Seed Systems, Household Welfare and Crop Genetic Diversity: An Economic Methodology applied in Ethiopia

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ESA Technical Paper
November 2005

Agricultural and Development Economics Division
The Food and Agriculture Organization
of the United Nations
http://www.fao.org/es/esa/

A Project Funded by the FAO-Netherlands Partnership Program
Agricultural Biodiversity Component

ESA Technical Paper
www.fao.org/es/esa

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October 2005

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Key Words: Seed system, crop genetic diversity, farmers'welfare, Ethiopia..
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Acknowledgements

The authors would like to acknowledge the FAO-Netherlands Partnership Program for funding the project. We are particularly grateful to Benjamin Davis for insightful inputs in the design of the project and instruments and for technical supervision during field work and data collection. We thank Dr Abebe Fanta and Prof. Desta Hamito as well as all other collaborators from Alemaya University for information and support provided during the implementation of the project and for facilities provided during field work. We are also grateful to Paolo Pironti, Zenebe Tsegaw, Yoannes Amare, Gezahegn, Belihu Negesse and Bekele Moges from Hararghe Catholic Secretariat for information provided, logistical support and for survey coordination. We would like to express our gratitude also to the team leaders and enumerators[1] for data collection and input provided during training. We thank the FAO-Office in Ethiopia, particularly Mr. Gebregiorgis Sissay, for help provided during first visits in Ethiopia as well as for contracting collaborators. We are very grateful to Mr Tabit Amhed for designing the data entry program, to Mr. Deepak Reijal for focus group exercise and to Mr. Tesema Tanto from the Institute of Biological Diversity in Ethiopia and Dr. Toby Hodgkin for conducting the agro-morphological survey. Last but not least we want to express our deep gratitude to Kostas Stamoulis and Peter Kenmore for their support and encouragement in the implementation of the project despite the many difficulties encountered. A special thank to Melinda Smale (from IFPRI), Louise Sperling (from CIAT), David Cooper (CBD), Regina Laub and Yhanna Lambrou from FAO-SDWG, Marcela Villareal and Mesko Natasha from FAO-SDWP, Bill Fiebig, Peter Kenmore from FAO-AGPP, Gijs VantKlooster, from FAO-AGAL and Shawn McGuire from UEA as for providing inputs as experts of different disciplines in the survey instrument. Our gratitude also to Annelies Deuss, Irini Maltsoglou and Emilia RInaldi for support in logistic before missions and for help editing, and many others from FAO for their insightful comments in project and survey instruments design.

[1] Name list provided in Annex 3

Glossary and abbreviations

Access = adequate income or other resources to acquire seeds

AU = Alemaya University

Availability=adequate quantity of seed;

EARO = Ethiopian Agriculture Research Organization

ESE= Ethiopian Seed Enterprise

FAO-ESAE =Agricultural Sector in Economic Development Service of the Food and Agriculture Organization of the United Nations

FBSPMS= Farmer Based Seed Production and Marketing Scheme
GxE= genotype by environment

HCS = Hararghe Catholic Secretariat

IBCR = Institute of Biodiversity Conservation and Research

IFAD= International Fund for Agricultural Development

IPGRI = International Plant Genetic Resources Institute

IPR= Intellectual Property Rights

MV = Modern Variety

NSIA = national Seed Industry Agency

NVRC= National Variety Release Committee
Seed renewal =decision to obtain fresh stock of a variety that they already grow

Utilization = acceptable quality of preferred crop varieties

Varietal replacement = A farmer's decision to change an adopted cultivar

WTO = World Trade Organization

1. INTRODUCTION

In June 2001 FAO initiated a project to conduct an economic assessment of how seed systems influence the on-farm conservation of crop genetic resources and the welfare of poor farmers. The project is funded by the FAO Netherlands Partnership Program (FNPP), under the Access, Exchange and Sustainable Utilization of Agricultural Biodiversity component of the program (AESU). The objective of the work conducted under this component is to provide the necessary information and tools for decision-makers on ways to promote the sustainable utilization of agricultural biodiversity and improve farmer welfare. The potential users of the output of this project include national and international policy-makers, researchers and operation specialists at bilateral and multilateral development banks.

The purpose of this paper is to describe the methodology developed in the first phase of the project, for an empirical study of the economic relationship between seed systems, access to crop genetic resources and farm level outcomes. The initial methodology was developed prior to conducting field work in the Hararghe region of Ethiopia based on the previous experience of the project team, reviews of the literature and discussions with experts in the area of seed systems and crop genetic diversity at FAO and the International Plant Genetic Resource Institute (IPGRI). The methodology was then updated based on visits to the field and in the design of the initial household survey. The methodology discussed in this document refers to the final approach taken, highlighting what was intended and what actually happened in the field. As part of this discussion, lessons learned are also noted. The intended audience for this publication includes researchers, technicians and specialists working in the field of agricultural biodiversity, seed systems and agricultural development. The hope is that by documenting the methodology and lessons learned this will provide assistance to those wishing to conduct similar research in this area.

To meet the objectives of the paper, the remainder of the paper is divided as follows. The next section provides a description of the study motivation and includes a brief review of the relevant literature. The section concludes with the research questions, we intended to address through this project. Section 3 provides background on the study area in Ethiopia to set the context under which the methodology was employed. In section 4, the methodology used and the lessons learned are discussed in detail. This includes a description of the survey instruments, sampling frame and other data collection activities. Section 5 briefly discusses the final product that came from the methodology and some of its strengths and weaknesses. Finally, in section 6 conclusions and general recommendations are presented.

2. MOTIVATION, BACKGROUND AND RESEARCH OBJECTIVES

A primary objective of the Convention on Biological Diversity (CBD[2]), the International Treaty on Plant Genetic Resources (ITPGR[3]) and the Global Plan of Action for the Conservation and Sustainable Utilization for Food and Agriculture[4] is the sustainable utilization of plant genetic resources for food and agriculture. Under these international agreements, signatory governments have committed themselves to promoting sustainable utilization. However, the specifics of how this is to be accomplished are not well defined. Part of the reason is a lack of information on policy instruments to effectively reach this objective, as well as how such interventions might impact other government objectives. In order to develop the necessary information, additional research is required that augments our current understanding of sustainable utilization and, correspondingly, methods for analyzing the constraints and opportunities for sustainable utilization of plant genetic resources developed.

What motivates this research effort is then the desire to provide information to assist in the development of policies that facilitate the sustainable utilization of plant genetic resources for food and agriculture. In this study, we focus on crop genetic resources, within the context of agricultural biodiversity, so we frame our definition of sustainable use around this subset of plant genetic resources. We consider the sustainable utilization of crop genetic resources to mean a system of utilization which allows for the maintenance or increase of the current and potential future services that such resources provide to food and agriculture, and ultimately to humans.[5] These services occur both in the present and in the future; the former is expressed in traits or characteristics of the crop varieties currently planted, while the latter is provided by the storage of genetic resources which may be useful to adapt to future conditions. The values derived from these services are realized in different forms and by different groups in society over differing points of time. These values, and costs associated with obtaining them, drive the pattern of utilization, as well as incentives for conservation.

Understanding the specific research objectives of this study requires clear definitions of the terminology used to discuss sustainable utilization and the background literature on agricultural biodiversity. Towards this end, this section provides a brief introduction to the relevant literature followed by the research objectives of this project. First, a brief outline of the value and use of crop genetic diversity and the implications for conservation and sustainable use are described. This includes a discussion of the private value of utilizing these resources as well as the public value of conserving such resources. The discussion of private values also examines the relationship between the use of these resources and farmer welfare. Following this discussion, we consider how the seed system in developing countries influences access to CGRs and correspondingly farmer welfare. Finally, the research objectives of this project are presented.

[2] http://www.biodiv.org/convention/articles.asp
[3] http://www.fao.org/ag/cgrfa/itpgr.htm
[4] http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPS/GpaEN/gpatoc.htm
[5] Under this definition of sustainability, the stock of natural capital under consideration (e.g. crop genetic resources) is allowed to decline as long as the current and potential services provided by CGRs are preserved. To the extent that CGRs are highly substitutable in providing services then, this definition would allow depletion.

2.1 Value and Use of Crop Genetic Diversity

In agricultural systems, crop diversity is affected by population structure[6], by natural selection from the surrounding environment[7] and by human selection and management. Crop genetic resources are passed from generation to generation of farmers and are subject to different natural and human selection pressures. Environmental, biological, cultural and socioeconomic factors influence a farmer's decision to select or maintain a particular crop cultivar at any given time (Heywood, 1999). Indeed, much of the diversity in agro-ecosystems is comprised of hundreds of thousands of landraces that have developed over the centuries in farmers' fields, through a combined process of human and natural selection. These landraces are customized to the local ecological, agronomic, social, and cultural traditions. Farmers make decisions in planting, managing, harvesting and processing their crops that affect the genetic diversity over time. They may modify the genetic structure of a crop population by choosing a particular farm management practice or selecting crops with preferred agro-morphological characteristics or by planting a crop population in a site with a particular micro-environment. Farmers make decisions (voluntary as well as involuntary) on how much of each crop variety to plant each year, the quantity of seed or germplasm to store from their own stock, and the quantity to buy or exchange from other sources. The farmers' choice is constrained by several factors, including the climate, the production conditions over a particular year, the micro-climatic conditions on the farm, the input and output market conditions, and the availability of varieties and seeds. The choice of crops and varieties that farmers make is linked to a complex set of environmental, cultural and socioeconomic influences on the farmer, and this ultimately determines the pattern of crop and variety utilization and its sustainability (IPGRI, 1997).

CGRs are embedded in seeds and the decisions farmers make on which seeds to plant is a critical determinant of the sustainability of CGR utilization. Since seeds are simultaneously a physical input to crop production and a source of genetic code, their utilization provides both a private value to the farmer, and also a public value through contributing to the conservation and evolution of genetic resources. This dual role may give rise to conflicts between public and private interests in terms of the desirable pattern of seed use (Smale and Bellon, 1999). This conflict is further complicated by the fact farmers select on visible characteristics (phenotype) which may not correspond to the level of genetic diversity (genotype) that is desirable. Furthermore, the public value of maintaining CGRs is not bounded by national borders adding an additional level of complexity. To understand CGR utilization, the nature of the private and public value associated with crop genetic diversity needs to be addressed.

