ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

Identifying Farmers' Derived Demand to Maintain Sorghum Genetic Diversity in Tehuldere Woreda, South Wollo Zone, Ethiopia

By

CHALACHEW TEMESGEN

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CHALACHEW TEMESGEN JEMBERIE

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Economics (Environmental Economics)

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"Identifying Farmers' Derived Demand to Maintain Crop Genetic Diversity: The Case of Local Sorghum Varieties; Evidence from Tehuldere Woreda; South Wollo Zone: Ethiopia."

By

Chalachew Temesgen Jemberie

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ACRONYMS

CBD.......................Convention on Biological Diversity

CGRs ....Crop Genetic Resources

CGIAR...................Consultative Group of International Agricultural Researches

CSA........................Central Statistical Agency

EPA....................Environmental Protection Authority

ESIP........................Ethiopian Sorghum Improvement Project

FAO........................Food and Agriculture Organization of the United Nations

FVs........................Field Varieties

IBC.....................Institute of Biodiversity Conservation

MoFED..................Ministry of Finance and Economic Development

MVs ....Modern Varieties

NBSAP...............National Biodiversity Strategy and Action Plan

PASDEP................ Accelerated and Sustainable Development to End Poverty

TWIO......................Tehuldere Woreda Information Office

TWARDO..............Tehuldere Woreda Agricultural Rural Devlopment Office

USDA......................United State Development Agency

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Abstract

To make operational on-farm crop genetic conservation strategy in Ethiopia, we have to understand the factors that determine farmers' for managing portfolios of crop varieties. Identifying farmers' derived demand for sorghum varieties and drawing policy implication for on-farm genetic resource conservation in Ethiopia is the main objective of this paper. Farmers' preferences for varieties conditioned on different preference parameters are the theoretical basis for this study. Count index and Shannon index are used to measure the on-farm sorghum genetic diversity of the studied area. Poisson and Tobit regression models are estimated using a rural household survey data collected from 205 households in Tehuledere Woreda, Amhara National Regional State of Ethiopia.

The findings of empirical estimation shows that family size of the household, land characteristics, concern factors, number of oxen ownership and access to cash crops are promoting factors for variety richness of sorghum genetic diversity in farm household. On the contrary, the most important factors detaching the link between farmers survival strategy and sorghum genetic diversity are access to extension services, experience on using improved varieties, access to road infrastructure and access to market services. The results imply that on-farm crop genetic resource conservation will be negatively correlated to the over-all agricultural development in a specific region. Therefore, there is a need for flexible incentive structures to maintain CGRs diversity at a social optimum and to off-set the negative effect of development interventions.

Key words: crop genetic resource, derived demand, on-farm conservation, *in situ*, *ex situ*, survival strategy, Poisson regression, Tobit regression model.

CHAPTER ONE

INTRODUCTION

1.1. Background

The Irish potato famine and the Southern corn leaf blight epidemic in USA are only two examples of food crises caused by wide-scale cultivation of genetically homogenous varieties. Even after these historical events, the importance of Crop Genetic Resource (CGRs) diversity had only got popular acceptance when the spread of green revolution [1]-cross crops threatened the conservation of land races (Turrent et al., 2004). Consequently, the Consultative Group of International Agricultural Researches (CIGAR)[2] initiated gene banks and research centres of domestication for conserving CGRs. The FAO sponsored International Treaty on Plant Genetic Resources(ITPGR) and UN-sponsored Convention on Biological Diversity (CBD) are international agreements that recognize the important role that genetic diversity conservation plays in current and future food and agriculture production (Smale et al.,2002).

Initially, 155 parties at the Earth Summit held in Rio de Janeiro signed CBD in 1992. This signaled the intention of the world community at large to forming a global alliance to protect habitats, species, and genes, to shift to sustainable modes of resource use, and to make the necessary policy, economic and managerial adjustments

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[1] Green revolution technologies introduced improved crop varieties that have higher yields, and it was hoped that they would increase farmers' income.

[2] Some crops (center for domestication): maize (Mexico), wheat and barely (middle/ near East and North Africa), rice (North China) and potatoes (Peru) for further see http:// www.cigar.org /center/index.html.

to guarantee that the benefits to be gained from the use of components of biological diversity is equitably shared across local, regional, and global societies (IBC, 2000; IBC, 2005). The number of parties that have ratified the convention has now reached 187 (IBC, 2005).

Ethiopia signed the CBD in 1993 and ratified it in May 1994 (Proc.98/1994). Article 6 of the convention on CBD demands the preparation of National Biodiversity Strategy and Action Plan (NBSAP) for each signatory country. Ethiopia as a party to the Convention, and in fulfillment its obligation, prepared its NBSAP document in December, 2005. This document defines the current status of, pressure on, options for priority actions to ensure the conservation, sustainable use, and equitable share of benefits accrued from the use of biological diversity in Ethiopia (IBC, 2005).

The Federal Environmental Policy focuses on directing environment and related activities that are being undertaken by the Environmental Protection Authority and various institutions. Article 3.3 of Environmental Policy, which is entitled as "genetic, species and ecosystem biodiversity" includes the policy elements which aims to promote *in situ* conservations as priority measure and *ex situ* conservation as a complement including a number of laws which should be as guide lines for biodiversity conservation practice in Ethiopia (EPA,1997).

Legislation support is required for the implementation of many of the articles of the CBD. Ethiopia has a wide range of laws relating to the conservation of the different components of biodiversity (forests, land, wild life, seed etc). With regard to the conservation of species a serious weakness in the relevant law is that it deals excessively animal species and no provision is made for the protection of threatened and endangered plant species (IBC, 2005).

The CBD recognizes also *in-situ* conservation as a primary approach to biodiversity conservation (Article 8). Of particular importance is the balance to be struck between conservation between conservation measures within Protected Areas (PAs) and measures for sustainable use of natural areas outside of PAs in the wider country side. It is generally recognized that activities, which occur in areas adjacent to PAs, may be critical to the viability of the PAs themselves. If local people are involved in the management of PAs and other forms development compatible with the goals of the protected area are promoted in adjacent areas, then the protected areas long term viability is likely to be enhanced (EPA,2004).

In Ethiopia, institutions involved in on-farm conservation of biodiversity include the Institute of Biodiversity Conservation (IBC), the Ethiopian Agricultural Research Organization (EARO). Among these, the IBC is the focal point to CBD since July, 2005 (IBC, 2005).

Ethiopian Biodiversity Conservation and Reasearch Policy was approved in April, 1998 with the view to provide for policy guidelines towards the effective conservation, rational development and sustainable utilization of the country's biodiversity. There were a number of specific objectives and directions towards the realization of to be followed for the stated overall objectives (IBC, 2000, IBC, 2005).

The general objective of the IBC is to undertake conservation and promote the biological resources, traditional knowledge and ecosystems. Ethiopia has set a clear national policy directive on the national biological resources. In the past, conservation efforts focused on the plant genetic resources and priority was given field crops. Since

1998, the institute was given a wider mandate of conservation and sustainable utilization all forms biological resources including plants, animals and microbial genetic resources. Ecosystem management is also recognized as one of the areas to be given highest priority (IBC, 2000).

IBC continues to implement the conservation and sustainable utilization of Ethiopian biodiversity. The existing strategies has been improved and refined in view of new development objectives and strategies of Ethiopia. International standards are adopted and special efforts are being made to tackle the enormous qualitative and quantitative dimension of conservation problems unique to Ethiopia. In addition to seed storage, the institute has been undertaken a major effort to increase *in situ* conservation in relevant ecosystems. A major component of these plans will be the conservation of species where many of the wild and weedy relatives of cultivated crops species will exist. On-site conservation of indigenous and local breeds of animals, both domestic and wild has been enhanced. New and appropriate conservation techniques and methodologies are going to be adopted for aquatic and terrestrial biodiversity. The rich indigenous knowledge associated with biodiversity had been studied and used for biodiversity conservation and promoting sustainable utilization (Fasil K., and Girma B., 2004).

In biodiversity conservation, basically there are two pillars of conservation *ex situ* and *in situ* systems. The conservation of crop genetic resources in areas where crops are grown is referred to as *in situ* conservation. The other method of keeping CGRs is in the gene banks which are referred to as *ex situ* conservation. Conservation in gene bank is increasingly complemented by on-farm conservation, the feasibility of which has been investigated by a variety of studies (Doss, 2003; Bellon and Smale, 1998, Edilegnaw, 2003). On-farm conservation is the willingness of farmers in their communities to continue cultivating diverse crops, in the agro-ecosystems where the crops have evolved historically through processes of human and natural selection. Farmers as economic agents, make choices about private goods. However, when these goods also have public attributes, the relationships among farmers in communities, as well as institutional considerations, affect their utilization. Economic theory predicts that, as far as CGRs is an impure public good, we would therefore predict that farmers as a group will choose to maintain fewer of the diverse crop genetic resources in their fields than society might find optimal. In that case, institutional structures are needed to compensate for the inability of markets to provide sufficient incentives for farmers (Van Dusen and Taylor, 2005).

Therefore, minimizing the 'trade-off' between economic development and on-farm conservation of CGRs is challenging for designing on-farm CGRs policy for developing countries like Ethiopia. For implementing on-farm conservation CGRs in Ethiopia, identifying locations and farmers those who could derive benefit from conserving local land races of sorghum is one of the main objectives of this thesis and to draw policy implication for on-farm crop genetic resource conservation programme in Ethiopia.

1.2. Statement of the Problem

Ethiopia is among those countries that are economically poor but still rich in biological diversity. It is a centre of diversity and one of the eight Vavilovian gene centres of the world for cereals such as barley, wheat, sorghum, finger millet, and teff

(Harlan, 1992; Vivilov, 1956). The genetic diversity found in Ethiopian landraces[3] has been used worldwide in developing new crop varieties and addressing acute yield constraints. For example, the number of crop accessions[4] of Ethiopian origin that have been introduced to various international crop improvement program and seed companies is enormous: more than 1800 for wheat and more than 4500 for sorghum, around 2500 for barely and more than 900 and large numbers also reported for chickpea, lentil and finger millet (ICPPGR/FAO, 1997; Cavatassi *et al.*, 2006).

Much of this crop diversity is found in small fields of peasants who, aided by nature, have played a central role in the creation, maintenance, and use of these invaluable resources. Peasant farmers in Ethiopia translate their deep understanding and use of different plants and animals, or the general biology of their surroundings, to farming systems that are best adapted to their own circumstances (Worede *et al.*, 2000).

The genetic diversity also allows farmers to exploit the full range of the country's highly varied micro-environments differing in characteristics such as soil, water, temperature, altitude, slope, and fertility (Demisse, 1999; Smale, 2006). Such diversity is also crucial to sustain current production systems, improve human diets, and support biological systems essential for the livelihood of local communities. Maintenance of species and genetic diversity in farmers' fields is, therefore, crucial to sustainable agriculture, especially for resource-poor farmers practicing agriculture under low-input conditions in marginal lands.

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[3] The land races (traditional varieties) are varieties of crop plants whose genetic composition is shaped by household agronomy practices and natural selection pressure over generations cultivations (Smale *et al.*,2001) while modern varieties that have been developed by professional breeders (Hintze,2002)

[4] Accessions are a sample of a crop variety collected at a specific location and time (Heywood, 1995).

Despite Ethiopia has made a national commitment to conserve genetic resources on farms and in gene banks over the past two decades (Worede et al, 2000), their continuous survival is, however, threatened by natural and human driven factors. In Ethiopia, the most drastic change has occurred in the natural high forest and their biological resources that once covered more than 42 million hectares(35% of the total land area), are now less than 3% (Getahun T., and Shiberu T.,2003) Together with this, animals, microbes and the associated indigenous knowledge are being lost before we know the benefit.

This threat has induced the need for designing conservation measures. Among the *in-situ* and *ex situ* conservation options available to conserve crop genetic resources, on-farm conservation has got the attention of concerned organizations since these crop genetic accessions contribute not only to farmers' survival first strategy but also used for international crop development program (Smale , 2006; Edilegnaw, 2003).

Hence, to make on-farm conservation operational, which is the focus of this paper, placing incentives (that link conservation with utilization) and removal of perverse incentives are believed to be crucial so that landraces conservation allocation on off - farm and on-farm conservation will be made efficiently (Edilegnaw, 2003). However, before designing sound incentives and / or removing perverse incentives, we have to understand the factors that determine for managing portfolio of crop varieties.

1.3. Objectives of the Study

The general objective of the study is to identify farmer's derived demand (determine the factors) for managing a portfolio of local varieties of crops draw implication for on-farm CGRs policy in Ethiopia. The specific objectives are:

1. To analyze farmers' 'survival motives' [5] that could promote sorghum diversity at farm household level.
2. To examine the farm household contextual factors inducing farmers to maintain multiple local varieties of sorghum.
3. To examine factors those detach the link between *de facto* sorghum genetic diversity conservation and farmers' survival strategy.

1.4. Research Questions

This thesis will give explicit account of farmers' heterogeneity (in terms of resource endowment, sensitivity to risk, concerns, objectives and constraints) and examine their in-built incentives[6] and in-built disincentives for managing portfolios of local varieties. The research question to be addressed is therefore:

1. What are the social and economic profiles of the farmers who are most likely to maintain higher levels of sorghum crop biodiversity compared with those who likely to specialize?
2. What are the incentives of farmers to maintain on-farm sorghum crop genetic diversity?
3. What is the relationship between access to development infrastructure and crop biodiversity?

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[5]Survival motives is the survival strategy of farmers in which farmers used crop biodiversity to minimize environmental risk to sustain food security at house hold level. In thesis, crop diversity used for farmers as *ex ante* strategy as copping mechanism for food security.

[6] In built incentives are farmers incentives to produce crop diversity derived from with in their house hold concerns, endowments and constraints while in built dis-incentives are house hold related contextual factors that detach the link between crop diversity and farmers survival strategies. (Edilegnaw ,2003)

1.5. Justification and Significance of the Study

Though Ethiopia has an enormous genetic resource stock, agriculture is still unable to generate sufficient food and fibre for the population. The available stock is dwindling mainly due to changes in incentive structures in agricultural production (Edilegnaw, 2003). Conservation of crop genetic resources, therefore, safeguards agriculture from potential losses through its future use value. As a result, the economy will be on a more stable footing since by enabling crops to adapt to variations in climate and degraded land; conservation decreases the probability of crop failure that is occurring more frequently in recent times than in the past decades.

