



The economics of conserving agricultural biodiversity on-farm

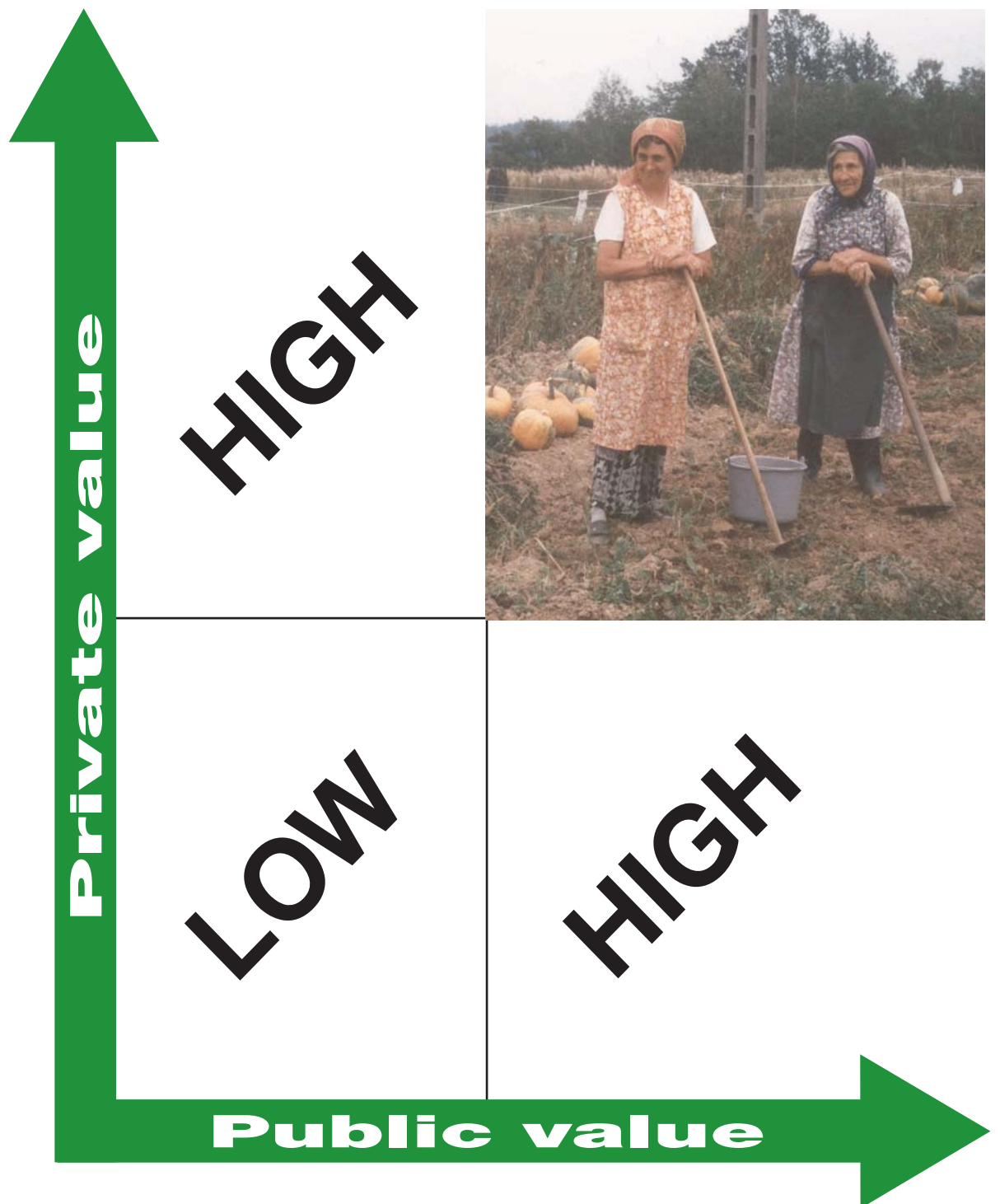
Proceedings of a Workshop hosted by the Institute for Agrobotany (IA), Hungary, and the International Plant Genetic Resources Institute (IPGRI), Italy. Gödöllo, Hungary, May 13–16, 2002

Melinda Smale, István Már and Devra I. Jarvis, editors



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IPGRI is a Future Harvest Centre supported by the Consultative Group on International Agricultural Research (CGIAR)



The economics of conserving agricultural biodiversity on-farm:

research methods developed from
IPGRI's global project 'Strengthening
the scientific basis of *in situ*
conservation of agricultural biodiversity'

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Citation:

Smale, Melinda, István Mar and Devra I. Jarvis, editors. 2002. The Economics of Conserving Agricultural Biodiversity on-Farm: Research methods developed from IPGRI's Global Project 'Strengthening the Scientific Basis of *In Situ* Conservation of Agricultural Biodiversity'. International Plant Genetic Resources Institute, Rome, Italy.

ISBN: 92-9043-544-5

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Acknowledgements

This work was carried out with the financial support from governments of Switzerland (Swiss Agency for Development and Cooperation—SDC), Germany (Bundesministerium für Wirtschaftliche und Entwicklung—BMZ), the Netherlands (Netherlands Ministry of Foreign Affairs Development Cooperation—DGIS), Canada (International Development Research Centre—IDRC), Hungary (Hungarian Ministry of Agriculture and Rural Development—FVM) and the European Union.

We owe special thanks to Evan Dennis and Annie Huie for their assistance in implementing the workshop, to Pablo Eyzaguirre for his support and guidance, and to the Institute for Agrobotany, Hungary for hosting the workshop.

I Definitions and context

Melinda Smale and Devra Jarvis

Agricultural biodiversity refers to the biological diversity found in crop and domesticated livestock and aquatic systems, as distinct from that of wild species of plants and animals. Supporting the maintenance of diversity on farms is one strategy for crop genetic diversity conservation. On-farm conservation is viewed as a complementary strategy to *ex situ* conservation strategies. Through on-farm conservation not only are materials conserved, but so also are the processes of evolution and adaptation of crops to their environment.

Public policy-makers and scientists have expressed renewed interest in the prospects for on-farm conservation of crop genetic resources in recent years, but understanding of the economic incentives for and mechanisms through which programmes might best be implemented remains sketchy. Working through national partners, the goal of IPGRI's Global Project, 'Strengthening the Scientific Basis of *In Situ* Conservation of Agricultural Biodiversity On-Farm' is to strengthen the scientific basis, institutional linkages and policies that support the role of farmers in conservation and use of crop genetic diversity through the application of sound theoretical principles in an interdisciplinary context. The current set of projects treats only crop biodiversity (livestock and aquatic biodiversity have not yet been included).

Sites were selected globally on the basis of their known importance as centres of origin or diversity for a crop and the willingness of national partners from formal and informal sectors to work together as teams with local farming communities. The earlier phases of the project resulted in formation of representative partnerships among national research and educational institutions, ministries of environment and agriculture, extension workers, non-government organizations and farming communities. Nesting of country case studies within a global framework is necessary in order that a unified, validated methodology framework emerge.

A primary task for those concerned with supporting maintenance of agrobiodiversity in general, and of crop diversity in particular, is to understand when, where and how this will happen, who will maintain the material and how those maintaining the material can benefit. The Global *In Situ* Conservation On-farm project has identified four aspects where information is needed to support farmers and local communities in crop genetic diversity conservation, management and use on-farm:

1. What is the extent and distribution of the genetic diversity maintained by farmers over space and over time?
2. What are the processes used to maintain the genetic diversity on-farm?
3. Who maintains genetic diversity within farming communities (men, women, young, old, rich, poor, certain ethnic groups)?
4. What factors (market, non-market, social, environmental) influence farmer decisions on maintaining diverse cultivars?

In the earlier phases of the project, research efforts focused on quantitatively answering the first three questions, with answers to the fourth question being descriptive and anecdotal in nature. This earlier research has provided a basic data set, focused on understanding the units of intraspecific crop diversity that farmers manage and the relationship of these units to genetic distinctiveness over space and time. The research has also begun to identify how these units are managed and maintained, and by whom.

Among the research efforts planned for the next phase of the Global Project is the design of interdisciplinary, applied economics research that builds on the groundwork laid in the initial phase. It is envisioned that this research will help quantify answers to the fourth

question and provide inputs to the knowledge necessary for supporting the maintenance of genetic diversity while economies develop. In May 2002, IPGRI convened the first economics meeting of the Global *In Situ* Conservation On-farm Project, hosted jointly by IPGRI, the Hungarian Institute for Agrobotany and the Institute for Environmental Management, St. Stephen's University (Szent István University), in Gödöllő, Hungary. The workshop, entitled 'The Economics of Conserving Crop Biodiversity on Farms: Methods, Case studies, and Future Directions for IPGRI's Global *In Situ* Project' brought together applied economics researchers representing different fields of inquiry and various countries. IPGRI's economics research on the Global Project is jointly undertaken with the International Food Policy Research Institute (IFPRI).