2.1.1 Private use values of crop genetic diversity

The farm level of crop genetic diversity is defined by the set or portfolio of CGRs the farmer uses. These CGRs provide services to farmers by producing an expression of product traits which are desirable under the specific production and consumption conditions of the farmer. For example, the CGRs embodied in seeds of a drought tolerant sorghum variety yields plants even under water scarcity. The particular portfolio of CGRs employed by farmers depend on complex set of demands for CGR services subject to specific agro-ecological and socio-economic conditions under which farmers operate. Generally, farmers with a more complex set of production and consumption demands and constraints in agricultural production will require a more complex set of CGRs and have higher levels of agricultural biodiversity. This is particularly the case in developing countries where rural areas are plagued by numerous market imperfections and high transaction costs. Understanding the use

[6] i.e. mutation rates, migration, population size, isolation, breeding systems and genetic drift.
[7] i.e. Soil type, climate, disease, competition.

and value of CGRs and on farm crop diversity therefore requires understanding the conditions under which rural households in developing countries operate.

One of the key factors that influence the use of CGRs is the yield and price risk associated with agricultural production. If markets functions perfectly, agricultural households should be able to cope with risk through credit and insurance markets. However, markets for credit and insurance are often missing or function poorly in the rural areas of developing countries. Unable to cope with risk through credit and insurance markets, households often seek to manage risk through diversification of income generating activities, crops planted or varieties used with the best means of managing risk depending on household conditions. If households are food insecure and production or price of the principle staple crop are risky, households may also use a varietal portfolio to manage risk and insure against the possibility of having insufficient food to consume. Any use of varieties and crops to manage risk has implications for the crop diversity at the household and community level and a number of studies suggest that varietal diversity insure against the risks of losing one or more crop and/or variety over a production season (Meng, 1997; Smale, 1998; Van Dusen, 2000).

Even without risk, temporal variability due to the seasonality of crop production may encourage crop and varietal diversity. If farmers are unable to smooth intertemporal food or income variability through credit markets, they may invest in crops or varieties that have different planting cycles to smooth consumption. Studies have also shown the value of a diverse variety set in terms of smoothing the labor requirements over a season and thus avoiding costs associated with peaks and troughs (Smale, 1999; Richards, 1986; Brush et al, 1992). The existence of CGRs that allow for flexibility in terms of the timing of production, particularly labor use, and harvest can have a great value for farmers. Observing a diverse crop or variety portfolio may reflect a household attempt to limit the variability of input requirements and outputs obtained over time. The availability of CGRs that allow for intertemporal management may have a significant value for producers in these circumstances.

Another factor influencing the portfolio of crops and varieties used is the high level of transaction costs associated with trading in rural areas. Markets for farm inputs, including seeds, and outputs may be subject to high transaction costs due to poor infrastructure and limited information. This creates a substantial price difference between the buying and selling price of products (de Janvry et a;., 1991; Key *et al.*, 2000). In some cases, such transaction costs may be significant enough to lead to complete market failures for certain crops or particular varieties. If so, to obtain varieties that are valued for their cultural significance or culinary characteristics households may need to produce the variety themselves. One indicator of access to public infrastructure and information is the distance to urban centers or markets. A number of studies have shown that these distance measures are positively associated with agricultural biodiversity suggesting higher transaction costs increase diversity (Gabre-Madhin and Eleni 2001; Badstue, 2004; Benin *et al.*, 2003).

Adding to these market imperfections are other historical and socioeconomic factors including the fact that households often endowed with numerous noncontiguous plots across a diverse range of agroecological conditions. In the presence of credit and insurance market imperfections, multiple plots may have the advantage of allowing for risk diversification. Even without these market imperfections, if property rights are not clearly defined and markets for land are poorly developed, it may be impossible to consolidate holdings. The presence of varietal diversity on farm may partially be explained as an attempt by farmers to respond to a range of agroecological conditions where farmers' plant varieties best suited for the individual plots. Previous studies clearly indicate that farmers choose higher levels of crop genetic diversity when they have multiple fields with highly heterogeneous conditions (Meng, 1997; Smale, 1998).

Underlying most of these explanations of crop diversity at the household level are the presence of market imperfections or failures (Stiglitz, 1989; deJanvry *et al.,* 1991, VanDusen *et al.*, 2005). These types of market imperfections are also associated with a lack of rural development. Given this is the case, an important issue in understanding the value of genetic diversity to poor farmers is the degree to which maintaining diverse crop genetic holdings is the result barriers to economic development. To the extent that this is the case, improving market performance for the poor can be expected to lead to a reduction in the in situ conservation of crop genetic resources, e.g. there is a trade-off between rural economic development and in situ conservation. This would seem to imply that policies that promote in situ conservation among the poor will deny them the possibility of economic development. Similarly, it would mean that policies designed to reduce rural poverty may lead to genetic erosion. However, the issue is not so simple. First, empirical evidence from a number of studies show a positive relationship between wealth indicators and crop diversity (McDonald, 1998; Zimmerer, 1996; Takasaki *et al.*, 2000). While these studies tend to focus on only a narrow range of poor households, they do suggest that there is not a linear relationship between development and crop diversity. It may be that there is a non-linear relationship, similar to the environmental Kuznets curve, in which diversity increases at lower levels of wealth and then decreases at higher levels of wealth. This is an area of research that still needs to be explored.

Second, even if there is a degree of genetic erosion at the household level associated with higher levels of wealth this does not necessarily imply that there is a reduction in genetic diversity at the community or regional level. Decreases in diversity across space may actually be associated with increases in inter-temporal diversity. It may be the case that while households specialize in the use of CGRs, the same set of CGR is available at the community level. Third, even if it is the case that rural development is associated with genetic erosion at the household and community level many parts of the world where on farm crop diversity is widespread the degree of development is very low and at least in the near future the risk of genetic erosion may be minimal. The relationship between rural development and agricultural biodiversity remains unclear and complex (Godoy *et al.*, 2000; Abbot, 2005).

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In summary, the private use and value of CGRs to agricultural households is a function of the conditions under which they operate. The widespread use across continents and crops of multiple varieties and crops suggest that there is a significant value at the household level to having access to diversity. The question that remains is whether this private value is sufficient to provide the incentives necessary to achieve the socially desirable level of diversity and if, with development, the desirable level of diversity maintained on farm will decrease over time requiring greater intervention. With this in mind, we turn to considering the public value of CGR conservation.

2.1.2 Public values of crop genetic diversity maintained in situ

The public value of in situ conservation is threefold: 1) providing a storehouse of genetic information at local level which may be accessed through seed exchanges, introgression or other means , 2) providing resistance to pest and diseases, and 3) providing an option for future generations to access the genetic materials and human knowledge associated with its use. In the first two cases the primary beneficiaries of the good are members of a local community. In terms of access to breeding material, the beneficiaries are members of seed exchange systems which may be geographically defined, but also may be built upon kinship networks, market interactions or other basis. In contrast, the second benefit of pest and disease resistance is clearly defined by geographic proximity, although the scale at which they are relevant may vary for different types of crops, pests and diseases. For the third value category, the benefits are realized at the global as well as local levels, in terms of holding something in trust which may be accessed and beneficial to any part of the global community in the future.

The dual role of CGRs as providers of both public and private benefits means that there may be some divergence between the private and socially optimal levels of conservation for crop genetic diversity. Take, for example, the case of the value to farmers of managing production risk through diversity. The private benefit to the farmer may well be dependent on the degree of diversity present at the crop population scale – e.g. the degree of diversity that exists overall in the village or region. This gives rise to a problem of managing a common pool good – local ability to resist disease and pests. The divergence between the level of diversity which should be maintained for the good over the commons versus that of the individual farmer may lead to an under use of diversity on farm, and the need for coordination mechanisms among farmers in a given region (Smale, 1998). That is, the individual private benefits of conserving an additional traditional variety may be small to the farmer, but there is a positive social value for maintaining broad portfolio of individual varieties across a large number of farmers.

A few studies have attempted to measure the value of diversity in delaying the breakdown of genetic resistance to various important pests. Widawsky and Rozelle (1998) modelled the regional effects of varietal diversity and provided empirical evidence that varietal diversity can reduce regional yield variability. Another study on the Punjab of Pakistan (Heisey, *et al.*, 1997) measures the costs of increasing genetic diversity in terms of decreased yield. The authors proposed a model of the tradeoff of yield and diversity on a hypothetical yield-diversity frontier. A socially optimal level of diversity would balance the benefits of delaying the breakdown of pest resistance against the costs of forgoing maximum short-term yields. Of similar relevance is a study by Smale, *et al.* (1998) on the impacts of the shift in the emphasis of CIMMYT's breeding program away from pest resistance based on "narrow" resistance to a specific race of pest to "broad" race-nonspecific resistance. The study showed measurable benefits in terms of the rate of return to agricultural investment.

The problem of managing CGRs is compounded by the fact that crop genetic diversity conservation produces public goods. Public goods are defined by economists as having two main characteristics: they are non-rival and non-excludable. CGRs are non-rival in the sense that one farmer using a certain variety does not diminish the yield of a second farmer using the same variety. Here is it important to distinguish between the seed and the CGRs it contains; the genetic information contained in a variety can be used by many farmers simultaneously and is non-rivalrous, while the seed itself cannot. The same is true in assessing the non-excludability of CGR; until recently there were very few barriers to accessing the genetic information embodied in CGRs since it was difficult to assign and enforce property rights. In recent years this situation has changed substantially with a growth in the use and stringency of intellectual property rights governing crop genetic resources, as well as the development of institutions and technologies which facilitate enforcement of Intellectual Property rights (IPRs), such as genetic use restriction technologies and TRIPS[8] agreement (Trade related aspects of Intellectual Property Rights) under the WTO. At this point CGRs are evolving into a semi-public good, with some aspects exclusive. Nonetheless the public good aspects of diversity conservation leads to an under provision of the good from society's point of view (Morris and Heisey, 1998; Smale, Bellon and Aguirre, 2001). Thus there is a need to develop some types of mechanisms to promote "optimal" levels of CGR. This leads to the obvious next question of determining what exactly those levels are.