Sorghum is closely linked to food and livelihood security for farmers in the semi-arid tropics across Africa and Asia. In Ethiopia, approximately a million hectares are sown to sorghum, making it the third most important crop (CSA, 2006), and a major staple in the diet. Ethiopia is a centre of diversity for sorghum, and the extremely diverse sorghum types found in the country are of global significance (Stemler *et al.*, 1977; Ayana *et al.*, 2000).

Ethiopian farmers have shaped and managed this genetic diversity, and continue to maintain a wide array of sorghum types on their farms (Teshome *et al.*, 1999; Tunstall *et al.*, 2001). According to CSA (2006) report, adoption of improved varieties of sorghum is minimal which is below 0.5 percent overall Ethiopia. This indicates that the contribution of local land races of sorghum still at significant level for food crop production in Ethiopia. Therefore, adequately dealing the incentives of farmers to maintain crop genetic resource of the sorghum is a critical aspect of increasing farm level productivity and meeting the food security objectives of the nation.

In conclusion, their importance from the perspective of conserving agricultural biodiversity, and the crop's importance to household subsistence is justifiable taking this crop and the area as focus of the study in this thesis. Therefore, the outcome will have policy implication for genetic resource conservation of sorghum in Ethiopia and guide future research areas on crop genetic diversity in different settings.

1.6. Scope and Limitation of the Study

The interdisciplinary nature of the subject was a challenge and sometimes a source of frustration when try to catch up the main concepts of the area. It is a challenge and at times an opportunity to think beyond economics to get into important elements of the topic. Moreover, the number of local varieties that farmers identify does not inform about the precise levels of diversity maintained as diversity definition used in this thesis is not reflecting any genetic information. It rather reflects farmers' variety identification which is the best option for measuring genetic resource diversity of a given locality. Therefore, data that are used in the thesis are all farmers' nomenclature[7] in which similar studies had been undertaken by Teshome *et al.*, (1999), Brush *et al.*, (1992) and Edilegnaw, (2003) in a number of case studies.

1.7. Organization of the Paper

The remainder of the research report structured as follows. The second chapter deals with reviewing relevant theoretical literature and empirical findings of different

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[7] Nomenclature is the identification of farmers of their seed using agro-morphological characteristics.

scholarly papers are presented. The third chapter deals with the methodologies, theoretical and empirical frameworks with description of the variables are discussed. The fourth chapter of the paper is the empirical analysis and discussion of the empirical findings. The fifth chapter summarizes the major findings and the policy implications and indicating future research areas of the topic.

CHAPTER TWO

LITERATURE REVIEW

2.1 Crop Genetic Resource Literature Related To Ethiopia

Agricultural intensification will be the primary source of crop production growth globally over the next 25 years (Bruinsma, 2003). Based on Bruinsma (2003) findings, there is a substantial gap exists between actual and attainable yields, which is approximately 2.8 tons/hectare for Ethiopia. Understanding this fact, currently the Ethiopian government plans with its PASDEP five year Program (2004/05 to 2009/10) to increase the over all average productivity of crops from the existing 1.44 tons/ha to 3.49 tons/ha during the plan period (MoFED, 2006). In doing so, the government pursues farmers to adopt and provision of an extended and improved supply of agriculture inputs including improved seeds, fertilizer, efficient pest control and better management practices.

However, the problem is especially modern crop varieties have been developed primarily for high potential production conditions and such varieties are often not suitable for low income farmers in marginal production areas facing highly variable production conditions (Evenson and Gollin, 2003). Land races or traditional varieties have been found to have higher stability (adaptation over time) in marginal environments, and thus their cultivation may contribute farm level resilience in face of production shocks (FAO, 1998; Ceccarili and Grando, 2002). This is especially true in some part of Ethiopia where agro-climatic conditions are challenging, technological progress is slow, and market institutions are poorly developed (Di Falco et al., 2006, Bruinsma, 2003).

In view of this, it is a challenge and an opportunity for policy makers to design a complementarily policies between on-farm crop genetic resource conservation and economic development policy options in Ethiopia. The following sections discuss the role of CGRs to farmers and to the society including Ethiopian experience crop genetic resource conservation strategy in detail.

2.1.1 Agricultural Productivity and Crop Genetic Resources in Ethiopia

Ethiopia is the second most populous nation in Africa and one of the poorest country in the world with an estimated population of over 77 million of which 40 to 50 percent is estimated to be food-insecure (USDA, 2005; CSA, 2006). The high density of the population together with the practice of dividing holdings between offspring, leads to land fragmentation and small field sizes (frequently less than one hectare) (Unruh, 2001). The resulting increased intensification, characterized by absence of fallowing, lack of technical change, absence of conservation practices and drought, is creating a high degree of land degradation and, therefore, a decline of land and grain productivity (Shiferaw and Holden, 1997).

The major food crops grown by the small-farm sector include cereals (teff, maize, wheat, barley, sorghum, millet, and oats), pulses (faba beans, field peas, lentils, chickpeas, and haricot beans), and oil crops (flax and noug) (CSA, 2006). Table 2.1 shows that the national cereals crop production for the cropping season 2006/2007. In terms of volume of production, maize accounts for 29.32% of total cereal crops production, while wheat accounts 19.12%, teff and sorghum took 18.93% and 17.98%

of the total cereal crops produced in Ethiopia respectively. In terms of yield, as shown in the Table 2.2 maize provides the highest productivity (2.23 tons/ha). Teff yields the least among the cereal crops (1.01 tons/ha) though teff has been cultivated the highest in terms of area coverage of cultivation among cereal crops and the principal staple food crop in Ethiopia.

Table 2.1 Estimated Areas, Production and Yield of Cereal Crops for 2006/2007 in Ethiopia.

Cereals	Area (in hectares)	Production (tons)	Production share (%)	Yield
Cereals	8,471,920	12,879,792.6	100	-
Teff	2,404,674	2,437,749.5	18.93	1.01
Barely	1,011,314	1,352,158	10.50	1.33
Wheat	1,473,917	2,463,063.9	19.12	1.67
Maize	1,694,522	3,776,439.7	29.32	2.23
Sorghum	1,464,318	2,316,040.9	17.98	1.58
Finger millet	374,072	484,408.9	3.76	1.30
Oats	49,103	49,931.7	0.39	1.02

Source: CSA (2006), Agricultural Sample Survey for the Year 2006/2007 (September-December, 2006) Volume I

Livestock production also plays a crucial role in Ethiopia's economy, contributing to about one-third of agriculture's share of GDP. The combination of, high population pressures, poor agricultural policy making, conflicts and environmental degradation have left Ethiopia a country with low agricultural productivity, high rates of food insecurity and high rates of dependency on external food source (USDA, 2005). At present, the grain productivity of Ethiopian agriculture is among the lowest in the world – around 1.2 tons per hectare (USDA, 2005).

Increasing the productivity in the intensive margin is the main means by which Ethiopia can increase domestic production due to a lack of new lands to bring into agricultural production (MoFED, 2006). Improving the productivity of crop genetic resources and their accessibility to farmers is a key aspect of the government strategy, particularly the promotion of improved technological inputs and practices in order to raise agricultural productivity (USDA, 2005).

2.1.2 Public and Private Values of Crop Genetic Diversity in the Ethiopian Context

As mentioned above, Ethiopian CGRs not only provides a private benefit to the farmer but also have a social value through contributing to the conservation and evolution of genetic resources and crop breeding improvement programme to the society. This dual role may give rise to conflicts between public and private interests in terms of keeping the desirable level of diversity at the country and global level (Smale and Bellon, 1999).

The public goods nature of CGRs in Ethiopia is always associated with its role for crop genetic diversity conservation to the society. In this regard, the contribution of Ethiopian farmers in generating and maintaining the diversity of many crops has been indispensable for the three main reasons.

First, Ethiopia is considered as the primary gene center for field crops such as Noug (*Guizotia abyssinica*), Teff (*Eragrostis tef*), and Ethiopian mustard (*Brassica carinata*) (Vavilov, 1956). Introduced field crops have also developed wide developed wide range of genetic diversity under local ecological conditions and agricultural practices.

Second, the tremendous variation in altitude, temperature, rainfall, soil type and ecological settings, as well as the diverse social and cultural conditions together with different levels of market integration are also some of the possible explanations for the existence of remarkable genetic variation of crop varieties in the country (Worede et al., 2000; McGuire, 2005).

Third, crop genetic diversity present in Ethiopian farmers' fields is the result of several thousands years of farming, sometimes under very harsh conditions. Landraces (farmer varieties) represent often the only source of agricultural production. Difficult farming conditions are one explanation for why Ethiopian landraces contain genetic properties such as drought tolerance and pest resistance of great value for breeding purposes. For example germplasm capable of resisting the gene of the Barley Yellow Dwarf Virus, was obtained from the Ethiopian barley collection and introduced into the genetic material of the California barley in the 1960s (Cavatassi *et al.*, 2006).

Studies have also indicated that the private values of landrace varieties to Ethiopian farmers (Gebremariam, 1992; McGuire, 2005; Unruh, 2001; Mulatu, 2000). Attributes such as yield under stressed or marginal production conditions, as well a desirable consumption characteristics are primary drivers of the demand for landraces. Unruh (2001) discusses the importance of landrace varieties in managing risk in the Ethiopian highlands. However, these private benefits are not equally weighted to all farmers and it varies from farmers to farmers; from location to locations (Edilegnaw, 2003). This indicates that there is a variation between private optimal level of CGRs and the socially desirable diversity level by the community which justifies public intervention for effectively conserving crop genetic diversity.

2.1.3 Crop Variety Use in Ethiopian Agriculture

Ethiopia is still heavily dependent on FVs for its national food production (FAO, 1996; cited on Edilegnaw, 2003; McGuire, 2005). According to CSA (2006) report, only 3.80% of total cultivated crops used improved seeds, for the year 2003/2004. Of total cultivated cereal crops, 4.91% used improved seeds for same crop season in Ethiopia. The adoption rate of improved seed for sorghum is only 0.47% while the largest adoption rate is maize (20.15%), and wheat (4.13%) for each respective total cultivated land, in the 2003/2004 season. This low adoption rate of improved varieties cereals crops especially to sorghum crop will imply how *de facto* conservation is still at significant level on small holder farmers of Ethiopia.

2.1.4 What are the Threats of Crop Genetic Erosion in Ethiopia?

The broad range of genetic diversity existing in Ethiopia, particularly the primitive and wild gene pool, is presently subject to serious genetic erosion and irreversible losses. The most crucial factors include the displacement of indigenous land races by new, genetically uniform crop cultivars, changes and development in agriculture or land use, destruction of habitats and ecosystems, and drought. The drought that prevailed in region of Wollo, parts of Shewa, and Northern Ethiopia, has directly or indirectly caused considerable erosion, and at times has even resulted in massive destruction of both animals and plants (IBC, 2005). The famine that persisted in some parts of the country has forced farmers to eat their own seed in order to survive or to sell seed as a food commodity. This has resulted in massive displacement of native seed stock (mostly sorghum, wheat, and maize) by exotic seeds provided by relief agencies in the form of food grains (Worede, 1991; IBC, 2000). The extent to which the displacement of native seeds by exotic or improved materials occurs in Ethiopia has not been fully documented. Rates of displacement vary depending on regions and crops. In many cases, farmers still plant both native and exotic types interchangeably or along side, each other, at times in mixtures, depending on their particular need, market demand, or other prevailing factors (Worede *et al.*, 2000).

In general, native barely and durum wheat among the crops threatened by new varieties and / or by other crops species such as teff and bread wheat ,which are expanding within the cereal growing highlands of Shewa, Arsi, and Bale regions (Worede *et al.,*2000) largely because of market demand.

With sorghum and millet, exotic varieties do not pose any immediate threat because expansion of such material is at present some what restricted. In the case of sorghum, however, genetic erosion is progressing on account of extensive selection and breeding of the native population. The distribution of these materials results in gradual displacement of the original farmer's seed stock, especially in the regions of Wello and South East Shewa (Woerede *et al.*, 2000). The next sections briefly discuss about crop genetic resource conservation strategies practices and potential of Ethiopia.

2.1.5. On-Farm Crop Genetic Conservation and Its Potentials in Ethiopia

On-farm conservation ventures are of recent innovations in Ethiopia and they are little tried (Demissie, 2001; Edilegnaw, 2003). On-farm conservation in Ethiopia is yet at its infancy. Despite the country's huge potential in its genetic resource, stock, the on-farm conservation activities are of limited nature in both coverage and scope. This is mainly due to the limitation in resource capacity. Lack of experience and absence of well established principles are the forefront hurdles. The dominant on-farm activities in place are yet in a pilot project form that can not necessarily proceed more than the project life (Edilegnaw, 2003). As they are not established with the understanding of farmers' motivations, expectations, endowments, and the institutional setting, they are no more important than learning from trial and error. Most of the on-farm conservation models suggested in Ethiopia is of dubious acceptability to farming communities (Demissie, 2001; Edilegnaw, 2003). Thus, one of the main objectives of this thesis which is supposed to inform policy makers about farmers concerns, household characteristics, market related characteristics and the agro-ecology characteristics where and when could on-farm conservation will be more feasible and efficient in Ethiopia.

2.1.6. Conservation on Farmers' Fields

Farming itself is the original method of conservation linked with utilization (Engels and Wood, 1999). On-farm conservation is a process managed by farmers themselves and not one to be imposed by institutions (Wells, 1998). Farmers are custodians of genetic resources and always retain some seed stock for security unless circumstances dictate otherwise (Worede, 1988). They have always been doing so well ahead before the gene bank came into the picture. Taking farmers as custodians of crop diversity, the history of on-farm conservation can, therefore, be traced back to the history of farming.

According to some studies, the concern of losing their local varieties and breeds has always existed among farmers. There are multiple examples of farmers who maintain crop and animal genetic diversity for their own present and future use (Mugwara and Gebreegziabher, 2002). However, one should not lose sight of the fact that farmers do no maintain local varieties for diversity sake in a way required by the public agency dealing with conservation.

Farmers' knowledge is believed to be important not only for retaining crop diversity in its natural environment but also in integrating scientific knowledge to their life styles. The Ethiopian farmers are said to be not only an adjunct to conserving and enhancing but key actors in maintaining genetic diversity (IDRC, 1995).

