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Full Length Research Paper

Costing on-farm conservation of crop diversity: The case of sorghum and wheat in Ethiopia and implications for policy

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The purpose of the paper is to estimate on-farm conservation costs based on household-level financial opportunity costs which, in turn, are estimated using sorghum and wheat household survey data from Ethiopia. The results suggest that opportunity costs need to be responsive to agricultural development opportunities, crop types and farmers' characteristics which will all affect the national level conservation costs. Farmers have to be contextually targeted (for on-farm conservation) and treated based on their attribute profiles. Different levels and types of compensation schemes might be required for different groups. Institutionalizing on-farm conservation and optimizing costs calls for fulfilling farmers' expectations based on the opportunity costs they forego.

Key words: On-farm conservation, crop diversity, opportunity cost, cost, sorghum, wheat, Ethiopia.

INTRODUCTION

Farmers are predominantly conservation agents for most indigenous crop varieties in developing countries. They always retain some seed stock for security reasons even during hard times. For instance, Ethiopian farmers had to bury some indigenous seeds covered in plastic even when they had to migrate due to drought (Worede, 1988). By growing traditional varieties of crops for private benefit reasons, farmers contribute to society. This is sometimes coined as '*de facto* conservation' (Meng, 1997). It is *de facto* because farmers are neither paid for it nor do they do it for conservation sake. It is the un-intended outcome of their attempt to address their household concerns.

However, farmers maintain traditional varieties only to the extent that the varieties generate private benefits, address household concerns and support their livelihoods. For this reason, there will be crop varieties not of private interest to any farmer. Such varieties will, consequently, be marginalized and lost. This makes farmers' contribution sub-optimal from the point of view of society (Maier and Shobayashi, 2001; Wale, 2004). Farmers' private contribution will, therefore, not eliminate the need to create government-sponsored biodiversity conservation initiatives (Rubino, 2000).

Access to markets, technologies and production methods that suppress biotic and abiotic stresses reduce farmers' demand for multiple traditional varieties of crops. Such tradeoffs and inadequacy of *de facto* conservation makes it imperative for public organisations to engage in conservation activities. One of the most plausible conservation strategies is on-farm conservation i.e. utilization of indigenous varieties of crops on farmers' fields (Wells, 1998). Institutionalized on-farm conservation involves costs about which decision makers have to be informed to mobilize institutions and resources. To illustrate one means of arriving at national cost of on-farm conservation, this paper scales-up household level opportunity cost estimates.

Regarding the structure of the paper, the study highlights the features of on-farm conservation. This is followed by a discussion on the importance of studying costs of on-farm conservation and the role of opportunity costs. Subsequently, the research methodology and the data utilized are discussed herewith. Finally, having presented and discussed the results, the paper concludes highlighting the implications for on-farm conservation policy.

ON-FARM CONSERVATION OF CROP DIVERSITY

Given that stress factors (global warming, land degradation, desertification and agro-ecological imbalance) are ever increasing, managing a portfolio of crop varieties has emerged to be important than ever before. To maintain traditional varieties of crops, decision makers can follow any combination of *ex-* and *in-situ* strategies. For technical reasons, it is impractical to conserve all potentially useful genetic materials *ex situ* (Hawtin and Hodgkin, 1997) and they are often considered as complementary.