Environmental and natural resource economists have attempted to model the option values of maintaining a wide range of diversity, although more has been done on wild biodiversity than agricultural biodiversity. An attempt to model the value of untapped genetic resources in tropical forests for pharmaceutical applications is one such example. The valuation of biodiversity for use as a productive input was pioneered by Simpson, Sedjo and Reid (1996) for the case of pharmaceutical research and then extended to agricultural research by Simpson and Sedjo (1998). These are search models, based on statistical distributions; they take the crucial step from individual economically valuable traits to the collection that holds them. A series of such studies has argued that the value of an average hectare of tropical rainforest is low, too low for the revenues from bioprospecting to fully fund the costs of conservation. However, Rausser and Small (2000) argue that the option values of agricultural genetic resources are likely to be sufficiently high to support market-based bioprospecting activities, since researchers have prior knowledge about where the most promising elads are likely to be found.

On the village level, economists looking at CGR conservation have documented that while each individual farmer may only hold one or two varieties; the set of varieties held village- wide may be

8http://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm higher (Louette *et al.,* 1997; Aguirre *et al.*, 2000; Brush, 1995). A key research question that remains to be developed is the relationship between farmer and village crop populations. For example, do farmers know which other minor varieties are maintained within their community? These types of questions are necessary to understand how a seed system can influence the divergence between the private benefits of conservation (the value to a farmer of a rare trait) and the social benefits of conservation (the value to society of a collection of such traits).

Other works from environmental and resource economists on biodiversity conservation are designed to allocate resources for conservation by comparing the diversity of two overall collections or by calculating the marginal contribution to diversity of a given species. Weitzman (1992), and subsequent work by Solow *et al.* (1993), developed a diversity measure that is closely related to the Shannon Index commonly used in ecology. In the case of CGR conservation, the indices can be used to determine which populations to target for conservation to maximize diversity or to model the services provided by diversity. In another study, Widawsky (1996) tried to estimate the social benefit of having a broad set of varieties deployed across a large region in order to reduce evolutionary pest pressures. He utilized the coefficients of parentage (which are documented by breeding programs) for Chinese rice varieties, and adapted the Solow and Polasky (1994) measure for agricultural applications by weighting the diversity measures by the area planted in each variety. He found that the coordination problems (costs) of organizing spatial diversity on a regional or national scale have so far been found to be larger than the public good benefits that would results (Morris and Heisey, 1998). Weitzman (1992) proposed a framework for assessing conservation priorities, in which priorities for species conservation are derived from a formula that includes the distinctness of the species, the utility of the species in terms of value to humans, the degree to which the species' potential for survival is enhanced by conservation activities, and the costs associated with the conservation.

Summarizing these findings we see that due to the public good and common property nature of some of the values of agricultural biodiversity, it is likely that a socially desirable level of in situ conservation will not be maintained by farmers operating based on private incentives alone, and thus some kind of public intervention may be necessary. This may be at a local level- to promote optimal levels of diversity to maintain plant and disease resistance, or at a global level to maintain the option of using genetic materials conserved today in future products. The findings presented also indicate that there is still a considerable gap in the information about the current and potential private values of agricultural biodiversity to farmers, particularly the poor. We know that there have in many cases been a trade-off between economic development and on farm crop genetic diversity, but we don't know very much about why this occurs, or when. Agricultural development strategies which build upon genetic diversity are being claimed to be more effective in reaching low income populations than the traditional system of modern variety development and dissemination, but we need to know more about when this is the case, and how best to deliver new varieties.

2.2 Seed systems and access to CGRs

In the previous section, we described the public value of crop genetic diversity as well as the private value they entail for for farmers. We concluded that the farmers' decision making process can be viewed as a constrained maximization problem where the farmer chooses a set of seeds to maximize his or her utility given a set of natural and socio-economic constraints. One constraint that farmers face in their choice of seed is the availability of varieties that are desirable given their needs, as well as the accessibility and utilization of the seeds of the variety[9] (Sperling and Cooper, 2003; Remington et al, 2002). Varieties which meet the particular set of demands of some farmers may not be in existence, if they have not been the focus of breeding programs. However, even if a variety does exist farmers may face barriers

[9] Availability (adequate quantity of seed); access (adequate income or other resources to acquire seeds); and utilization (acceptable quality of preferred crop varieties) (Remington et al 2002).

to accessing it, which also constrains their choice of CGR. Farmers' choice of seed is constrained by what is available and the cost of obtaining it.

The seed system, which comprises all different channels through which farmers may access CGRs, is then a critical system to understand in assessing the farmers' use of crop genetic resources. But evaluation of seed system performance is relevant only in the context of the demands of farmers for genetic services from seeds. Thus we need to think of seed systems as the interaction between seed supply and demand which results in the farm level utilization of seeds and thus crop genetic resources. Seed systems affect the private incentives of farmers in making their seed utilization choices – which in turn affects the degree to which the public goods aspects of diversity are provided. Understanding the extent to which seed systems constrain farmers is important in designing efforts to increase on farm productivity, as well as in situ conservation. Our next step is therefore to characterize the seed system.

2.2.1 Characterization of seed systems

Seed systems are often characterized as formal versus informal or local, although the meanings assigned to these terms may vary. Most frequently the formal seed system refers to seed supply systems which have been set up since the 1950s to improve the quality of seeds and distribute improved and modern varieties to farmers (Almekinders and Louette, 2000). The formal system usually consists of plant breeding institutions which generate new varieties that are then released for multiplication and distribution through commercial seed enterprises, extension programs and other forms of government and non-governmental enterprises. A key feature of formal seed systems is a clear distinction between "seed" and "grain" (Louwaars, 1994). There have been a series of studies on formal sector seed systems in Sub-Saharan Africa, and the constraints faced by formal seed systems in delivering varieties to poor farmers. Notable examples are Cromwell *et al.* (1992) in Zimbabwe, and Longley (1997) in Sierra Leone. These applied level studies concord with a region-wide study by Byerlee and Heisey (1997) that the formal seed system often fails to deliver varieties appropriate to the constraints and preferences of small farmers.

The informal or farmers' system comprises all other forms of seed production, exchange, storage and savings through which farmers produce, disseminate and access seed (Sperling and Cooper, 2003). Varieties include landraces, creole or mixed races which may include crosses between local and improved materials. Several types of supply mechanisms exist in the informal sector: through farmers saving seeds, non-market exchanges with relatives, friends or other community members, and purchases in local markets. The distinction between grain and seed is less defined in this system, with no distinction made in some cases. Within informal systems we also find variety selection, breeding and testing, as well as seed multiplication, dissemination and storage but as integral parts of farmers' seed systems, rather than externally driven mechanisms as in the formal system (Sperling and Cooper, 2003). Most of the seeds utilized by small and low income farmers in developing countries are generated in the informal system, although this varies considerably by crop and country.

Characterizations of the informal seed system are evolving just as the definition of what exactly defines an informal seed system evolves. In a study of agricultural production in the Sierra de Manantlan of Mexico, Louette (2000) looked at the flows of pollen between fields, the flows of seeds between farmers, the flows of seeds into a community, and the impacts of selection on a crop population. Louette used isoenzyme analysis to show that in a highly outcrossing crop like maize, the farmer variety is like a meta-population, the genotype can be from a variety sources while farmers are selecting towards a type defined by phenotypic characteristics. Another Mexican study in Sierra Santa Marta, documented the informal system through the history of varieties. The researchers recorded a range of reasons that a variety would be "lost" in the community, from drought to neglect to hunger, and concluded that the status of improved local varieties would be delicate in the face of such pressures (Rice *et al.*, 1998). A more recent study in Nepal did a broad characterization of different aspects of the informal system, including storage, selection and seed sources, disaggregated by gender and wealth (Baniya *et al.*, 2000). The Nepali researchers found that informal sources of seed were the most important, even for varieties that were basically adaptations of modern varietal material. They also found migration, inter-village marriage, and itinerant traders to be important sources of dynamic change to the seed supply.

There are considerable linkages between formal and informal systems, and sometimes a blurring of the lines between them. Materials often flow between the two systems, such as with crosses between improved and local varieties (Bellon, 1996b; Bellon, 2004). Modern varieties are based on breeding lines that include landraces, and in some cases may include pure line selections from local varieties (Sperling and Cooper, 2003; Bellon, 2001). Farmers are usually engaged in both formal and informal systems, varying by crops, as well as production and market conditions. Even for the same crop, farmers may use different channels for seed access, in order to meet different requirements they face, including the need for reliability as well as the desire to experiment (Bellon, 1996a; Bellon, 1997; Sperling and Cooper, 2003).

In evaluating how the supply of seed affects on farm crop genetic diversity understanding the seed system is critical. This is complicated by the mix of formal and informal systems and the variety of mechanisms farmers use to access seed and CGR. Much will clearly depend on local circumstances.

2.3 Research questions

The literature review presented in the previous section was conducted in order to help the reader understand the issues related to sustainable utilization of crop genetic diversity and identify key gaps in the literature. The review identifies factors that influence farmers' use of CGRs and, in particular factors driving the on farm demand for CGR, have been the subject of a significant amount of work. Less has been done on the influence of specific supply side factors on agricultural biodiversity. Furthermore, while some studies have attempted to determine the value of diversity to agricultural households, it remains unclear whether expanding the supply of the CGRs at a community or regional level will increase on farm agricultural biodiversity and the welfare of farmers. Given the limited information and research on the supply side impacts on farm level diversity, the objective of this research was to understand seed systems and, in particular, to assess the impact of seed systems on farmer welfare and agricultural biodiversity.

A set of specific research questions the project set out to answer are in the box below:

BOX: research questions

A. What are the levels and determinants of the supply of crop genetic diversity to the farmer?

a. What are the sources of seeds farmers use? (How many varieties for each crop are obtained and are they all obtained from the same source?
b. How does the type of seed and CGR content vary by source?
c. How does the choice of seed source vary among households and communities?
d. What kind of linkages exist between formal/informal seed sectors?

