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Research Paper

Intra-Specific Diversity of Sorghum (Sorghum bicolor (L.) Moench) and Determinant Factors in Konso, Southern Ethiopia

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ABSTRACT:*Sorghum is the most important staple crop for Konso people. It is very important crop for food security of the area as food for the households and feed for livestock. Therefore this study is conducted to assess the level of sorghum diversity in Konoso special district. To meet this objective three sorghum growing Kebeles, namely Arfyidie, Fasha and Gaho were selected based on the dominance of cultivated are of sorghum in the district. A total of 190households were selected randomly based on probability proportional to size technique. Households were interviewed using a structured questionnaire. Results of the study revealed that a total of 12 sorghum varieties under cultivation were recorded which indicate the decline of sorghum diversity in Konso compared to the study conducted 20 years ago that found24 varieties. High diversity in terms of varieties richness were found at Fash(Mg = 2.57) followed by Gaho(Mg= 2.55)kebeles. Arfayide kebele was found to be less diverse in terms of number of varieties (Mg = 1.62). Poisson regression model that was applied to estimate determinant factor of sorghum intra-specific diversity showed that while demographic characteristics (sex, age and farm experience), socioeconomic factors (farm size, and annual income), institutional linkage (participation in cooperatives, market distance)and biophysical factor such as altitude affected intra-specific diversity positively and significantly crop diversity and frequency of development agent visit affect negatively . This implies that there is a need of awareness creation on diversity for development agents, women empowerment, capacitating cooperatives and systematic germplasim collection.*
Keywords*: Sorghum; Intra-Specific; Diversification; Varieties; Richness*

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I. INTRODUCTION

Sorghum (Sorghum bicolor (L.) Moench) is cultivated in wide geographic areas of America, Africa, Asia and the Pacific. Globally, sorghum is the fifth most important staple food crop after wheat, rice, maize and barley (FAO, 2012). It is the second major crop (after maize) across all agro ecologies in Africa. Ethiopia is the top producer of sorghum in East Africa (FAO, 2012). Sorghum is the third primary staple food crop in Ethiopia after teff and maize in area coverage and the second in total production next to maize. Sorghum is cultivated in all region of Ethiopia between 400m and 2500m altitude. Oromiya, Amhara and Tigray regions are the three major producer of sorghum covering 86% of the total area and 89% of the total production in the last 9 years (Tekle and Zemach, 2014). Sorghum also is becoming a high potential crop in the lowland areas of Southern region. Konso special Woreda is the major sorghum growing area in SNNP region which covers 18,274ha (52% of the area covered by cereals).It is also the dominant crop in Konso district in terms of production (76,908qt) which accounts 49% from cereals (CSA, 2012).

Farmers in Konso use a wide variety of sorghum, and select particular species depending on specific site conditions and the production objectives. This approach also results in the potential opportunity/benefit of growing sorghum with different qualities, and subsequently reaping the benefits from the different types as some varieties are good for animal feed, and others are good for drought, weed and disease resistance (Tadesse, 2010).

Crop diversity loss is a decline of crop species or crop varieties and their wild relatives (Wale, 2011). Crop diversity loss is one of the emerging but less visible rural development problems in Ethiopia. While landraces are used and maintained in traditional agriculture, the objective of farmers in such systems is not so much conservation but economic benefit (Wale, 2011). As a result farmers maintain traditional varieties only if the varieties generate private benefits, address household concerns and support their livelihoods. The crop

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genetic resource loss affects smallholder farmers in two ways: first, losses of crop genetic diversity reduces the capacity of farmers to cope with external shocks. Second, it limits the potential information and genetic material that could be available for future agricultural research and development in the world.

Crop/sorghum collecting missions organized by the Plant Genetic Resources Centre of Ethiopia to the Konso area/district concluded that some of the varieties described by earlier workers do not exist anymore. Therefore systematic collection of indigenous germplasm is therefore an urgent matter (Engels and Goettsch, 1991). Therefore, this study is initiated to identify sorghum intra-specific diversity and factors that influence farmers' sorghum variety diversification.