2.1.7. *Ex Situ* and On-farm Crop Genetic Resource Conservation: Why Complements?

The purpose of this section is to explain the complementarities between on-farm conservation and *ex situ* conservation strategies. *Ex situ* strategies generate stock information for future decision making. While on-farm conservation strategies supply a flow of information (Swanson and Goschl, 2000a). On-farm conservation is basically production (or utilization) along with conservation whereas *ex situ* conservation in the gene bank is purely meant for static conservation involving only the use of the germplasm for breeding purpose. Both have some common outcomes depending on factors like the rate at which *ex situ* collections are done, the communalities of the genetic resources considered for conservation on-farm and *ex situ,* and the rate at which evolution in the field occurs.

To utilize both options efficiently and to capitalize on the dynamic features of on-farm, one has to ask 'how fast is crop genetic variability occurring under the natural environment?' the faster the rate of variability, the more on-farm conservation is justified. If it takes 50 years for a genetic material to change its attribute, there is little economic and biological ground to justify on-farm conservation of the genetic material as this duration is so long and beyond the public decision horizon of the present generation (Swanson and Goschl, 2000a; Edilegnaw, 2003). If the rate of change in genetic structure of certain crops changes so fasts, on-farm conservation of that crop will be sounder. This is because the different between the stock and the flow of information will be high enough to justify the costs (Edilegnaw, 2003)

Most authors agree that *ex situ* conservation should serve as a back-up for on-farm conservation and they should be considered as complementary (Shands, 1991; Brookfield and Stocking, 1999; Brush, 2000; Hawkes et al., 2000, Edilegnaw, 2003). Even though both *ex situ* and on-farm conservation ventures are expensive, they are both necessary in order to approach an efficient method of resource conservation (Swanson and Goschl, 2000a). Their complementary emanates from the fact that they are serving different conservation purposes: conservation at a point in time and conservation over time. Having this in mind, the two systems are adopted into the conservation strategy of Ethiopia (Demissie, 2001). Above all, establishing the linkage between on-farm conservation and *ex situ* conservation is the most crucial and challenging task ahead (Demissie and Arega, 2000). This can help to avoid redundant conservation options (Edilegnaw, 2003).

Mostly, the question of optimum combination of on-farm and *ex situ* is raised (Swanson and Goschl, 2000a). However, the question should rather be as to how to make their outcomes supportive and non- redundant. How much should a country invest in conservation strategy depends on the type of genetic resource it is dealing with and its resource endowment. This is mainly because each strategy needs different types of crop diversity depending on the nature of the crop.

For all the above reasons, policy makers have to recognize that *ex situ* and on-farm conservation are neither substitutes nor mutually exclusive in outcomes. Based on the features of the genetic resources and scarcity of the resources required to undertake the different conservation strategies, the country needs to capitalize on the complementarily of these strategies.

From the assessment of crop variety use in Ethiopian agriculture, it has been clear that local land races play an important role not only for livelihoods and for survival strategies, its global public attribute for the international world should consider that how the system is complex and dynamic. As far as the role of CGRs concerned, its high private benefit to farmers and public attribute to the society have pay the attention of national and international institutions to implement on-farm crop genetic resource conservation in Ethiopia. This is an opportunity for implementing on-farm crop genetic resource conservation in Ethiopia. However, the government ambition to increase productivity and achieve food security through improving the constraints of access factors and disseminating improved varieties of crops with improved technologies could increase the opportunity cost of on farm CGRs; this has been a challenge to pursue conservation strategy on farm in this country. The coming section will discuss the existing empirical literatures regarding 'what are the exogenous factors that determine CGRs on farmers decision model?'

2.2. Empirical Literature Review

The choice to continue growing traditional varieties is not merely the opposite of adopting modern varieties. Different models have been developed to explain why farmers grow more than one local variety simultaneously that provides insights and background of the study. Summaries of this literature are found in Feder *et al.*, (1985), Feder and Umali (1993), Meng (1997), Smale et al., (1994), Edilegnaw (2003), Van Dusen (2000) and Van Dusen and Taylor (2005).

If on-farm conservation of crop genetic resources becomes a policy concern, it will be important to understand the factors that influence household decisions to partially adopt new agricultural innovations and to understand how adoption decisions influence on-farm diversity.

In this section, theoretical and empirical research regarding technology adoption and on-farm conservation of crop genetic resources are reviewed. It begins with reviewing the main determinants of crop choice of farmers. Following this, the diversity measures and on-farm diversity empirical studies are examined.

2.2.1. Risk Aversion

Households potentially face production and consumption risk after the planting decision has been made, and risk aversion has been the most widely cited theory to explain why households continue to cultivate landraces (Meng, 1997; Hintze, 2002; Edilegnaw, 2003).

A risk-averse household is willing to trade-off higher expected yield in return for lower yield variance. To make this trade-off, a risk-averse household can diversify its crop portfolio by choosing among available alternatives that could include modern and traditional varieties (Smale et al., 1994). The household has expectations about the yield of the landraces through years of cultivation experience. Although the expected yield of landraces may be lower than modern varieties in optimal growing conditions, they are viewed as less risky by the household because the household has more information about their yields through experience. The higher-yielding modern varieties may have larger expected gains in yield, but they may also present more risk because they are less known to the producer (Feder, 1980).

Feder (1980) discusses risk aversion and the choice between modern and traditional varieties. Using the expected utility model, the risk-averse household is theoretically shown to plant less area to modern varieties as risk aversion increases. Similarly, an increase in yield variability of modern varieties, *ceteris paribus*, leads to less land allocated to modern varieties. In addition, as landholding increases, area planted to modern varieties increases, though Just and Zilberman (1983) theoretically demonstrate that the proportion of land allocated stays fixed as farm size increases if relative risk aversion is constant[8]. Risk aversion is represented in both studies as a farmer's decision to adopt a modern variety given modern or traditional varieties' mean yields, variances, and the covariance, and given that households can reduce risk by planting land races.

All the above mentioned studies, however, focus extensively on production risk. Finkelshtain and Chalfant (1991) theoretically extend the concept of risk to include consumption risk since many agricultural households in developing countries consume part of their production. The authors find that traditional univariate risk models that solely consider production risk do not apply to agricultural households in developing countries because most face production and consumption risk from their on-farm agricultural production.

2.2.2. Socio-economic/Household Indicators

Socio-economic/household characteristics that influence the wealth perception of a household, such as asset wealth and livestock holdings, can also influence technology adoption. Other determinants, such as education, farm experience, and the number of dependents in the household have also been shown to affect technology adoption rates in agriculture.

Perrin and Winkelmann (1976) empirically study the effect of farm size on technology adoption. They found that farm size plays a significant role in adoption rates, with large farmers more likely to adopt a modern variety before small farmers, though small farmers eventually catch up in adoption rates. They postulate that this can result for several reasons. One is that large farms possibly benefit from economies

[8] This conclusion is empirically demonstrated in Brush, Taylor, and Bellon (1992)

of scale in transactions costs. Second, large farmers are probably able to reduce the risk of experimenting with new crops much more easily than small farmers experiment. A large farmer can dedicate a small cropping area to a new crop with less risk relative to a small farmer who is dependent on a smaller amount of land for consumption and market production. In addition, large farmers may have lower per-unit input costs relative to small farmers. If they can obtain quantity discounts, they are more likely to choose to experiment with the intensive technology

Brush *et al.*, (1992) empirically examine the effects of on-farm fragmentation on the adoption of technology. Fragmentation refers to the number of separate plots that a household cultivates per unit of cultivated land. As the number of separate plots increases, so does the level of fragmentation. As fragmentation increases, the authors argue that environmental heterogeneity also likely increases because the plots can be spread out over several agro-ecological zones. This could make it riskier to cultivate only one crop because the plots of the farm may vary drastically in terms of overall land quality. The authors argue that more fragmented farms are likely to contain more diversity because several variety types could be needed to match the varying agro-ecological conditions. Although the authors conclude that fragmentation does not have a significant effect on area planted to improved varieties, it does have a significant positive effect on the level of on-farm diversity.

Other household characteristics that have been empirically shown to influence land-use decisions include education (Lin ,1991; Meng ,1997), asset wealth and livestock holdings (Meng,1997; Winters *et al.*, 2005), years of experience farming and the number of dependents living on-farm (Edmeades *et al.*, 2005), and livestock holdings

(Kurosaki,1996; Edmeades *et al.,* 2005).

Previous empirical studies of technology adoption by agrarian households in developing countries have shown these factors play significant roles in land-use decisions and crop choices for the households make. Thus, on-farm diversity model in this thesis includes socioeconomic/household characteristics.

2.2.3. Agro-ecological Heterogeneity

Another important set of determinants that could influence variety selection at the household level is that of agro-ecological constraints. The quality of the land that a household cultivates can strongly influence the decision to adopt a new technology or to continue to plant a landrace.

Households' cultivated land characteristics can vary from one plot to another (e.g., soil quality, rockiness and the slope of the plot). This can affect land-use decisions because modern varieties typically perform better than traditional varieties under optimal farming conditions (Feder, 1980; Bellon and Taylor, 1993).

Perrin and Winkelmann (1976) empirically examine agro-climatic conditions and topography (degree of slope of the plot) as explanatory variables in their study of adoption rates between large and small farmers. They conclude that, "relatively subtle agro-climatic changes in gradients can lead to dramatic changes in farmer behaviour" Heterogeneity in land quality can lead to large variation in expected yield for households within a small geographic area. Hence, the rate of technological adoption of a farmer is depending on the quality of a given household's land.

Jansen *et al* (1990) empirically test agro-ecological constraints in their study of adoption ceilings (i.e., upper limit of adoption within a population of households) in India for coarse cereal cultivars. They find that agro-ecological variables have significant explanatory power in adoption rates.

Meng (1997) finds that high quality soils are less likely to be planted to landraces, but highly sloped plots of land (degree of topography) are associated with landrace cultivation. Van Dusen (2000) finds that increasing degrees of topography and elevation correlate positively with the number of varieties planted.

2.2.4. Market Access

Another determinant of land-use decisions is market access and how it influences a household's ability to participate both in the market for seed and input acquisition and in the market to sell output. Households in less developed countries may be confronted with markets in which not all inputs are available or in which they may not be able to sell their output, and at times with no market structure at all. This could influence the quantity of traditional and modern varieties the households decide to cultivate.

Along with risk aversion, socioeconomic/household characteristics, and agro-ecological constraints, Meng (1997) uses market access to empirically explain the crop choice of farmers. Distance to market and road quality both influence the variety choices of households. Omamo (1998) empirically finds that high transport costs directly influence households and result in the decision to plant low-return food crops. Hintze (2002) also empirically tests road quality as an indicator of transactions costs and finds it to be positive and significant for modern maize variety adoption.

Distance to market, road quality, and access to input and output markets have been shown to affect households' land-use decisions. This thesis includes variables to measure the effect of market access on crop variety choice by households. The next section briefly discusses the relevant research about the factors determines the link between crop choices of farmers and on-farm diversity outcomes.

2.2.5. On-farm Conservation

As discussed in chapter one, *ex situ* and on-farm conservations is practiced by gene banks and households respectively. *Ex situ* conservation depends on the willingness of research institutions to take on caretaker roles for crop genetic resources by managing gene banks. On-farm conservation, on the other hand, is the result of production decisions of households. That is on-farm conservation currently continues without policy intervention does not ensure that the practice will continue in the future.

The study of technology adoption models is key to gaining an understanding of on-farm conservation and if and to what extent it will continue. Many empirical technology adoption studies have been used to study levels of on-farm diversity and how the introduction of modern varieties has affected this diversity.

2.2.5.1. Diversity and On-Farm Conservation

Van Dusen (2000) empirically tests socioeconomic/household indicators, agro-ecological conditions, and market access on land-use decisions that households make and then links these variables to on-farm diversity outcomes within cropping systems.

He uses a Variety Count index and the Shannon index of morphological traits to measure diversity. His results show that the land-use determinants in his empirical model have varying effects on the levels of diversity for individual crops within cropping systems and that the factors are jointly significant in explaining on-farm diversity. He also shows that the Variety Count and Shannon indices produce statistically different diversity outcomes for the same individual variables estimated, showing that linking land-use decisions to diversity outcomes can be sensitive to the type of diversity index chosen for the study.

Smale *et al.*, (2001) incorporate the use of variety characteristics into the agricultural household model to explain diversity outcomes. They empirically show that increases in consumption characteristics positively influence on-farm diversity.

Edmeades *et al.*, (2005) link demand for banana cultivars to diversity levels in Uganda. They empirically test the importance of consumption and production variety attributes socioeconomic/household characteristics, market access, and agro-ecological heterogeneity on diversity outcomes using the variety Count index and the Shannon index. Production characteristics of banana cultivars are found to increase on-farm diversity, yet consumption attributes do not significantly impact diversity outcomes. Livestock holdings increase diversity, but cash income decreases diversity. Off-farm characteristics, both plantation age and stock of village cultivars positively impact diversity outcomes, but high rainfall tends to reduce diversity. Also, banana sales in the market have a positive influence on diversity outcomes.

Winters *et al.*, (2005) examine the determinants of on-farm diversity levels of potatoes in Peru with a specific focus on the household's decision to diversify agricultural income sources, in this case with milk production. They measure diversity using the Variety Count, and Shannon indices and empirically test diversity outcomes on human capital variables of the household, agro-ecological variables of the farms, and rural development variables, including a wealth index, milk production, non-farm income share, access to credit and potato markets, and household participation in programs to reduce blight by planting new, blight-resistance tubers. Area of land owned, fragmentation, and altitude all have a significant, positive effect on on-farm diversity, while the cultivation of potatoes in only black soils negatively affects diversity outcomes. An increase in the number of harvests is associated with a decrease in diversity. The wealth index is found to be positively associated with diversity, as is access to an output market. Milk production and off-farm income both negatively affect diversity outcomes. Participation in programs associated with planting cultivars that are resistant to late blight is found to be positively associated with diversity.

Gauchan *et al.*, (2005) empirically examine the determinants of rice diversity at the household level in Nepal and how the land-use determinants used to investigate diversity outcomes affect the probability that a landrace is cultivated. The authors use the Variety Count, Berger-Parker, and Shannon indices as measures of diversity. The education of the decision maker and availability of on-farm labor both positively affect rice diversity. Likewise, distinct land types and irrigation on-farm both positively contribute to diversity. Distance to market positively influences diversity outcomes, yet the sale of modern varieties on the market negatively affects diversity.