As a social science discipline, economics is the study of the choices individuals and societies make about the allocation of resources available to them. For our purposes, we define on farm conservation as *the choice by farmers* to continue cultivating diverse crops in their communities, in the agroecosystems where the crops have evolved historically through processes of human and natural selection. Economics research about on-farm conservation focuses on the varieties and variety attributes that farmers recognize in their fields rather than the genetics of the crop or the crop's performance in a controlled environment.

The initial objective of the economics research undertaken by IPGRI and IFPRI is to document and analyse in a systematic (as opposed to anecdotal) way the economic factors that encourage or discourage farmers from choosing to grow diverse crops, while controlling for biophysical factors. There are several fairly demanding requirements for satisfying this objective. Clearly, a sound empirical analysis is based on tests of hypotheses using representative data sets collected for that purpose. In addition, if implications are to be derived for crop genetic resource conservation, these choices must be linked in a meaningful way to genetic analyses of the crop in the relevant production environment. Such data sets must therefore have been developed in cooperation with knowledgeable biological scientists. To better comprehend the feasibility and relative costs and benefits of conserving diversity on farms as economies develop, we also need to apply a common conceptual framework that can be applied across farming systems, crop reproduction systems, and agricultural economies at different stages of development.

The goal of the economics research will be to identify solutions, and the policies that support them, that promote the maintenance of diversity even as economies develop. This will be done through enhanced utilization of genetic resources by key actors—farmers who are consumers as well as breeders in their own right, professional plant breeders and scientists, and genebank managers. A winning solution is by definition one which meets a given conservation objective at least cost to society. To begin to identify this set of solutions for on-farm conservation, we need the empirical basis that provides the basis for comparative analyses of policy options.

Three fields of economic inquiry, each of which makes its own contribution to this applied economics research process, were represented and discussed at the workshop. The first field is the theory of decision-making by the farm household, applied with econometric analysis. This microlevel research investigates the determinants of farmers' choices and links their choices to crop biodiversity measured at a local (farm and community) scale. The second involves econometric applications of methods for valuing environmental goods such as crop biodiversity, whose public value is not captured in market prices. The third field, institutional economics, employs various approaches in order to comprehend the organizational, rather than the physical, environment within which farmers and other actors involved in biodiversity conservation make their decisions.

This brief report presents a summary of the methods papers presented followed by reports of ongoing and planned studies in India, Nepal, Mexico, Burkina Faso, Morocco and Hungary. Economist partners from Peru also attended. It is hoped that further development of these methods and their applications will allow empirically based comparisons that will

inform policies in a way that is not currently possible. The proceedings updates the brief section on economics analysis included in the training manual by Jarvis *et al.* (2000), and also presents some previews of ongoing research.

II Economics methods

The conceptual framework for economics research in IPGRI's Global *In Situ* Conservation On-farm Project¹*Melinda Smale***Introduction**

Economics is the study of decision-making and the allocation of scarce resources. Applied economics research in the context of IPGRI's global *in situ* conservation on-farm project focuses on how farmers' decisions affect the stock of genetic resources that continue to evolve *in situ*, and the relationship of these outcomes to what is considered optimal from the perspective of society as a whole.

The diversity within and among crop varieties that is conferred by genes can be expressed and measured in many ways. Only some of these are visible to farmers in the traits of the crop varieties they grow. Although conservationists, plant breeders and society as a whole may be concerned about the genetic diversity that can be identified in laboratories, it is the choices that farmers make based on what they observe that will determine whether diverse crop genetic resources continue to be maintained on farms.

There are several essential reasons why the diversity of crop genetic resources grown on farms is of economic importance. The first relates to aggregate crop productivity. The pattern of crop varieties and the genes they carry determines annual yields and the crop's vulnerability to disease and abiotic stress. Yield growth and yield instability have economic value, and maintaining diversity on farms may entail efficiency trade-offs in the short term. A second concerns options for the future, which have economic value in the longer term. Crop varieties are not like endangered species, but if a farmer ceases to plant the seed of a traditional variety or abandons a breeding practice, the variety may be 'lost' to future generations. Even if this traditional variety were sampled for storage in a genebank, it would not serve as a perfect substitute because accessions sampled from that variety and regenerated under *ex situ* conditions tend to evolve differently.

A third reason is related to social equity. Many farmers in the developing world depend on the diversity of the varieties and crops they grow for their own consumption and well-being—particularly in production environments areas that are agroecologically heterogeneous or risky, where a commercial seed market has not developed because there are few opportunities for profit, or where economic opportunities are limited aside from labour migration. In areas where crops have evolved over centuries, crop diversity is part of the cultural endowment. By contrast, in some advanced economies, there are niche markets for scarce traditional varieties and consumers may be willing to pay to conserve certain attributes of agriculture, such as its biodiversity. In both the European Commission's revised common agricultural policy (CAP) and in the current U.S. farm bill, references are made to the multiple functions served by agriculture, including the provision of social amenities.

The next section summarizes how economists perceive the policy problem presented by on-farm conservation of agricultural biodiversity. Economics research methods that can be used to address the information needs of policy-makers are then described in general terms, followed by a research plan. Methods are addressed more fully in the presentations of Van Dusen, Birol and Smale in this section.

¹ Several of the points presented here, and the accompanying figures, are explored in greater detail in Smale M, Bellon MR, Jarvis D and Sthapit B. 2002. Economic concepts for designing policies to conserve crop genetic resources on farms. *Genetic Resources and Crop Evolution* (in press).

Economic theory predicts that, to the extent a good is public rather than private, and is a 'good' (desirable) rather than a 'bad' (such as pollution), it will be underproduced. We would therefore predict that farmers as a group will choose to maintain fewer of the diverse crop genetic resources in their fields than society might find optimal. In that case, institutional structures are needed to compensate for the inability of markets to provide sufficient incentives for farmers. These institutional structures are both culture- and scale-specific (community, region, world). The International Undertaking and the Convention on Biological Diversity are elements of global institutional structures. As one consequence of this specificity, the extent of public investment and the policy mechanism needed to narrow the divergence between what individuals and societies perceive as optimal also varies. Since public funds are those generated by taxes or donations, economists generally believe that these forms of public interventions are more 'costly' to society than market-based incentives. However, public expenditures may be justified if the magnitude of the benefits that accrue to society outweighs the cost. The cost-benefit analysis that would be needed to assess policy options quantitatively presents some particular challenges in the case of crop biodiversity (see Birol, Chapter 3).

Research needs for informing policy

Applied economists need to work closely with biological scientists in order to generate the information required to design policies for conserving agricultural biodiversity on farms.

The following research steps are proposed given a set of candidate conservation sites located within national boundaries:

1. Find 'least cost' candidate sites for on-farm conservation of agricultural biodiversity.
2. Articulate the role of agricultural biodiversity conservation in the policy priorities expressed by government decision-makers in the nations where these sites are located.
3. Identify the circumstances in which maintaining agricultural biodiversity on farms is consistent with economic development ('win-win' policy options) across locations.
4. Assess the costs and benefits of policy options to support on-farm conservation of agricultural biodiversity in these locations, by applying suitable valuation methods.

First, we need to know in which locations conserving agricultural biodiversity on farms costs least in terms of public investments that compete for scarce funds. In principle, this will occur in locations where both the public value of the resources is believed to be greatest (as in a biodiversity 'hotspot') and where the private net benefits farmers earn (monetary and non-monetary) through maintaining diverse crop genetic resources is high. Costs include the opportunity cost of growing these resources. Our premise is that it does not make economic sense to trade productivity for conservation or thwart the opportunities that farmers may have to *choose* to grow modern varieties rather than traditional varieties. Application of theoretical models of farm household decision-making in candidate sites can be used to develop a profile of least-cost sites and farmers to target (Figure 2).

Once a set of candidate locations has been identified, the role of agricultural biodiversity conservation in national development priorities must be examined. For example, in poor countries, crop genetic diversity and species diversity may play a key role in food security and the livelihood strategies of the rural or peri-urban poor. If so, it must be demonstrated systematically rather than anecdotally. For most poor countries, it will be necessary to find ways to conserve agricultural biodiversity that are consistent with economic development or equity goals. Richer countries may be willing to pay farmers to conserve agricultural biodiversity because it provides a means of conserving cultural or other lifestyle amenities at the same time that it supports farmers. In that case, exactly which set of crop varieties, seed selection or seed management practices to conserve and how conservation fits into overall environmental policy must be fully articulated.