B. What is the on-farm demand for diversity?

a. Which varieties (or crops) are used? Requires definition of how varieties are identified by farmers and possibly agro-morphological characterization to establish link between variety name and genetic content.
b. How and why are varieties selected and by whom? Requires identification of the traits seeds are selected for, the method (timing) of selection and the household member (particularly important to get gender of selector)
c. What cost/price is associated with PGR by trait/variety? If households rely principally on informal exchange for seed supplies, this information will be hard to gather, but if varieties or traits are able to command price premiums (or cause lower prices) this can be recorded to explain varietal choice.

C. What are the determinants of on-farm utilization of crop genetic diversity?

D. How do variations in seed supply impact the on farm utilization of crop genetic resources and thus the on farm level of crop genetic diversity and farmer welfare?

To answer these questions, a methodology was developed to collect and analyze the necessary information. In this effort, it is important to carefully define seed systems and determine what information to gather to measure and evaluate the relationship between these systems and the on farm use of seeds. The manner of defining agricultural biodiversity at the farm and community level had to be determined as well as the instruments to use to collect that information. Similarly, the definition of farmer welfare had to be specified along with the means of measuring welfare. Finally, other variables that are expected to directly influence seed systems, farmer welfare and agricultural biodiversity or influence the relationship between these variables were also required. In the following sections, the practical definitions used for this analysis and the methods applied are described and discussed.

3. DESCRIPTION OF THE CASE STUDY: HARARGHE ETHIOPIA

The strategy adopted to meet the research objectives outlined in the previous section was to carry out a case study as a tool for testing the methodological approaches. The case study selection criteria included the following:

1. A site with a good pool of crop genetic diversity and for where some threat of genetic erosion or vulnerability exists;
2. A site where food and seed security is of major concern.
3. A site where some readily verifiable variation in the seed supply system was evident to allow for studies of the impact of variation in the seed supply.

With these criteria in mind, early in the study design, the country of Ethiopia was selected for the test case study site. Ethiopia is, indeed, very rich in terms of crop diversity being a primary or secondary center of origin for several crops, including sorghum, wheat, barley and coffee. Ethiopia is also a country where improving seed system management is a critical aspect of improving farm level productivity and meeting the food security objectives of the country.

For this study, the specific area chosen was the Haraghe region of eastern Ethiopia. In this section, background information on Ethiopia relevant for this study is provided. Following this discussion, the reasons for choosing the Hararghe region are noted.

3.1 Agricultural and rural development in Ethiopia

The Federal Democratic Republic of Ethiopia is the second most populous nation in Africa, next to Nigeria and one of the poorest of the world with an estimated population of over 67 million[10]. Forty to 50 percent of the population is estimated to be food-insecure. The rate of population growth (about 3%) exceeds that of agricultural production undermining the economic progress since 1980 (FAO-GIEWS, 2005).

Ethiopia is characterized by a significant variation in physical and ecological features accounting for eighteen different major agro-ecological zones. The total land area amounts to approximately 113 million hectares (ha), of which about 66% is calculated to be potentially suitable for agricultural production. The climate of Ethiopia comprises two main rainy seasons: a small rainy season (*Belg*) from March to May and the main rainy season (*Meher*) from July to November. Elevations, which range from 115m below sea level at Dallol depression to 4620 meters above sea level at the top of mount Ras Dashen, are the basis for the identification of six different climatic zones. Most of the population (88%) is concentrated in the highlands, represented by any area above 1500 masl. The highlands supports 90% of the economic activities of the country. In contrast, the lowlands cover 55 % of the total land area but hosts only 20 percent of the population with a contribution to the country's economy of only 10% (Mwangi and Verkuijl, 1998; Zegeye *et al.,* 2001; Tanto and Demissie, 2000).

Ethiopia's economy is mainly based on small-scale agriculture, which represents the principal engine of the economic growth. Accounting for half of the GDP, the agriculture sector

[10] US Bureau of the Census based on statistics from population censuses, vital statistics registration systems, or sample surveys pertaining to the recent past and on assumptions about future trends (2004) http://www.cia.gov/cia/publications/factbook/docs/notesanddefs.html#2119.

employs 85% of the labor force, contributes to about 90% of exports and provides about 70% of the country's raw material requirement for large-and medium-scale industries (MEDAC, 1999; Zegeye *et al.*, 2001; Shiferaw and Holden, 1999).

Agricultural policy in Ethiopia has undergone several changes over the past decades, moving from a feudal system in the 50's and 60's in to a socialist controlled economy in the 70's and 80's and finally towards a market based economy in the early 1990's. Market reform represented the first encouragement of market-based activities through land reform, facilitation of off-farm activities and gradual removal of subsidies for fertilisers. Nonetheless, land reform has been more formal than substantial as land is still publicly owned and excessively fragmented with the only difference that now households are entitled to transfer and sell their long-time possession rights on land (Unruh, 2001; Dercon, 2001). The resulting increased intensification, characterized by absence of fallowing, lack of technical change and total absence of conservation practices and furthermore complicated by frequent drought, is creating a high degree of land degradation and, therefore, a decline of land and grain productivity (Shiferaw and Holden, 1997).

In the mid 1990's the Ethiopian government adopted a policy of "agricultural development led industrialization." This policy called for the nationwide promotion and dissemination of agricultural extension packages, resulting in a significant increase in food production. Nonetheless, due to poor market infrastructure and development, farmers were not able to market the surplus production and cereal prices plummeted in regions of high productivity. This in turn prevented farmers from making repayment on the extension loans and thus being barred from further participation. More importantly, it resulted in a decreased willingness of farmers to partake in crop productivity improvement programs. Thus input use and productivity fell significantly in 2001-3 (Bramel *et al.*, 2004)

Recent estimates (USDA, 2005) indicate that Ethiopia's annual food deficit is 4.7 million tons (the amount required to bring the poorest up to a minimum nutrition standard), making it the least food-secure country in the world. This food deficit persists despite the fact that food aid constitutes about 10 percent of total food availability in Ethiopia.

Increasing agricultural production is the primary path open to Ethiopia to increase food security, since agriculture is the main economic activity of the country. 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. Increased agricultural productivity is expected to result in increased food security by increasing both food supply and household incomes. Food production in Ethiopia is expected to grow at 4.2% per year over the next ten years, while population is expected to grow at only 2.5%. Estimates are that in 2014 the food deficit will be less than half what it is today USDA (2005).

The Ethiopian agricultural sector suffers from frequent drought, poor cultivation practices and limited farm endowments. Problems with communal and insecure land tenure have also been cited as a problem in increasing agricultural production (Zegeye *et al.,* 2001; Unruh, 2001; Dercon, 2001). The high density of the population together with customary land tenure arrangements, consisting in dividing holdings between offspring, leads to land fragmentation and to very small field sizes (frequently less than one hectare) (Unruh, 2001). Highland smallholders, thus, cultivate microplots using almost exclusively family labor and traditional technologies. In much of Ethiopia, the level of use of purchased yield increasing inputs is very low. Oxen ownership is often vital for crop production and represents a good wealth indicator. Farmers are directly dependent on farm production for subsistence requirements, low level of productivity, total absence of farm mechanization and low degree of specialization. The resulting increased intensification is characterized by reduced fallowing, slow pace of technological change and limited use of conservation techniques. These conditions in turn are creating a high degree of land degradation and a decline of land and grain productivity[11] (Shiferaw and Holden, 1997).

Ethiopia is a landlocked country and uses the seaports of Assab (by road) in Eritrea as well as the port of Djibouti, connected to Addis Ababa by rail, for international trade. Mountainous terrain, lack of good roads, insufficient vehicles and poor infrastructures make land transportation and getting goods to the market very difficult and expensive (FAO, GIEWS, 2005).

The major food crops grown by the small-farm sector include cereals (sorghum, maize, wheat, barley, millet, tef, and oats), pulses (faba beans, field peas, lentils, chickpeas, and haricot beans), and oil crops (flax and noug) (CSA, 1999). One of the most critical cash crop to the Ethiopian economy is coffee, with exports of some $156 million in 2002 (FAO-GIEWS, 2005).

In Eastern Ethiopia farmers have been shifting to khat, another case crop in recent years. Khat is a mild narcotic with growing market demand in Djibouti and Somalia located near to the Eastern Ethiopian production areas. The shift in production has come about due to low returns to grain crops and to some extent falling coffee prices (Mulatu and Kassa, 2001; Mulatu *et al.*, 2005).

3.2 Crop diversity in Ethiopia

Ethiopia is recognized as a center of primary or secondary diversity for several crops. 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 some of the possible explanations for the existence of remarkable genetic variation of crop varieties in the country. Ethiopia is centre of origin for crops such as: sorghum, teff, coffee and enset, and is centre of diversity for many others such as: wheat, barley, Ethiopian mustard, chickpea, lentils and finger millet (Tanto and Demissie, 2000; Vavilov, 1956; McGuire, 2005). The number of crop accessions of Ethiopian origin that have been introduced to various international and foreign national crop improvement programs and seed companies is enormous: more than 1800 for wheat and more than 4500 for sorghum, around 2500 for barley. Large numbers are also reported for chickpea, lentil and finger millet (ICPPGR/FAO, 1997).

The 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

[11] At present, the grain productivity of Ethiopian agriculture is among the lowest in the world – around 1.2 tons per hectare (USDA, 2005).

from the Ethiopian barley collection and introduced into the genetic material of the California barley in the 1960s. Combining varieties in even very small plots is a strategy to protect harvest from stresses like pests, birds, soil fertility and drought and to meet different needs. Crop's stalks are used also as fodder and food and sometimes, as in the case of sorghum for instance, as fuel and construction material. From two up to ten different varieties have been identified in the same plot (McGuire, 2005).

3.2.1. Major crops for which Ethiopia is centre of origin or diversity

Tef, maize, sorghum wheat and barley represent the major crops in Ethiopia both in terms of area and of total production on a national basis (FAOSTAT, 2004).