Edilegnaw (2003) also found that access to extension and market, experience in using improved varieties (IVs) and growing cash crops and "chat" are the most important factor that declines sorghum poly-variety for East Hararge zone farmers in Ethiopia. The implication of study is that, there is a policy trade-off between productivity, development and CGRs in Ethiopia

Gebremedhin *et al.,* (2005) empirically test household characteristics, agro-ecological heterogeneity, market access, modern variety adoption, and village and regional factors on inter- and intra-specific crop diversity[9]. In addition to use the household as the unit of analysis, the authors use aggregate, village-level associations in Amhara and Tigray regions. The diversity metrics used are the Variety Count, Berger-Parker, and Shannon indices. The results of the regression analyses depend heavily on the crop of study, as maize, wheat, and barley are all used. The results showed cultivation of modern varieties of maize and wheat has no statically significant impact on genetic diversity level of crops grown at household level. Factors that are significant differ markedly between the highlands of Amhara and those in Tigray. These findings revealed that the location specific nature of any policies or programmes that are designed to encourage the maintenance of diversity, and the danger of drawing generalization from any single case study. The following chapter discusses the theoretical formulation of the model, model specification and the methodology of the research.

[9] Inter-specific crop diversity is genetic diversity among varieties of more than one crop. Intra-specific crop diversity refers to genetic diversity found between varieties of the same crop.

CHAPTER THREE

THE CONCEPTUAL FRAMEWORK, MODEL SPECIFICATION AND METHODOLOGY

3. The Conceptual Framework

As noted in the previous chapter, no cohesive theoretical models provide hypothesis predictions due to complexity nature of the model and therefore definitive comparative sometimes is difficult to make at priori. In this chapter, however, theoretical models regarding on-farm crop genetic diversity have been reviewed and one cohesive model is derived and then testable hypothesis will be formulated.

3.1. Microeconomic Theory of the Farm Household

The farm household is the basic unit of management where decisions and actions are taken together which affect crop diversity. The household is a consumer, consuming goods produced by its members on the farm and goods purchased with income from the farm or wage labour. Basically, there are two basic versions of the farm household model, which are referred to as the separable and non-separable cases Van Dusen (2000) and Van Dusen and Taylor (2005).

In the separable model, the market in effect separates production from consumption decisions. This model assumes that there is no risk, i.e. neither production nor prices are stochastic, and the household faces perfect markets (i.e. exogenous prices) for all consumption goods and variable inputs. Family labour is a perfect substitute for hired labour and the household is indifferent between on-farm and off-farm labour. In these settings, the household is a perfect neoclassical farm household, and farm decisions are solved recursively; that is, farm input and output decisions are made first and the resulting income is used to solve the consumption decisions (Smale et al., 2002)

In such scenario, farmers should be indifferent between using own produced and bought crop varieties (perfect substitution). Their input endowments should be equally suitable for all varieties (absence of asset fixity). Had profit been farmers single household objective and had there been constant returns to scale for every variety, specialization would have been the rule and species diversity on each farm would have been zero (Edilegnaw, 2003)

Unfortunately, these conditions do not hold in almost all the cases. Market imperfections are endemic in rural areas of less developed countries (LDCs). Missing or incomplete markets result from high transactions costs in factor or output markets (Stiglitz, 1989; De Janvry *et al.*, 1991; Van Dusen and Taylor, 2005). For this reason, most farmers are managing a portfolio of varieties to address their livelihood concerns. Hence, one coherent model that incorporates each of the explanatory variables is taken into consideration and consequently testable hypotheses are derived from this model.

3.1.1. The House Model

As noted in the previously, theory suggests that there are different factors that motivate farmers to diversify the portfolio of their variety and crop choice. The possible factors under play are market orientation or subsistence, income diversification, heterogeneity of farmers' resources (mainly land), resource endowment (education, labour, and wealth), multiplicity of farmers' concerns (livestock ownership, poverty and risk) and the impossibility to address them with a single variety. As far as designing incentive mechanisms for on-farm conservation of crop genetic resource conservation (CGRs) is concerned, partial analysis does not generate adequate information (Edilegnaw, 2003, Van Dusen, 2000; Van Dusen and Taylor, 2005). Thus, a change in any single economic factor is unlikely to cause farmers to change their variety and crop choice behaviour (Smale *et.al.*, 1994; Meng, 1997; Smale, 2006; Edilegnaw, 2003).

Farmers in Ethiopia both produce and consume their cereal harvests, and they grow modern varieties of wheat, maize, and teff simultaneously with their own traditional varieties (or landraces), as well as barley, sorghum, millet, and finger millet (Bennin *et al.*, 2003). Our conceptual approach is based on the theory of the household farm (Singh *et al.*, 1986; De Janvry *et al.*, 1991) and the literature on partial adoption of agricultural innovations (Feder et al. 1985; Feder and Umali 1993; Smale *et al.*, 1994).

Economic models of crop biodiversity that are based on either or both of these theoretical approaches and applied with econometric analysis of survey data are found in Meng (1997), Brush *et al.* (1992), Smale *et al.*,(2001), Van Dusen (2000), Bennin

Where the choice variables are area shares (α) planted for sorghum crop (in our case only one crop) for varieties j=1, 2... n. When all relevant markets function perfectly, farm production decisions are made separately from consumption decisions. The household maximizes the net farm earnings subject to constraints and then allocates these with other income among consumption goods. Farm production decisions, such as crop and variety choices, are driven by net returns, which are determined only by wage, input and output prices (w, p and p_x) and farm physical characteristics (represented by vector Ω_f as referred to in equation (2)). A diverse set of crops and varieties is still possible when land quality is heterogeneous and yields depend on land quality (Bellon and Taylor, 1993; Smale, 2006).

The production and consumption decisions of the household cannot be separated when labour markets, markets for other inputs, or product markets are imperfect. Then, prices are endogenous to the farm household and affected by the costs of transacting in the markets. The specific characteristics of farm households (represented by vector Ω_{HH}) and physical access to markets (represented by vector Ω_M) influence the magnitude of transactions costs and hence, the effective price governing the households choices.

The reduced form equations (5) can be derived and then express optimal area allocations sorghum crop and varieties as functions of a vector of the following variables.

$$\alpha^* = \alpha^*(P, A^0, Y, \Omega_{HH}, \Omega_{F0}, \Omega_M, \Omega_R) \quad \text{....... optimum area allocation (6)}$$

Where α,*, P, A^{0}, Y, Ω_{HH}, Ω_{FO}, Ω_M, Ω_R refers to the optimum land allocation of sorghum crop among varieties, price including wage, total land area they farm in each growing season, vectors of farm household characteristics, farm physical, market and regional specific characteristics respectively. Equation (6) defines the basis for the econometric estimation to examine the factors affecting diversity of sorghum crop on hose hold farms.

Reduced form of equations estimated econometrically takes the following conceptual form, as in Van Dusen (2000), Vandusen and Taylor, (2005), Bennin et al., (2003). The diversity of the crop is an outcome of choices made in a constrained optimization problem rather than an explicit choice.

$$DD = DD(\alpha^{*}(\mathrm{P}, \mathrm{A}, \Omega_{HH}, \Omega_{F}, \Omega_{M}, \Omega_{R}) \text{.......... On- farm diversity (7)}$$

Where DD is on farm diversity index at house hold level in which is the interest of this paper assume that household do not directly derive demand for diversity, their demand diversity depend on optimal allocation and variety choice of each farmer which in turn depend on household characteristics, farm characteristics, market related characteristics and agro-ecological variables. These factors are the main determinants of crop biodiversity on the house hold farms. Having specified the basic frame work, the next section will briefly describes the dependent and independent variables that are used in econometric analysis. The econometric method and structure of the regression models are then discussed.

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3.2. Description of Variables Included in the Model

The dependent variable represents the extent of adoption and continued use of conservation structures implemented on farmers' plots and it is a function of social, institutional, physical, economic and attitudinal factors. The definitions of the explanatory variables are presented in Table 3.1.

Formation of the model was influenced by a number of formulated hypotheses. Based on the literature reviewed, it was hypothesized that a farmers' decision to maintain on farm conservation at any point in time is influenced by combined effect of a number of factors related to the farmers and farm characteristics. The following section describes both dependent and the explanatory variables that used in estimation of the model.

3.2.1. Dependent Variables

The dependent variables are diversity indices. Diversity at the farm level can be measured by the number of indices, depending on the mode of reproduction of the crop, the type of data available to the researcher and diversity concept (Meng et al., 1998; Benin *et al.*, 2003). Some methods to measure diversity examine morphological traits (physical characteristics observable to scientists and farmers), while others molecular analysis to discern variation across crop populations. Economic studies that link between the crops choices to the levels of on-farm diversity vary in methods that are quantify diversity.

Spatial diversity refers to the amount of genetic diversity found over a given geographical area. It is the most commonly used indicator of diversity, measures the number of species with in the region. The number of species can be measured as simply the number of named varieties provided by farmers. For this study, two spatial diversity indices used the Count Diversity index and Shannon index, using variety names of sorghum and frequency of distribution obtained from the surveyed households.

Count index simply shows the richness of the crop which is the number of varieties planted in the household. A compromise between categorical choice and a diversity index that can be continuously measured is a count model. The dependent variable in this model is the number of varieties or the number of crops planted. In the ecological literature the count is called species *richness*. While limited in explanatory power for complex ecological processes, a count variable has the simplest data requirements, especially when the underlying population distributions are unknown. Certainly, knowing the number of varieties or crops planted is among the most basic of information collected in a survey. In addition, it is relatively closely linked to the behavioural model.

In the interpretation of the count diversity index, it is relatively straightforward to look at the signs of the coefficients as the increase in the probability that a household will grow an additional variety of a given crop. The count process can also be simpler than a linear specification because moving from zero to one variety can be modelled in the same way as moving from one to two varieties. If there is reason to believe that a different process governs whether a household plants a given crop and whether it plants multiple varieties, a mixture model can be adapted to the count model.

Shannon index measures both the number of varieties cultivated and their frequency over the study area. This is an index that combines both richness (count) and relative abundance (or evenness) concepts and sometimes called heterogeneity index for this reason (Magurran, 1998). It is constructed by first multiplying the percentage of each variety grown on a single farm by the natural log of that proportion. The products of each variety grown on a single farm are then summed and multiplied by negative one (see Table 3.1). For those households who grow one variety of sorghum, the Shannon index takes the value of zero and the maximum value will increase to positive rational numbers depending on the number of varieties grown and their frequency of distribution over the fixed land of a household. Generally, the higher the index indicates the higher on-farm genetic diversity in a given locality. Table 3.1 describes how each index is computed.

Table 3.1: Spatial Diversity Indices Used for Diversity Regression Analysis[10].

Index	Concept	Construction	Explanation
Count	Richness	D=n	n is number of sorghum varieties grown in the farmer.
Shannon	Evenness, equitability, proportional abundance(both richness and relative abundance)	$D=-\sum a_i \, lan \, a_i$ $D \geq 0$	Where α_i area share of sorghum crop variety occupied by a farmer. managed unit of diversity.

Source: Meng et al., (1998) and Smale, (2006)

[10] Table 3.1 is adopted from Meng et al (1998) and Smale, 2006. A farmer- managed unit of diversity in this analysis is variety of sorghum, regardless of the intra-variety diversity it may exhibit.

3.2.2. Independent Variables

As we discussed in the theoretical model, it is assumed that the household decision is non-separable that is the diversity of sorghum crop is affected by not only by farm physical characteristics, but also by household specific characteristics. The independent variables that are taken from the right hand sides of equation (7).

- Farm characteristics such as farm size (A^0), farm characteristics (Ω_F) and farm fragmentation factors are physical factors that explain the diversity level of crop.
- Endowment factors (Ω_{HH}), which is proxies by education level of household head, total house hold labor endowment, age of the household, and access to oxen will be examined.
- The access factors (access to nearby market, access to extension services, experience using improved seeds, access to credit services and access to non-farm income) .
- Risk factors, cash constraints and concern factors, these are food income gap (the number of months that is house hold is food deficit in a year), access to cash crops and concern factor the number of purpose of the sorghum used for, and cash constraints are used for our next analysis.

3.3. Econometric Method

The general structure of the regression equation is expressed in simple form by;

$$DD_i = \beta_0 + \beta_1 H_i + \beta_2 L_i + \beta_3 R_i + \varepsilon_i \text{.......................................} (8)$$

Where $DD_{i=}$ measure of sorghum diversity index of household i; which either measured in count index or Shannon index

H_i= Household variables of i farmer (age of the house hold head, head education, household size, oxen ownership, the food security status of the house holds)

L_i= Natural capital and agro-ecological variables of the house hold (Area of land owned, number of plots owned, the type of soils do have in plots on farm).

R_i= Variables associated with rural development of the household (wealth index, non-farm income share, credit access, experience in using improved seeds, access to fertilizer application, access to market, access to nearby weather road , access to town and kebeles dummies).

ε_i=error term

Having specified the regression model, the methods of econometric estimation are Poisson regression model and Tobit regression models based on genetic diversity measures of sorghum (count index and Shannon index). The next section discusses this in detail.

3.3.1. Poisson Regression Model

As noted in equation (7) and the reduced form of the regression equation specified in equation(8), the Poisson regression model is justified for count diversity index which was used in many ways for crop diversity analysis (Van Dusen, 2000: Benin et al., 2003, Edilegnaw, 2003). The Poisson regression models are often used for count data that take non- negative integer values and where the out come zero for at least some member of the population (Woodridge, 2002). Despite count data alternatively be modelled using discrete choices methods like multi nominal logit as surveyed in (Maddala, 1983), its application often not suitable as far the outcome is naturally ordered. Alternatively ordered probit or logit model can be used but assumes that the data generating process is a continuous one. By contrast, the Poisson model treats the data generating process discrete that is as result of point process resulting from direct observation, considered to stationary and homogenous (Cameron and Trevid,1998). Since we assume that the count process is discrete one, we employed Poisson regression model. The brief econometric structure of Poisson regression model is presented in Appendix A

3.3.2. Tobit Model

The choice of diversity index can play an important role for key policy related questions regarding on-farm conservation of (CGRs) who should be targeted for on-farm conservation? Is it those maintaining more number of traditional varieties (count index), or those allocating their land dominantly to a single variety (Edilegnaw, 2003)?