II. METHODOLOGY

Description of the study area

Konso district is located between latitude 5°15'N and longitude 37°29'E in Southern Nations, Nationalities and People's Regional State (SNNPR) of Ethiopia. The elevation of KW ranges from 550 - 2100 masl. The ditrict receives a total average annual rainfall of 750 millimeters with highly variable distribution pattern. The temperature varies from 25-30°C with annual average temperature of 27°C. The soil type chiefly found in KSW is a black and red (KW Bureau of Agriculture, 20016).

The district has a total population of 235,087, of whom 113,412 are men and 121,675 are women. With an area of 2,273.km^2, the /district has a population density of 103.39 with only 4% of the population residing in urban areas (Central Statistical Agency of Ethiopia, CSA, 2007).

The people of Konso are known for their internationally recognized stone-walled terraces registered by UNESCO as World Heritage Cultural Landscapes (UNESCO, 2011). The Konso people are also known for their indigenous intensive agricultural landscape management with unique mixed crop-livestock agriculture and agro forestry systems that have been maintained for hundreds of years despite the social changes (Tadesse, 2010).

A UNESCO World Heritage Site since 2011, the Konso Cultural Landscape is named after its agriculturist inhabitants, who have moulded their 230km2 homeland of semi-arid hills into productive agricultural land. A striking feature of Konso is the ancient hilltop paleta (terrace and walled villages) - strange hobbit-warrens towered over by generation poles felled from a sacred forest, and studded with curvaceous thatched community houses. The Konso are also renowned for their waka grave-markers, anthropomorphic hardwood statues carved to mimic the deceased, and for their communally constructed reservoirs.

The Konso animal husbandry involves rearing of major livestock such as cattle, goats, sheep and sometimes chickens and donkeys. Crop production is dominated by great variety of cereals, while other crops such as pulses, root and tuber crops are also known and cultivated in the area. The most commonly cultivated cereal crops are sorghum followed by maize.

III. RESEARCH DESIGN AND SAMPLING METHODS

Two-stage sampling was followed to select respondents for the study. In the first stage three Kebeles namely Fasha, Gaho and Arfayide were selected from the district base on their dominance in sorghum production area coverage. In the second stage a total of 190 households (159 male and 31 female) were randomly drawn from the three Kebeles. Probability to proportional size technique was used allocate respondents to each of the three Kebeles.

Both qualitative and quantitative data were collected and used in the study Data collected include demographic, socioeconomic, institutional and others aspects of households and sorghum production. Specifically, data related to sorghum intra-specific diversity as well as factors shaping on-farm sorghum diversity was collected from sampled households. The data were collected using combination of tools such as pre-tested survey structured questionnaire, focus group discussion (FGD), and farm observation.

IV. DATA ANALYSIS

Descriptive and inferential statistics, diversity indices and econometric analysis methods were employed to meet the objectives of the study. Descriptive analysis was used (frequencies, percentage, mean and standard deviation) to analyze the socio-economic characteristics, types of crops, cropping systems and type of sorghum varieties. The statistical significance of the variables was tested through chi-square and t-test for dummy and continuous variables, respectively. Econometric method was applied assess the determinants of sorghum intra-specific diversity. To analyze the date Statistical Package for Social Science SPSS 20.0 and STATA version 12 application software were used.

Richness index and Sorenson's coefficient were used to determine sorghum intra-specific diversity and evenness both per household and per Kebeles. Richness is a total count of sorghum varieties (Magurran, 1988). The Margalef richness index which is a count of sorghum crop varieties, normalized by the scale of the sorghum area was used as a measure of richness at community level (Magurran, 1988). The Margalef index has a lower

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limit of zero if only one variety is grown. The higher numbers denote a higher level of richness in sorghum varieties grown at the community level.

The Margalef richness index is constructed as:

$$Mg = \frac{N-1}{\ln A}$$

where N refers to total number of varieties, while A refers to total area planted to each variety.

