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Abstract

This paper explores the relationship between social capital and crop diversity. The study is conducted in an area of Ethiopia where inter-specific diversity is significant and that diversity includes crops that are of important in terms of their genetic value since it is a center of origin or diversity for these crops. The results indicate that linking social capital does not lead to a decline in crop diversity but actually increases it suggesting that interventions by formal organizations need not lead to reduction in inter-specific diversity. However, the results also suggest that households with strong social links within a community (bonding social capital) are less likely to be diversified implying that policies that seek to promote sustainable utilization should be wary of only working to promote greater grassroots organization since this may not support crop diversity.

Key Words: social capital, crop genetic diversity, risk management, agro-biodiversity, agricultural household decision making.

JEL: D13, D71, O13, Q12, Q56.

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Sowing the seeds of social relations:

the role of social capital in crop diversity

Crop diversification is a key strategy in agricultural and rural development programs targeting low income agricultural producers, due to the opportunities it offers for managing risk and heterogeneous production conditions, as well as increased income generation through entry into new markets. The promotion of crop diversification has important implications for agricultural biodiversity. Modern agriculture is increasingly reliant on a small number of crop species with three cereal crops; wheat, maize and rice, providing over 50% of the world's plant derived calorie intake (FAO 1998). Farming systems with high levels of inter-specific crop genetic diversity are more likely to include production of minor or indigenous crop species which are high in diversity (FAO 1998). Entire pools of genetic resources are lost when a crop species is no longer cultivated and becomes extinct. In addition, inter-specific diversity is likely to have impacts on infra-specific diversity, as the two may be either substitutes or complements. With implications for agricultural productivity and human welfare as well as agricultural biodiversity, understanding the determinants of the diversity of crop species grown by farmers is an important area of inquiry. The research also has important policy implications as increasing attention is being focused on strategies and policies to promote the sustainable utilization of plant genetic resources which incorporates both environmental and development objectives. Both the International Treaty on Plant Genetic Resources (IPTGR) and the Convention on Biological Diversity (CBD) require signatories to adopt policies to promote the sustainable utilization of plant genetic resources. While these may be desirable objectives, the policy instruments that should be used to attain sustainable utilization are not clearly identifiable. In fact, it has been argued that some agricultural policies, such as the promotion of modern crop varieties, while achieving the objective of increased on-farm productivity may actually lead to a narrowing of the genetic resource base[1] which runs counter to the principles of sustainable utilization. Questions clearly remain regarding the best methods of achieving the objectives of the ITPGR and CBD.

The literature on farmer motives for crop diversification indicates that both supply and demand factors determine diversity levels both at the farm and more aggregate levels. Three key factors emerge as important motives driving farmers' "demand" for crop diversity: i) managing risk, ii) adopting to heterogeneous agro-ecological production conditions; and iii) diversification to meet market demands. There is a particularly rich literature on risk management and diversification in agriculture.[2] In this literature, crop diversification is viewed as providing an ex ante means of insuring against failure in any one crop, which is particularly important in situations where formal insurance mechanisms are non-existent and ex post coping strategies are limited. In addition, crop diversification is associated with a diminished risk of pest and disease invasion contributing to stability of yields (Guy, Spann and Brooks 2005; Sullivan 2003). Pingali and Rosegrant (2005) also argue that agricultural diversification is an important strategy to manage price risk as well,

[1] Brush (1995) acknowledged that the adoption of MVs caused genetic erosion, while some other studies have found that the introduction of HYVs had broadened the portfolio of varieties held by farmers (Brush 1992, Bellon 1996).

[2] See for example Chavas and Holt (1990), Rosenzweig and Binswanger (1993), Newberry and Stiglitz (1981) and Fafchamps (1999).

but only at a macro level, with little impact at the household level. Maintaining crop diversity has also been found to be a strategy adopted by farmers to exploit the highly heterogeneous agro-ecological conditions, as well as to efficiently utilize other factors of production such as labor and animal power and avoid bottlenecks particularly when off-farm opportunities are available (Worede, Tesfaye and Regassa 2000). Finally, crop diversification is considered an important step in the transition from subsistence to commercial agriculture. With economic growth, households start to produce for markets and adopt new crops to meet demand. In the transition from subsistence to commercial production farms become semi-commercial operations with mixed cropping systems which are associated with higher levels of crop diversity than subsistence systems (Pingali and Rosegrant 1991). As commercialization proceeds, however, farms become more specialized although the agricultural economy may be more diversified.

Recognizing these motivations for crop diversity, one key factor in determining actual crop diversity outcomes relates to access to crops and specifically the seeds for planting. In most developing countries, the access to seeds and information about crops and seeds is often obtained through non-market channels including formal organizations, such as the government, international donors and NGOs, and informal networks that include some form of association with other households. In the social capital literature, these are referred to respectively as linking social capital and bonding social capital (World Bank 2000). Social capital is defined as a variety of different entities with two common elements: they all consist of some aspect of social structure and they facilitate actions of actors within that structure (Coleman 1988). The entities have mutually beneficial goals and are usually characterized by trust, cooperation, involvement in the community, and sharing (Putnam

1995). Linking social capital consists of vertical ties between distinct social and economic classes such as between poorer households and those with influence in formal organizations including government agencies. This form of social capital involves intercommunity links. In contrast, bonding social capital refers to the strong horizontal ties connecting family members, neighbors and business associates usually at an intra-community level. These groups tend to be more homogeneous in that they share a similar economic and social background. This can be beneficial in that it allows for easier flow of information but it can be limiting in that the similarities between participants limit the range of information. According to some theorists, the process of economic development involves individuals moving from forms of bonding to linking social capital as they transition from "getting by" to "getting ahead" (Foster, Meinhard and Berger 2003).