The problem of the count diversity index is that it assumes that all landraces contribute equally to diversity which is not the case. Among the available diversity indices meant to address this problem, the Shannon index, inculcating both richness and relative abundance, is given as (Magurran, 1988, Edilegnaw, 2003) and used for this analysis. As this index expected to have many zeros or censored to the left, it is plausible to use Tobit model in our empirical analysis (see the structure of the model on Appendix A-2).

Amemia (1984) has shown that the Tobit maximum likelihood estimator remains consistent under serial correlation but not under heteroscedasticity or non-normality. We need to estimate Tobit both with heteroscedasticity and without heteroscedasticity and in all cases the Likelihood ratio test for checking, the correct standard errors will be reported. Its decomposition, a marginal derivative and log likelihood derivative is presented in Appendix A-2. The following section discusses sampling procedure, the structure of the household survey, data source and finally the methodology of the study will be reviewed.

3.4. Sampling Procedure, Data Collection and Analysis Approach

3.4.1. Sampling

Sampling in practice is a compromise between the ideal and the affordable. From the study woreda, for this research purpose, four kebeles from the three agro-ecological Zones have been selected in consultation with the offices of woreda agriculture and rural development, woreda administration, and woreda Agri-Service Ethiopia. The criteria considered for the selection of kebeles were: representativeness, accessibility, affordability (in time and cost), and possibility of getting data both from the peasants and development agents.

The sampling process has been multi-stage sampling. At stage one, based on the set criteria, four kebeles (Wahilo, Mutebeleg, Gudegudet, and Sebelen) from Woinadega and Kola agro-ecologies respectively have been selected. At the second stage, three villages from these kebeles have been selected in consultation with the Kebele development agents and kebele administrators following the aforementioned criteria. The initial plan of the researcher was to select villages randomly from the selected kebeles; however, the situation in the field made me to shift from random selection technique to purposive selection, in consultation with the said parties. The reason for this shift is the fact that a single kebele consists of two or more of the agro-ecological zones; hence, it is impossible to select villages randomly for they are heterogeneous. Based on this, four villages are selected at each kebeles. At stage three; households have been selected from these villages based on proportionate stratified random sampling technique. In the study communities, household heads have been stratified in to two: male headed and female headed. The purpose of this stratification is to thoroughly investigate the gender effects of on-farm genetic resource conservation and to increase the heterogeneity of the data and then to find out the reason(s) for this variation.

For household survey, over all 205 (158 male household heads and 47 household heads) have been selected randomly. The sampling frame was done with the respective development agents of woreda agriculture and Agri-service development agent offices.

Regarding the distribution of sample taken among different kebeles, Gugudet Kebeles takes the largest that is 78 households are interviewed due the fact that its accessibility for our sample survey. In general we take adequate care to distribute the sampled households to different villages with in each kebele for representness of the sample to the population parameter. Table 3.4.1.shows the distribution of samples taken in each sampled household survey.

Table 3.2: Total Number of Household Heads, Sex Distribution and Samples Drawn at each Kebels

Kebeles	Total household head			Sampled drawn		
	Male headed	Female headed	Total	Male headed	Female headed	Total
Segelen	1203	401	1604	38	9	47
Wahilo	1112	312	1424	26	14	40
Mutebeleg	1305	214	1519	32	8	40
Gudegudet	1468	509	1977	62	16	78
Total	5088	1436	6524	158	47	205

Source: TWARDO, 2005and Own survey, 2007

3.4.2. Structured Household Survey

Household survey is the commonly used approach in various enquiries. The structured household survey has been mainly used, basically to collect quantitative data. The survey consists of four parts: demographic information; access to resources (land, labour, draught power, credit, extension package); livelihood activities/sources (crop production, livestock rearing and non-farm activities) and number and type of crop diversity particularly to sorghum variety at the household level had been raised and discussed. The order of the question had been revised after presetting with 10 household survey responses. Questions such as household income and food security conditions were asked towards to the final section of questionnaire as they were too sensitive to be answered easily.

The survey has been conducted on the selected 205 households. It has been handled by five development agents of the respective kebeles after taking appropriate training. One day training was organized and appropriate orientation was provided for these five enumerators and discussions were also made with them so as to make the questionnaires clear. Development agents have been preferred for many reasons. First, they are all diploma holders in agriculture; second, they do have a list of households of each category that could be included in the survey and making sampling frame could be easy; third, they do have knowledge and experience on the subject matters and can easily understand the questionnaire; fourth, they are more familiar with the community thereby communication and getting reliable data could be easy While the survey has been handled by the enumerators, the researcher has been inspecting the enumerators, and side by side undertaking in-depth interviews with the selected households.

Focus group discussion helps to generate data on group dynamics, and allows a small group of respondents to be guided by a skilled moderator, to focus on key issues of the research topic. The focus group discussions were held with the households of the respective selected gotts. At each kebeles /*gotts*, one focus group discussion was hold with the community (consisting of adult men, female headed households, and landless youth). The main purpose of focus group discussion was to clearly understand the livelihood opportunities and challenges which are more of communal in nature.

The major discussion topics were: constraints to production and productivity (both crop and livestock), environmental protection practices and challenges, availability of local varieties of sorghum, morphological characteristics of each local varieties of sorghum, availability of improved varieties of sorghum in area, productivity performance of modern varieties in their area etc. At each focus group discussion panels a total of eight to ten households were involved.

3.4.3. Data Analysis

The objectives of the study are various. To address the various objectives described above, the framework has an inherent character to encompass all variables that have direct and indirect influence on the issue of crop genetic resource conservation in general and sorghum crop genetic resource conservation in particular are considered.

Both descriptive as well as econometric analysis has been employed to address the objective of the paper. Frequency, means, ratios and percentages were computed for different variables. With regard to econometric analysis as noted above, Poisson regression and Tobit are employed to analyze the data. The key empirical question was what factors are associated with farmers' on-farm conservation of sorghum genetic resource in the study area? The explanatory variables included in the Tobit and Poisson regression models will be discussed under the following chapter. The data analysis was carried out using the Sata version 9 sand Limdep 8 software packages.

Data have entered in to the computer after coding the variables and descriptive statistics such as: percentages, mean and standard deviation have been computed through the above mentioned software program and results have been presented in tables and interpreted accordingly. Similarly, qualitative data obtained through interviews and focus group discussion, so that the real picture of the crop genetic resource situation of the community is revealed which supplement the regression output. Various archival and policy documents have also been reviewed and applied to substantiate the primary data. Data on agricultural production, natural resource degradation and conservation and farm household characteristics were collected. To complement the questionnaire and to have a detailed insight into crop biodiversity conservation practices in the area, a discussion covering different topics with agricultural experts and farmers have been conducted. This helped to capture some points that were not clearly obtained from structured household interview.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Description of the Study Area

The study was conducted in Tehuledere woreda, South Wollo zone, Amhara National Regional State (ANRS). It is among the 18 woredas of south Wollo Zone of ANRS. The woreda is situated in the Northern part of South Wollo Zone. The woreda is bordered by Worebabu and Kalu woreda in the East, Kutaber woreda in the west, Ambasel woreda of North Wollo Zone in the West, and North West, Habru woreda North Wollo Zone in the North, and Dessie Zuria woreda in the South and South West. The woreda is crossed by the Addis- Mekel road. The capital of the woreda, Haik, is situated 430 km away from Addis Ababa. Haik is 30 kms away in the Northern direction from the South Wollo Zone capital city, Dessie.

The study area is characterized by diverse topography. The major relief features are mountain, undulate, plane, and valley. The common topographic features that cover up to 48% of the woreda is undulate. Of the woredas total area land mountains account 26.4%. Plane is the third major total area relief features as takes up 13.3% of the study area. The share of the valley 12.3% of the total area of the woreda (TWARDO)

Another good indicator of the areas topographic characteristics is the range of elevation. The highest elevated spot of the woreda reaches 2,928 m.a.s.l. The lowest elevated point has an altitude as high as 1,400 m.a.s.l.

Climatically, the study area is divided into three regions namely, Dega, Woinadega, and Kolla (TWARDO). The agro-ecological zone that carries the highest population and the largest area with 74.1% and 72% respectively is woinadega. Area wise, Kolla is the second largest agro-ecological Zone. However, there is more number of peoples in the dega than kolla (see Table 4.1). The annual temperature varies from 15 c^0 to $20c^0$.The Average annual rainfall is 1030 millimetres (TWIO).

Table 4.1: The Agro-ecological Pattern of the Studied Woreda

Agro-ecological Zones	Area Share (%)	Population Share (%)
Dega	13.0	13.4
Woinadega	72.0	74.1
Kolla	15.0	12.5
Total	**100.0**	**100.0**

Source: TWARDO, 2005

The land use features that cover the area are forest and bush land, built up area, barren land, agricultural land, and water covered land. The land use features that takes up the largest part of the study area is agricultural land with a total area of 21,539 hectare and a share of 47% out of the total area. The second major land use is forest and bush land as it accounts 31.2% of the total area (See Table 4.2).

The average land holding of the woreda, indicates the shortage of land in the woreda among the inhabitants. The average land holding of the woreda is 0.29 ha (TWIO).

Table 4.2: The Land Use Pattern of the Study Woreda

Land Use types	Area(ha)	Percent
Agricultural land	21,539	47
Forest and bush land	14,308.20	31.2
Built up Area	4,490.80	9.8
Water Covered	3800	8.3
Barren Land	1000	2.2
Grazing	662	1.4
Total	**45,800**	**100.0**

Source: TWARDO, 2005

The area is a predominantly rural woreda as 88% of the total population resides in rural areas. Only 12% of the total population lives in urban areas (see Table 4.3). The woreda posses 24,890 households, in which on the average 5 people live in each household.

Table 4.3: The Population Pattern of the Study Woreda With Respect To Area and Population Share

Location of Settlement	Population Size	Population proportion
Rural	133,802	88.0
Urban	18,305	12.0
Total population of the woreda	152,107	100.0

Source: TWARDO, 2005

As the largest portion of the woreda is rural, most of inhabitants of the woreda rely on farming. As much as 91.25% of the total population rely on farming. The second major income source is daily labour as 3.6% of the total population relay on it. The third major economic activity is livestock production as it accounts 3.5% of the total population. Petty trade (1.8%) and craftsmanship (0.15%) are also among the economic activities under which the inhabitants of the woreda use as a source of livelihood (TWARDO).

In the study area, the major types of crops grown are cereals such as tef, barley, sorghum, bread wheat, finger millet, and others pulses , oil crops, root crops such as fababean, , linseed, noug and potato. Double cropping and crop rotation are widely practiced. Crop production is mostly rain-fed and subsistence-oriented. As to the discussion of the farmers and agricultural experts most of the discussants confirm that the productivity of the crop is very low and most of farmers had the experience of failure of crop production. Environmental problems taking the primary cause for the failure of the crop production while crop diseases and pest have also a significant share for the loss of production and productivity.

Table 4.4 and Table 4.5 show South Wollo Zone and Tehuldere woreda production and productivity of sorghum as complied from CSA (2003) agricultural sample enumeration statistical reports and Sirinka Agriculture Research Centre respectively. According to these reports, the zonal average productivity of sorghum crop is 1.36 tons per hectare while in the study woreda (Tehuldre Woredea), the average productivity of sorghum is 1.48 tons per hectare which is more by 0.12 tons per hectare than zonal average productivity. While Sirinka Agricultural Research Centre, have been doing research on the productivity of sorghum improved varieties at research station and on-framers' field. They found yield gap between the research station and farmers' field. At the research station the highest is 9 tons per hectare while yield on farmers field the highest yield is 6.6 tons per hectare (taking the highest range). Comparing the productivity of local varieties of sorghum to that of productivity of improved varieties even at farmers field, according to this report, all improved varieties provides an average productivity of (1.65 tons per hectare) than the woreda average productivity of (1.45 tons per hectare) which is less by 0.2 tons per hectare (See Table 4.5).

Table 4.4 Statistical Report on Area and Production of Sorghum for 2001/02

Geographical Area	Number of holders	Area in (hectares)	Production (tons)	Yield (tons/ha)
South Wollo Zone	185,600	59,588.38	809,902.98	1.34
Tehuldere Woreda	16,577	5,544,.33	81,846.03	1.45

Source: CSA (2003) Ethiopian Agricultural Sample Enumeration Reports 2001/02 (PART II-A).

Table 4.5 Report on Sorghum Yield at Research Station and On-farmers' Land in Tehulder Woreda.

Modern variety name	Yield at Research Station (tons/ha)	Productivity range on farmers' land (tons/ha)
Yedu	5-9	2-6
Techale	5.5-9.5	2-6.6
Berhan	4.1-8	1-1.4
Hormat	2.3-3	1.6-2.2

Source: Sirnka Agricultural Research Centre, Research out put (2005/2006).

The statistic reported in Table 4.5 indicates that local varieties of sorghum provide a comparable productivity to that of improved ones in Tehuledere Woreda. However, it is difficult to make comparison and arriving at conclusion based on this aggregate level of data which were taken for different cropping season, different plot characteristics and farming practices. Since data on yield comparison between local varieties relatives to modern varieties could not be found in the area, it is difficult to make conclusion and recommendation now. Therefore, the only purposes of this (reported Table 4.4 and Table 4.5) is to provide an insight on the yield of sorghum of local varieties vis-vis modern varieties not to make a perfect and complete yield comparison between local varieties and modern varieties. The coming section describes the socio-economic characteristics of the sampled households that are used for regression models.

4.2. Data Description of Sampled House Hold Survey

Almost all (98.5 percent) of the sampled farm households are Muslim. About 79.08 percent of the sampled households are males and 64.88 percent of the head households are able to read and write in the sampled survey. Among the sampled farm households 45.85 % (94 farmers) are participating in extension package and about 34.15 % (75 farmers) of the sampled households have access to radio. About 79.8 percent of them have been rearing livestock with crop production (for detail see Appendix B).

As far as their income sources are concerned, 43.9 percent (90 farmers) of the sampled farm households have other income sources outside agriculture. They are involved in diverse set of non-farm economic activities including firewood and charcoal selling, daily labourer, black smith, local trading, handicrafts, selling bricks and guard. In the study area people are vulnerable to drought and natural calamities hence it is a food insecure area. About 43.1 % (89 households) from sampled survey are reported their own agricultural output could cover the family food requirement only for six months in a year. Thus 14 percent of households have reported that they are participating in safety-net program as the second most important sources of income to supplement the food shortage months of the household. Selling fixed assets, off- farm work, migration to cites, selling fuel wood and charcoal, government aid are also the most means for farmers to survive when the crop fail. Most of these activities reveal to what extent farmers survival strategies are directly affecting the natural resource base.