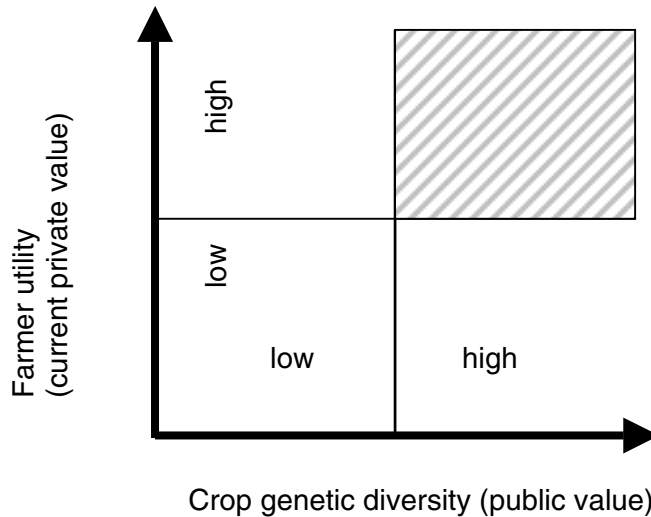


Figure 2. Least-cost sites for on-farm conservation. Adapted from Smale and Bellon 1999, p. 395.

In general, research should aim to identify policies that favour conservation without impeding the progress of economic development. The world's poor cannot be asked to shoulder the burden of conserving agricultural biodiversity unless they can benefit by doing so.

Once these elements are understood in each specific context, feasible policy interventions can be proposed. These options can then be assessed *ex ante* using cost–benefit criteria based on environmental valuation methods.

Research plan

The economics research initiated through IPGRI's global project has begun to address these questions. First, the global project sites were selected by national and international scientists and are located in centres of origin, primary or secondary centres of crop diversity. Second, the project is implemented by national partners, who are scientists already engaged in research related to on-farm conservation. In many instances they have begun a dialogue with national policy-makers. Third, the sites represent a range of crop species, agroecosystems, types of agricultural economy, and national income levels.

Only a common methodological framework across the study sites enables the generalization of results from case studies. Workshop participants identified three fields of economic inquiry that provide useful tools for this framework. The first is the microeconomic theory of the farm household, applied with econometric models to cross-sectional data sets collected with household surveys. The second field is environmental economics and valuation, also applied through econometric analysis of survey data. The third field is institutional economics.

Empirical studies investigating the economics of conserving agricultural biodiversity on farms have been few, and these have so far been limited exclusively to the first approach. Both the environmental and institutional approaches are now planned for the Hungarian national project. The first approach is summarized next in general terms, and explained in detail by Van Dusen (Chapter 2).

The objective of this approach is to identify the factors that predict in which locations within a nation and by which types of farm households diverse crop genetic resources are most likely to be conserved as economic development occurs. On a global scale, for highly bred, staple food crops such as rice, wheat and maize, factors such as labour to land ratios, land use intensity, agroecological heterogeneity (variation in soil types and altitudes, or

variation in moisture regimes), productivity potential, as well as the density of market infrastructure have explained to a large extent in which regions traditional varieties persist. The heterogeneity of environments and the distance of communities and households to markets for crop products are good predictors of candidate sites since they condition the decisions of farmers about the numbers of varieties to cultivate, the number of and proximity of plots, and how to manage seed sources—all determinants of crop genetic diversity.

These generic factors are outside the control of farmers, and vary at a regional level. To test related hypotheses, the sample of farm households must be large enough to encompass wide enough variation in the factors and may need to be stratified. For example, including only isolated areas does not enable us to test the fundamental hypothesis that access to market infrastructure increases the likelihood that farmers will specialize in modern varieties. Only by testing such a hypothesis across a range of sites can generalizations be drawn.

Within strata, households are then sampled and data collected in order to analyze the factors that explain variety choices and diversity management. Variables measured correspond to the reduced-form econometric model derived from the theory of the farm household (Van Dusen, Chapter 2). This theory enables us to portray decision-making for both commercially oriented and subsistence-oriented producers. The farm household's objective is to maximize utility (satisfaction) by choosing levels of consumption goods, given a physical production function that relates farm technology to farm outputs, a supply of family labour, and the constraint that expenditures cannot exceed income. A profit-maximizing farmer is a special case of the model, in which the choice of crops and varieties to produce is determined only by market prices and farm technology. This occurs when markets function perfectly. When markets do not function well, crop and variety choices are influenced by consumption preferences as well as production considerations. The asset and human capital characteristics of the household shape preferences over consumption goods, the household's access to resources, and the effective prices paid. As a consequence, the choice of crops and varieties is affected not only by market prices and farm technology, but also by farm household characteristics.

Species and variety diversity measured at the scale of the farm household is an outcome of crop and variety choices. The significance of explanatory factors that vary at the household and regional levels can be tested through the application of an econometric model. The dependent variable is a household-level diversity index. Once the genetic structure of the crops under study is well understood by biological scientists, named varieties can be linked to this structure and diversity indices constructed. Elements to consider in constructing the appropriate dependent variable are listed in Table 1. Meng *et al.* (1998) also provide an explanation geared toward the use of diversity indices in applied economics analysis.

Table 1. Aspects to consider in selecting the appropriate diversity index to use as a dependent variable in an econometric application of the farm household model.

Crop reproduction	Farming system	Concept	Level	Conservation goal	Data needed to construct index
Self	modern	non-apparent /apparent	plot	rarity	molecular
Cross vegetative	traditional mixed	spatial/temporal inter/intra-variety	household community	diversity	agromorphological pedigree
		inter/intra-species	region		ecological

There is a small but growing literature (see references at end of chapter) in which this theoretical approach has been applied to the analysis of crop genetic diversity and species diversity on farms—related to maize in Mexico, potatoes in the Andes, and wheat in Turkey. Variants of this model will be applied in Nepal (Gauchan, Chapter 5), India (Nagarajan, Chapter 6), and Hungary (Biol *et al.*, Chapter 9).

Hypothesis tests from this literature indicate that fragmentation of plots and variation in soil types on farms is often associated with farm-level diversity. Relative market isolation and the degree of farmer participation in these markets are generally significant. The effects of such economic factors such as household wealth, income levels, and off-farm employment differ in direction and significance according to the context and how these variables were measured. Greater income from off-farm employment is not always negatively associated with variety diversity on farms, nor is greater wealth. In one case in Mexico variety attributes were also incorporated into the analysis. Cultural autonomy is a good predictor of intraspecies diversity since it may lead to strong tastes and preferences concerning food preparation which are in turn reflected in farmer variety and seed selection. Cultural factors are not well addressed in econometric models, however.

Once candidate sites (sites with both high public and high private value) for on-farm conservation of agricultural biodiversity and target farmers have been identified, any one of several policy options might be proposed.

Those proposed until now include instruments that enhance the demand for and supply of diverse seed types. When markets are incomplete, public awareness activities such as diversity fairs and educational campaigns, as well as participatory plant breeding, have been proposed as ways to increase the farmers' demand for diverse crop varieties. When markets are more fully developed and in higher income areas, consumer demand for scarce traditional varieties may be supported through niche markets of restricted labelling. Options that focus on the supply include, in marginal production environments, community seed banks and biodiversity registers. In better production environments, they include the revamping or disassembling of conventional technical packages, the revision of extension messages, and modification of seed regulatory frameworks.

Most of these options have not yet been assessed with cost-benefit analyses. Valuation methods developed by environmental economists can be used to assess policy options in each case, and include the stated and revealed preference methods described in Biol's presentation (Chapter 3). Examples in which revealed preference methods have been used to value variety attributes are provided by Smale (see Chapter 4).

Institutional analysis is also important in understanding the roles and motivations of the actors involved in conservation of agricultural biodiversity. Formal and informal seed systems must be analysed, as well as the implications of new IPR (Intellectual Property Rights) regimes. To predict how seed systems will affect diversity maintained on farms, it will be important to characterize the structure of seed systems and norms of seed access within communities. While workshop participants discussed the importance of addressing these issues, the elaboration of these tools remains to be accomplished.

Finally, economics should be informed by social and cultural research, though it is poorly equipped to model it. The work by Sawadogo (Chapter 10) and Lope-Alzina (Chapter 11) is based on social research.

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Identifying the determinants of crop biodiversity on-farm with econometric applications of the household model

M. Eric Van Dusen

Introduction

The first section presents the microeconomic theory of the farm household (Singh *et al.* 1986; de Janvry and Sadoulet 1991) as adapted by Van Dusen (2000). Though employed to analyze the determinants of crop biodiversity on farms in the Mexican *milpa* system, the approach is generalized here. As a theoretical construct, the farm household model has numerous potential applications. In applications related to crop biodiversity, the specification of the econometric model that is derived from the theoretical model depends on the crop, farming system and economic context as well as statistical considerations. The second section discusses some of the issues related to econometric specification and the selection of diversity index that serves as the dependent variable.