In this paper, we focus on how seed supply limitations influence crop diversity and the role that social networks play in overcoming this barrier. We focus on social capital as it is considered an important feature of informal seed systems which involve seed exchanges in the context of social interaction. The expectation is that different forms of social capital influence access in a unique manner and thus have a differential impact on the farm level choice of crop and variety to plant, and therefore on-farm crop diversity. Much of the literature on seed systems cites the importance of exchanges within networks built on family, community or other social ties, a form of bonding social capital (McGuire 2005; Almekinders, Louwaars and de Bruijn 1994; Badstue 2004). With this type of social capital, ties are likely to be stronger than in linking social capital thus are expected to provide better access. However, given the close geographic proximity of such ties, there may be lower crop diversity available through such ties. On the other hand, linking social capital, whose vertical structure requires connections to individuals and organizations outside the community, might provide greater choices among crops and varieties to plant. Although these ties may be weaker, the greater availability may lead to higher levels of on-farm crop diversity, as farmers can select and plant the materials needed to meet heterogeneous production and consumption conditions.

To meet the objectives of this paper the remaining sections are organized as follows. In section 2, we develop a model that examines how agricultural household decision-making determines on-farm diversity and the role of social capital in this process. Section 3 then presents the necessary background information on the study site as well as basic information on the method of data collection and a description of the data. Section 4 presents the empirical approach used to analyze the data while section 5 provides results of the analysis. Finally, section 6 provides conclusions.

Crop diversity, social capital and the agricultural household model

To understand on-farm crop diversity and the influence of social capital on diversity, it is important to begin by considering the behavior of agricultural households with respect to crop choice. A common approach toward investigating household decision-making in these contexts is to employ an agricultural household model where households are both consumers and producers of agricultural goods and face market constraints (Singh, Squire and Strauss 1986). In the case of on-farm crop diversity, this approach has been formally used by Van Dusen (2000) and Van Dusen and Taylor (2004) and conceptually by a number of other authors (see Smale, Lipper and Koundouri 2005). In this paper, we follow a similar approach developing a model that helps understand the factors that influence household decision-making and lead to a certain crop diversity outcome.

While following the Van Dusen and Taylor (2004) approach, the model presented below differs from their model in one key way. In their model, agricultural households choose, among other things, output directly and the household maximization problem yields a set of optimal production levels. Assuming that the household does not value diversity itself, it is this optimal set of production levels that determines the diversity outcome. Since these optimal production levels depend on prices, production constraints and other factors, diversity also depends on these factors. The approach taken in this paper is similar except that instead of choosing output directly, output is considered a function of the resources allocated to crop production, particularly land and labor resources. As will be seen, specifying the model this way allows for examining the trade-offs between using household resources, particularly labor, for crop production or for other activities including nonagricultural activities and investment in social capital. Including the relationship between diversity and these activities in the analysis is important in the context of this study, which is why this approach is taken.

Before proceeding to the model a note on the relationship between crops and seeds is necessary. On-farm crop diversity is related to the crops a household chooses to produce, and therefore the seeds planted to produce those crops. In the context of agricultural areas of developing countries such as Ethiopia, the grain produced for consumption and sale is often no different than the grain used for seed (Sperling and Cooper 2003). Farmers often use seed saved from their own output for planting or obtain grain from other sources to use as seed that could also be consumed. If a market for a particular crop does not exist, it is unlikely that the seed market would exist independently. For simplicity, the model below focuses on crop production and the allocation of resources when markets for particular crops do or do not function. For our purposes, this can be considered equivalent to the seed market not functioning. Either situation will have a similar effect on on-farm crop diversity.

Proceeding to the model, consider an agricultural household that maximizes utility of consumption of crops, X_i for $i=1\ldots\overline{X}$ and a nonagricultural consumption good, C. Household utility depends on the preferences and other factors, z^h, that are determined by cultural factors, socioeconomic conditions and other household characteristics. The household produces crops, Q_i, for $i=1\ldots\overline{X}$, using a combination of labor, L_i, and land, A_i, subject to production constraints particularly agroecological characteristics, z^p. The ability to obtain crops for consumption and produce crops depends on characteristics of the market, z^m, which includes such factors as the transaction costs in purchasing and selling crops. Under certain circumstances, transaction costs may be sufficiently high to make a particular crop inaccessible. The household can also allocate labor, L_y, to a nonagricultural productive activity to earn outside income, Y, the returns to which depend on conditions in the nonagricultural market, z^y. The household is endowed with family labor, $\overline{L}$, and land, $\overline{A}$. Households are assumed to be unable to rent land in or out and land is a fixed factor of production. Similarly, households are assumed to be unable to hire in workers and are therefore constrained by their labor endowment.

To incorporate social capital into the model, note that in this context the benefits of such ties are in the provision of crops (or seeds) under certain circumstances. Presumably, the right to such crops requires some sort of investment on the part of the household both in time and other costs. For our purposes, we assume the only cost is in the time devoted to developing and maintaining such ties, $L_{s.}$ The investment in this time provides the household with additional crop for consumption, *S*, and depends on local conditions that influence access to social capital, z^s.

The household can therefore obtain agricultural output, or equivalently seed, through production, through market channels if the market functions adequately and through the use of non-market channels by using social capital. For simplicity, we assume two extreme cases of market functioning for agricultural goods: one in which the market functions perfectly and the other in which there is no market for the good such that $X_i = M, N$ where *M* is the marketable crop and *N* is the non-market crop. This assumption simplifies matters by allowing us to consider only two commodities and to consider the extreme of zero transaction costs in the market and transaction costs that are so high as to make the market not function at all. The household therefore produces the consumption commodity *M* in the amount Q_m using a combination of labor, L_m, and land, A_m, and commodity *N* in the amount Q_n using a combination of labor, L_n, and land, A_n both subject to production constraints, z^p. The household can buy or sell Q_m if production levels do not match the desired consumption *M*. For commodity *N*, the household can obtain more than Q_n through the use of its social capital *S*.