In recent times, *in-situ* conservation is attracting considerable attention because it maintains not only the indigenous crop varieties but also the evolutionary processes and farmers' indigenous knowledge (Oldfield and Alcorn, 1987). Moreover, *in-situ* is participatory and it gives a chance to link conservation with use and farmers' livelihoods. In satisfying all these desirable features, on-farm conservation, a sub-set of *in-situ*, is one of the most plausible conservation strategies that offers the opportunity to decision makers to harmonize policy decisions with farmers' needs and concerns. However, one major practical challenge at the policy level is that on-farm conservation is often dismissed and seen as promoting continued rural poverty (Brush, 1992). This perception is, however, misleading because, as an institution, on-farm conservation does not mean growing local varieties on all farmers' fields (Wale, 2004) and it does not reject modern agriculture (Bardsley and Thomas, 2005). It only aims to ensure continuous survival of traditional varieties of crops amid rural development activities (e.g. use of modern varieties). If selected farmers (on-farm conservation partners) are targeted, the size of the national level opportunity cost is a small proportion of the total national benefits of maintaining traditional crop varieties. Thus, it would be unproductive to rule out either the products of modern breeding or products of farmers' indigenous knowledge-based breeding (Tripp, 1996). The daunting task is to design strategies that can enhance agricultural productivity and maintain agro-biodiversity. Development interventions (e.g. seed policies and technology adoption) cannot ignore agro-biodiversity as agricultural productivity and genetic resources issues are not sequential (Wale et al., 2009). In what follows, the paper explains the importance of estimating the cost of on-farm conservation.

ESTIMATING COSTS OF ON-FARM CONSERVATION: WHY?

There is a need to develop simple models for estimating the total cost of conservation (Copeland et al., 2007). There are various reasons for research and development practitioners to look into costs of conservation. Estimating costs is an input to generate the required resources from local and international sources. As international public goods, the benefits of genetic diversity go beyond national boundaries (Perrings, 1995). Hence, the estimation of the national costs of conservation can inform the international community (such as the Global Crop Diversity Trust) to contribute to required funds (Saxena et al., 2003).

The other reason is to optimize the costs whenever possible. If conservation strategies can be harmonized and integrated, conservation agents can exploit economies of scale benefits by consolidating fragmented conservation activities (Koo et al., 2004a). The cost information is also an input for the allocation of scarce resources among competing natural resources and conservation methods (Saxena et al., 2003). Estimating costs can also be used to set fees that users of crop genetic resources have to pay to providers (e.g. local farmers). For instance, gene bank costing is useful to set fees for distribution services (Koo et al., 2004b). The cost information is also the basis for designing equitable access and benefit sharing laws and negotiations.

Since the 1990's, research on costs of agro-biodiversity conservation has attracted considerable attention (Jarret and Florkowski, 1990; Burstin et al., 1997; Epperson et al., 1997; Virchow, 1999; Pardey et al., 1999; Dyer Leal, 2002; Koo, et al., 2004a; Zander et al., 2009). However, most of these studies are just for *ex-situ* per se or aggregated for all types of conservation activities. There is hardly any research done on on-farm conservation costs of crop diversity, which is partly because of lack of experience and information about on-farm conservation. Only recently have Zander et al. (2009) quantitatively estimated thethe costs of on-farm conservation of Borana cattle breeds in Kenya and Ethiopia. The present paper aims to contribute towards this gap. The opportunity cost of on-farm conservation, to which we now turn, is the conceptual basis of the cost estimation strategy.

THE ROLE OF OPPORTUNITY COSTS FOR ON-FARM CONSERVATION

One can identify three types of cost concepts relevant for on-farm conservation[1]: transaction costs[2],, opportunity costs, and financial / accounting costs. The opportunity costs of conservation refer to benefits foregone from alternative uses of the land and other resources used for conservation (Aretino et al., 2001). The major thrust of computing financial opportunity cost estimates is that targeted farmers will be contracted to maintain certain

[1] The three cost concepts are not necessarily mutually exclusive.

[2] For on-farm conservation, these costs might include costs of conducting on - ground activities such as negotiation, identification / targeting and monitoring.

crop varieties and be compensated the income they forego. Rewarding farmers for their contribution to genetic conservation is an accepted practice in Europe and North America (Swaminathan, 1996). Countries like Nepal are also adopting it. Such schemes should also be extended to farm families of biodiversity-rich developing countries to make up for the foregone net income (Chistensen, 1987; Swaminathan, 1996). Farmers' rights include the recognition of their rights to receive compensation for their contribution (Hardon, 1996). Although their contribution is recognized, there is as yet no agreed mechanism for accomplishing compensation (Swaminathan, 1996).