Tef, the major staple crop in Ethiopia, is endemic to the country and represents the one crop that has mysteriously remained indigenous both in origin and consumption. As with several other crops, the exact date and location for the domestication of tef is unknown. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ (Seyfu, 1997). Most of the Ethiopian farmers use traditional landraces of tef which are adapted to a very broad range of conditions and therefore cultivated under various agroclimatic conditions all over the country. Tef is usually grown during the Meher season as a monocrop, however it can be also grown during the belg season and under a multiple cropping system (Refera, 1999). In their study in Shewa and Wello, Geleta *et al.* (2002) surveyed a total of 1050 sorghum and tef fields distributed in six study sites. They studied the status of integration of edible oil crops into the cereal-based farming system and the frequency of intercropping of tef and sorghum among them and with other crops. The cultural practice of intercropping by farmers seems to have positive contributions to on-farm conservation of oil crops along with tef and specific sorghum landraces.

Ethiopia is also the centre of origin and domestication of sorghum (Teshome *et al.,* 1999; Vavilov, 1956; Harlan, 1969) where it is currently grown at altitudes from 400-3000 m above sea level in areas where annual rainfalls vary from 400-2000 mm. In Ethiopia sorghum provides more than one third of the cereal diet and is almost entirely grown by subsistence farmers to meet needs for food, income, feed, brewing and construction purposes (Teshome *et al.,* 1999; McGuire, 1999, 2005). Sorghum ranks as the fourth most important world cereal in area of production, following wheat, rice and maize. Some landraces of different cultivars are reported to possess excellent resistance to pest damage, including insects (Arnason *et al.* 1993; Teshome *et al.*, 1999). Ayana and Bekele (1998) in their multivariate analysis of morphological variation of sorghum germplasm found that the morphological variation in the materials studied is structured mainly by environmental factors. The range of diversity for sorghum includes different maturity groups, adaptation to different soils and fertility levels, moisture regimes, panicle types, seed colors and sizes etc.

Ethiopia is the second largest wheat producer in sub-Saharan Africa (Hailu, 1991; Zegeye, *et al.*, 2001) next to South Africa. It is thought to be the centre of origin for durum wheat, which occupies about 50 to 60% of the total area under wheat production, 85% of which is represented by landrace varieties (Bechere *et al.*, 2000). On the contrary, bread wheat is believed to be of recent introduction and is the subject of intensive breeding activities since the 50s with the result of a significant replacement rate of landrace durum wheat with modern varieties of bread wheat (Kebebew, *et al.,* 2001; Mulatu, 2000; Zegey *et al.,*, 2001).

Barley is another major crop for which Ethiopia is considered centre of diversity[12]. Ethiopia ranks second, following Morocco, with regard to annual per capita consumption of barley. Barley is used in Ethiopia in many different forms for food consumption and its stalk is used to feed livestock. More

[12] Vavilov initially considered Ethiopia to be a centre of origin for barley, but later, as a secondary centre of diversification because the existence of wild forms has never been confirmed (Kebebew *et al*, 2001)

than 90% of the barley produced by subsistence farmers is from landraces. Several barleys accessions have been successfully used as sources of genes for good protein content and for disease resistance (Negassa, 1985; Kebebew *et at*., 2001; Alemayehu, 1995). In their research Lakew *et al.* (1997) tried to incorporate the collection of barley landraces available in the Institute of Biodiversity Conservation and Research of Ethiopia (IBCR) in the Ethiopian barley breeding program. Six-hundred pure lines extracted from thirty Ethiopian barley landraces were evaluated and selected. Three of the lines identified out yielded considerably the local landrace in some of the testing sites and had a higher average yield across and therefore are currently under multiplication for release (Lakew *et al.*, 1997).

Conversely, maize is not a crop for which Ethiopia is either center of origin or diversity. However is one of the most important crops and for which breeding and research activities have been very intense since the 1960s (Hassan *et al*., 2001; Gemeda *et al.*,, 2001).

3.3 Ethiopian seed systems

Extensive state intervention in both the grain trade and seed industry characterized Ethiopia until the 1990s. With regard to grain trade, in 1979/1980 the then socialist government through the Agricultural Marketing Corporation, adopted a set of measures collectively called the "quota system", which strongly taxed both farmers and wholesale traders, restricted trading licenses, and imposed severe penalties (including imprisonment and death) on violators. Similarly in the seed industry, plant breeding research and varietal development were entirely carried out by state-owned institutions and research centres. The formal plant breeding sector was established in 1979 for the purpose of serving the state-owned farm sector.

In the 1990's the Ethiopian government introduced major reforms into the agricultural sector, with a set of measures aimed at liberalizing both input and output markets. Controls in grain markets were lifted removing official pricing and quotas, and eliminating the monopoly of the marketing board. Reforms were introduced into the seed sector with the intention of improving the quality and quantity of seeds available to growers, and to increase the participation of the private entities in the sector. In 1993, a national seed policy was introduced and the National Seed Industry Agency (NSIA) was established as the implementing agency, with the responsibility of advising the Government on policy and regulatory issues to improve the efficiency of the seed sector and to increase the flow of seed to farmers (Hailu Gebremariam, 1992; Beyene *et al.,* 1998). Reforms are still continuing in 2004 the NSIA was closed down and its responsibilities were transferred to a Department under the Ministry of Agriculture and Rural development (Mulatu personal comm.).

Despite the reforms in the seed sector and the abolition of the quota system in 1990–1991, the seed system in Ethiopia is still in the second stage of seed industry development[13] characterized by the existence of a formal and an informal sector operating side by side. (Gemeda *et al,* 2001; Tafesse, 1997; Beyene, 1998). The former includes research institutions, agricultural ministries and public and private seed enterprises while the latter consists of farmer-to-farmer exchanges, development projects, NGOs and relief agencies activities. The formal system is concerned with the development and distribution of seeds of modern, or improved varieties, while local cultivars or landrace varieties are handled by the informal system. The line between the formal and informal seed sectors can become somewhat blurred, as seeds of modern varieties can be saved by farmers and eventually become considered a "local variety" after some years. In addition, in Ethiopia there have been attempts made by the

[13] See Box 1.

government and NGOs to promote quality seed production and distribution through market channels for landrace varieties, although until now the volume they represent is quite small. The evolution of the seed system into the third stage, would require the linking of the formal and informal systems and the promotion of private sector provision of seed. Through this linkage farmers could maintain seed quality, the informal system could widely distribute seed, and the formal system would be more effective in selecting and distributing appropriate varieties (Gemeda *et al.,* 2001; Thiele, 1999).

BOX: Life cycle model of seed industry development (Douglas, 1980):
The seed supply systems in most countries pass through four evolutionary stages characterized by increasing technological and organizational complexity:

1. During the first stage, farmers save their own seed from crop to crop by selecting the most productive plants and exchange seed with a few farmers.
2. In the second stage, a specialized government agricultural department emerges under pressure from farmers and conducts plant breeding research and varietal development. A few farmers specialize in multiplying and distributing seed released by the government research stations.
3. During the third stage, private seed companies enter the seed industry and invest in plant breeding research and development and seed growing, processing, and marketing.
4. In the fourth stage, plant breeding and seed production and marketing become highly organized and technologically intensive. Both public and private organizations engage in seed production, marketing, and international trade.

3.3.1 The formal sector

Despite attempts at privatization, the formal seed sector in Ethiopia is still almost entirely managed by government agencies. Variety development, evaluation and release is handled primarily by the Ethiopian Agricultural Research Organization (EARO), which has 15 main centers and 29 sub-centers located throughout the country. Breeding is focused primarily on grain crops. In addition, breeding activities are conducted by Alemaya University, Addis Ababa University, Debub University, and four Regional state Agricultural Research Institutes (RARIs). Hence plant breeding has been done mainly by public institutions (Beyene *et al.,* 1998).

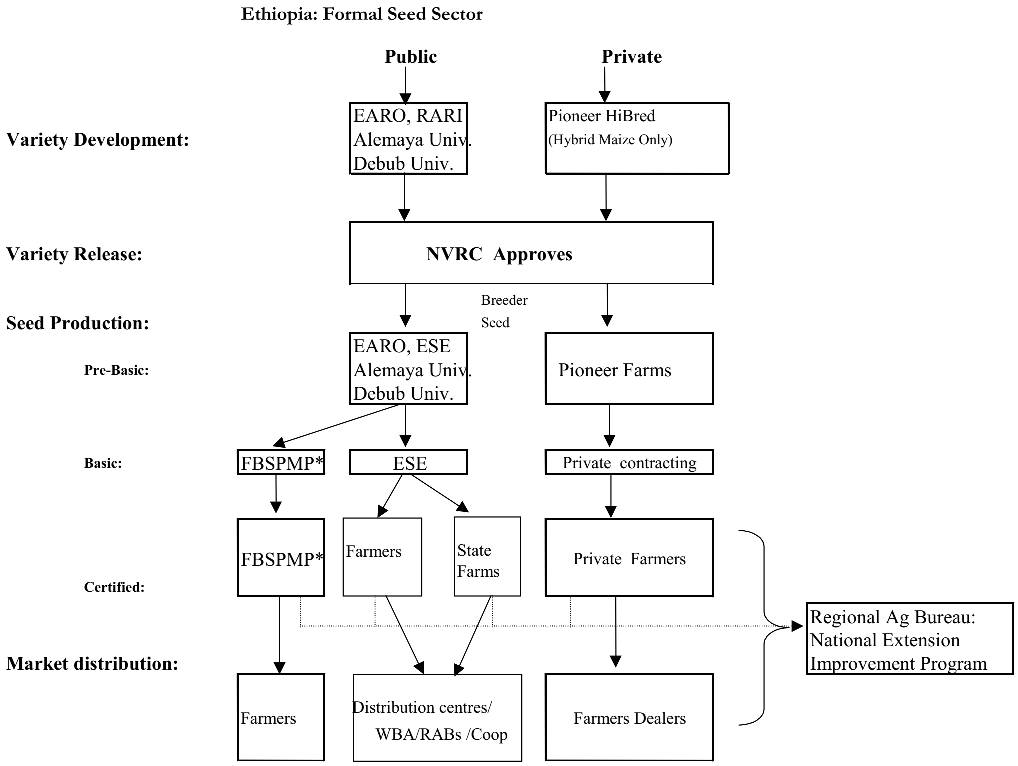
Before a variety can be recommended for release, it must be evaluated in farmers' fields for disease resistance, productivity, stability, and quality. After on-farm verification and evaluation, varieties are officially released by the National Variety Release Committee (NVRC), which is composed of representatives from the Ethiopian Seed Enterprise (ESE) (the government entity primarily concerned with seed multiplication and distribution), the Institute of Biodiversity Conservation and Research (IBCR) and the Ministry of Agriculture and Rural Development.