The agricultural household model can be therefore expressed as follows:

$$\underset{M,N,C,L_i,A_j}{Max}\; U\left(M, N, C; z^h\right) \qquad (1)$$

subject to:

$$Y + p_m\left(Q_m - M\right) = p_c C \qquad (2)$$

$$N = Q_n + S \qquad (3)$$

$$Q_m = Q_m\left(L_m, A_m; z^p\right) \tag{4}$$

$$Q_n = Q_n\left(L_n, A_n; z^p\right) \tag{5}$$

$$S = S\left(L_s; z^s\right) \tag{6}$$

$$Y = Y\left(L_y; z^y\right) \tag{7}$$

$$\overline{L} = L_m + L_n + L_s + L_y \tag{8}$$

$$\overline{A} = A_m + A_n \tag{9}$$

where p_c is the price of the consumption good and p_m is the price of the market crop. Substituting equations (4)-(9) into equations (2) and (3), defining λ as the shadow value of the income constraint (equation 2) and γ as the shadow value of the market constraint on N (equation 3) and assuming an interior solution, the first-order conditions are as follows:

$$U'_m = \lambda p_m \tag{10}$$

$$U'_n = \gamma \tag{11}$$

$$U'_c = \lambda p_c \tag{12}$$

$$\lambda p_m Q'_{mL_m} = \gamma Q'_{nL_n} \tag{13}$$

$$\lambda Y'_{L_m} = \gamma Q'_{nL_n} \tag{14}$$

$$S'_{L_s} = Q'_{nL_n} \tag{15}$$

$$\lambda p_m Q'_{mA_m} = \gamma Q'_{nA_n} \tag{16}$$

Equations (10)-(12) show that households consume goods to the point at which the marginal utility of consumption is equal to the marginal cost of the good. For the market crop *M* and the nonagricultural consumption good *C*, the optimal level of consumption is related to the market price of the good and the shadow value of the income constraint. For the non-market crop *N*, optimal consumption depends on the shadow value of the non-market constraint. Equations (13)-(15) indicate that, as would be expected, the household allocates labor so that the marginal return to each labor activity is equated. The household equates the marginal return to the value of investing in the market crop, the non-market crop, nonagricultural productive activities and the development of social capital. Equation (16) shows that the household allocates land to the two productive activities such that the value of the marginal product of land – measured using shadow values – for each activity are equated.

From the first-order conditions the optimal labor, land and consumption levels of the three goods can be determined. Since our interest is in understanding crop diversity, we are particularly interested in the optimal level of land and labor allocated to production, which are defined as follows:

$$L_j = L_j^*\left(\overline{L}, \overline{A}, p_m, p_c, z^h, z^p, z^y, z^s\right) \text{ for } j = m, n, y, s \qquad (17)$$

$$A_j = A_j^*\left(\overline{L}, \overline{A}, p_m, p_c, z^h, z^p, z^y, z^s\right) \text{ for } j = m, n \qquad (18)$$

The optimal level of land and labor are then a function of initial land and labor endowments, prices, household characteristics, production (agroecological) characteristics, characteristics of the nonagricultural economy and conditions that influence social capital formation.

The optimal level of labor and land in turn determine the optimal quantity produced of each crop. For simplicity, our model assumes two extremes market possibilities: one (*M)* in which the crop can readily be bought and sold and one (*N)* which can never be sold. Furthermore, it is assumed that social capital can only be used to obtain the non-market crop. Of course, it is likely that markets for outputs do not completely fail but are plagued by high transaction costs creating a difference between the buying and selling price of a commodity (Key, Sadoulet and de Janvry 2000). In a model with multiple crops that are consumed and produced, X_i and Q_i for $i=1\ldots\overline{X}$, the expectation is that the same factors will affect decision-making along with the characteristics of the product markets, z^m. The household makes a consumption decision based on where the marginal utility of X_i is related to price of the commodity, shadow value of the income constraint and/or the shadow value of constraints related to market functioning. Assuming an interior solution, the household allocates labor and land to the produce crop *i* in a manner that equates the value of the marginal product of labor across all crops as well as nonagricultural productive activities (*Y*) and the development of social capital (*S*) and equates the value of the marginal product of land across all crops. The optimal level of production of crop *i* is determined by the optimal level of labor and land as follows:

$$Q_i = Q_i^*\left(L_i^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right), A_i^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right)\right)$$

Or

$$Q_i = Q_i^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right) \text{ for } i=1\ldots\overline{X} \qquad (19)$$

Following Van Dusen and Taylor, we assume that households do not value diversity in itself and that the diversity outcome is the result of household behavior with respect to the choices of resources allocated to different crops. Diversity, *D*, can be expressed as a derived demand as follows:

$$D = D\left(Q_1^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right),..., Q_{\overline{X}}^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right)\right)$$

Or

$$D = D^*\left(\overline{L}, \overline{A}, p_1,..., p_{\overline{X}}, p_c, z^h, z^p, z^m, z^y, z^s\right) \qquad (20)$$

The results indicate that diversity is a function of initial endowments of labor and land, prices, household characteristics, production constraints, characteristics of the nonagricultural economy and conditions that influence social capital formation. This relationship is similar to the model presented by Van Dusen and Taylor except that it adds the characteristics of the nonagricultural economy and the importance of social capital and explicitly includes initial endowments.

Generally, crop diversity is measured through different indices based on data on the number of crops planted and the area planted of each crop (Baumgartner 2004; Meng et al. 1998; Magurran 1988). The analysis above assumes interior solutions in all cases so that the household produces some of each crop and therefore allocates some land and labor to that crop. It is likely to be the case, however, that corner solutions emerge in which the household decides not to plant a particular crop because, for example, the value of the marginal product of land allocated to that crop is consistently less than land allocated to other crops. In such a case, no resources (land and labor) should be allocated to that crop. The household decision can then be viewed as one where within a given community or region there are $\overline{X}$ crops available but access to those crops, which is determined by the factors noted in equation (20), may make it so the household does not allocate land to all crops and allocates different amounts of land to individual crops. This allocation decision partially determines the on-farm crop diversity outcome.