The cost of on-farm conservation program can be expressed as the cost necessary to raise the comparative advantage of local crop varieties to be conserved above that of competing species, or economic activities (FAO, 2007). The incentive has to be large enough to persuade targeted farmers to grow traditional varieties. The opportunity cost estimates are meant to indicate the magnitude of the required incentives because the value of the contract and the level of compensation depend on the opportunity costs. A similar argument was made by Zander et al. (2009).

RESEARCH METHODOLOGY

How are financial opportunity costs computed?

Broadly, any loss (monetary or non-monetary) faced by farmers when they switch from varieties in use to varieties worth maintaining (for policy purpose) is the opportunity cost. Taking improved varieties as the best alternative use of farmers' land, the financial opportunity cost is defined as:

$$\text{Opportunity Cost} = (GMPH_{IVs} - GMPH_{FVs}) \quad (1)$$

Where $GMPH_{IVs}$ and $GMPH_{FVs}$ refer to gross margin per hectare in Birr (the Ethiopian local currency) of the improved and local variety (ies), respectively.

To estimate opportunity costs, Gross Margins (GMs) are computed on a per hectare basis as:

Gross Revenue from the respective crops (Birr/ha) - Costs of variable inputs (Birr/ha)

Non-purchased inputs, mainly labor and compost, are imputed. However, the simple gross margin difference is not the result only of farmers' failure to use improved seeds[3]. There are also other household and environment-related contextual factors which will affect the gross margin differences. Due to non-random distribution of those non-variety factors and unobservable variables (such as farmers' indigenous management skills), selection bias could arise in such analysis (Heckman, 1979).

[3] This difference will reasonably capture the gross margin foregone only if we have farmers using both improved and local varieties side by side on similar quality plots which are very few in both data-sets.

Farmers who have a better comparative advantage with the use of improved seeds join the use of improved varieties and thus will benefit more from it than would be the case for a randomly selected farmer. Sample selection could also arise due to differential treatment of the Agricultural Extension Department targeting the so-called 'high potential areas or farmers' in the dissemination of improved seeds and other inputs. If the users of improved seeds have better access to agricultural services, this could make them more productive than a randomly selected farmer. The models used (matching, instrumental variable regression and treatment regression) to generate the opportunity cost estimates are meant to address these selection problems (Wale, 2006; 2008). The value of the opportunity cost depends on the suitability of farmers' working environment to the production and marketing of products of improved and local seeds. If the environment happens to be more suitable to improved varieties, the opportunity cost will be higher. The choice of variables to explain opportunity costs is dictated by theory and previous studies (Birkhaeuser et al., 1991; Bindlish and Evenson, 1997; Ouédraogo, 2003).

Data

Sorghum and wheat are the crops used for empirical illustrations. For sorghum, the relative importance of the crop in the Ethiopian national economy (second to Tef), its rich genetic diversity (Teshome et al., 1999) and its endemic nature are the major reasons for taking this crop as an example. Wheat is one of the top four important food crops in the country (Gavian and Gemechu, 1996) and Ethiopia is the largest wheat producer in SSA, second only to South Africa. It is one of the crops introduced to Ethiopia from Southwest Asia (Wood, 1988). Introduced crops are interesting to maintain because most crops have not originated in the area of their importance. More importantly, the introduced wheat in Ethiopia is diverse, adapted to local conditions, and unique in its features (Tesfaye and Efrem, 1998).

The sorghum data come from a rural household survey conducted in Eastern Ethiopia. A total of 198 sorghum growing farmers were sampled and interviewed from July 2001 to March 2002. The data collection details for sorghum can be found in Wale (2004). For wheat, the fifth round of the nationally representative Ethiopian Rural Household Survey data (1999 / 2000) is used.

In both data-sets, we have two groups of farmers: users of traditional varieties and users of improved varieties. The input-output data are collected for each plot and the financial opportunity costs are computed for each farmer on per hectare basis.