The approach used here addresses the questions: (1) which are the factors that explain higher levels of crop biodiversity maintained at the farm level; (2) what is the social and economic profile of the farmers who are most likely to maintain higher levels of crop biodiversity compared with those who are most likely to specialize; (3) which are the farmers who are most likely to plant minor types that are being abandoned by farmers but might nevertheless contribute rare alleles to the crop genetic resources grown in the region?

One important caveat concerns the use of the term diversity. The diversity index used here can be calculated from measurements of numbers, range, or areas planted in commonly recognized crops, farmer-recognized varieties (grouped by name or by the agromorphological characteristics that farmers use to distinguish among varieties), or seed lots. These are the observed units over which farmers make choices. While the biological sciences can provide us with increasingly sophisticated measures of genetic diversity that employ a range of metrics, it is necessary to begin an economic model with a choice (dependent) variable that is grounded in farmer behaviour.

Finally, applications of the theory of the farm household to the analysis of crop biodiversity also draw from the agricultural economics literature about 'partial adoption' of modern varieties. While the choice to continue growing traditional varieties is not merely the opposite of adopting modern varieties, models developed to explain why farmers grow more than one variety simultaneously provide insights and background. Summaries of this literature are found in Feder *et al.* (1985), Feder and Umali (1993), Meng (1997), and Smale *et al.* (1994).

Microeconomic theory of the farm household

The farm household is the basic unit of management where decisions and actions are taken which affect crop biodiversity. The household is a consumer, consuming goods produced by its members on the farm and goods purchased with income from the farm or wage labour. The household is also a producer, combining its own endowments of labour, land and other capital as well as purchased inputs in order to produce agricultural commodities that are consumed or sold on the market. In addition to constraints on their endowments, households face constraints with respect to specific resources, input or output markets. These constraints affect the range and relative amounts of crops and varieties they choose to manage, and hence, crop biodiversity as we have defined it. The model portrays activity choices, focusing on the variables that are hypothesized to explain why the addition of the j th variety or crop to a household's activity set may increase household welfare.

There are two basic versions of the farm household model, which are referred to as the separable and non-separable cases. In the separable model, the market in effect 'separates'

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

The household maximizes utility over a set of consumption levels, X_i , of its own crops i , X_1, X_2, \dots, X_N , and all other market consumption represented by income, Y . Household utility is affected by Φ_{HH} , a vector of exogenous socioeconomic, cultural or other characteristics that condition household consumption decisions. Household consumption is subject to a full income constraint, with income composed of farm income from producing j crops $Q_j, j=1\dots J$ (net of consumption X_j), exogenous income \bar{Y} , and an endowment of family time T valued at the market wage, w . Household production is subject to a technology function and profits are subject to prices for inputs and outputs. Production constraints such as fixed input factors are embedded within the production technology equation. Production technology is represented by a vector of exogenous farm characteristics, Φ_{Farm} .

$$\max_{X, Q} U(X_i, Y; \Phi_{HH}) \quad (1.1)$$

$$p_q(Q_j - X_j) - C(Q_j; \Phi_{Farm}) + \bar{Y} + w\bar{T} = \sum_{i=1}^I p_i x_i \quad (1.2)$$

$$G(Q; \Phi_{Farm}) \quad (1.3)$$

The household chooses a vector of consumption levels, \mathbf{X} , and output levels, \mathbf{Q} . The solution of the maximization problem yields a set of optimal production levels, Q^* , income level, Y^* , and consumption levels, X^* :

$$Q = Q_i^*(p, \Phi_{Farm}) \quad (1.4)$$

$$X_i = X_i^*(p, Y, \Phi_{HH}) \quad (1.5)$$

The crop biodiversity outcome, or the range of crops and varieties managed by the household, is derived from the optimal production levels, $D = D(Q^*(\Phi_{Farm}))$. Crop biodiversity does not enter the model as a choice variable. In other words, farmers do not choose diversity directly but indirectly, through the choice of agricultural commodities to produce, according to market prices and farm technology (p, Φ_{Farm}) . If there are decreasing returns to scale in production activities, then an interior solution for a diverse production set may occur. For example, if yields for different crops depend on land quality and the quality of the farm's land endowment is heterogeneous, a mix of crop activities is possible. In most cases, however, we would predict that in the separable version of the farm household model, when markets are complete and neither production nor prices are stochastic, farmers would specialize in the crops and varieties that generate the highest net returns per hectare, or profit.

However, such is rarely the case—especially in most candidate sites for on-farm conservation of agricultural biodiversity. Markets may be present in some form, but households may not use them for transactions or base their choice of activities on exogenous market prices. Individual households in centres of crop genetic diversity may face high transaction costs caused by geographic and cultural isolation. These transaction costs may cause market failures, which prevent a fully recursive, separable model solution. When

transaction costs create a wide enough price band, the household's internal equilibrium of supply and demand may fall within the band, leading to production for subsistence. Then, household production and consumption decisions are determined by subjective valuations or 'shadow prices'.

An interesting case with important implications for modelling diversity on farms is when markets are missing for a crop that supplies diversity. This could be a commodity with a consumption trait that the family values but for which high transaction costs create a missing market, forcing the household to satisfy all of its demand for the good through its own production. If households demand diversity in their consumption of staples, high transaction costs for staples tend to promote on-farm diversity in staple crops. Markets may exist, but many are 'thin' markets with few buyers and sellers that generate high costs of search and information. If there is a level of risk in the product's availability and in prices at the time of demand, either can create price bands the width of a certainly equivalent, making the price higher for products sold and lower for products purchased. This can be exacerbated in village economies where all households harvest at the same time; a large harvest for everyone will decrease the opportunities to sell, exactly when the opportunity to sell is greatest.

One important example that has been cited in empirical studies is the lack of market for a particular quality attribute of some traditional varieties. Then the separable case of the farm household model is relevant. Simplifying the model in (1), the household derives utility from consuming self-produced goods, X_i , and all other consumption goods with market prices represented by total income Y . For any non-tradable good X_{NT} consumption is constrained to exactly equal own production. The market constraint is represented by a vector of exogenous characteristics that describe market access and transactions costs, Φ_{Market} . The market characteristics describe the degree of integration into regional markets and affect whether the household will be able to use the market for consumption of that good. The farm technology function is simplified to a cost function, and the reduced farm profit function is substituted into the cash income constraint, which is a combination of farm profits (from production of tradeables) and exogenous income \bar{Y} . In the case of one or more missing markets, the household maximization problem (subject to income and market constraints) becomes:

$$\max_{X, Q} U(X_i, Y; \Phi_{\text{HH}}) \quad (1.6)$$

$$Y = \sum_{i \neq NT} p_i (Q_i - X_i) - C(Q_i; \Phi_{\text{Farm}}) + \bar{Y} \quad (\lambda) \quad (1.7)$$

$$Q_{NT} = X_{NT}(\Phi_{\text{Markets}}) \quad (\gamma) \quad (1.8)$$

where λ and γ are the shadow prices on the cash income and missing market constraints, respectively. The first order conditions for all commodities except the market-constrained good are:

$$\text{for } i \neq NT : U_y [p_i - C'(Q_i)] = 0 \text{ or } p_i = C'(Q_i) \quad (1.9)$$

In the case of the subsistence good, however, the first-order conditions include another term which reflects the need to meet the subsistence constraint:

$$\text{for } i = NT : U_y [C'(Q_{NT})] + U_{X_{NT}} = 0 \text{ or } C'(X_{NT}; \Phi_{\text{Farm}}) = \rho_{NT} \quad (1.10)$$

where

$$\rho_{NT} = \frac{-U_{x_{NT}}}{U_y} = \frac{\gamma}{\lambda} \quad (1.11)$$

Similar to a safety first formulation in the risk literature, the right hand term is the household shadow price or subjective valuation of the subsistence crop. The endogenous household shadow price, ρ_{NT} , is affected by household and market characteristics, and becomes the price that is used in making household production and consumption decisions. The solution to the household's maximization is

$$Q = Q_i^*(p, \rho_{NT}, \Phi_{Farm}) \quad (1.12)$$

$$X_i = X_i^*(p, \rho_{NT}, \bar{Y}, \Phi_{HH}) \quad (1.13)$$

$$\rho_{NT} = \rho^*(p, \Phi_{HH}, \Phi_{HH}, \Phi_{Markets}) \quad (1.14)$$

The demands $Q^*(p, \Phi_{HH}, \Phi_{Farm}, \Phi_{Markets})$ are functions of variables influencing subsistence requirements (e.g. household demographics and preferences). The diversity outcome, or the range of crops and varieties produced,

$$D = D[Q^*(p, \Phi_{HH}, \Phi_{Farm}, \Phi_{Markets})], \quad (1.15)$$

is no longer derived only from production needs but is also affected by consumption preferences and market conditions.