Along similar lines, corner solutions may be found in the allocation of labor for non-agricultural productive activities and for the development of social capital. If the value of the marginal product of either of these activities is consistently less than that of crop production, labor should not be allocated to these activities. Furthermore, it would be straightforward to extend the model to distinguish between linking (vertical ties) or bonding (horizontal ties) social capital with households choosing to allocate labor to neither, one or the other or both, based on the marginal value of allocating labor to developing each type of social capital. Such an allocation would depend on the value to the household of obtaining access to additional output for consumption from creating these ties. The model predicts that diversity will be a function of the factors identified in equation (20) and formalizes what is generally included in empirical analysis of diversity outcomes. The addition of this model is to explicitly show the role social capital may play in influencing diversity outcomes. Below we test the impact of linking and bonding forms of social capital on-farm level inter specific diversity.

The Ethiopian context and data

The data used in this paper was collected as part of a study to examine the relationship between seed systems and crop utilization patterns in the eastern part of Ethiopia. Ethiopia is a centre of origin and diversity for several agricultural crops and the population is highly dependent on low productivity agriculture and food insecurity rates are high.

The specific study site is located in the Hararghe zone, an area in the eastern part of Ethiopia that has been a repeated recipient of both food and seed emergency relief supplies because of chronic food deficits and problems of seed insecurity. Hararghe is also of interest because it 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). In addition to sorghum, farmers in Hararghe also produce maize, wheat, haricot bean (often intercropped with sorghum and maize), khat – a stimulant and mild narcotic as well as a profitable cash crop – and a host of other crops depending on local conditions. Because of the food security situation there have been numerous interventions in the seed system by the government and NGOs. Among the NGOs of particular interest is the Hararghe Catholic Secretariat (HCS), which has been active in the Hararghe region since the early 1990's with a range of seed system interventions, including seed selection, multiplication and distribution for both landrace and improved varieties of wheat, sorghum and haricot bean.

Studies of seed systems in the Hararghe area indicate that the informal seed sector is the primary source of seed supply (McGuire 2005; Storck et. al 1991; Mulatu 2003). For most crops, saved seed from the farmer's own harvest is the primary seed source. Other important sources are exchanges with family members and friends, markets, extension program and emergency seed relief. The relative importance of the source varies among crops and production season. Social relations are an important part of the seed system and thus seed sourcing decision. McGuire (2005) finds that access to off-farm sources of supply are critical for a high percentage of farmers and that social networks both within and among communities are an important source of such supply. He also notes that social interactions can be an important aspect even in market exchanges which require some level of trust between buyer and seller and in some cases involve patron-client relationships. Mulatu (2004) finds the informal seed sector very active in the provision of wheat seed, primarily consisting of "recycled" modern varieties that are exchanged under a wide range of arrangements, ranging from gifts to cash sales. Wheat and sorghum are representative of very different types of crops; wheat is an introduced crop to the area and most seeds are improved varieties, as compared with sorghum which is native to the zone and has a high level of local diversity. Wheat is used primarily as a cash crop and sorghum for subsistence. Yet in both cases the informal seed sector is the primary source of seeds.

The data used in this paper was designed to evaluate the effects of the HCS intervention and to minimize sources of variation not related to seed systems. The sample was limited to woredas (counties) where HCS had been active and included peasant associations (PAs) only within the mid and highland areas, which have similar agro-ecological zones and fairly uniform cropping patterns. PAs that participated with the HCS program and those that did not were included in the sample. In the three woredas, a total of 30 PAs were selected: 15 PAs in which HCS project had been implemented and 15 similar PAs in which HCS did not distribute seeds. The principle governing the selection of non-participant PAs (i.e. the control group) was to identify those as similar as possible to the HCS project areas and households. The program targeted farmers who were known to be good farmers and with good farming conditions (in terms of land owned, type of soils etc), but who had fallen into debt due to crop failures beyond their control. Within the communities that HCS selected for their project, the PA committee nominated candidates for project participation based on HCS criteria.

To select the sample, households were divided into three groups: 1) households that participated in the HCS seed program (HCS); 2) households that did not participate, but lived within communities where the program was implemented (non-HCS I), and 3) households that did not participate and lived in communities where no program was implemented (non-HCS II). Approximately 24 households from each of the 15 HCS PAs were randomly selected from a list of names of HCS participants for inclusion in the sample. The remainder of the total sample was equally divided between the two types of non-participant groups. Non-participants in project area were selected for the sample with the assistance of the PA committees. PA committees were asked to identify farmers within the community that fit the criteria but who had not (yet) participated in the HCS project. Since the demand for project participation was greater than HCS could meet, there were ample numbers of households on the waiting list for HCS participation. This list was used as the non-HCS I sample frame. Similarly, for households in non-HCS communities (non-HCS II), households within these areas were selected for inclusion in the PA sample frame through a process of consultation with PA committees.

A number of different survey instruments were used to collect data on household and community characteristics, crop production and the cropping systems, but this paper is based primarily on the household and community data. Of the 720 households in the sample, data for 699 was complete enough for this analysis.[3] The scope of the survey is the cropping season of 2002. The household survey instrument was implemented in two rounds in order to ensure sufficient detail on agricultural production. The first round was conducted towards the end of the Meher (main crop) planting season in August 2002. The second round was done after the harvest of the Meher crop in early 2003. In each of the 30

[3] There appears to be no systematic differences between the 21 households with some missing data and the remaining households. Dropping these observations does not appear to pose a problem for the analysis.

PAs surveyed, data on community characteristics was gathered through the use of a community level survey instrument administered to key informants, usually PA leaders.

Table 1 presents summary statistics of the households included in the analysis. Households have on average 3.4 units of household labor defined as adults 15 and over. Less than 2% of households have one adult and just over 75% have two to four adults in the household. The remaining 20% of households have five or more adults. On average, households have access to 4 timmad of land. A timmad is equivalent to approximately one-eighth of a hectare so on average households have access to one-half of a hectare for farming. Ninety-two percent of households have less than eight timmads (one hectare) with the largest household holding less than three hectares. Given the widespread poverty in the area, the small size of holdings is not surprising. In terms of household characteristics, the average age of the household head is just below 40 and the average education of adults is only 1.1 years. Forty-two percent have no adult members with any education and only one percent has an education level of six years or more. The dependency ratio, measured as the number of children divided by the number of adults, is 1.24 on average suggesting for each adult there is over one child to feed. Given the high level of poverty ownership of animal traction in the form of oxen is a key measure of wealth. On average household own 0.4 oxen but nearly two-thirds of households own no oxen.