RESULTS AND DISCUSSION

Household level opportunity cost estimates

To scale up on-farm opportunity cost estimates to the national level, the average opportunity cost estimates are reported in Table 1. The results of the various methods are reported to show the extent to which the estimates are sensitive to the choice of the estimation method. Depending on the method of estimation used, average opportunity cost for sorghum ranges from 108 to 538 Birr /ha ($13.5 to $67)[4]. The average opportunity cost for wheat ranges from 277 to 886 Birr / ha ($35 to $111).

[4] In July 2001, $ 1 ≈ 8 Birr.

Table 1. Farm household level opportunity cost estimates.

Method	Sorghum (Birr/Ha)	Wheat (Birr/Ha)
Simple OLS	168.2	435.4
Mean difference[a]	151	299
Matching	433.8	276.5
Instrumental variable regression	537.7	885.9
Treatment regression	107.8	341.3

Source: Wale (2006) for wheat and Wale (2008) for sorghum. [a] For sorghum, the mean difference is computed as gross margin difference considering users of both varieties side by side on similar quality plots. For wheat, due to lack of data of similar nature, different farmers (one group using improved and the other indigenous) on plots of the same quality are considered.

It has to be noted that these estimates hold only for the respective survey years, crops and household types. The estimates are aggregated and scaled up to the national level.

National level on-farm conservation cost estimates

In what follows, costs of on-farm conservation at the national level are estimated ex ante by aggregating the household level financial opportunity costs (Table 1) taking the land requirement information gathered from plant breeders. Having estimated household level conservation costs for livestock, Zander et al. (2009) have noted that the household level data can be used for costing an entire conservation program.

According to the information from plant breeders, a hectare of land with at least three replications is necessary to maintain a given crop landrace. Experiences from the Ethiopian pilot On-farm Conservation Projects also suggest that the optimum farm size for maintaining a population should be similar to the farm size the farmers usually allocate to the different crops (Demissie and Arega, 2000). For these reasons, a hectare of land with three replications is taken as the required land to maintain a landrace and implement on-farm conservation. This is used as a benchmark to scale up the opportunity cost estimates and compute national level on-farm conservation costs.

Few notes are in order before proceeding. Mostly, improved seeds and fertilizer are subsidized which artificially inflates opportunity cost estimates. Thus, the above opportunity cost. Thus, the opportunity cost estimates are inflated to the extent that improved seeds are subsidized. Following Zander et al. (2009), other financial costs involved in the negotiation, identification / targeting, and monitoring are taken to be 5% of the compensation costs. One last cautionary note is the possibility of aggregation issues that could call for further research, taking data that can account for agro-ecological, weather scenarios and other contextual differences across on-farm conservation sites. Last but not least, the estimates below are meant to illustrate the possible method of estimation. To be of practical use, the figures have to be updated considering current prices and costs.

National level on-farm conservation cost estimates for sorghum

Using the National level on-farm opportunity cost estimates, covering the opportunity cost of one landrace of sorghum would cost the government between 324 Birr ($41) and 1 614 Birr ($202) annually. A 5% increase would take these estimates to 340 Birr ($43) and 1 695 Birr ($212). If 100 landraces of sorghum have to be maintained at the national level, requiring three replications of 1 hectare each, annual opportunity cost compensation ranges from 32,020 Birr ($4 253) to 169,470 Birr ($21 184) per annum. If one is to use the matching results, maintaining one landrace of sorghum would cost 1,367 birr ($171). The annual compensation cost will then be 136,647 Birr ($17 081).

One of the attractive features of the opportunity cost approach is that, as the contract is to be concluded in advance not conditional on the yield outcome, it is in the interest of farmers to comply because they are getting their financial opportunity costs, which reflect their expectations and the required compensation. If the contract were based on the yield difference (between the improved variety that farmers would have grown and the traditional variety which they plant for on-farm conservation purposes) as it was done in Ethiopia through the UNDP/ GEF-supported project (Demissie and Arega 2000), there would be a moral hazard problem[5]. Moreover, yield differences are misleading because they do not account for input use differences between improved and local varieties.

[5] If farmers are given the contract based on yield difference, they will not have incentive to exert the required effort to get the best yield from their varieties as higher yield difference or lower yield from the traditional varieties would mean more compensation. This is what we call problem of moral hazard in this paper.