Equation (1.15) is the reduced form diversity equation to be estimated econometrically. The vectors p , Φ_{HH} , Φ_{Farm} , and Φ_{Market} are a set of variables that are measured empirically with household data collected through sample surveys (see Smale, Chapter 1). To see which version of the farm household model best represents the empirical situation, we can statistically test the joint hypothesis that market and household variables explain variation in D . Hypothesis tests on individual regression coefficients indicate the direction, statistical significance, and magnitude of the explanatory factors on crop biodiversity measured at the farm level. Definition and construction of explanatory variables that compose the vectors, as well as discussions of sample survey design, can be found in the references cited in the previous presentation or in the bibliography provided in this volume. The next section discusses the construction of the dependent variable and the implementation of regression analysis.

Empirical model—selected issues

Dependent variables

There is a range of structures for testing the hypotheses put forth by the behavioural model beginning with the structure of the dependent variable that represents diversity. A behavioural model is an abstracted, mathematical representation that depicts, in terms that are consistent with economic theory, how economic agents such as farmers make decisions. The econometric model is a statistical model that applies the behavioural model using statistical regression models in which causality is assumed between independent and dependent variables. Therefore, the structure of the dependent variable has implications for behavioural interpretations related to the theoretical model and for statistics through the econometric specification. Various indices have been employed in the literature.

One issue seems to be limited to semantics but is actually rooted in an essential economic question that has yet to be resolved. Does the farm household 'demand diversity'? Is diversity an outcome of a decision or the choice itself? The point of departure from the theoretical model above is that households are not demanding diversity *per se* but are

demanding a specific variety or a specific trait contained in that variety. It is also possible that households are directly demanding diversity more explicitly in the way that a risk-averse investor demands a portfolio with a degree of difference between investments to spread risk. Furthermore, households may demand bundles of attributes rather than the commodities themselves, and since different varieties provide these attributes in different amounts, if markets are also imperfect for attributes, they are obliged to grow combinations of varieties simultaneously (Smale *et al.* 2001).

The other issue relates to the biological definition of diversity. The genetics and ecological literatures offer a range of sophisticated options for calculating levels of diversity, some of which have been employed by economists. Yet as the level of complexity increases in these indices, the explicit connection to farmer behaviour decreases and the econometric techniques describe a relationship to an implicit form of diversity that farmers may not observe.

Discrete, censored and multinomial models

The simplest econometric model for estimation of the reduced form diversity equation is a probit or logit, where the dependent variable is a zero-one variable indicating whether the farmer plants a specific crop or variety but the assumptions regarding the underlying statistical distributions are different. If a specific variety has been identified as being of conservation interest, the statistical model will be used to identify which factors increase the likelihood it continues to be grown and predict which farmers will grow it. The variety needs to be identified through consultation with breeders or geneticists who have studied the materials *in situ*. In a relative sense, the diversity implications of a dichotomous variable are the most limiting, while the link to the behavioural model is most direct and the statistical properties of estimators are well defined.

Truncated or censored regression models such as the tobit or double-hurdle models enable the estimation of both the effects of factors on the likelihood that a farmer grows the specific variety as well as the extent of the area planted to it. Multinomial or nested logits may also be appropriate if there is some way to order the choice among several specific varieties. Like the probit model, the behavioural and statistical implications of using these approaches are well established in the literature. The major drawback is how little they tell us concerning crop biodiversity, because very few crops or varieties can be incorporated into the model. Seemingly unrelated regression (SUR) models can be used to jointly estimate a set of equations with dependent variables such as crop or variety area shares, but it is rarely feasible given that not all farmers in the sample will grow all of the crop varieties.

Count models

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

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

Models with diversity indices as dependent variables

The Shannon diversity index, which was adapted from the information theory literature for use in ecology and agronomy, is a way to combine a number of qualitative or quantitative traits into a single index (Magurran 1988). The formula is:

$$H' = -\sum_i p_i \ln p_i \quad (1.16)$$

Another commonly used index is the Simpson index, which is related to the Herfindahl index used by economists to measure industry concentration. The formula for the Simpson index is:

$$1 - \sum_i p_i^2$$

The Simpson is a dominance index, which is suited for intervarietal diversity combining the number of varieties planted with their relative importance (Meng *et al.* 1998). While the Shannon index was used for the regression model in the *milpa* study, both the Simpson and Shannon indices were calculated and are presented in Table 1.

Table 1. Sample calculations for diversity indices calculated from area shares.

Area planted to each variety			
Percent of variety having characteristic			
Shares = p_i			
0.25	0.30	0.40	0.49
0.25	0.30	0.40	0.49
0.25	0.30	0.10	0.01
0.25	0.10	0.10	0.01
=$p_i \cdot \log(p_i)$			
-0.15	-0.16	-0.16	-0.15
-0.15	-0.16	-0.16	-0.15
-0.15	-0.16	-0.10	-0.02
-0.15	-0.10	-0.10	-0.02
=-SUM [$p_i \cdot \log(p_i)$]			
0.60	0.57	0.52	0.34
Shannon			
0.60	0.57	0.52	0.34
Simpson			
0.75	0.72	0.66	0.52
Count			
4.00	4.00	4.00	4.00

How the shares (p_i) are calculated has important implications for the practical issues of generating the diversity indices and for the analysis that can be applied. A basic unit for the calculations of these shares is the proportion of the crop area that is planted to each variety or species. The area shares can be collected from basic information on areas planted, and total area, that is basic to any survey. The area shares have a direct link to the models of portfolio choice that are a key part of the adoption literature mentioned in the introduction.

More complex analysis that provides a closer link to the underlying genetic structure of a crop population employs groupings of varieties based on agromorphological descriptors or molecular analysis. Agromorphological analysis involves measuring key attributes of a sample of seed heads, seeds or plants grown out from a sample of seed. Molecular analysis employs a set of marker genes to generate relative frequencies of given genes within a sample of seeds. Both types of analysis entail additional expense and experimental design to ensure diversity is accurately measured. A second limitation, as mentioned above, is that the unit of diversity in these cases becomes a unit that the farmer is unable to perceive. When this analysis is being conducted as part of an interdisciplinary research project, however, the economist has an opportunity to work with biological scientists in linking the units that farmers observe with the units that are meaningful to geneticists. Nevertheless, the findings from the econometric regression of the reduced form, theoretical model become more difficult to interpret when the dependent variable is not observable to farmers.

Table 1 and Figure 1 provide comparisons of calculations for Shannon, Simpson, and count indices. In Table 1, there are four scenarios, with a farmer planting equal shares (%) of each crop (25–25–25–25) and increasingly unequal area share distributions among the crops (30–30–30–10), (40–40–10–10) and (49–49–1–1). The total area and total number of crops remain fixed. A spreadsheet is used to calculate the indices. Diversity decreases as the evenness in the distribution of area among the crops decreases. Figure 1 shows these results graphically. The slices of the pie in the chart illustrate the area shares of each crop, and the increase in diversity can be seen as the four crops are planted more evenly on a fixed area of land.

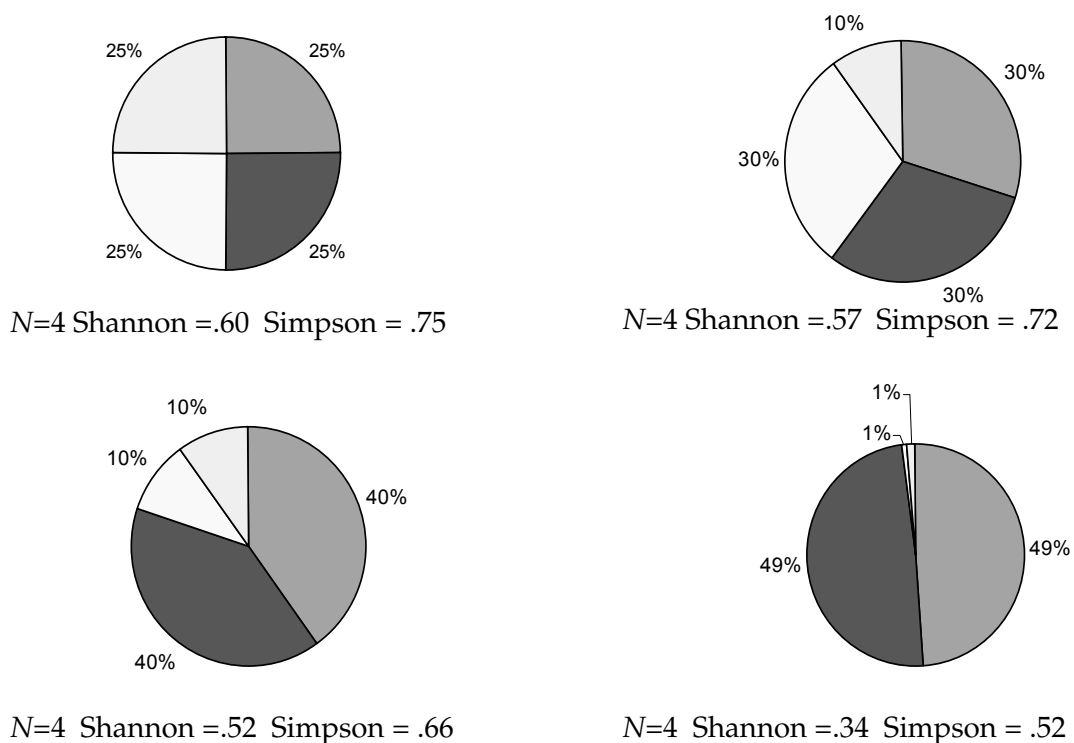


Figure 1. Graphical representation for comparisons of diversity indices.

