmers use the diverse sorghum landraces to meet their multiple livelihood security. Sorghum landraces can be broadly categorized as Dry grain, Sweet stalk, Fresh green immature and Wild relative. Landraces used as sources of dry grain dominate in all the five farming communities of the research area. Dry grain is used as a source of staple food at the household level and is also sold in the local market as a source of cash or bartering, while meeting the food and beverages needs of the nearby urban population and other communities.

The Borkena farming community has the largest number of distinct sorghum landraces used as Sweet stalk. Borkena also grows the largest number of sorghum landraces for fresh green immature consumption bridging the growing and harvesting seasons. Sorghum landraces for fresh immature consumption were not represented at all in the Bati farming community in the 2000/01 cropping season.

Sorghum wild relatives were sampled in all the farming communities except in Hayk. The absence of sorghum wild relatives in Hayk is due to the prevalence of highly adapted and valued temperate small grain crops flourishing well at a higher altitude. Figure 11 and Table 5 show the distribution of sorghum landrace categories in five farming communities of the research area.

8.1 Wild Relatives

As for the cultivated crops, the wild relatives of sorghum landraces that fall along the transect lines of each field were identified, named and measured. Farmers identified and named sorghum wild-relatives that were encountered in their respective fields. Different farmers have different management strategies towards the presence of sorghum wild-relatives in their fields. Almost all of the farmers tolerate the presence of sorghum wild-relatives in their fields for use primarily as livestock fodder, and to minimize the effects of land degradation by protecting the soil resources from wind and water erosion. Intercropping, stagger planting, non-clean cultivation, and relaxed weeding are the major farming practices by which farmers intentionally tolerate wild and weedy relatives of sorghum, including *S.aethiopicum* and *S.arundinacium*, to encourage gene flow, to enhance organic matter accumulation, soil conservation and nutrient cycling, and to increase and preserve the natural enemies of the cultivated crop pests. Thus, sorghum and its wild and weedy relatives coexisted and co-evolved over a long period of time with each other and with the farming practices.

The research team has also observed in the project area farmers uprooting and throw sorghum wild-relatives in their fields as mulches when the occurrences of sorghum wild-relative was more frequent. A good number of farmers deliberately maintain sorghum wild relatives along with the cultivated crops in their fields. These farmers believe that cultivated sorghum hybridizes with its wild relatives conferring the former with characters of drought tolerance, disease and pest resistance.

A group of farmer experts from the study area proudly demonstrated *in situ* to the research team freshly sampled ranges of sorghum landraces along a human selection line starting from wild populations followed by weedy and wild-relatives up to the highly selected cultivated landraces that are being used by the farming community to meet their livelihood security at the household level. The research team learned a lot from the demonstration *in situ* the agromorphological differences of individual panicles representing the wild, wild-relatives, weedy and cultivated sorghum populations of the research area.

In all the five farming communities, except in the Hayk farming community representatives of sorghum wild-relatives were measured and sampled. GPS devices were employed to map the occurrences of each measured sorghum wild-relative at each farmers' fields. The GPS mapping of sorghum wild-relatives will help to understand further their biological interactions with cultivated sorghums and the strategic role of farmers in facilitating gene-flow among with closely related populations generating a highly adapted, more resistant to diseases and pests, more tolerant to drought and other stresses, more yielding and socially and economically acceptable landrace populations.

Farmers demonstrating a range of sorghum landraces in the production system from wild to highly selected cultivars

9.0 CONCLUSION

This research has demonstrated that the Spatio-temporal dynamics of the generation and maintenance of crop genetic diversity on-farm is influenced by both human-related and natural factors (Teshome, 1996 and Teshome et al., 2001). Altitude, Farmers' fields (location, distance from homestead, aspect, size, heterogeneity, fragmentation, and continuity), soil (type, fertility, texture, and water holding capacity), and climate (rainfall and temperature and their distribution and effectiveness through time and space) are the main natural factors influencing the inter- and intra-specific diversity of crop genetic resources on-farm.