Regarding the crop biodiversity, in the study area has shown a wide variety crops found. About 34.15 % (70 farmers) of the total sampled household had grown three crops for 2005/2006 cropping season. The maximum crop diversity maintained in the sampled is 10 crops (see Appendix B). Almost all respondents used local varieties for the past two consecutive cropping seasons. The proportion of farmers who solely used local varieties is 96.4%. Farmers reported that when climatic hazards such as high rainfall, low rainfall, erosion, erratic rainfall and hailstorm are occurred, local varieties have better performance than improved ones. Another 3.6% use local varieties together with the improved ones. Through the household survey, households were asked to identify the major bottlenecks for crop production that constrain the food availability; accordingly, insufficient landholding is the top problem followed by erratic rainfall distribution, drought, shortage/lack of farm oxen and poor soil fertility in descending order.

The diversity purpose of growing a crop has a direct impact on the number of varieties to be used on-farm as survival of the household members will heavily depend on the crop. Farmers have reported six major benefits of sorghum (food, cash, animal feed, fuel wood, house construction and fence construction) of growing sorghum in the study area. Among the sampled households 48.7 percent and 39.5 percent of them have been producing sorghum for three and four purposes of the farm household respectively (see the Appendix B).

4.3. Data Description of Variables Included in the Model and Their Hypothesis Effect

As noted above, the dependent variables are count index and Shannon index were used in the regressions explaining sorghum crop variety diversity in the study area. For count index the mean value is 1.98 with a minimum of 0 and maximum of 6 varieties per household in the sampled households. Among these, 6.83 percent of the sampled households did not grow sorghum (See Appendix B; Table 2). While for Shannon index (expressing the concept of evenness) is censored at 0 for 82 sampled households with mean values of 0.509, for a minimum value of 0 and a maximum of 1.39 in the sampled survey.

The definitions of each explanatory variables included in each independent variables category are presented in Table 4.6. Formation of the model was influenced by a number of working hypotheses. Based on the literature reviewed above, it is hypothesized that a farmers' decision to maintain on farm conservation at any point in time is influenced by combined effect of a number of factors related to the farmers and farm characteristics.

Below are the summary statistics of dependent and independent variables.

Table 4.6: Data Description of Dependent and Independent Variables Used in the Empirical Analysis

Variable name	Description	Mean	Standard Error	Minimum	Maximum	Hypothesized effect
Dependent Variables						
Count	The number of traditional varieties cultivating in the household	1.98	1.20	0	6	NA
Shannon	The number of varieties and abundance of sorghum crop varieties in the household.	0.509	0.472	0	1.39	NA
Independent Variables						
House hold characteristics						
Age	Age of household- head (years)	42.9	11.93	22	85	(+)
Sex	Sex of the household head (=0 females;1=male)	0.790	0.408	0	1	(+,-)
Educat	Education status of the house hold head (0= illiterate; 1=literate)	0.649	0.478	0	1	(+,-)
sizeh	Number of household members	5.20	1.99	1	14	(+,-)
Farm characteristics						
sizeland	The average land size allocated to all crops in (Hectares)	1.17	0.848	0.125	5.5	+

Numbsolt	Number of different soil type in all cultivable lands	1.85	0.729	0	4	+
Numbplot	Number of plots operated by the household	2.44	1.14	0	7	+
Market characteristics and information constraints						
Exteension	Access to extension services (experience in using improved seeds, fertilizer and formal credit services) =1 access; =0 not have access	0.459	0.499	0	1	-
Acessmarket	The average walking time taken to reach the nearby market (in minutes)	102.4	58.6	5	300	+
Acessd	The average walking time taken to reach the development agent office (in minutes)	28.65	25.41	1	180	+
Risk proxy						

Fdefictmon	The number of months in which the household is expected to be food deficit in a year	4.32	2.56	0	9	+
nonfarminco	The amount of income generated in non farm activates in a year	494.09	755.59	0	4802	-
Acesscashcro	The amount of income generated in selling chatt, coffee and fruits in a year	214.21	663.30	0	800	-
noo	The number of oxen in the household	1.20	0.96	0	4	+
Nposor	The number of purposes in which sorghum used in the household	3.29	0.728	0	5	+

Note: NA refers to not applicable

Source: own survey

Household characteristics affect crop biodiversity both through preferences and household-specific costs of market transactions as well as through labour stocks and opportunity costs. The average age of the sampled household head is 42.9 while the mean size of a household is 5.29 in the sampled survey which is similar to Woreda statistics of 5 people per household. Age, education, the gender composition and family size of the household are expected to influence the set of crop varieties chosen for cultivation through the preference of household members and their farming experiences.

The age of the production decision makers may have positively related to sorghum diversity since older farmers are more likely to have experience and knowledge about cultivating a range of varieties, and particular to land races. Similarly active adult labour on-farm is hypothesized to have positive effect on sorghum diversity since more labour allows households to engage in the cultivation of a larger set sorghum varieties with different management requirements. The educational levels of the decision makers (production or consumption) may have either a positive or negative influence on sorghum diversity. For one thing it may relate to acquire information and be able to experiment with diverse varieties, or it may be associated with a preference for modern varieties. In our case, due to collinearity problem of sex with education, the education variable is dropped from our model estimation.

With regard to the descriptive statistics of livestock assets, exogenous income and food income gap variables in the sampled house household survey, we found the average oxen in a household to 1.29 with a minimum of 0 and a maximum of 4 oxen in the house hold (see Appendix B Table-3). While for income other than agriculture is on the average 494.0 birr in the year in the sampled household survey to the minimum value of 0 and for maximum of birr 4802 in the year. To the variable food income gap, the household is reported that they were in food deficit on the average for 4.32 months in year. For the variable access to cash crops, the area is min cultivation of cash crops such as coffee, chaat and other perennial fruits which likely to generate cash income for alleviating their cash constraints in the study area. We found the mean income that likely to generate in cash crops is birr 214.21 per annum with in one household.

Livestock assets, exogenous income and food income gap are wealth related variables hypothesized to affect variation in crop diversity levels through their association with ability to bear production risks. Households owing a larger number of oxen and animals are expected to grow more diverse sorghum varieties through increased access inputs or because of greater demand for fodder. Ownership of oxen also induce farmer to maintain diversity because these allows for timely land preparation, threshing and harvesting of products[11]. Cash income might be either positively or negatively associated with diversity. On one hand cash income enhances farmers' capacity to hire labour and purchase inputs in order to engage in a wider range of activities. On the other hand, it may simply that households are allocating household labour to non-farm activities or specializing in the production of a few modern varieties for the market.

Descriptive statistics of a proxy information constraints and development related variables were used: among these the average time taken to reach the nearby market and development agent office shows that on the average 102.4 minutes and 28.65

[11] The number of live stock unit is dropped from the model as collinearity problem with number of oxen ownership in the estimated model.

minutes respectively. This provides insight how the sampled house holds far from the market and information access problems. These are one of the most determinates of crop genetic diversity which is tested empirically in the next regression model.

Market related variables affect diversity through the extent to which the household trade their sorghum crop and purchase inputs, foods and other households' needs in the market. The distance of the household from the market is a major component of engaging in the market transactions. The more removed a household from a household from a local market centres, the more likely it will be rely on its own production to meet its consumption needs. Consumption needs may include a range of food products as well as fodder.

4.4. Estimation Results and Related Discussions

To test the relationships outlined in the theory, we have estimated the Poisson model with a robust covariance matrix. Based on the descriptive statistics presented above, the independent variables included are categorized as household characteristics, market-related characteristics, farm characteristics and the risk and concern factors. The variables Wahilo, Seglen, and Gudegudet are all the kebeles dummy variables meant to capture any village differences not accounted by the other variables. The village Mutebeleg is left randomly as a reference. Table 4.7 reports the parameter estimates of the Poisson model and the importance of the different variables considered to its marginal effects.

Table 4.7: Poisson Regression Results to Explain Farmers' Motivations to Diversify On Traditional Sorghum Varieties (Count Index).

Variable	Coefficient	Marginal effects: Dy/dx
Age	-0.0014 (-0.72)	-0.0043
Sex••	-0.0685 (-1.07)	-0.2122
sizeh	0.02634**(1.89)	0.0799
sizeofland	0.0724***(3.13)	0.2198
Numbsolt	0.0826** (1.70)	0 .2506
Noxen	0.0448*(1.35)	0.1360
Exteension ••	-0.1762*** (- 3.07)	-0.5422
Acessmarket	0.00084 (1.14)	0.0026
Acesscashcro	0.000091* **(3.09)	0 .00027
Fdefictmon	-0.0086 (-0.68)	-0.026
Nopurpo	0.1073 **(2.72)	0 .3257
nonfarminco	0.0000145(0.48)	0.000044
Wahilo••	0.4225***(5.41)	1.46
Gugudet••	0.1645** (1.78)	0.5097
Segelen ••	0.0902(0.68)	0.2806
Constant	0.2077(1.08)	
Dependent variable is count index		Number of obs = 205
Wald Chi^2(15) = 175.02		Prob chi^2 = 0.00
Loglikelihood = -340.43		Pseudo R^2 = 0.0611
Goodness-of-fit chi2 = 76.41172		
Prob > chi2(189) = 1.0000		

NOTES: *** -Significant at 1%; **- Significant at 5% and *- Significant at 10%. Values in parenthesis are the ratio of the coefficient to the estimated asymptotic standard error. The method of estimation is Stata's robust option following Huber/White standard errors and covariance. (••) dy/dx is for discrete change of dummy variable from 0 to 1.

Diagnostic static for goodness of fit (Goodness –fit-χ^2 =76.41and Prob> χ^2 (189)

=1.00 indicating that the Poisson is appropriate model to explain count diversity. The Wald (Chi^2 (15) = 175.02, Prob chi^2 = 0.000) has been used to check significance of the inclusion of a set of variables. This test fails to accept H_0 in all cases implying that all set of variables are important in explaining farmers' demand for variety diversification. The variables considered were classified into household characteristics (Age, sex and sizeh), farm characteristics (sizeland, numplot and Numbsolt), access factors (Noxen, Extension, acesscashcro, Acessmarket), risk factors (Fdefict and nonfarminco) and agro-ecological heterogeneity dummy variables (Wahilo, Gudegudet and Seglen)[12]. Because the alternative explanations are not mutually exclusive and as there is no single theoretical argument fully explains farmers' land allocation decisions (Smale, *et.al*, 1994, Edilegnaw, 2003), failure to estimate a comprehensive model overstates the significance of an individual explanation. Hence, misspecification tests had been practiced for the adequacy of the model before any hypothesis testing of individual variables. These variables overall therefore, are fully explaining the Poisson regression of count diversity index of the study area.

In order to test for dispersion of Poisson model, checking in our data set using regression based tests for over and under dispersion suggested by Cameron and Trivedi (1990) and Wooldridge (2003) for testing equi-dispersion of the variance of the error term. Consequently, we found that mean variance ratio of the model which is represented by δ (finally, we found that δ is less than one) indicating that our data set is under dispersion. The easiest way to solve this problem is to use the Poisson model with robust (sandwich) covariance matrix because the Poisson model is consistent under violation of the eqi-dispersed assumption (Winkelmann, 1995; Edilegnaw,

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[12] For their operational definitions and data descriptive of these explanatory variables were presented in table 4.6

2003). For this reason, the robust methods of estimating Poisson model have been used to compute the Huber (White robust standard) reported in Table 4.7.

Most of the results confirm a priori expectations. The factors such as diversity of farmers' concerns being met by producing sorghum concern factors (sorghum purpose), farmers' endowment factors (access to oxen, family size of the household), farm characteristics (land size, and type of soil type) are the key factors for variety diversification. These factors are factors that encourage farmers to produce diversity by managing a portfolio of traditional sorghum varieties. On the contrary, access to extension services is the key factors that significantly dissociating factor for managing a portfolio of sorghum diversity at a household level.

A simple way to interpret the regression results is by using the concept of factor change (Long, 1997, Edilegnaw, 2003). From the household characteristics, as size of the household increases by one more person, the expected count index of sorghum varieties increase by 2.6 % holding all other variables constant. This result is similar to the empirical works of Smale *et al* (2001), Winters, *et al* (2005) and Edilegnaw (2003).

In the farm characteristics, as size of the land for a farmer increases by one more hectares, the expected value of on farm diversity increases by 7.24%. Large farmers can experiment with unknown varieties or trade off yield for consumption attributes such as taste with less production and consumption risk than small farmers (Smale, 2006). Therefore, a household who have a greater area of farm land will grow more types more crops and varieties of crop than a household who have smaller land area.

The number of soil type that a household has on their plots of land is a proxy for uniformity of lands holdings and it is the incentives for farmers to match varieties to different agro-ecological conditions. Accordingly, form the regression result, if types of soils in the farm increase by one more units, on-farm sorghum diversity increase by 8.26%. Hence, as the type of soils that a household cultivate is more than one type, the more the probability of planting more than one variety of sorghum.

As to endowment factors, when the farmer has one more number of oxen, the expected richness of on farm diversity increases by 4.48%. Our empirical result confirm, oxen ownership is expected to contribute positively to diversity among cereals through ensuring draught power for ploughing when it is needed.

When a farmer yearly cash crop income increase by one more birr, the expected value of on farm diversity index increased by 0.0091%. That is access to cash crops results shows a positive and a significant effect on sorghum on-farm genetic diversity at a household level. This implies that where intensity of cash crops is minimal, it supplements the on-farm sorghum crop genetic diversity as far as risk exposure and market imperfection is dominantly prevailing in the study area. This result contradicts the previous result of Edilegnaw (2003) who found that there is a negative association between cash crop and on-farm genetic resource diversity in Harereghe. In that case, the income generated from cultivating 'chaat' crop and coffee crops is significant and the likelihood that the replacement of financially rewarding crops by financially non-rewarding sorghum crop is high. The implication is that the cost of intervention for on farm genetic resource conservation as on-farm strategy is too expensive to implement in those areas while in our case cultivating cash crops will motivate to grow multiple varieties of sorghum. To this end, cost of intervention for on-farm conservation is cheap where cultivation of cash crop is not as extensive as to replace important food crops such as sorghum.