Variability of production characteristics is likely to lead to a wider range of crops planted. To measure variability, we use the number of plots with different slopes, soil colors and soil texture. The data indicate that on average households have 0.42 plots that are of a different slope, 0.48 plots with different soil types and 0.42 plots with different texture. However, two out of every five households have differing slopes, differing colors and differing textures, suggesting some household face significant agroecological variability. Another measure of agroecological circumstances is the altitude of the plot. Data at the plot level however was not available so community level altitude was used. The average reported altitude is 2056 meters with the altitude ranging from 1100 meters to 2650 meters.

In terms of market characteristics, 26.2% of households in the sample are found to be constrained in the credit market which is likely to influence their production decisions. Car access and distance to market are used as indicators of market performance with those with limited car access and further from cities facing greater market imperfections and transaction costs. Approximately one-third of households live in communities that are not accessible by car suggesting they are very remote. This is confirmed with the data on distance to the nearest city which shows an average distance of 103 kms. There is a wide range of distance to the nearest however with the closer communities being within 7 km and the farthest at 346 km. In terms of alternative income generating activities of households, around one-half of households have at least one member who participates in off-farm activities.

The key variables of interest are the measures of social capital. First, note that by the design of the survey around half of the households participate in HCS. Furthermore, just under 50% of households participate in some other organization, including other NGO's, national and internationally based groups and the private sector. Of these other organizations approximately 90% focus on agriculture and 75% have a principal focus on seed provision. Thus these other organizations are likely to also be linked to diversity. These two types of affiliations – HCS and other organizations – are proxies for the household's vertical ties or linking social capital. Second, households on average belong to two associations with nearly 30% belonging to three or more associations. This is used as a measure of horizontal or bonding social capital. The associations that households belong to are peasant associations (77% of households), self-help (idir) groups (77%), women's groups (17%), farmers' groups (14%) and other groups (18%) most of which are related to production. Peasant associations (PAs) are responsible for the implementation of government decrees in the rural areas and all recognized household heads are supposed to be members of the PA. PAs are empowered by the government to form service cooperatives that are combinations of two or more peasant associations for the provision of basic economic services, such as production inputs, credit, consumer goods, and marketing services. Once a service cooperative is formed, members are required to pay fees to provide funding for the cooperative (Hogg 1990). Self-help groups, referred to as Idir, are associations established among neighbors to raise funds that will be used during emergencies and can be characterized as traditional financial associations. Idirs are long-term associations that are informal, bottom-up, and widely practiced among Ethiopian (Bekerie 2004).

To measure inter-crop diversity at the household level, three indices that are adapted from the ecological literature are used. The *richness index* is a count of the total number of crops that the household reports planting over the season of interest. The *Shannon index* expresses proportional abundance or evenness, accounting for the land shares allocated to each crop as well as the number of crops. The index gives less weight to rare species than common ones, but is more sensitive to differences to small degrees of relative abundances than the Simpson index, another widely used evenness index measure of diversity (Baumgartner 2004; Magurran 1988). The *Berger-Parker index* of inverse dominance reflects the relative abundance of the most common species (Baumgartner 2004; Magurran 1988), or in the case of this study, the most widely grown on each by each household.

In Table 2, the mean values of the three indices have been summarized. The count data indicate that households planted on average 2.73 crops during the period of study with a range from one crop to seven. Seventeen percent of households only produced one crop and the majority (74%) producing 2-4 crops. The Shannon and Berger-Parker diversity are based on area planted and are therefore left-censored when the household only produces one crop. In the case of the Shannon index by definition it is censored at 0 and in the case of the Berger-Parker index it is censored at 1.

Empirical approach to analyzing diversity

To evaluate the factors influencing diversity and in particular the role of social capital, we want to estimate equation (20). As noted in the previous section, diversity is defined using three measures, a count of the number of crops planted, the Shannon index and the Berger-Parker index. Since the count variable is the number of crops planted and takes a nonnegative integer value, a Poisson regression model is appropriate. Both the Shannon and Berger-Parker indices are censored at zero and one respectively and therefore a censored regression model is appropriate and a tobit model is used. Following the literature on agricultural diversity, diversity is specified as a linear function of the factors identified in equation (20).

Although efforts were made to create a sample with a proper control and treatment group that allows for the analysis of HCS participation and its effects on diversity, attempting to collect data that replicates an experimental design after the fact is always problematic. Even though the same criteria were used to select control groups as was used by HCS to identify participants, there is still the possibility that in a regression the coefficient on HCS will suffer from program placement bias. A number of steps are taken to avoid this bias. First, equation (20) includes a number of observable factors that, other than influencing diversity, may influence participation. Assuming common support, including these factors potentially limits bias in the HCS coefficient. Second, an instrumental variable approach is used to instrument HCS. The instruments used are those that are uncorrelated with diversity but influence participation thus overcome the bias that is caused by the correlation between participation and the error term. In the case of the count variable, using an instrumental variable approach with the Poisson model proved to be complicated. We therefore run a least squares regression to show that results for the least squares and Poisson are remarkably similar and proceed to use a standard instrumental variable approach for the count data. For the Shannon and Berger-Parker indices instrumental variable tobits are used. Finally, a third approach followed is taken from the evaluation literature. To evaluate the impact of HCS on diversity, a propensity score matching (PSM) procedure is used.[4] In PSM, the treatment group (HCS participants) is matched to a control group based on observable characteristics using a propensity score which is calculated using a probit on the probability of participation in HCS. In our case, we use non-participants in both the HCS and non-HCS communities as potential matches and a kernel-based matching procedure is used. After matching HCS participants with controls using this procedure, the difference between diversity in the treatment and control is determined to see how HCS influenced

[4] See Smith and Todd (2005) for a recent discussion of this technique.

diversity. The benefit of this procedure over the other methods is that the PSM procedure confines attention to a matched sub-sample where there is common support and unmatched observations are dropped if appropriate (Ravallion 2005). The range of methods employed to evaluate the impact of HCS on crop diversity is used to ensure an accurate assessment of impact. If the results are consistent across these different techniques, this provides greater support that the measure of impact is accurate.