Farmers as primary creators, users and conservers of crop genetic resources on-farm influence the levels, status and dynamics of both inter- and intra-specific diversity through their decision making processes, selection criteria, strategic management practices, storage systems, seed sources, local markets, cultural exchange mechanisms, and processing and consumption diversity and intensity at the household levels. Markets, gender and socioeconomic factors, population size and growth, ethnic and linguistic diversity, government policies related to land ownership, land redistribution and uses and conservation of genetic resources are the other major factors influencing tremendously the population size and diversity levels of both inter- and intra-specific crop genetic resources on-farm.

It is evident that within the last eight intervening years (1992/1993 and 2000/2001 cropping seasons) the Spatio-temporal dynamic of sorghum landraces, farmers' selection criteria and the field sizes have changed dramatically. The landrace richness (representativeness) has shown positive changes at the landscape level while the direction of landrace evenness/equity (how equally each landrace is represented) is worrisome. Less than 15 landraces were identified as dominant and abundant genotypes cultivated across most of the agricultural landscape of the research area. These landraces are widely adapted to the agricultural, market, cultural, and socioeconomic conditions of the production systems of the five farming communities of the study area. The majority of the landraces (>50) represent, however, niche-specific genotypes grown to meet patches of the heterogeneous agricultural environments, cultural, and socioeconomic conditions distributed randomly across the agricultural landscape of the research area.

The dominant and abundant landraces (<15) are flourishing both in terms of their richness and evenness. The bulk of the landraces (>50) are well represented but their evenness/equity is below the threshold of mean viable population size (MVP). Farmers expressed lack of adequate seed supply both in terms of type, quality and quantity to grow landraces from this category. Consequently, they are forced to grow a range of landraces (15-25) per fragmented field to derive their seasonal livelihood security. Looking at the standing crop population on such fragmented fields one appreciates the ranges of richness of sorghum landraces ready for harvest. The disappointing fact, however, to the farmers is that they cannot select enough seed materials from each of the landraces for next planting season as each of the sorghum landraces are not equally available to meet farmers' seasonal needs. As the cycle of planting more landraces in a progressively fragmented land continues, the risk of genetic erosion increases as a result of lack of seed and adequate agricultural habitats to plant a diverse crop genetic resources in the coming cropping seasons.

To reduce the risk of genetic erosion, a comprehensive program incorporating factors related to space (farmers' fields), time (seasonality changes), farmers decision making processes, policy, markets and socioeconomic factors should be embarked on through participatory research and development, and enhancement of the diverse genetic resources on-farm.

Any program designed to address the bigger picture of poverty reduction, agricultural sustainability, food security, natural resources management, and the sustainable conservation and uses of the diverse crop genetic resources in the research area should, therefore, incorporate the natural and human factors influencing the generation and maintenance of crop genetic diversity on-farm.

Farmers should be at the center stage of any program related to the sustainable conservation and uses of crop genetic resources on-farm. North Shewa and south Welo region is endowed with rich cereal crop genetic resources adapted to both widely and niche-specific heterogeneous agricultural landscape. The diverse crop genetic resources are nurtured and maintained by time-tested experiential knowledge, farming practices, selections, and seed exchange mechanisms. A genetic resources program designed to address the food security and agricultural sustainability issues should work on the diverse genetic resources along with the time tested experiential farmers' knowledge of management, conservation and utilization of these resources in a dynamic way over space and time.

The outputs of this project and other researches (including Teshome, 1996; Teshome et al., 1997; Teshome et al., 1999a; Teshome et al., 1999b; Teshome et al,. 2001; Tunstell, 1997; Derbe, 2000; Mulat, 2001; Medhane, 2000; and Abdi, 2000) could be used as basis to develop an applied research and development project in north Shewa and south Welo region to monitor the dynamics of diversity factors over space and time; to add value to the diverse genetic resources through Participatory varietal selection and Participatory Plant Breeding; to inform policy makers; community gene-banking; to strengthen the complementarity between in situ (on-farm) and ex situ (off-farm) conservation approaches; and to establish networking and partnership among formal and informal stakeholders facilitating exchange of ideas, information, methodology, expertise and genetic materials, to empower communities over their resources and address food security, natural resources management and agricultural sustainability issues at the household and community levels.

Figure 11

Sorghum Landrace Category By Use
In Bati, Epheson, Hayk And Merewa Adere Farming Communities

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