Sample selection bias

One of the first estimation issues to face is selection or censoring bias for the sample of farmers involved. If some farmers in the sample of households plant the crop or variety of interest and others do not, bias is generated if the regression model is applied only to those who do. Usually we would also imagine that a different process determines whether the farmer will plant a crop or variety at all. The preferred econometric method is to use all

available observations. Mixture models allow the treatment of both decisions as generated by different processes. A well-known example is the Heckman model, which consists of two steps. The first step addresses the likelihood that the farmer will grow the crop or variety, while the second addresses the determinants of the number of varieties planted of the crop or the extent of area allocated to the crop. Information from the first step is carried into the second, and the properties of the estimators in this model are well known.

Multiple crops

An important problem in econometric specification is whether or not there are multiple crops as well as multiple varieties. Almost all indices of diversity are constructed over a single vector of measurements among varieties of a single crop or among crops. Just as, in the ecology literature, different species of cranes can be valued based on genetic distance, but not between cranes as well as herons, there is no obvious way to integrate diversity across wheat and rice varieties. One approach is to count each distinct species and variety individually, or construct indices over both species and variety area shares. In econometric specification, it may be useful to measure impacts of household or community variables on total cropping system diversity measured across crops, and compare these results to those estimated for diversity measured across variety components of the crops.

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Applying environmental valuation methods to support the conservation of agricultural biodiversity

Ekin Birol

Introduction

Environmental valuation methods are fundamental tools for the design of appropriate policies to conserve agricultural biodiversity. The field of environmental economics emerged from the need to assess the monetary worth of environmental goods such as clean air, natural habitats and endangered species as these became increasingly scarce. Environmental valuation methods are founded on the notion that only through recognizing the full economic value of these natural resources can the 'right' policies to conserve them be identified. Generally environmental goods are not valued in market prices or are undervalued because of their public good nature.

The following discussion has two purposes. The first is to introduce the three main building blocks of the field of environmental economics. These are: (1) the use of cost benefit analysis as a tool for designing policies that have implications for the environment, (2) the concept of total economic value of an environmental good, and (3) the measurement of total economic value for use in cost benefit analysis. The second purpose is to consider ways in which these concepts and methods can be applied to the conservation of agricultural biodiversity. Key references are also provided.

Cost–benefit analysis

The environmental good of interest to us is agricultural biodiversity on farms. In order to design policies that both encourage the maintenance of agricultural biodiversity on-farm and ensure that development occurs, environmental economists argue that it is necessary to establish the value of what we seek to conserve. The most common way of assessing whether a development policy or project constitutes a social welfare improvement is by conducting a Cost Benefit Analysis (CBA). CBA aggregates the expected benefits and costs of a project or policy over the individuals affected and over the project or policy lifetime. A policy or project is desirable if and only if it generates a welfare improvement—that is, if the total expected benefits accruing to all the individuals exceed the total expected costs to be borne. Moreover, policies may be prioritized according to criteria such as the total amount of net benefits they yield. Critical to the decision is the measurement of the value for expected costs and benefits and choice of discount rate, or the time value of money. When these are reliably estimated, CBA can assist decision-makers in allocating finite economic and environmental resources in the most efficient manner.

Measurement of costs and benefits is particularly challenging for environmental goods because most are public goods or have public good attributes. As mentioned elsewhere in this volume (Smale, Chapter 1), some goods like crop genetic resources are neither purely private nor purely public. A good is public to the extent that (1) one person's consumption does not reduce the amount available to others (non-rival), and (2) the costs of excluding those who do not choose to pay for it are high (non-excludable). A related issue concerns the good's 'transparency' or the extent to which the good is equally well observed by both consumers and sellers.

Pure private goods are efficiently allocated through market mechanisms, but this is not the case for public goods. Producers cannot withhold a public good for non-payment and there is no basis for establishing a market price because the quantity a person consumes cannot be measured. The market 'fails' to send the appropriate signals, the public good is underproduced, and government intervention is needed. In many cases, and in most developing country contexts, however, governments may not intervene to correct such

market failures because the conservation of environmental goods like agricultural biodiversity is a less pressing priority than growth in agricultural productivity and income.

The inability of a national government to correct market failure has been referred to in turn as 'government failure'. When goods have global importance and their utilization (or conservation) has intergenerational consequences, institutions with larger jurisdictions, such as regional and international institutions, may need to intervene in order to implement policies that take into consideration the full value of the resources. This is clearly the case for the conservation of agricultural biodiversity.

CBA is difficult for goods whose benefits have no prices attached to them. Environmental economists have also pointed out that individuals may derive values from non-market goods through means other than by direct consumption. The broader concept of Total Economic Value (TEV) incorporates other sources of value.

Total economic value

In the TEV context, environmental goods have both use value and non-use value. Individuals may derive both use and non-use value from the good (Figure 1). Use values can be further classified into three broad categories: direct use value, indirect use value and option value.

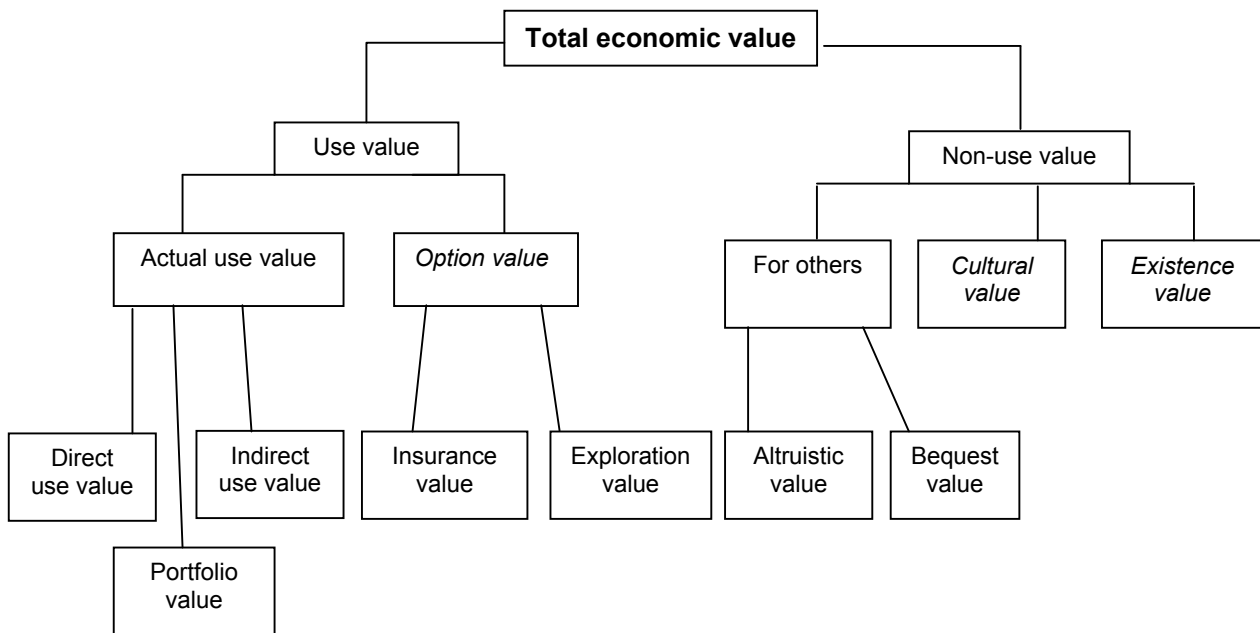


Figure 1. Components of total economic value of agricultural biodiversity.

The direct use value is the value from consuming the good. Direct use values of agricultural biodiversity flow from the quality and quantity of food produced, the cash income it generates for farmers, the productivity gains from crop genetic improvement, and amenity value associated with agricultural landscapes. For most private goods value is almost entirely derived from their direct use. Many environmental goods, however, perform an array of functions that benefit individuals indirectly. Indirect use values of agricultural biodiversity include production effects such as resistance to biotic and abiotic stress, functions such as ecosystem productivity, soil or water quality, and habitat protection for other components of biodiversity. When the cultivation of a broader set of crops or crop varieties stabilizes yields or farmer incomes, agricultural biodiversity may also have a 'portfolio value' (Swanson *et al.* 1993). An important extension of use value is option value, consisting of insurance and exploration value. Although individuals may not use a resource

today, they may value the option of using it in the future to combat as yet unknown, adverse conditions (insurance value) or to exploit undiscovered sources of information (exploration value).