Sorghum intra-specific diversity between study Kebeles was estimated using the Sorenson's coefficient (Cs) formula(Sørensen, 1948):

$$Cs = \frac{2C}{a+b}$$

Where a= the number of varieties in Kebele A, b= the number of varieties in Kebele B, □ C= the no. of varieties common in both Kebeles).

We adopted Poisson regression model to assess the determinants of sorghum intra-specific diversity because of the preponderance of small values and the clearly discrete non-negative integer nature of the dependent variable (sorghum diversity-richness). The log-linear regression in the Poisson model naturally accounts for the non-negativity of the Poisson distribution dependent variable. The count data specification for richness measure was utilized because of the way it gives the model flexibility to explain variety diversity within a crop. The Poisson regression model is given as:

$$logDi = \beta o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots + \beta nXn$$

Where, Di = Measure of sorghum diversity-richness of household i, β_0= constant ;X explanatory variables(Tabble 1)

Table 1: The Summary of Explanatory Variables, Measurements and Expected relationship with sorghum diversity

Abbreviation	Variable name	Variable types	Units of measurement	Expected sign
EDUC	Educational level	Continuous	Years	(+,-)
AGE	Age of household head	Continuous	Years	(+)
SEX	Sex of household head	Dummy	1 and 0	(+)
FAMSIZE	Family size	Continuous	Number	(+,-)
FARM_AREA	Farm area	Continuous	ha	(+)
TOTINCOME	The total annual income	Continuous	Birr	(+)
TLU	Livestock holding	Continuous	TLU	(+)
CREDIT	Access of Credit	Dummy	1 and 0	(+)
MKT_DIST	Market distance	Continuous	km	(+)
DAVISIT	Extension services	Continuous	Number	(+, -)
COOP	Involvement in cooperatives	Dummy	1 and 0	(-)
FARMEXP	Farm experience	Continuous	year	(+)
OTHRCRP	Crop diversity	Continuous	Number	-
FARMSLOP	Farm slope	Dummy	1, 2 & 3	-
ALTITUDE	Altitude	Continuous	masl	(+, -)

To analyse the date Statistical Package for Social Science SPSS 20.0 and STATA version 12 application software were used.

V. RESULTS AND DISCUSSION

There was a variation of household demographic characteristics, resource and socio-economic characteristics, institutional linkage and biophysical factors between study Kebeles. All variables found to be significantly different among Kebeles except age, family size and access to credit. Gaho Kebele found to be nearest to market with average distance 2.22km (SD=0.83) while Fash and Arfayide the second and third with average distance 2.96 (SD=2.95) km and 3.51(SD=2.79) km respectively. Farmers from Gaho found to be more educated with average year of schooling 6.7 (SD=4.38) years while farmers from Fasha found to be more experienced and with average year of farm experience 26.48 (SD=10.18).

Concerning the extension services and institutional linkage Gaho found to have better access to extension and credit while Arfayide has better access to cooperatives. Arfayide also has higher farm size and TLU than others with an average 1(SD=0.75) hectare and 4.1(SD=3.67) respectively, and have higher level of income. More number of crop was also grown in this Kebele .

Household demographic, socio-economic and institutional link characteristics considerably varied among farmers growing more than one sorghum varieties (diversifiers) and only one sorghum variety (non-diversifiers) (Table 2). Among the variables, HH age, farming experience, farm size, family size, farm slope,

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altitudinal location, other crop diversity, access to credit and participation in cooperatives were very significantly differed between diversifiers and non-diversifiers (P < 0.01).