Finally, for concern factors, when the number purposes for sorghum crop increases by one more units, the expected value of on farm diversity for the crop increase by 10.73%. This implies a single variety does not satisfy multiple purposes of to which farmers wish to place for satisfying multiple objectives of the family. According to the results above, farmers are not able to get multiple attributes they want from a single variety and the increase in the relative importance of sorghum to household utility is one of the motivating factors for diversification of traditional sorghum varieties.

For the disincentive factors, access to extension factors which is dummy variables, being a farmer have been practicing extension packages ,decreases the on farm sorghum diversity by a factor of 1.19 (=exp(.1762) or decrease by 19 percent (1.19-1), holding all other variables constant. Farm households with better access to extension and improved seeds have reported less number of sorghum on their farm. The utility that farmers derive from growing multiple varieties declines with the availability of these public goods. This result confirm that using improved seeds and fertilizer package will decline the number of land races cultivated on the farm which warns the long term potential of improved varieties will likely replace local varieties. The result is similar to Edilegnaw (2003) findings.

For kebeles dummy variables, a household located in Wahilo kebele increases on-farm sorghum diversity richness index by a factor of 1.53 or increase by 53% as compared to Mutebeleg Village. Similarly being on Gudegudet kebele increases sorghum richness (count) index by a factor of 1.18 or increases by 18% holding other variables constant.

The estimated coefficient for age of the household head variable is negative and insignificant in the above Poisson regression result. This implies that cultivation of more varieties and its derived demands less and less as age increases. The reason is that cultivation of more varieties demands for more labours or input intensity of those varieties such as oxen ownership, timely cultivation, weeding, and other farming practices. This is particularly true in areas where the dissemination of modern varieties is minimal and technological progress is low and labour market is imperfect. The result is similar to Bennin et al, (2003). However it contradict the previous empirical work of Edilegnaw (2003) who got a significant and positive relation between sorghum land race cultivation and age of the house hold head.

Result of Tobit regression model with LIMDEP 8, on variety richness and abundance of sorghum crop has shown in the Table 4.8.

Table 4.8: Tobit Estimation Results to Explain Sorghum Farmers' Variety Diversification (Shannon Index)

Variable	Coefficient	Marginal effects	Mean value of independent variables
Sex••	0.0725 (1.194)	0.09436	0.79
sizeh	-0.00503(-0.366)	-0 .01482	5.2
sizeland	-0.00146 (-0.039)	-0 .09370	1.16
Nosolt	0.1204 **** (3.649)	0.15194	1.8
Nooxen	0.0629**(2.24)	0 .06053	1.19
Extension••	-0.10786 **(-2.112)	-0.00041	0.43
Acessmarket	0.000038 (0.061)	0.000441	102.4
incomecoffe	0.000045 (1.241)	0.000056	214.2
Nonfarminc	0.00004 (1.179)	0.000053	494.09
Nopurpo	0.1006*** (3.741)	0.0842	3.29
Segelen ••	-0.0424(-0.353)	-0 .50013	0.22
Wahilo••	0.407****(5.187)	1.703	0.20
Gudegudet••	0.041629 (0.541)	-0.6821	0.38
Constant	0.1979(0.602)		
Dependent variable is Shannon Index Number of obs. = 205 LM(13) = 69.875[13] Log likelihood = Log likelihood function -74.47			

NOTES: *** -Significant at 1%; ** Significant at 5% and *- Significant at 10%. Values in parenthesis are the ratio of the coefficient to the estimated asymptotic standard error.

(••) df/dx is for discrete change of dummy variable from 0 to 1. Partial derivatives are the expected value with respect to the vector of independent characteristics. They are computed at the means of the independent variables.

Source: Own survey

Diagnostic test shows that the LM test for over all specification test of the model {LM 69.875[13] } is rejecting the null hypothesis that shows the inclusion of a set variables is important to explain the Shannon index of the sorghum. Regarding the LR ratio test for the model, the LR ratio test was under taken without heteroscedasticity and with heteroscedasticity. The calculated statistics is significantly rejected the null hypothesis which indicate that the model is heteroscedasticity problem. Thus, the standard errors reported in Table 4.8 are with heteroscedasticity or with robust standard errors.

Referring to the results of Table 4.8, household characteristics such as sex[13] variable and household size do not significantly affect on the variety richness and abundance of sorghum crop variety.

The most important factors positively affecting sorghum richness and abundance are soil heterogeneity or the existence different soil types, number of oxen ownership and the number of purposes in which the household used sorghum in the household. Regression results are reported in Table 4.7 and Table 4.8 are almost similar implying that the soil heterogeneity, the number of purposes of sorghum and oxen asset are statically significant and positively related to all measures of diversity; producers with more types of land, number of purposes and oxen asset are likely to be growing varieties of a crop that are more evenly distributed in terms of land area. These findings are consistent with those reported in the developing countries. In the northern Ethiopia, Bennin *et al.,* (2003) also found that land crop area and soil types were to be positively associated with the crop biodiversity.

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[13] The age variable is dropped due as soon as we recognized that the log maximum likelihood is difficult to converge or singularity of matrix.

On the negative side, the factors under play are accesses to extension and accesses to market are negatively affecting sorghum genetic diversity not only the variety richness but also the variety abundance of sorghum crop in the study area. This result confirms that maintaining the crop biodiversity on the shoulder of the poor marginalized farmers who have no access to market and far from extension services.

The similarity of results of Table 4.7 above and Table 4.8 also indicate that variety count is a very good proxy to study farmers' derived demand for on-farm crop diversity. In addition, most of the factors are significant in explaining the richness (count) and both richness and equitability (Shannon) among varieties growing for sorghum crop that are consistent in sign. In this setting, a program that conserves the variety richness of the crop is not likely to have a negative impact on the evenness in land allocated to among the varieties on the representative farms.

CHPATER FIVE

CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Conclusion

The purpose of the empirical work in this thesis is to answer the following questions: 1) what are farmers' factors that maintain the on farm sorghum crop genetic diversity? and 2) what is the relationship between access to development infrastructure and crop biodiversity? In attempting to answer these questions, relevant literature and theory have been reviewed, description of the survey data has been provided, and empirical testing has been conducted.

This paper has been about the key variables that characterize and induce farmers (individual members of local community) to contribute for *'de facto'* conservation of CGRs. Characterizing them and studying their 'survival first' motives for undertaking on-farm conservation is crucial to design the best mechanisms of influencing their behaviour regarding variety management.

Overall, the empirical results have shown that *'de facto'* conservation is mainly farmers' undertaking with no access to markets, credit, and extension. CGRs diversity is mainly produced by subsistent and marginal farmers as a positive externality of their 'survival first' strategies. These farmers are maintaining non-optimum level of crop diversity through their farm-specific production system according to the individual optima of the decision-making process at the farm level. While some level of conservation is produced to society for free through *'de facto'* conservation, moving to the social optimum needs designing an incentive framework.

The results further confirm that more risky (in terms of frequent occurrence of disease and pests) and more diverse farming systems are less vulnerable to crop uniformity. Accordingly, maintaining a diverse set of varieties is a poor, subsistent and marginalized farmers' undertaking with limited access to markets, roads and extension services. These farmers seem to have recognized various benefits of poly-variety of sorghum for risk reduction, food tastes, tolerance to environmental stress (weather, pests and weed), addressing their multiple concerns, and asset specify benefits.

Access to market and extension detaches the link between *de facto* conservation and farmers survival first strategies. In sorghum growing farmers, cash crops farming are found to have positive effect on its diversity unlike to the previous empirical work of Edilegnaw (2003) conclude that access to chaat is a negative effect on sorghum richness of the household. In our case study, cash income may enhance farmers' capacity to hire labour or purchase inputs to participate a wide range of activities including multi varieties of sorghum crop.

In general, farmers' multiple objectives and concerns, risk and yield considerations, land heterogeneity, labour endowment, and lack of access to market have been the factors inducing the production of sorghum diversity. On the contrary, access to extension and market integration and experience in using improved varieties are detaching the link between '*de facto*' conservation and farmers' economic decisions.

The most important factors positively affecting sorghum richness and abundance (as measured by Shannon index) are the number of purposes of growing sorghum, land holding with type of soil heterogeneity. On the negative side, the factors under play are distance from market and extension services and experience in growing improved varieties. These factors dissociate farmers' survival strategy and *de facto* sorghum genetic conservation in the household economic decision making process in the studied area.

5.2. Implication

The key policy question regarding on-farm genetic conservation is 'Which areas and whom to target? To this end, we have examined the most important factors affecting farmers' derived demand for sorghum diversity.

Economic development, poverty reduction and income distribution argue that the economically and ecologically marginalized areas, in which most of CGRs diversity is produced until now, need external investment in infrastructure and technology to improve the production, marketing and distribution limitations. However, as rural development interventions are put in place (improved access to extension and market integration, and experience in using improved varieties), the amount of area utilized by traditional varieties and the amount of varieties per farm and therefore the level of diversity will shrink. This trend implies a potential risk of losing traditional varieties.

Here there is a need for flexible incentive structures to maintain CGRs diversity at a social optimum and to off-set the negative effect of development interventions. Policy should start with creating awareness and rewarding farmers who have maintained unique traditional varieties of crops. As long as farmers' contribution to agro-diversity is not valued and as long as CGRs are not valued for their own sake, the level of crop diversity produced mainly by farmers will be negatively correlated to the over-all agricultural development in a specific region, leading to an uncontrolled loss of CGRs.

If our point of interest is to target farmers who have higher propensity to plant multiple traditional varieties, then those farmers who are using sorghum for many purposes, those who access to oxen ownership, with less potential in using improved varieties, and less market orientation and more importantly those who access to chaat and coffee are worth targeting. Our results imply that on-farm conservation gives more sense with farmers who are using crop variety portfolio as a risk management strategy. On the other hand, if our objective function is to target areas with high probability of losing traditional varieties, localities and farmers with better market access and better comparative advantage in improved variety use are the priority for action. In this scenario, *in-situ* conservation can be more costly as it will be harder to convince these farmers to stick to traditional varieties for the sake of diversity.

5.3. Future Research

Most of the works cited in this paper have provided a base of evidence that socio-economic/household characteristics, agro-ecological heterogeneity, market access, and risk factors impact technology adoption decisions that agrarian households make and can affect diversity outcomes. Yet the estimation of diversity outcomes can be strongly influenced based on the measure of diversity used. Several of the papers cited above showed differing results for diversity outcome estimation based on the type of index chosen to measure diversity. This research, on the other hand, shows a considerable amount of homogeneity between the diversity outcomes estimated, which results from a large correlation coefficient between the count and Shannon indices.

Hence, one direction for further research into technology adoption and diversity studies could be the implementation of better diversity metrics. If the on-farm conservation of crop genetic resources from landraces is important, for example, indices could be constructed to give weight to landraces over modern varieties.

An additional direction for future research is the use of panel data to test changes over time in the importance of land-use determinants and diversity levels as modern technologies become increasingly available. Most of the studies cited in this paper were done using cross-sectional data. While these studies provide insights about land-use determinants and diversity outcomes, changes over time may reveal important trends in technology adoption and diversity outcomes, and may help to formulate stronger policy prescriptions to prolong landrace cultivation and maintain or increase on-farm genetic diversity.

APPENDICES

Appendix A: Brief Description of the Poisson and Tobit Regression Model.

Appendix A-1 The Poisson Model

The Poisson regression model assumes that yi given xi is Poisson distributed with the following density function:

$$f(y_i / x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!},\ y_i = 0,1,2 \text{.................Poisson distribution (1)}$$

The mean parameter, E[yi|xi] = λi = exp($x_i'\beta$) = exp(β0) + exp(β1x1i) + exp(β2x2i) + … + exp(βkxki).

Having independent observations, the model to be estimated is:

$$\gamma_i = e^{x\beta i} + \varepsilon_i = e^{(\beta_0+\beta_1 x_{1i}+\beta_2 x_{2i}+...+\beta_k x_{ki})} + \varepsilon_i \text{ .... Poisson regression model (2)}$$

$$lany_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + ...\beta_k x_{ki}$$

Where the count index of diversity in the spatial crop genetic resource conservation and xi the variable that determine the type of sorghum crop varieties of the house hold its operational definition and expected sign will be presented in the next chapter.

Since $\beta_j = \frac{\partial E[y_i \mid x_i]}{\partial x_{ji}} \frac{1}{E[y_i \mid x_i]} = \frac{\partial \log E(y_i \mid x_i)}{\partial x_{ji}}$, the coefficients of the Poisson model can be interpreted as the proportionate change in the conditional mean if the jth regressor changes by one unit (semi-elasticity). The marginal effects in Poisson are computed as:

$$\frac{\partial E[y_i \mid x_i]}{\partial x_{ji}} = \exp(x_i') \times \beta_j \text{ .... Marginal effects in Poisson (3)}$$

The Poisson model is, however, typically restrictive as it imposes the restriction that the variance of the data is equal to the conditional mean (i.e. var(yi/xi, β) = E(yi/xi,B) (Cameron and Trivedi,1990). Accordingly, the variance-mean equality has been rejected in numerous applications (Wooldridge, 2003) the statistical inference is depend on rejection or accepting the variance of the data is equal to the conditional mean.

Our data set is tested based on this, if it is found over dispersion problem, the negative binomial estimation method would be used. However, we found the data set has under dispersion problem, thus covariance-variance sandwich estimation of the asymptotic standard error is reported in Table 4.7 (Wooldridge, 2003).

Appendix A-2.The Tobit Model

The stochastic model underlying Tobit may be expressed by the following relationship:

$$Y_i = x_i\beta + \varepsilon_i \text{ ; if } x_i\beta + \varepsilon_i > 0$$

$$= 0 \text{ ; if } x_i\beta + \varepsilon_i < 0.$$

where Y_i refers to either of the variables reported in Table 1, x_i is the vector of the regressors, β is a vector of parameters to be estimated, and ε_i is an independently distributed error term assumed to be normal with zero mean and constant variance (δ^2).