An important impetus for reform of the seed system was provided through the Seed System Development Project (Cr. 2741 ET) which was implemented between 1997-2001 through financing support from the World Bank and IFAD. This project had two main components: seed enterprise development and capacity building. The former component was intended to improve the supply of quality seed of landrace and modern varieties by providing support to the ESE. In addition, support for the promotion of seed multiplication among farmers through the Farmer Based Seed Production and Marketing Scheme (FBSPMS) came under this component. The capacity building component included institutional strengthening of several government agencies involved in the seed sector including the NSIA, ESE, NVRC, IBCR, EARO and Alemaya University.

Seed production in the formal sector is conducted primarily by the ESE, which produces pre-basic and basic seeds on its own farms, as well as those of breeding centers. ESE has four basic seed farms. ESE was the only seed enterprise in Ethiopia until December, 1990, when it entered into partnership with Pioneer Hi-Bred International (Hailu Gebremariam,1992). Pioneer Hi-Bred International produces seeds of maize hybrid varieties derived from parent stock from Zimbabwe and South Africa. It contracts with large private farms for multiplication services. Both Pioneer and ESE purchase the seeds back from the multipliers for distribution as certified seed. Initially, the ESE supplied improved varieties only for state farms and producers' co-operatives that were the foundation of the socialist economy that prevailed in Ethiopia between 1974-1991. Now the ESE is governed by an inter-ministerial Seed Board and has been given autonomous status to function as a profit-making enterprise (Beyene *et al.,* 1998; Gemeda *et al.*, 2001; Tafesse, 1997).

The Farmer Based Seed Production and Marketing Scheme (FBSPMS) has been another important source of seeds for some selected crops (OPV maize, bread wheat, and dry beans) in recent years (1997-2001). The program was implemented by the then NSIA through the regional and woreda agricultural bureaux and involved the provision of a package of basic seed, fertilizer, credit and technical assistance to farmers for the purposes of stimulating seed production at the local level and encouraging farmer-to-farmer exchanges of high quality seeds. The program focused on the production of improved varieties of grain crops, and most of the output was been marketed through the Regional Agricultural Bureaux through extension packages or sold as grain in situations of excess supply. Currently, FBSPMS' operations has slightly changed and has been transferred to the Ethiopian Seed Enterprise whereby farmers produce and sell seed directly to the ESE by receiving certain premium over the grain market price.

Excess supply occurs with crops whose reproductive nature allows for reuse of farm-saved seed, thus dampening demand for purchases of seed. Thus, it should be made clear that while there may be farmer demand for the variety – this is different than the demand for purchased seeds of that variety, with the latter greater than the former. Factors that influence farmer demand for purchased seed include issues of farm-saved seed quality (for example disease, mixing with other varieties) and the lack of on-farm storage capacity. In recent years, the primary mechanism for the distribution of certified seeds in the formal sector is through the Regional Agricultural Bureaux (RABs), under the National Extension Improvement Program (NEIP). This program involves the provision of improved seeds, fertilizers and credit to participating farmers. ESE, Pioneer Hi-Bred and the FBSPMS supplied seeds to the RABs for distribution under the NEIP. However in 2002, the NEIP started a substantial reform due to a lack of demand from farmers for the packages resulting from rising fertilizer prices and declining grain prices. Both ESE and Pioneer have alternative distribution channels: ESE has seed distribution points located near its seed plants, and Pioneer uses "farmer seed traders" who are usually retired extension personnel or technically advanced farmers, to distribute seeds. A schematic design of the formal seed system in Ethiopia is shown in Figure 1.



* FBSPMP: Farmers Based Seed Production Marketing Project

The bulk of seed supply in Ethiopia is provided through the informal system. According to data obtained from the NSIA in 2003, the total demand for food grain seeds in the country is approximately 1.4 million quintals per year. In 2005 the formal sector provides around 200000 quintals or between 10-15% of the total. The remainder is made up by supplies from the informal sector. The actual percentage supplied by the informal sector is likely to be even higher, as the formal sector supplies are not always fully utilized, due to a lack of farmer demand. As noted above, the lack of demand for purchased seeds is not to be confused with the lack of demand for the variety. (A report from 1998 estimated that 96% of seed supply in Ethiopia came from the informal system (Beyene, 1998).

3.3.2 The informal sector

Most seed needed at sowing time is farmer-saved from the previous harvest. Nonetheless, farmers periodically obtain seed from beyond the farm gate mostly from other farmers, local markets, from NGOs, relief agencies or development projects. Seeds may be brought in the farm to cover deficits following harvest failures, but also to introduce new varieties and/or provide better quality seed, either physiologically or/and genetically (Gemeda *et al.*, 2001).

The informal seed sector offers advantages to farmers over formal seed exchange in accessing seed in some circumstances. Farmer to farmer exchanges are primarily based on social relations for information flow and exchange of goods that in some cases may make it less rigid than the formal sector. Furthermore, it frequently operates at the community level between households, strengthening social ties and reducing the transactions costs of obtaining seeds as farmers know and trust the farmer from whom they obtain the seed (Badstue, 2004) The large variety of exchange mechanisms used to transfer seeds between individuals and households, (i.e. cash, exchanges in kind, barter, gifts or transfers based on social obligations) enhance availability, particularly for households that have limited cash resources to purchase seed. Last but not least, this exchange system allows farmers to acquire seed in the quantities they want, whereas the formal sector may supply only in large bulk quantities (Cromwell *et al.*, 1992). The disadvantages of the informal sector are the weak links to sources of new and improved genetic materials from the formal sector.

Farmer to farmer exchanges may exclude households that do not belong to social networks along which seed is traded. Finally, informal seed systems are currently under pressure in most parts of the world due to changes in agricultural production, markets, population growth and environmental changes.

The role played by NGOs and relief agencies in the Ethiopian seed system is difficult to assess because their activities are dispersed and uncoordinated especially in the case of relief interventions. A few NGOs are now focusing on providing source seed, other inputs, and technical assistance aimed at strengthening local community-driven multiplication of improved open pollinated varieties, and in a few cases, enhanced local varieties. With regard to the distribution of relief seed after emergencies such as war or drought, NGOs were initially responsible for acquiring and providing early maturing varieties seed to service cooperatives at cost, including transport. However, the distribution of free seed by NGOs and relief agencies has caused negative effects; creating dependency on free services, disrupting the informal farmer-to-farmer seed exchange system, and weakening sustainable development in the seed sub-sector (Hailu Gebremariam, 1992; Gemeda, 2001).

NGOs have played an important role in improving the distribution of seeds and technical information, although better coordination among the activities is needed to increase their overall effectiveness. Despite the difficulties in assessing the impacts of underdevelopment and inefficiencies of the formal seed supply and the effects of poorly coordinated NGO interventions, seed marketing and trade still represent the weakest link in the seed production/marketing chain in Ethiopia (Tefesse, 1998).

3.3.3 Marketing

Seed pricing was deregulated in Ethiopia in the early 1990's. The deregulation produced many entries with the effect of a dramatic increase in market integration and efficiency (Dercon, 1993; Osborne, 2005). However, barriers to entry in the form of market imperfections (i.e. asymmetric information) together with high fixed costs still dominates the scene and, as a result, pricing has not really become competitive. Seed and grain prices vary substantially by quality, color, and point of origin. However, the inexistence of quality standardization makes price comparisons difficult. Moreover, poor farmers are usually liquidity-constrained at the time of the harvest and therefore tend to sell grain at a "low" price worsening market structure and contributing to imperfect competition (Lirenso, 1987; Osborne, 2005).

Both ESE and Pioneer expressed concern over the inability to fully market their seed supplies and noted that excess capacity has been sold as grain. The biggest problem is reported to be a lack of farmer demand for purchasing improved seed, particularly in 2001-2002 when grain prices dropped precipitously while fertilizer prices have been climbing and many farmers have been unable to repay the credit received under NEIP, therefore reducing the demand in the following seasons. Lack of demand is also due to over-production of easily recycled seed type (wheat, OPV maize, dry beans) without assessment of farmers' eed replacement rates, and neglect of production and supply of seed for market oriented crops, vegetable seed in Hararghe, for example. Another problem is the complete reliance of ESE on RBA and WBA to market their seed and the complete absence of promotional works like demonstration, distribution of small seed for farmers observation, lack of road infrastructure to reach remote areas (Mulatu personal comm.).

As of 2002, the seed supply system in Ethiopia is undergoing something of a crisis, due to rising input costs and falling grain prices. Areas of surplus supply are experiencing rapidly decreasing output prices. The squeeze on farm revenues from increasing input and decreasing output prices has lead to a major drop in demand for certified seed. The decline in demand has come about primarily from the decreased participation of farmers in the extension package program, which was a major consumer of seed supplies produced in the formal sector.

Faced with this situation, the Government of Ethiopia is shifting priorities away from input supply to marketing output, and major changes are occurring in the management of the agricultural sector, with a greater devolution of powers to the Regional and Woreda levels of administration. The NEIP , has been structured towards a holistic extension service provision to include several commodities and enterprises of the farm the management of the FBSPMS has been transferred to ESE, whereby farmers became contract seed growers for ESE.