Table 2: Profile of determinants of sorghum diversity

Continuous variables	Diversifiers Mean(SD)	Non-diversifiers Mean(SD)	Total Mean(SD)	Test value t value
Altitude (masl)	1776.14(127.48)	1620.79(143.33)	1705.81(155.25)	7.901***
Age (year)	45.88(9.68)	34.95(8.67)	40.9(107)	8.147***
Family size	8.44(3.24)	7.10(3.09)	7.8(3.2)	2.890***
Education level (years)	2.33(3.77)	2.58(3.70)	5.4(3.45)	-0.467
Farm experience (years)	24.19(9.96)	18.91(10.60)	21.8(10.5)	3.544***
Farm size (ha)	8.44(3.24)	7.10(3.09)	3.19(1.15)	2.908***
Total income (ETB)	12717.28(11163)	10254.48(9270)	11602.5(10396.2)	1.632
Frequency of DA visit	1.58(1.29)	1.71(1.38)	1.64(1.33)	-0.682
Market distance (km)	3.05(2.58)	2.76(2.31)	2.91(2.46)	0.825
Livestock (TLU)	2.78(2.43)	2.52(2.66)	2.67(2.53)	0.694
Number of crops grown	2.40(0.99)	2.85(1.15)	2.61(1.09)	-2.861***

Household variables		Diversifiers	Non-diversifiers	Total	X^2value
Sex of HH head	Female	15	16	31	0.146
	Male	71	88	159	
Access to cooperative	No	82	92	174	2.895*
	Yes	4	12	16	
Access to credit	No	33	68	101	13.794***
	Yes	53	36	89	
Farm slope	Flat	14	25	39	
	Sloppy	72	70	142	10.520***
	Both	0	9	9	

Significance level: *** = P < 0.01, **=P<0.05 and * = P < 0.1

1 Spatial Distribution of Sorghum Varieties

1.1 Number of Varieties

The interviewed Konso sorghum growers recognize and maintain diverse group of sorghum varieties. In this study, a total of 12 sorghum varieties under cultivation were recorded from 190 HHs in the three visited Kebeles. On average one farmer cultivated 1.78 (SD=0.82) varieties at a time although the highest number of varieties grown was four. Engels (1990) found 24 varieties named and distinguished locally in Konso but this study recorded only half (12 sorghum varieties) under cultivation. This indicate that there is a rapid sorghum diversity decline in Konso.

Farmers recalled more number of variety names than what they had under cultivation during the survey. Konata, Morota, Sergota, Haribora, Etegera and Kortinkorta were verbally listed varieties.

1.2 Spatial Distribution of Sorghum Varieties

Spatial pattern of occurrence of the recorded sorghum varieties across HHs, and Kebeles showed variation in variety distribution (total number of Kebeles where a given variety occurred) and variety frequency (total number of individual HHs where a given variety was reported).Occurrence of a given sorghum variety on individual farmland (variety frequency) ranged from 1-123 HH farms (mean = 28.25 and SD=35.46) (Figure 4). From the three most frequent varieties Shulayita was cultivated in about two-third (64.7 %) of the total 190 HH farmlands whereas Uataand Bicha were cultivated in slightly higher than one-fourth (27.9 % and 29.5% respectively) of the 190 studied HHs farmlands. Two of the sorghum varieties Tagnga and Masarasa that were cultivated only in a single farm had very narrow frequency of occurrence. Over all, these three varieties covered a total of 77.55% of the total area under sorghum in surveyed farmlands. Likewise, similar study in Tigray, Ethiopia reported that sorghum diversity is dominated by 4 varieties out of 31 total varieties (Yemaneet al., 2009).

Shulayita dominated sorghum production among studied Konso communities in covering 40.76% area of land cultivated by sorghum in Konso while Uata and Bicha were the second and third dominated variety 21% and 14.95% area coverage respectively (Figure 1).