Non-use values are those derived from neither direct nor indirect use, and these also consist of three types: bequest value, altruistic value and existence value. Some individuals may value the fact that future generations will have the opportunity to enjoy an environmental asset, known as bequest value. Others may be concerned that the good is available for others in this generation, whether or not they use it themselves (altruistic value). They may value the simple fact that an environmental asset exists, whether or not it is used (existence value). In particular, agricultural biodiversity may also generate cultural value through the traditional or indigenous knowledge associated with certain crop varieties, seed management or farming techniques.

Environmental goods like agricultural biodiversity are not easy to assess with CBA, because they generally have high public good content and are complex in the multiple types of values they generate. Environmental economists seek to measure these values through the methods they have developed, which are summarized below and explained more fully in the references listed at the close of this section.

Environmental valuation methods

Valuation methods used in environmental economics fall into the two broad categories of revealed preference (or indirect) methods (RPM) and stated preference (direct) methods (SPM) (Figure 2). Examples of RPM include hedonic pricing and travel cost methods, in which prices in markets related to the environmental good or in which the good is implicitly traded serve as proxies. SPM include contingent valuation (CV) and attribute-based choice modelling (ABCM), in which values are elicited from respondents using survey techniques.

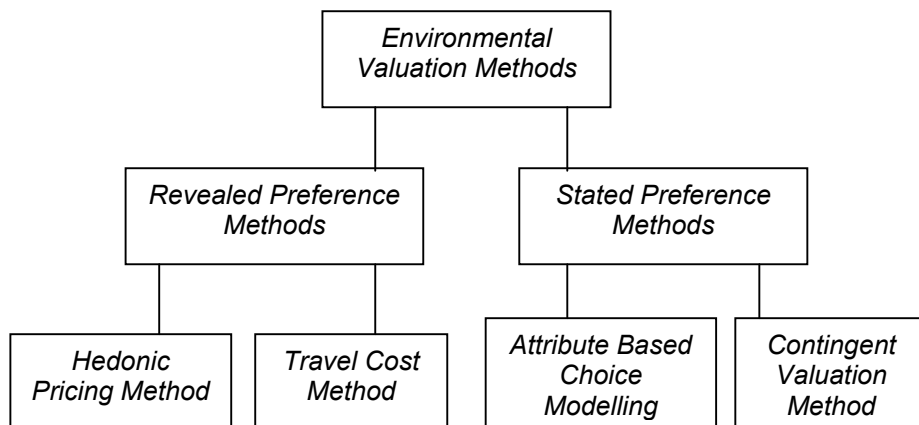


Figure 2. Most commonly used environmental valuation methods.

The travel cost method was initially developed to estimate the demand for and value of environmental goods that provide input services to the production of outdoor recreation activities and related amenities, such as parks, beaches or nature reserves in higher-income countries. Since these goods are consumed *in situ*, individuals incur a number of costs in order to consume them. The demand price, or value of the resource, can be computed from the value of the time spent in recreation activities (in terms of wages foregone), the cost of travel (e.g. cost of petrol), combined with entrance and other site fees. In our context, one suitable application of the travel cost method would be to assess the demand for crop or livestock diversity as part of an agrotourism package. Agrotourism consists of recreational

activities on the farmland, such as participating in traditional farming methods, observation of fauna and flora, or feeding livestock.

Hedonic pricing methods have been widely employed to value environmental goods, such as air quality, through the impact that these goods have on property values. The basic notion underlying hedonic pricing is that every good is composed of a bundle of attributes (Lancaster 1966) and the price of the good depends on these attributes. If an environmental good is one of the attributes of the property, then the price differential associated with the good, controlling for other attributes, is a measure of consumer willingness to pay. There is a sizeable literature (Miranowski *et al.* 1984; Palmquist and Danielson 1989) in which implicit prices of such functions of agricultural systems as drainage, erosion control and soil quality are related to farmland values. In a number of other applications in the agricultural economics literature, the marginal value of traits associated with particular crop or livestock types (which might include those unique traditional varieties or landraces) has been estimated with the hedonic pricing method.

There are two major limitations to revealed preference approaches such as travel cost and hedonic pricing methods in valuing agricultural biodiversity. First, as for many other environmental goods, real or surrogate markets may not exist and even if they do, their value may not be well represented in observed prices owing to market imperfections. While implicit prices of crop and livestock biological diversity might be related to farmland values, in many countries land markets are likely to function imperfectly. Markets for grain types may be thin, without good systems of grades and standards that enable consumers to differentiate quality. Governments may regulate prices. Second, even if markets exist, the market price might not be a good approximation of the value of the environmental resource because by definition market values tend to reflect use values only. Therefore, they provide only an indication of the existence of a market-based incentive for maintaining unique crop or livestock types that embody specialized traits, rather than an estimate of value.

Stated preference methods

Stated preference methods (SPM) were developed to address these limitations. These methods have the potential to reveal the total economic value (use and non-use value) of any non-marketed environmental good, given that the surveys used to elicit them are properly designed.

Survey questions are designed to elicit the monetary valuation of a change in the provision of the non-marketed good in question. Respondents reveal their demand for the good through either their willingness to pay (WTP) to have more of the good or their willingness to accept a payment (WTA) in order to give up the good. Whether demand is elicited using WTP or WTA depends on with whom the property rights of the good reside. If the respondents do not have the right to the resource, they are asked their WTP to have it; if they own the resource already, they're asked their WTA compensation for giving it up. Moreover, elicitation of the value of WTP or WTA could be either direct or indirect.

Contingent valuation is a direct elicitation method. Indirect elicitation procedures, called attribute-based choice modelling, involve rankings or ratings by respondents across alternative options, each of which is associated with a set of attributes, one of which may be a price. Both of these methods estimate the TEV of a change in the provision of a non-marketed good. However, attribute-based choice modelling can also be employed to estimate the WTP for (or WTA) a change in the attributes of the good. Each method is discussed in greater detail next.

Contingent valuation method

Contingent valuation is the most commonly used SPM, so named because the values revealed by respondents are contingent upon the constructed, hypothetical market represented in the survey questionnaire. The respondent's valuation of the environmental good is elicited through bidding games, open-ended questions or dichotomous choice questions.

In bidding games, the respondent is presented with a random value (the starting point) and asked whether he/she is willing to pay this amount in the contingent market for the provision of the environmental good. If the respondent replies 'yes', a higher amount is specified and the respondent is asked whether he/she is willing to pay this amount. The iterative bidding game is continued until the maximum WTP of the respondent is reached. In open-ended questions, the respondent is asked directly what he or she is willing to pay for the environmental good in monetary terms. With dichotomous choice questions, the respondent is asked simply whether or not he/she is willing to pay some specified amount for the environmental good. The dichotomous choice approach is easiest to answer for most respondents, since individuals make similar choices in real markets when faced with market prices.

The initial steps involved in the design of a contingent valuation survey are similar to those used in any social science survey. First, the group of individuals who are most likely to be affected by a change in the level of an environmental good are identified and the sample selected. If the environmental good in question has an obvious user group then the population from which the sample should be drawn is well defined. However, as stated above, individuals who do not directly use the resource may value it as well. Sampling from larger populations than the user group may allow researchers to assess the extent of non-use as well as use values, but the criteria for sample selection are not obvious.

The second step is for researchers to decide whether the survey is best conducted by mail, phone or in person. The choice depends on a number of factors including the cultural context, the importance of the valuation issue, its complexity, and the size of the research budget. Personal interviews generally have higher response rates, especially for complex questions. Mail and telephone surveys must be kept fairly short, or response rates are likely to drop dramatically. Telephone surveys may be less expensive, but it is often difficult to ask contingent valuation questions over the telephone, because of the amount of background information required. In most developing country situations, only personal interviews are feasible.

The third, and the unique feature of the contingent valuation survey, is the *construction of the hypothetical market*, which consists of three steps:

1. *Scenario description.* The purpose of the scenario description is to provide all respondents with a carefully presented, standard explanation of change in the provision of the environmental good that they will be asked to value. Verbal descriptions are standard and visual aids such as photographs, charts and maps are often used. This is perhaps the single most important determinant of the quality of results.
2. *WTP or WTA?* Respondents achieving benefits from a change are asked their WTP for the change in the provision of the environmental good, while those incurring costs are asked their WTA for the losses they suffer.
3. *Choice of the payment vehicle.* The final stage in the construction of the contingent market is to describe to the respondent how they will be asked to pay for the project or policy that will bring about the change in provision of the environmental good. In CVM the mechanism for payment is known as the payment vehicle. Examples of payment vehicles are general taxes, local taxes, one time versus annual payments, a charge on utility bills, entry fees, etc.