If decision makers want to rent farmers' land, land markets have to be consulted or opportunity cost of land needs to be computed (James et al., 2001) thus accounting for land quality differences. The opportunity cost of land can be estimated as the net-return perhectare from the most profitable crop on that land or using the informal land transactions (e.g. share cropping) made in rural areas. Farmers' willingness to accept for renting-out their land is still the other option. Auctions can also be used to reveal the opportunity cost.

National level on-farm conservation cost estimates for wheat

Maintaining the assumptions as in the case of sorghum, the cost of maintaining one landrace of wheat would range from 872 Birr ($109) to 2 791 Birr ($349) annually. If one is to use the treatment regression results, maintaining one landrace of wheat would cost 1 075 birr ($134). The total annual costs can be estimated similarly as is done for sorghum. Higher cost estimates for wheat imply that more commercial and rewarding crops cost more to maintain on-farm.

Are these costs affordable?

For practical purposes, one could ask: Are all these costs affordable? Are they worth paying? And who should pay? Globally, lack of understanding of the costs of agro-biodiversity conservation has contributed to the impression that global conservation strategies are unnecessarily expensive, when in fact they are within our means (James et al., 2001). They are small when compared to the scale of 'perverse' subsidies – the environmentally harmful payments already being made to support agricultural production, energy use and so on (James et al., 2001).

Due to their international public goods nature, once crop genetic resources are maintained, greater pay-offs can be realized by making these resources and their products accessible to all potential users at a lower extra cost. The more widely they are used, the higher the benefit-cost ratio due to economies of scale advantages. Comparing the public benefits of conserving traditional crop varieties with the aforementioned cost estimates would justify the investment. Given that most of the crops under cultivation in many parts of the world are introduced, maintenance of agro-biodiversity is of transnational concern and conservation in one area can produce pay-offs in another region (Srivastava et al., 1996). To support *in-situ* conservation, contributions can come from multinational companies, monopolies, and treasury (Bardsley and Thomas, 2005). It is possible to create public-private partnerships (Rubino, 2000).

CONCLUSIONS AND IMPLICATIONS FOR ON-FARM CONSERVATION POLICY

The cost estimates reported in the present paper illustrate the question of how on-farm conservation can be institutionalized by making up for farmers' financial opportunity costs. On-farm conservation costs have to respond to changes in opportunity costs temporally and spatially. The relevant factors affecting opportunity costs have to be entrenched. To be of use for policy, the figures will have to be adapted (crop- wise) and regularly updated as per input costs, output prices and genetic technology developments.

The cost estimates reveal that as the crop becomes more valuable (e.g. sorghum vs. wheat) in the market, the unit cost of maintaining its traditional varieties on-farm increases. Farmers facing higher opportunity costs have to be targeted because, though it will be costly, their farming systems are potentially more threatened in terms of potential replacement. Farmers facing lower opportunity costs have to also be targeted because they are more likely to comply and these farming systems are maintaining most of the remaining crop diversity. It is also possible to compensate farmers for their land and use the land to grow the identified traditional crop varieties.

If compensation turns out to be politically unattractive and difficult to exercise, the opportunity cost concept and the estimates are still relevant to design other arrangements (e.g. input subsidies, price premiums for the products of traditional crop varieties and commercialization of traditional varieties of crops etc.). When information on opportunity costs is not available, auctions or willingness to accept estimates can be used to know what farmers need to cooperate in on-farm conservation.

The opportunity costs are functions of agricultural development. As agriculture becomes more productive and commercialized, the compensation schemes have to be more attractive. Essentially, the schemes have to be responsive to new opportunities and developments that affect productivity and marketability of crop varieties (improved and local).

In designing the compensation schemes, farmers have to be grouped by their attribute profiles in such a way that different types and levels of compensation schemes can be designed for different groups. Some of the possible means of grouping are poverty, accessibility (to output markets, extension and inputs), resource endowment (land and labor), enterprise type (commercial cash crop versus subsistent food crop), and suitability of the natural environment to improved seeds.

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