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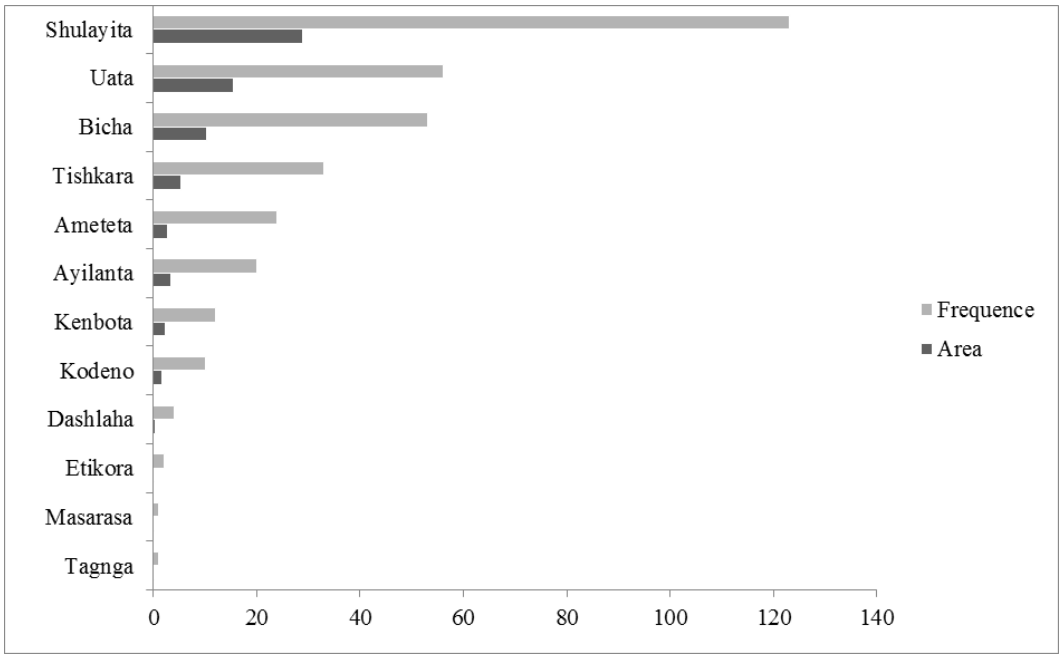

Figure 1: Distribution of Sorghum Varieties among Individual Farmers and Area Coverage of Each Variety

At Kebele level about 10, 8 and 6 sorghum varieties were grown at Fash, Gaho and Arfayide Kebeles, respectively. Gaho and Fasha shared the highest sorghum varieties (the most similar) (Cs=0.67). Arfayide and Fasha was the second similar Kebeles(Cs=0.63) while Arfayide and Gaho was found the least similar (Cs=0.57) among all Kebeles. This might be due to distance difference between Kebeles and the access of main market at FashsKebele.

1.3 Determinants of Sorghum Intra-Specific Diversity

To delineate factors that shape intra-specific diversity of sorghum at HH level, the log-linear Poisson regression model was fit using the HH demographic, socio-economic and institutional link characteristics as predictors for intra-specific sorghum diversity richness at HH level. The independent variables had no multi-co linearity problem between each other, all the variables had square root of variance inflation factor (VIF) < 2.00.

Table 3: Poisson Regression Analysis on HH Factors Affecting Sorghum Intra-specific Diversity in Konso Kebeles

HH characteristics	Coef.	z	P>|z|	Marginl effect
Household demographic characteristic				
Sex of HH head	-0.114106	-2.36	0.018**	-0.1968547
Age of HH head(years)	0.0061247	2.33	0.020**	0.0101624
Family size	-0.0002595	-0.03	0.973	-0.0004305
Education level (years)	-0.0059856	-0.21	0.836	-0.0099316
Farm experience (years)	0.007093	3.23	0.001***	0.011769
Household resource and socio-economic characteristics				
Farm size (hac)	0.075298	3.34	0.001***	0.1249374
Livestock (TLU)	-0.0009109	-0.08	0.935	-0.0015114
Total income (ETB)	6.49e-06	3.01	0.003**	0.0000108
Number of other crops grown	-0.081037	-4.56	0.000***	-0.1344598
Household institutional link				
Market distance (km)	0.0420326	5.66	0.000***	0.0697422
Frequency of DA visit	-0.0302474	-1.81	0.070*	-0.0501877
Access to cooperative	0.158021	2.84	0.004***	0.2765866
Access to credit	-0.0307213	-0.72	0.473	-0.0509265
Biophysical factors				
Altitude (masl)	0.0014673	8.19	0.000***	0.0024347
Farm slope	-0.0447282	-1.26	0.207	-0.0742148
_cons	-2.213265	-6.96	0.000***	