Social capital and on-farm crop diversity

Table 3 presents the results for the analysis of on-farm crop diversity. Note that in all cases the regression is run using both actual HCS participation and predicted HCS participation following an instrumental variable approach. For the count variable, the least squares results are also shown and as can be seen are very similar to the Poisson. Recall that the count of the total number of crops is considered a measure of richness, the Shannon index expresses proportional abundance or evenness and the Berger-Parker index reflects the inverse of the relative abundance of the most widely grown crop by each household or the inverse of the degree of specialization into any one crop. The covariates included in the regressions represent the variables that are found to be determinants of diversity in equation (20) with the exception of the price variables. There are two reasons for excluding prices. First, many of the farmers in this study do not sell in the market and therefore there is no data available. Second, even if there was data available the reported price would not necessarily reflect the market price since the farm gate price would include transaction costs. Given the limited geographic area under which this study is conducted we assume that market prices of the relevant commodities do not vary and thus do not include prices in the analysis. We proceed by examining each of the variables included in the regressions and discussing how they influence diversity as measured by each of these indicators. Note in all cases, the marginal effect of the variables calculated at the sample mean is reported rather than the coefficient. This allows for better comparison of the different regressions. Given that results for the variables other than HCS participation tend not to vary substantially across the basic regression and instrumental variable model the results of each specification are not specifically discussed except in the case of HCS.

According to equation (20), the household endowment of labor, $\bar{L}$, and land, $\bar{A}$, will influence the diversity outcome. The labor endowment is expected to be negatively related to diversity. A household with less labor resources and thus more binding labor constraint will be less able to spread labor over competing crop activities. The results do indicates a negative relationship between a household's labor endowment and diversity but in no cases is this relationship statistically significant. The land endowment is expected to be positively related to diversity at least for these very small size land holdings. Recall that households on average have one-half a hectare of land (4 timmad) and greater land holdings are likely to be employed with additional crops. The results indicate a significant positive relationship for both the count variable and the Shannon index. For the Berger-Parker index, the results are positive but insignificant. This indicates that farmers are using additional land to plant more crops and put more area into those crops but that the principal crop they produce still tends to dominate the production area.

The next set of variables control for household characteristics (z^h). The age of the household head indicates both the experience of the household in agriculture as well as the life cycle stage of the household. While positive in all cases, the age of the household head does not appear to significantly influence the number of crops produced but does affect the area of production as indicated by the significant results for both the Shannon and Berger-Parker indices. Older household heads appear to plant a more equal share of land to each crop. The results for adult education suggest that education leads to greater diversity as measured by the count variable and Shannon index. More educated households, possibly because they have better information, tend to plant more crops and have them more evenly planted. Finally, the dependency ratio measures the ratio of dependents to the number of adult laborers. Given that many households produce for home consumption this characteristics of the household may influence crop choice. The results suggest that the ratio of dependents is negatively associated with evenness. This may be because households with more dependents feel compelled to produce more of certain food crops although based on the results from the Berger-Parker index this is not the primary crop. As noted, oxen ownership is a key indicator of household wealth given the high level of poverty in the study region. The results indicate that wealthier farmers tend to plant a greater number of crops which may because they have a greater capacity to access seeds for these crops as well as draft power to cultivate different crops.

Measures of the production characteristics (z^p) of the farm are indicated by agroecological variables. The expectation is that greater variability in agroecology leads to greater diversity. The results provide strong support for this hypothesis and indicate that having plots with different slopes and different soil textures positively influence diversity. Having plots with different colors, however, does not appear to influence diversity. Although PAs are at a range of altitudes this does not appear to influence diversity in any way.

Characteristics of the market (z^m) and conditions in the nonagricultural market, (z^y) are the next set of variables to consider. When markets for credit are limited the expectation is that this limits the ability of household to access seed of certain crops. Thus a negative relationship between credit constraints and diversity is expected. The results provide strong support for this hypothesis with negative and statistically significant results for all regressions. Accessibility by car and distance to the near city are both attempts to measure transaction costs with inaccessible and more distant communities facing higher transaction costs than accessible and less remote communities. Higher transaction costs can impact diversity both through output markets and seed markets. High transaction markets limit the opportunity to buy and sell output and thus the household will produce based on their own requirements rather market considerations. The expectation is this would lead to greater diversity if the market limits the range of crops households produce. On the input side, higher transaction costs may limit the ability of households to access seed and thus certain crops thereby limiting diversity. The results of the analysis indicate a negative relationship between accessibility and distance to market and diversity. These relationships are significant for both the Shannon and Berger-Parker indices indicating that areas accessible by car have lower diversity and those that are further away from the city have lower diversity. The negative sign on distance to market indicating that high transaction costs limit crop choice and thus, being Hararghe largely a subsistence farming area, our sample farmers' decisions are mainly driven by input side conditions. Finally, the anticipated impact of participation in non-farm activity by a household member on diversity depends largely on the motivation for participation in such activities. If participation is primarily done with the intent of relaxing liquidity constraints, it may enhance diversity by allowing households to purchase inputs and seed. If it is done as an alternative to agricultural production and thus takes away labor from crop production it may lead to lower diversity. The results indicate that it is positively and significantly related to diversity suggesting it helps overcome liquidity constraints.

Overall the results indicate that responding to agro-ecological heterogeneity and market opportunities may be more important drivers of crop diversification than risk management. We would expect to find a negative relationship between crop diversification and other means of risk coping if indeed they are substitutes. The primary means of coping with risk in the Ethiopian countryside is sales of livestock and thus oxen holdings represent insurance as well as draft power. Other risk coping mechanisms are diversification into non-farm income-generating activities, which is also found to have a consistently positive relationship with all three measures of crop diversity.