The log likelihood function for the Tobit is:

$$l_{Tobit} = \underbrace{\sum_{y_i|y_i=0} \ln\left[1-\Phi\left(\frac{x_i\beta}{\sigma}\right)\right]}_{P(y_i^* \le 0)} + \underbrace{\sum_{y_i|y_i>0}\left[\ln\frac{1}{\sqrt{2\pi\sigma^2}} - \frac{1}{2}\frac{(y_i - x_i\beta)^2}{\sigma^2}\right]}_{P(y_i|y_i)}$$

where Φ is the cumulative density distribution (CDF). The first part is the probability that y_i =0 (given x_i). The second part is the distribution of y_i given that it is positive. The Tobit model, therefore, measures not only the probability that diversity on-farm will be greater than zero but also the level of diversity as measured by the Shannon diversity index.

Amemiya (1984) has shown that the Tobit maximum likelihood estimator remains consistent under serial correlation but not under heteroscedasticity or non-normality. We have estimated Tobit both with heteroscedasticity and without heteroscedasticity and in all cases the Likelihood ratio test do supports the Tobit with heteroscedasticity. The Tobit results we presented in the paper (Table 4.8) are, therefore, with limped heteroscedasticity or robust estimation results.

The Tobit model has an advantage in that its coefficients can be further disaggregated to determine the effect of a change in the i^{th} variable on changes in the probability of having a non-zero Shannon index and the size of the index (McDonald and Moffit, 1980). The decomposition is given as:

$$\frac{\partial E[y_i \mid x_i]}{\partial x_k} = \left\{ \underbrace{\Phi\left(\frac{x_i\beta}{\sigma}\right)}_{prob(y_i^*>0)} \right\} \underbrace{\beta_k \left[1 - \frac{x_i\beta}{\sigma} \frac{\phi\left(\frac{x_i\beta}{\sigma}\right)}{\Phi\left(\frac{x_i\beta}{\sigma}\right)} - \left(\frac{\phi\left(\frac{x_i\beta}{\sigma}\right)}{\Phi\left(\frac{x_i\beta}{\sigma}\right)} \right)^2 \right]}_{\frac{\partial E[y_i|x_i, y_i^*]}{\partial x_k}} + \underbrace{\left\{ \frac{\beta_k}{\sigma} \phi\left(\frac{x_i\beta}{\sigma}\right) . \left(x_i\beta + \frac{\phi\left(\frac{x_i\beta}{\sigma}\right)}{\Phi\left(\frac{x_i\beta}{\sigma}\right)} \right) \right\}}_{\frac{\partial prob(y_i^*>0)}{\partial x_k} E[y_i|x_i, y_i^*>0]}$$

Where ϕ is the probability density function? From the decomposition, one effect works by changing the conditional mean of the diversity index, given that it is observed (greater than zero) and the second by changing the probability that an index will be positive. While the first is about the effect of a unit change in any of the regressors on the level of diversity (once it is positive), the second is about the effect of a unit change in any of the repressors on the probability of having a positive level of diversity.

Appendix B: Descriptive Statistics of Data

Tables 1: Frequency of the Count Index Variables for Annual Crops Cultivated in the Sampled Household Farms

Count index for all annual crops	Freq.	Percent	Cum.
1	16	7.80	7.80
2	54	26.34	34.15
3	70	34.15	68.29
4	38	18.54	86.83
5	10	4.88	91.71
6	14	6.83	98.54
7	2	0.98	99.51
10	1	0.49	100
Total	**205**	**100**	

Table 2: Frequencies of the Count Index Variable for Sorghum Crop in the Sampled Household Survey

Count index for sorghum crop	Freq.	Percent	Cum.
0	14	6.83	6.83
1	67	32.68	39.51
2	63	30.73	70.24
3	38	18.54	88.78
4	18	8.78	97.56
5	3	1.46	99.02
6	2	0.98	100
Total	**205**	**100**	

Source: own survey

Table 3: Frequency of Discrete Variables Employed in the Regression in the Model

Variables	Description	Value	Freq	Percent.	Cum.Fre.
Educat.	Education level of the house hold head (illiterate=0 and =1 literate)	0	72	35.12	35.12
		1	133	64.87	100
Sex	Sex (=0 female =1 male)	0	47	23	20.98
		1	158	77	100
Education	Number of educated household members in the household	0	16	7.80	7.80
		1	43	20.98	28.78
		2	47	22.93	51.71
		3	46	22.44	74.15
		4	30	14.63	88.78
		5	11	5.37	94.15
		6	9	4.39	98.54
		7	2	0.98	99.51
		8	1	0.49	100

Workers	Number of workers in the household	1	12	5.85	5.85
		2	57	27.80	33.66
		3	31	15.12	48.78
		4	40	19.51	68.29
		5	28	13.66	81.95
		6	18	8.78	90.73
		7	9	4.39	95.12
		8	7	3.41	98.54
		9	1	0.49	99.02
		10	1	0.49	99.51
		11	1	0.49	100
Numplot	Number of plots operated in the household	0	1	0.49	0.49
		1	67	32.68	33.17
		2	101	49.27	82.44
		3	34	16.59	99.02
		4	2	0.98	100
Oxen owner	The number of oxen owner in the house hold	0	63	30.73	30.73
		1	51	24.88	55.61
		2	82	40.00	95.61
		3	6	2.93	98.54
		4	3	1.46	100
Cattle	The number of cattle units owned in the household	0	48	23.41	23.41
		1	25	12.20	35.61
		2	35	17.07	52.68
		3	32	15.61	68.29
		4	26	12.68	80.98
		5	15	7.32	88.29
		6	10	4.88	93.17
		7-14	14	6.83	100
Acessextension	The household access	0	111	54.15	54.15

		1	94	45.85	100
Owner radio dummy	The access of radio of the household (=0 not have access, =1 have access)	0	135	65.85	65.85
		1	75	34.15	100
Food deficit	The number of months in which the household reported that under food shortage in a year.	0	40	19.51	19.51
		2	9	4.39	23.90
		3	13	6.34	30.24
		4	31	15.12	45.37
		5	4	1.95	47.32
		6	89	43.41	90.73
		7	8	3.90	94.63
		8	4	1.95	96.59
		9	7	3.41	100

Source: Own survey

Appendix C: Summary of the Questionnaire Used

I. Basic Household Characteristics

1. Date of interview	2. Kebele name
3. Name of household(head)	4. Gott name
5. Sex a) Male b) Female c)Youth	6. Age a) 20-30-------------b)31-60------------ c)>60------------------------
7. Marital status a) Single------------- b) Married --------------- c) Divorced -------------- d) Widowed-------------- e) Separated---------------------	
8. Place of birth Kebele Wereda Zone	
9. Continuous duration of stay at current place of residence / year	
11. Educational status a) ------------ b) --------- c) ----------- d) Other (specify)	
12. Is the head economically active?	a) yes b) no
13. If in active, why?	a) ----------- b) ----------- c) ----------- d) ----------- e) Other (specify)
14. Number of permanent household members at the time of survey	Male ---------------------- Female-------------------- Total-------------------------
15. The roof of the house for the household is made of	a) ----------- b) ------------ c) Other
16. Age of permanent household members at the time of survey	0 <5 years ---------------------- 5-10 years ---------------------- 11- 16 years ------------------- 17- 55 years ------------------- > 55 years -------------------------
17. Educational status of permanent household members	Illiterate ------------- Church school -------------- Read and write --------- Other (specify) -----------
18. How many of them are economically active? -------------------	
19. Relations of the household members with the head. a) Spouse-----------b) Son/daughter-------------c) Non-relative- --------------------d) Grandchild-----------------e) Hired as labourer-----------------------	

II. Access to Natural Capital and Land Tenure Situation

a) Do you have access to land for agricultural use? a) yes b) no

b) Total sizes of the following land you use pattern

Land type	In timad	In hectare
Cultivated land		
Fallow land		
Grazing land		
Settlement land		
Other		
Total		

c) Would you tell us abut the characteristics of your farm plots?

Plot identification	Topography a) Plain b) Moderate c) Sloping	Plot agro ecology 3 Woinea dega 4 Dega 5 Kolla	Soil	
			Type soils a) Black b) Red c) Brown	**Fertility status** a) Poor b) Moderate c) Fertile

d) Have you ever share cropped out your plot to other peasants? a) yes--------- b) no------------------

e) If yes, on what type of crop do you share cropped out? If so, did you have any influence the type of crop and varieties grown in your land a) yes b) no

f) Have you ever been share cropped in land from other people? a) yes b) no

g) If you share cropped in, did the preference of the owner of the land have any influence the type crop and varieties grown? a) yes b) no

III. Access To Draught Power

1. If your household cultivated the farm during the last season, how did you plough?

   a) Using animals--------------- b) Using hand hoe------------------

2. If you ploughed with animals, what type of animals you use?

   a) ---------- b) ----------- c) -------- d) Other (specify)

3. If you used animals, did you own, borrow or hire them?

   a) -----------b) ------------- c) ------------ d) ------------ e) ----------- f) ---------

4. If you used hand tillage, what is/are the reason (s)?

   a) ----------- b) ------------ c) -------------- d) ------------ e) Other (specify)

IV. Access To Agricultural Extension Package, Market Characteristics, Credit Services

1. In the last 3 years, how many times has your household received agricultural input package from Development Agent? None------------- once---------------twice---------- three times-------------more than three times----------------
2. If you used once or more times, did you use modern varieties for any crop you received it?

   a) yes b) no

3. How long you have an experience using modern varieties of crops in your farm land?

   a) one year b) two years c) three years d) four years e) five years f) more than five

4. Have you ever been used credit facilities in your hose hold affair?

   a) yes. b) no

5. If you used credit facilities, for what purpose did you use your credit scheme?

   a) Purchasing fertilizer c) purchasing improved seeds d) purchasing household consumables.

6. The average time required to reach (on foot) to the extension agent---------------
7. The average time required to reach (on foot) to dry weather road----------------------
8. The average time required to reach (on foot) local market---------------

V. Question Regarding Sorghum Traditional Varieties

1. How is important sorghum crop to the house hold?

   a) Very important b) important c) not so important

2. For what purpose do you use sorghum in your household?

Purposes of sorghum crop to the household	a) Yes	b)No
For food consumption of the house hold		
For a source of cash income		
Using as animal feed		
Using for fuel wood, hose construction, and fence		
Others please specify		

3. Sorghum varieties you have grown in the year 2006(1999) crop season? (Proxy for diversity indices)

No	Type of sorghum varieties	1998 E.C Belg		1998 - 1999 Meher	
		Farm size	Amount of harvest	Farm size	Amount of harvest

4. What is your most important reason to maintain local variety (ies) of sorghum on farm as compared to modern varieties?

a) yield b) yield stability c) disease resistant d) tolerance to environmental stress e)food quality f) others

VI. Questions Regarding Your Over All Attitude Towards Sorghum Diversity

1. What is the trend of sorghum varieties that you have gown in your farm?

   a) Increasing b) decreasing c) remain as it is

2. If it is increasing why? --
3. if it is decreasing why--
4. What do you think the main reason each those varieties are treated to be lost?

   a) Climate change b) disease and pest problems c) replaced by modern varieties d) others

5. Would you please mention the mechanisms to conserve sorghum varieties not be lost in your community? --

   ----

6. Suppose you have two options. One is a single variety of sorghum with a yield of 10 quintals per hectare and the other is three varieties with the same yield. I. Which one would you choose? (a)three varieties (b)one variety Why?---------------------

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7. Suppose you have two options. One is a single variety of sorghum with a yield potential of 12 Qt./Ha and 6 Qt./Ha in good and bad season, respectively. The other is three varieties with a yield potential of 10 Qt. /Ha and 8 Qt. /Ha in good and bad season, respectively. Which one would you choose? Why?----------------------------

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VII. Crop Production and Livestock Rearing

1) Would you tell us the size of farmlands and the amount of crops you harvested during the Belg season of 2006 (1998 E.C) and Meher season (2006 - 2007) (1999 E. C).

No	Crop type	1998 E.C Belg		1998 - 1999 Meher	
		Farm size	Amount of harvest	Farm size	Amount of harvest

2) Tell us about your perennial crops, fruits and vegetables and the income you earn from them.

No	Crop type	Number/stand	Monthly income	Annual income

3) Would you tell us the number of livestock you own?

Type	Number	Possession
Cows		
Oxen		
Heifers		
Calves		
Sheep		
Goats		
Mules		
Horses		
Donkeys		
Chicken		
Beehives		

VIII. Non-Farm Employment Opportunities

1) Did any of your household members work in activities apart from crop production and livestock rearing? a) yes b) no
2) If yes, would you tell us about the types of activities, persons engaged in, amount of income from the job, and the purpose for which you used the money?

Activity type	Member participated	Time spent on work per month	Estimated annual income from the job		Cash equivalent
			Cash	In kind	

IX. Food Security

1) Do you meet the all-year round food requirements of your household members from own? a) yes b) no

2. If you are not self - sufficient, for how many months do your own production cover the food requirements at home? (Mention name of months) --------------------
Three---------four---------five-----------six-------eight--------nine----------ten------
eleven--------twelve---------

4. Does the income you earn from non-farm activities enable you to buy food for bridging the deficiency? a) yes b) no

5. According to your own self-assessment, is your household: a) Food secure-------
b) Food insecure------------------- c) Varies from one year to another -----------------
d) Do not know---------------------

6. What do you think the role of sorghum for being food secure for your household?
a) very much b) much c) poor d) very poor

7. If it is important, what have been the main constraints to expanding your sorghum crop production, as well as for keeping sufficient numbers of varieties in order to become self-sufficient in food year round?

X. Constraints to Sorghum Production

Drought	Yes	No
Frost		
Water logging		
Pests and disease		
Erratic rainfall distribution		
Weeds		
Shortage/ lack of farm oxen		
Poor storage		
Insufficient land holding		
Poor soil fertility		
Lack of access to appropriate technology		
Limited know - how and skills		
Shortage of cash		
Inadequate extension services		
Inability to apply sufficient modern farm inputs		
Dependency on rain - fed farming		
Failure to utilize irrigation		
Lack of access to post - harvest technology		

8. If you sorghum crop is lost by drought, pests and disease, what is your copping strategy and survival strategy during the crop season?

   a) Replanting by another crop b) leave as it is for fallow land c) rent out the land d)used for gazing for cattle's e) any other mechanism please specify--------------

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Any other suggestion (s); please tell us about not mentioned regarding your day to day agriculture works

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Thank you too much for providing this valuable experience in your faming practice.

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Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all source of materials used for the thesis have been duly acknowledged.

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