Significance level: *** = P < 0.01, **=P<0.05 and * = P < 0.1

Household Demographic Characteristic

Female HH maintained 19.69 % more sorghum varieties than their male counterparties; this might be related to a number of preference and selection criteria female HHs employ to maintain and utilize sorghum. In the present study, female HHs used 5 different selection and preference criteria for sorghum varieties (taste for different food and drinks, easily cook, easy to mill and weevil resistant) compared to only few that men use which increases the number of variety that female farmers had to meet the demand. This finding is consistent with Rehimaet al. (2013) and Dube et al. (2016).

Farmer age and farm experience was positively and significantly associated with the number of sorghum varieties grown implying that older farmers are more likely to grow more sorghum varieties than their younger counter parts. When age and farm experience of household head increased by 1 year, number of sorghum variety grown by farmer increase by 1.02% and 1.18%, respectively. This is expected as the older and the experienced farmers have more knowledge, value for diversity and are aware of the benefits of maintaining multiple varieties for different preferred uses and for aversion of crop failure risks than younger farmers. Studies complementing the positive and significant effect of HH age were also reported by Abayet al.(2009).Mwangiet al. (2013) reported the positive and significant effect of HH farm experience on diversity.

Household resource and socio-economic characteristics

HH land size had significant and positive effect on sorghum diversification. An addition of one hectare of land found to increase the probability of diversification by 12.49%. This implies that large farm may enable households to allot their land to multiple sorghum varieties or it may be because of larger fields have a greater range of microhabitats which farmers take advantage of to grow a greater range of sorghum varieties. This finding consistent with previous studies (Rehimaet al., 2013and Abayet al. (2009)).

Crop diversity, which is the measure of number of crops grown by farmer other than sorghum, had a negative and significant effect on the number of sorghum varieties maintained by HH. The trend of reducing diversity of a particular plant species, as the number and diversity of the other species sharing the same field increases was reported for home garden agro-forestry (Wiersum, 1982.

Total annual income of a household was significantly and positively affected the sorghum diversity. HHs with higher annual income had tendency of maintaining higher number of sorghum varieties than HHs with lower income rate in the study area. Partly, this might be related to access to the market to purchase seeds of new varieties with their higher incomes. The finding is consistent with Nagarajan et al. (2007).

Household institutional link

As expected, HH distance from market centers was significantly and positively affected the richness of sorghum diversity. The further the distance of farm plots and households from the local markets, the higher the likelihood of maintaining more number of sorghum varieties. Farmers closer to the market might favor production of few varieties that are highly demanded by the market where those distantly located produce as many variety as possible because households are required to be self-sufficient. Likewise, Yemaneet al. (2009) and Rehimaet al. (2013) found the same result.

Being a member of a cooperative makes HHs to increase their diversity by 5.45%. This might potentially be related to the HH network improvement for informal seed exchange with other fellow cooperative participant members, which might have played positive role in increasing on-farm diversity of sorghum diversity. This study results are in agreement with findings by Dubeet al. (2008).

Extension service negatively and significantly affected the number of sorghum varieties grown by farmers. This may suggest that farmers who get frequent visit from development agents were less likely to grow more varieties of sorghum. Likewise, the finding of Abayet al. (2009) reported that extension contact adversely affected barley variety diversification in Tigray.

Biophysical factors

Altitude had significantly and positively related with number o sorghum varieties grown by HHs. Farms on higher altitude were associated with higher diversity. An addition of one meter above sea level brought to increase in the probability of diversification by 0.24% Given the fact that sorghum is mid-land to high-land cereal crop best distributed from 400-2500 masl(Nida et al., 2016), this finding is expected as crop species perform better and appear rich in diversity in their natural altitude ranges.

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