As can be seen in the table, the social capital variables (z^s) that measure both linking and bonding social capital are significant in all regressions across all specifications. As expected, the HCS variable is positive for all the measures of diversity indicating that the program increases both the number of crops and leads to a more even share of area to each crop. For the instrumental variable approach four variables are used that are considered exogenous to diversity but matter to placement: frequency of PA meetings, whether the community received emergency relief in the last 10 years, the PA level share of wheat produced and a poverty index. The first two variables are taken from the community survey and reflect communities that are well-organized and previous experience in receiving outside assistance. The third community variable reflects HCS selection of communities in which wheat was important. Finally, the poverty index is used to control for any selection bias towards wealthier or poorer farmers in the program. Although testing the exclusion restriction is not possible, all of the instruments are significant in the participation equation and none significant when included in any of the diversity regressions. Looking at the results for the instrumental variable specification, we see that in all cases the marginal effect of HCS is slightly higher than in the base specification. This suggests that these estimates were a downward biased estimate of the effect of HCS on diversity and that HCS has even a greater impact than initially observed. Along with HCS, affiliation with other organizations also has a significant and positive effect on all measures of diversity. The results strongly suggest that linking social capital enhances crop diversity in the context of very poor agricultural producers. In contrast, the number of associations the household is affiliated with – a measure of bonding social capital is negative and strongly significant for all measures. The results suggest that bonding social capital limits diversity in these contexts.

As noted in the previous section, to confirm our results for the HCS participation variables a matching procedure is used using a kernel based matching procedure.[5] Table 4 presents these results. Before discussing the results it is worth noting that as the first step of the matching procedure a propensity score is determined for participants and non-participants in order to match the two sets of households. This process also allows a comparison of whether the households are similar in their observable characteristics; that is, whether there is common support. Note that no households are trimmed from the sample and that the

[5] Note that matching is done using a Gaussian kernel. Tests using alternative kernel estimates as well as using nearest neighbor matching gave results similar to those presented in Table 4.

propensity scores for participants and non-participants clearly overlap. This suggests that there is common support implying that participants and non-participants are similar and that the design of the survey was relatively successful at replicating an experimental design. Looking to the results in Table 4, the results indicate a clear positive relationship between HCS participation and the diversity measures although the magnitude of the results for the Shannon index and Berger-Parker index are lower and not significant in the case of the Berger-Parker index. The actual impact is closer to the marginal effects found in the basic regression raising some uncertainty of the results for the instrumental variable regression. Given this result, it is difficult to draw a clear conclusion about the magnitude of the impact of HCS on diversity but it does suggest there is clearly a positive and substantial impact of HCS on the number of crops planted.

Returning to Table 3, note that the levels of diversity in woreda of Dire Dawa are significantly lower than for the base category Chiro. Wheat production is much lower in Dire Dawa than in the other regions and there is some concern that this may be somehow influencing the results. Rerunning the model with only the other two woredas (Chiro and Meta) leads to the same results as presented above. There is also a concern that some variables may be capturing differences across PAs that are not controlled for in the regressions. As an additional test of the results the regressions were run using PA-level fixed effects (excluding the PA level data.) Again, the results remained fundamentally the same suggesting this as not a problem.

Conclusions

A number of international treaties related to crop genetic diversity require signatories to adopt policies that will promote the sustainable utilization of plant genetic resources. While a range of policies is possible, one set of likely policies in poorer areas such as the study area of Ethiopia is to provide farmers with access to seeds of new crops and varieties using both the formal and informal seed sectors. There is some concern that such a policy while improving farmer welfare might lead farmers to specialize in their agricultural production and thus lead to a reduction in crop diversity. In this study, we explore the possibility that farmers participating in organizations with links external to the community, e.g. linking social capital, are more likely to have reduced levels of crop diversification. The study is conducted in an area of Ethiopia where inter-specific diversity is significant and that diversity includes crops that are of important in terms of their genetic value since it is a center of origin or diversity for these crops. The results indicate that linking social capital does not lead to a decline in crop diversification but actually increases it in these particular contexts. The results suggests that interventions by formal organizations need not lead to reduction in inter-specific diversity and may in fact enhance it and bring about sustainable utilization. However changes in inter-specific diversity are likely to also have impacts on infra-specific diversity and these are not well understood. Future research is needed to assess this relationship.

Our results indicate that the access to seeds and information is a strong determinant of household's capacity to diversify their crop production, and that social capital has a critical role in the household's access. The impact of social capital on the household's utilization of crop genetic resources can occur through changes in the household demand for crop diversity by improving information about market opportunities and/or the supply of seeds needed to diversify. It is not surprising that households with links to organizations that span community and national boundaries have better access to information and seeds. It is surprising that households with strong social links within a community are less likely to be diversified, and that the effect is quite strong and significant. One possible explanation is the possible tradeoffs between infra and inter specific diversity; if links within local communities are more likely to lead to diversification within crops then the demand for diversification between crops may be lessened. The result may also be tied to the characteristics of the households which are associated with each type of social capital. The degree of access farmers have to linking social capital is likely to be restricted, and factors such as wealth and education important in acquiring this type of capital. The opposite appears to be true for bonding social capital which is widely accessible and built on principles of mutual aid and generosity. Our results indicate that liquidity constraints are a barrier to crop diversification and thus to poorer producers and this may be an effect that is expressed in the negative relationship between bonding social capital and diversification.

Policy-makers interested in promoting the sustainable utilization of crop genetic resources need to consider not only seed supply and inclusion of the informal sector into seed programs, but also the role of social capital in the effectiveness of measures to improve the flow of seeds and information to farmers. Efforts aimed at improving farmers' ability to accumulate linking social capital are clearly an important part of a strategy to improve access to crop genetic resources. It is also important to consider the policy implications of the negative relationship between bonding social capital and crop diversity. The results suggests that policies that seek to promote sustainable utilization should be wary of only working to promote greater grassroots organization since it may not support crop diversity.