Some interest has been expressed in improving the production and distribution of high quality landrace varieties, although so far this is still mostly in the discussion, rather than implementation phase. Potential participants are ESE as well as farmer based supply schemes, although government policy is still firmly oriented towards increasing agricultural productivity through the dissemination of improved varieties and technical packages. The rationale for a move towards landrace seed supply is based both on demand and supply: for crops where a rich local diversity exists such as sorghum, wheat and barley, a wide range of traits may be accessible through the informal seed system, thus restricting demand for new material from the formal system to varieties which provide traits missing in the native populations. Higher seed quality in seed of modern varieties that provide the same traits as local varieties is another potential source of farmer demand for seed from the formal sector, particularly in areas with high disease pressure.

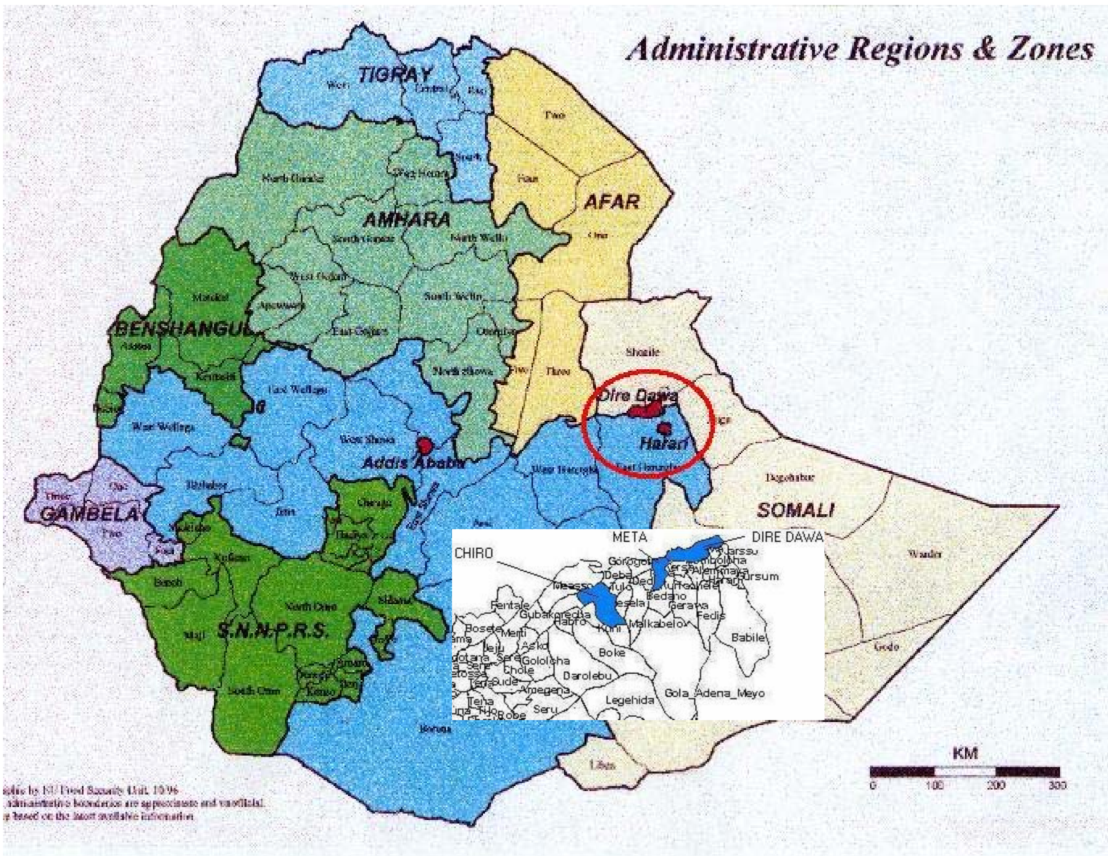
Obviously, there is a problem with a mismatch between seed supply and farmer demand in Ethiopian formal seed sector, but it is not clear if this is because of a lack of effective demand on the farmers' part (e.g. inability or unwillingness to purchase seeds) or because the seed costs are too high vis a vis the return they generate - or more profound problems like the varieties being produced are not those which meet the farmers' needs, or the formal seed distribution system is not effective in reaching farmers. Effective demand for seed is highly linked to the overall situation in the grain market – farmers will not purchase seeds which require increasingly expensive inputs in order to produce for markets with steeply dropping prices. When market conditions are bad, it appears that the characteristics the farmers demand from a variety shift – away from high productivity but reliant in purchased inputs, towards lower yielding but less input intensive varieties. Increasing seed production towards landrace varieties may be one way to increase the supply shortfall for varieties that are in demand in crisis times.

Another important issue which also needs to be considered is the extent to which the lack of demand is related to the seed per se, as opposed to the variety. Given the direction the seed sector appears to be taking in Ethiopia it seems that the Government, as well as NGO's operating in Ethiopia assume the answer to this question is affirmative, but clear evidence of the existence of this demand and the crops, agro-ecological and market conditions under which it will occur is not yet available. What is clear is that increased productivity in agriculture is critically important in Ethiopia.

3.4 The choice of Hararghe

In March 2002, part of the study team visited Ethiopia to select the study site. Identifying and selecting the specific geographic site and crops to focus upon were the two most critical issues to decide. These decisions were closely related since the diversity of crops varies by agro-ecology and thus geography. During the visit several governmental and non-governmental agencies and research institutes were contacted and information about their activities and capacity to collaborate on a field study on seed systems were obtained. Interviews and briefs with seed producers, seed traders and farmers were also conducted in order to get a picture of the farming system as well as of seed supply and demand from different points of view.

In Hararghe, the agricultural sector is characterized by (1) steadily diminishing size of holdings, (2) steadily increasing population pressure on farm lands, (3) frequent occurrence of drought situations associated with incompatibility of long cycle cereals like sorghum linked to changing climate (reducing rainfall amount or abnormal distribution), (4) increasing opportunity for market integration through international trade by changing crop mixes, which seems to represents the best approach for improving farmers' welfare at this stage (Mulatu, personal comm.).



Hararghe region is located in the eastern part of Ethiopia covering about 22% of the country area and it is inhabited by about 10% of its population (FAO, 2000; Stork *et al.*, 1991). The former Hararghe region is administratively divided into East and West Hararghe zones (Oromiya region) their administrative capitals being Harar and Chiro, respectively; Harari, Somali and Dire Dawa are administrative regions It has been a repeated recipient of both food and seed emergency relief supplies because of chronic food deficits and problems of seed insecurity. Dire Dawa is the main commercial center with road, railway and air connection to Addis Ababa, and Djibouti and road and air connections to Somalia. Elevations range from 1300 to 3400 masl, however 75% of the territory is below 2200 masl. Albeit not very well documented, except for the study run by Stork *et al.* (1991), the average agricultural holding is only 0.5 ha, Over 95% of the population is rural and derives their livelihood from agriculture. Major grain crops are sorghum, maize, wheat, barley, haricot beans and groundnut. Hararghe is not a surplus production area, yet a main supplier of grain to Harar and Jigjiga markets as well as chat to Jigjiga, Djibouti, Somalia and Addis Ababa markets. Sweet potatoes represent one of the coping mechanisms used by food insecure households for the grain deficit months of July and August. The main irrigated crops in the area are chat, Irish potatoes, onion, and other vegetables (Stork et a., 1991; Adenew *et al.*, 1991; FAO, 2000).

Site Selection

One of the main criteria used in selecting the site for the case study was to identify areas with variation over time and space in seed systems and with good potential collaborators to conduct the study. To study the impact of changes in seed supply on farm level utilization, it was necessary to look for situations where some identifiable difference in supply variation was evident. Three possibilities were considered: a) comparison of areas where a seed system project had been implemented by the government, NGO or international organizations with similar areas without such an intervention; b) look at areas where there had been partial adoption of modern varieties, but with still a significant portion of farmers using landrace varieties; c) select areas where there was some variation in the degree of market integration, which has a major impact on seed systems.

We concluded that a comparison of participant and non-participant households and communities in a seed project would be the most effective way to try to capture differences in seed system management at one point in time. Several NGO interventions in the seed system have been made in Ethiopia. In Hararghe, the Hararghe Catholic Secretariat (HCS) project in Hararghe provided an interesting case study for this type of analysis, because of its size, the number of crops and varieties involved in the program, and the innovative approach it took in trying to strengthen seed system management. In addition, the area is also drought prone and seed and food security are of crucial importance. Finally, FAO was initiating a technical assistance project in the region focused on strengthening seed systems and the research project could provide information useful to its implementation. To confirm the value of choosing this site, members of the project team visited this region, Alemaya University and HCS in May 2002.

Selecting collaborators

Another critical issue considered was the presence of a good collaborator to implement the study. Candidates were assessed on their capacity to conduct a major field survey effort in terms of managerial, staffing, transportation and data entry capacity and their availability to take on such a project within the 2002 cropping year. In addition, the degree of familiarity with the subject of seed system management, farmer benefits and agricultural biodiversity, and experience with fielding household and community surveys were considered criteria to be applied.

The **HCS** project involves an innovative approach to improving the supply of local and improved genetic resources to seed insecure farmers. In particular it involves the production of high quality seeds of local and improved varieties of sorghum, as well as improved varieties of wheat, haricot bean and distributing it to areas where seed supplies are chronically insufficient. They focus on working with specialized seed producers to identify and multiply seeds, and village seed banks to distribute seed. The project started in 1992, in order to provide a better way of responding to seed shortages caused by droughts or other problems and which always lead to the need for emergency seed relief. The program consists of "reselecting varieties", which means that they collect seeds from farmers which contain a wide mix of varieties and then, among these, reselect for developing a pure line of the landrace. In general, farmers mix at least 4 to 5 varieties so that their seeds will contain more than one variety.

The HCS project involves identifying and multiplying varieties which are of value to farmers, given current production and marketing conditions. The improvement status of the varieties provided by HCS varied by crop; local varieties selected for good performances were distributed for sorghum, while wheat and haricot beans were improved varieties.