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Table 1: Household characteristics

Number of household = 699

Category	*Variable*	*All households*
Labor endowment	Household labor	3.4
Land endowment	Land access (timmad)	4.04
Household characteristics	Age of head (years)	39.7
	Average adult education (years)	1.15
	Dependency ratio	1.24
	Oxen owned	0.41
Production constraints	No. plots with different slope	0.42
	No. plots with different colored soil	0.48
	No. plots with different texture	0.46
	Altitude of PA (meters)	2056
	Credit constrained	26.2%
Market characteristics	Community accessible by car	67.1%
	Distance to closest city (km)	102.5
Nonfarm market	Participation in non-farm activity	50.8%
Social capital	Participation in HCS	51.6%
	No. organizational affiliations	0.48
	No. memberships in associations	2.03
Woreda	Dire Dawa	13.7%
	Meta	52.4%

Table 2: Diversity measures

Number of household = 699

Diversity measure	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Count	2.73	1.25	1	7
Shannon index	0.79	0.47	0.00	1.79
Berger-Parker index	1.92	0.74	1.00	4.53

Table 3: Factors influencing crop diversity

Number of household = 699

	Count						***Shannon index***				***Berger-Parker index***			
	Poisson		*OLS*		*IV*		*Tobit*		*IV Tobit*		*Tobit*		*IV Tobit*	
Variable	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*
Household labor	-0.019	0.54	-0.016	0.64	-0.017	0.62	-0.015	0.29	-0.016	0.28	-0.022	0.35	-0.024	0.44
Land access	**0.041**	**0.01**	**0.049**	**0.01**	**0.041**	**0.04**	**0.018**	**0.01**	**0.013**	**0.07**	0.018	0.12	0.018	0.24
Age of head	0.006	0.11	0.005	0.17	0.005	0.16	**0.004**	**0.02**	**0.004**	**0.02**	**0.006**	**0.01**	**0.008**	**0.02**
Adult education	**0.058**	**0.02**	**0.070**	**0.02**	**0.065**	**0.03**	0.010	0.39	0.008	0.53	0.020	0.30	-0.007	0.80
Dependency ratio	**-0.091**	**0.09**	-0.067	0.18	-0.069	0.17	**-0.053**	**0.03**	**-0.055**	**0.02**	-0.022	0.61	-0.073	0.19
Oxen owned	**0.110**	**0.07**	**0.151**	**0.03**	**0.162**	**0.03**	0.045	0.12	**0.051**	**0.08**	0.060	0.23	0.082	0.21
Plots-slope	**0.198**	**0.02**	**0.199**	**0.05**	**0.198**	**0.06**	**0.083**	**0.02**	**0.082**	**0.02**	0.104	0.11	**0.145**	**0.07**
Plots-colored soil	0.025	0.77	0.020	0.85	-0.015	0.89	0.031	0.43	0.011	0.78	0.063	0.37	0.072	0.42
Plots-texture	**0.385**	**0.00**	**0.463**	**0.00**	**0.479**	**0.00**	**0.123**	**0.00**	**0.132**	**0.00**	**0.133**	**0.03**	**0.181**	**0.02**
Altitude	0.000	0.45	0.000	0.45	0.000	0.89	0.000	0.43	0.000	0.78	0.000	0.75	0.000	0.70
Credit constrained	**-0.206**	**0.02**	**-0.193**	**0.03**	-0.141	0.16	**-0.117**	**0.01**	**-0.089**	**0.05**	**-0.190**	**0.00**	**-0.222**	**0.03**
Accessible by car	-0.128	0.14	-0.155	0.11	**-0.166**	**0.09**	**-0.078**	**0.05**	**-0.084**	**0.04**	**-0.129**	**0.06**	**-0.152**	**0.09**
Distance to city	**-0.002**	**0.10**	-0.002	0.11	-0.002	0.21	**-0.002**	**0.01**	**-0.001**	**0.04**	**-0.003**	**0.00**	**-0.004**	**0.01**
Non-farm activity	**0.173**	**0.02**	**0.183**	**0.02**	**0.190**	**0.02**	**0.082**	**0.02**	**0.086**	**0.01**	**0.129**	**0.03**	**0.170**	**0.03**
Participation in HCS	**0.204**	**0.01**	**0.207**	**0.02**	**0.501**	**0.05**	**0.114**	**0.00**	**0.276**	**0.01**	**0.159**	**0.01**	**0.554**	**0.03**
Organizations	**0.170**	**0.02**	**0.148**	**0.05**	**0.159**	**0.04**	**0.118**	**0.00**	**0.124**	**0.00**	**0.128**	**0.02**	**0.239**	**0.00**
Associations	**-0.158**	**0.00**	**-0.156**	**0.00**	**-0.148**	**0.00**	**-0.073**	**0.00**	**-0.069**	**0.00**	**-0.115**	**0.00**	**-0.135**	**0.00**
Dire Dawa	**-1.249**	**0.00**	**-1.240**	**0.00**	**-1.229**	**0.00**	**-0.863**	**0.00**	**-0.856**	**0.00**	**-1.495**	**0.00**	**-2.052**	**0.00**
Meta	-0.309	0.19	-0.257	0.31	-0.142	0.60	-0.219	0.05	-0.156	0.20	-0.419	0.02	-0.470	0.07

Notes: In all cases, constants were included in regressions but are not reported. In all cases, robust standard errors were calcuated. Marginal effects are calculated at the mean and for censored regressions are for the latent variable. Instruments used for IV regressions are a poverty index, frequency of PA meetings, whether the community received emergency relief in the past, PA share of production of wheat, and whether sorghum seed was avaiable at the fair. Bold indicates signficance with at least 90% confidence.

Table 4: Verifying the effects of HCS using propensity score matching

Number of household = 699

	Count		***Shannon index***		***Berger-Parker index***	
	Mean diff	*P>|z|*	*Mean diff*	*P>|z|*	*Mean diff*	*P>|z|*
HCS impact on diversity	**0.231**	**0.02**	**0.084**	**0.01**	0.068	0.27

Notes: Standard errors are determined through bootstrapping and are used to calculate p-values.

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