At the time of the present project design, the HCS project involved 540 seed producers who received credit through a revolving fund. They used this for tool and the purchase of basic seed. These producers also received technical assistance from the project via Alemaya University.
The project purchased 75% of the seeds produced by the multipliers at a price that was 25% above market prices for the grain. This 75% of seed output was then given to a community seed bank and distributed to farmers on credit. Farmers receiving the seed were required to repay in-kind with 20% interest added. The HCS project also provided some technical assistance to the participants. With this package the credit component would require a 9-11 percent revolving loan system which HCS believes would be sustainable for both the borrower and the lender.

Since the study would focus on the evaluation of the project experience of households participating in the HCS project, it was considered essential to have their involvement. At the same time, Alemaya University had greater capacity in socio-economic research and also the capacity to provide a large number of survey enumerators through their pool of graduate and post-graduate students. Fortunately, HCS and Alemaya University had a history of collaboration in conducting field studies, so the decision was taken to work with the two organizations together in conducting the study. It was decided that HCS would take on the overall supervisory role, as well as field support operations, while Alemaya would provide staff for the survey teams, including team leaders as well as enumerators. In addition HCS

Alemaya University is located about 510 Km from Addis Ababa in the Eastern Hararghe Zone at a distance of about 20 km and 40 km from the two nearby towns: Harar and Dire Dawa respectively. It is the second biggest university in Ethiopia with (now 10,000) students. Another 1,800 are in the continuing education program term. They have an academic faculty of 205 staff and 75 are being trained for their doctorates in various countries around the world. Alemaya University has a college of agriculture, health science, teacher education, veterinary science, law, technology and business. The Department of Ag. Economics has done several socio-economic surveys in the region. They also have a farming systems group who has done several survey works. They worked with HCS on conducting surveys for a seed multiplication project.

agreed to take over the management of data entry tasks and of market data collection.

Given that one of the main objectives of the research is measuring agricultural biodiversity, it was also necessary to collect agro-morphological data to complement data gathered through community focus group, household, community and market level surveys. For the agro-morphological part of the study the International Plant Genetic Resources Institute (IPGRI) together with the Ethiopian Institute of Biodiversity Conservation and Research (IBCR) were identified as good potential collaborators.

Due to the complexity of agricultural biodiversity measurement, and the need for a strong collaborative relationship between involved institutions, a workshop was held (with participants from IPGRI, IBCR, AU, HCS and FAO) in Rome with the purpose of deciding upon strategies and methodologies to measure agricultural biodiversity for this project. IPGRI would have supervised IBCR in designing the survey instrument necessary for collecting agro-morphological information, provided appropriate survey procedures and sample protocol for sorghum and wheat diversity measurement to be used for data collection and produced work sheets and guidelines for field workers.

IBCR was responsible for collaborating with IPGRI in designing the survey and for providing training in how to use the survey instrument to HCS project staff. The training and survey design would have been conducted by the Institute with financial and technical support from FAO, and technical support from HCS. Finally IBCR would collaborate in analysis of data collected to measure sorghum and wheat diversity.

FAO ESAE had the task of providing training for survey enumerators as well as finalizing draft instruments and sampling designs for the household and community surveys.

The Institute of Biodiversity Conservation and Research (IBCR) was legally established by the government of Ethiopia in 1998. The general objective of the Institute is to undertake conservation, study, research and promote the development and sustainable utilization of the country's biodiversity. The Institute has power and duties related to the conservation, research and utilization of biodiversity including maintaining and developing international relations with bilateral and multilateral bodies. IBCR has one Plant Genetic Resources Center (PGRC), five departments and four services. The PGRC cares principally for plant genetic resource conservation. It undertakes the collection, conservation, multiplication, characterization/evaluation research, utilization and documentation of the various categories of plants. Moreover, the center has cold storage and herbarium units that provides services in conservation, identification and classification of plants.

Founded in 1974, **IPGRI** is the world's largest international institute dedicated solely to the conservation and use of plant genetic resources. It has a staff of around 300, in 22 offices around the world. IPGRI undertakes, encourages and supports research and other activities on the use and conservation of agricultural biodiversity, especially genetic resources, to create more productive, resilient and sustainable harvests.

IPGRI's work has had considerable impact on the conservation and use of plant genetic resources worldwide. IPGRI has sponsored over 550 germplasm collecting missions in 136 countries. Many national gene banks have been established with the Institute's assistance, and more than 2000 national scientists have been trained. Over 150 countries now participate in the 50 or so networks whose development has been supported by IPGRI. Through its research, IPGRI has contributed to a better understanding of genetic diversity and to major advances in conservation strategies and methods, especially in such areas as *in vitro* conservation and ultra-dry seed storage.

AU was also in charge of providing facilities for training workshops for the survey enumerators and for appointing one staff member to serve on a data quality control board for the data collected in the household and community surveys.

Crop Selection

Concerning crop selection, it was decided to focus on only a limited number of crops owing to the volume of data required for the analysis. There are two criteria for selecting the crops for intensive study: 1) their importance to food security and 2) their importance from the perspective of conserving agricultural biodiversity. The first criterion should be measured in terms of the crop's importance to household subsistence, either as a direct consumption good, or as a source of income through market sales, which in turn is used to purchase food supplies. For the second criterion, the crop should be one in which Ethiopia is a primary or secondary center of diversity. In addition, the crop should be one in which some degree of genetic erosion has occurred, either via the introduction of modern varieties or through disasters such as drought, wars etc.

Sorghum quickly emerged as an interesting crop to study, being one with high local diversity and importance to food security and also a crop for which landrace varieties had been distributed by HCS. Another factor in the decision to focus on sorghum was the fact that several studies had already been done on the crop; including studies of seed systems and diversity and these could provide an important base of information for the project to build upon (McGuire 2005; Teshome 2001). In addition, wheat was selected as a focus crop as it too is important to food security through market sales of the grain and also was widely distributed by HCS. Ethiopia is a center of diversity for durum wheat and it was thought that some interesting patterns of local diversity might be found in wheat seed selection patterns. Concerns about genetic erosion of durum wheat varieties due to replacement by modern bread wheat varieties had been raised for the country. However Hararghe is not a center of wheat diversity and thus only modern varieties of bread wheat were in production, but this only became clear as the study was implemented in the field.

Sorghum and wheat production in Hararghe provide some interesting contrasts: sorghum is a long season crop, grown mainly for subsistence purposes, while wheat is more likely to be marketed and has a short growing season (Mulatu, 2000). Sorghum is the most important crop in the drought prone areas of Hararghe. Hararghe is considered a primary centre of origin for sorghum and most varieties planted in the region are landraces, although formal sector breeding has been undertaken for almost 25 years (McGuire, 1999**).** Native Ethiopian sorghum varieties are not early maturing and thus difficult to grow in lowland areas. The introduction of this trait to improved varieties has been done through the use of ICRISAT germplasm.

Having a long tradition with sorghum production, farmers have developed a good storage system and technology to select and save seeds, which is not the case for wheat seeds. Sorghum is a multipurpose crop used for many different applications (food, fuel, housing materials, livestock feed etc.) and, according to local experts, landraces are preferred to early maturing modern varieties because modern varieties generally provide one, rather than several traits. In highland areas sorghum landraces are preferred over pure line selections because they prefer a mix of varieties rather than pure lines the improved materials provide (Mulatu, personal comm.).

Ethiopia is a primary centre of origin for durum wheat, and much of the production in the country relies upon durum landraces. However, most of the modern varieties released from the formal system in Ethiopia are bread wheat (Beyene *et al.*, 1998; Mulatu, 2000). Although a significant number of durum wheat MVs (about 22 currently) developed through selection from local germplasm were released the formal seed supply system is not willing to produce and supply such seed due to fear of poor demand compared to bread wheat. The Hararghe region of Ethiopia is neither a centre of origin for durum wheat nor a major wheat production area of the country, although wheat is an important crop in terms of area planted. Since wheat is a short-season crop it is planted to capture the benefits of early rains or as a relay crop in sorghum plots to exploit residual moisture or late rains (Mulatu , 2002). Most of the wheat planted in the Hararghe region are improved varieties introduced through the extension system (although frequently recycled as farm-saved seed) and in most cases were substituted for other short season grains crops such as barley (Dr. Tesfaye Tesema, Ethiopian Agricultural Research Organization, Ethiopia, personal communication).

The multiplication and distribution of improved bread wheat varieties has been considerable in Ethiopia, in comparison to sorghum. In the late 1990's, the High Input Extension Package (HIEP) program was initiated which boosted the distribution of improved seeds throughout the country. The program focused on seeds of improved varieties of wheat, maize and teff. Under this program farmers had to satisfy a set of criteria on land, labor and animal power availability, as well as the capacity to pay 25% of the costs of the input package (including fertilizer, seeds and pesticides) in order to participate. The HIEP program was active in the Hararghe region with wheat distribution and a survey of households in the area from 1998-99 revealed that over 40% of the wheat producers had obtained their wheat seeds from the program (Mulatu, 2000).

In the case of sorghum there has been much less seed production and dissemination of MVs. The breeding program has focused on yield characteristics, ignoring key characteristics desirable to farmers such as disease resistance. In contrast, less attention has been given to multiplication and distribution of modern sorghum varieties, and may be one reason for low adoption rates, although attempts to increase distribution networks in the past were not successful in stimulating demand (Mulatu, personal comm.) Formal sector highland sorghum breeding in Ethiopia is mostly based on pure-line selection of local materials. Breeders think it is unlikely that an introduced variety will replace local varieties, due to the multiple attributes farmers demand from sorghum which local varieties are more likely to provide (Dr. Ketema Belete, Alemaya University, Ethiopia, Personal communication). Farmer feedback on sorghum MV development has indicated that if varieties could be developed that had some desirable characteristic such as striga resistance or drought tolerance and which could produce and acceptable amount of stalk for use in contruction or feed and fuel – then they would be highly desirable to farmers. The problem is the breeding program lacks capacity to develop and provide such varieties. There is no convincing reason why farmers suffering from crop failures while growing landraces would not adopt MVs exhibiting attributes that the landraces lack (drought and disease resistance mainly). However, farmers are not willing to pay for varieties that provide no additional traits from what they already have in their stock (Mulatu, personal comm.).