The fourth stage of a CV survey is the collection of supplemental data on the social and economic characteristics of each respondent, including income, age, gender, education and family size. In addition, researchers gather details concerning the respondents' attitudes toward the environment, their current use of and proximity to the resource in question. These variables represent parameters in the demand function or bid equation to be estimated.

The bid equation represents the variation in WTP or WTA as a function of parameters hypothesized to be significant in the economic theory of consumer choice. Estimating a bid equation serves several purposes. First, it allows researchers to check whether responses to the contingent valuation question are consistent with economic theory (e.g. that demand or WTP increases with income). Second, it allows researchers to investigate policy-related issues concerning the factors that affect individuals' valuation, such as education. Finally, to the extent that the sample is representative of a larger population, the bid equation allows inferences to be drawn concerning the total benefits of (or costs from) the change in the provision of the environmental good. These estimates can in turn be used for CBA.

Selection of the econometric regression model to estimate the 'bid' or demand equation depends to a large extent on the elicitation method. For WTP data collected using an open-ended question format, ordinary least squares (OLS) regression may be appropriate for WTP data collected with an open-ended format. When the format employed elicits a dichotomous choice, regression models for limited dependent variables are needed.

Contingent valuation can be an ingenious way of eliciting the value of goods that do not have prices. However, the results are reliable if and only if the surveys are designed, administered and analysed with extreme care. Several biases are known to arise most frequently:

1. *Starting point bias* arises in bidding games and suggests that the WTP variable is anchored on the first suggested bid price.
2. *Interviewing bias* occurs when the attitude of the interviewer can influence the values given by respondents.
3. *Non-response bias* is present if those that refuse to answer the survey are not a random part of the population but those with a particular attitude (e.g. strongly against the proposed project).
4. *Strategic bias* refers to a deliberate understatement or overstatement of WTP. Respondents may understate their WTP if, rightly or wrongly, they believe that the actual fees they will pay for provision of the environmental good will be influenced by their response to the CV question. Conversely, realising that payments expressed in a CV exercise are purely hypothetical, respondents may overstate their true WTP in the hope that this may increase the likelihood of a policy being accepted.
5. *Yea-saying bias* reflects the fact that respondents may express a positive willingness to pay because they feel good about the act of giving for a social good although they believe that the good itself is unimportant. Respondents may state a positive willingness to pay in order to signal that they place importance on improved environmental quality in general.
6. *Insensitivity to scope or embedding bias* arises when the respondent expresses the same WTP for some part of an environmental asset as he or she does for the whole.
7. *Payment vehicle bias*. Respondents may give different WTP amounts, depending on the specific payment vehicle chosen. Payment vehicles—such as a contribution or donation—may lead people to answer in terms of how much they think their fair share contribution is, rather than expressing their actual value for the good.
8. *Information bias*. This bias contends that the WTP expressed by an individual in response to a CV question is not a reflection of previously held preferences but is constructed in the interview procedure.

9. *Hypothetical bias*. Perhaps this is the most serious criticism of CVM. Hypothetical bias contends that respondents may be prepared to reveal their true values without strategic bias but are not capable of knowing these values without participating in a market in the first place.

To correct for these biases, environmental economists developed guidelines and protocols for bias reduction and detection. Biases are minimized when (1) the key scenario elements are understandable, meaningful and plausible, (2) the WTP questions are clear and unambiguous, and (3) the respondents are familiar with the good being valued. This third point implies that respondents have had prior valuation and choice experience with respect to consumption levels of the commodity so that they can have reasonably well-formed values. The likelihood that this condition will be met is small since environmental goods are not marketed goods.

Over the last two decades, interest in valuation of environmental goods has grown rapidly owing to their increasing scarcity. Interest in contingent valuation has also increased given improvements in the survey design and implementation, as well as data analysis methods. The balance of the evidence suggests that estimates obtained from carefully designed and properly executed surveys appear to provide reasonably good estimates of TEV, and are therefore useful in CBA and policy formulation.

In the context of agricultural biodiversity, contingent valuation has not been widely employed, though it has been applied extensively in valuing rare and endangered animal species such as pandas (Kontoleon *et al.* 2000a), habitats like the riparian forests (Desaigues and Ami 2001), and landscapes. It has been especially useful in *ex ante* and *ex post* assessment of conservation policy (Pearce and Moran 2001). Contingent valuation has not been widely employed in the context of agricultural biodiversity. One reason why is that even if provided with details, respondents would likely find it challenging to value unfamiliar species or complex processes such as ecosystem functions and traditional management processes for crop and livestock types in centres of origin and diversity.

To the extent that (1) respondents are familiar with participating in real markets (implying that markets are in general well developed), and (2) the component of agricultural biodiversity that one is seeking to value is tangible and observable (such as a uniform, stable crop variety), contingent valuation may prove useful. However, a defining feature of many on-farm conservation sites is relative market isolation. Furthermore, traditional varieties are rarely uniform or stable. Nor are they uniquely identifiable unless some combination of scientific methods (such as molecular analyses and agromorphological descriptors) can be used to characterize them.

Attribute-based choice modelling

Controversy over contingent valuation has led more recently to the development of alternative Stated Preference Methods, including attribute-based choice modelling (ABCM). ABCM is similar to contingent valuation in that it employs survey research to generate estimates of both use and non-use values. Similar to hedonic pricing methods, it is based conceptually on Lancaster's theory of consumer choice (1966).

ABCM provides four types of information about the values of environmental goods that may be of use in a policy context: (1) which attributes of an environmental good are significant determinants of the value people place on it, (2) how these determinants are ranked, (3) value of changing more than one attribute at a time, and (4) the total economic value of an environmental good (Bateman *et al.* 2001). ABCM has four principal formats. In the Choice Experiment (CE) format, respondents are asked to choose between two (or more) alternatives as compared to the status quo. Contingent Ranking asks the respondent to rank a series of alternatives, while Contingent Rating asks for scores on a scale of 1 to 10. In Paired Comparison, the respondent is asked to score pairs of scenarios on similar scale. Only in the

Choice Experiment can a monetary value be used as one of the attributes, enabling the results from application of this method to be interpreted as being equivalent to marginal (or total) WTP or WTA values.

The design of a CE includes the following defining features:

1. *Selection of attributes.* If they are not self-evident, relevant attributes of the environmental good to be valued are selected through literature reviews, focus group discussions or direct questioning. A monetary value is typically one of the attributes. Since the minimum acceptable sample size increases exponentially in attributes, the number of attributes should be kept relatively small (4-6) unless very large sample sizes are feasible.
2. *Assignment of levels.* Attribute levels should be practically achievable levels and span the range over which respondents are thought to have preferences. Results are sensitive to the price levels selected. Setting price levels too low biases the results toward acceptance, inflating the monetary value of the attributes. The reverse is true if they are set too high.
3. *Choice of experimental design.* Once attributes and levels have been selected, statistical design theory is used to generate various combinations that represent alternative scenarios or profiles. Complete factorial designs allow the estimation of the full effects of the attributes upon choices, including main and interaction effects, though they often generate an impracticably large number of combinations. Subsets of complete factorial designs, known as fractional factorial designs, can be employed in order to efficiently reduce the number of scenarios, though not without some loss in the power of the estimation.
4. *Construction of choice sets.* The profiles identified by the experimental design are then grouped into choice sets to be presented to respondents. Generally in a choice set respondents are asked to choose between two or more alternatives.

Once choice sets have been created, the criteria used for any sample survey design are employed, though the optimal sample size is affected by the number of attributes, levels and choice tasks per respondent. Econometric models of discrete choice, such as multinomial logit, are used to estimate the relative values of the attributes (see Van Dusen, Chapter 2).

The choice experiment method appears to have several distinct advantages over contingent valuation. First, respondents may be more comfortable with decisions among choice sets than with direct questions concerning WTP or WTA. Second, the strategic bias of stating an extreme monetary value to get a point across is minimized with the choice experiment method since the prices of the goods are already defined in the choice sets. Yea-saying bias and insensitivity to scope are also eliminated.

Overall, it is probably too early to make a fair comparison between the two methods (Smith 1997). A few noteworthy applications of the choice experiment method include the study designed by Boyle *et al.* (2001) to value the attributes of countryside in the USA, and that conducted by Hanley *et al.* (1998) as part of the Scottish agri-environmental scheme, which offers payments to farmers in return for adoption of conservation practices.

Two other examples provide insight into the potential suitability of this method for valuing crop biodiversity or the attributes of crop genetic resources. Scarpa *et al.* (2001) compared the value of the attributes of creole pigs to those of more productive, but less well adapted, exotic breeds in Yucatán, Mexico. Respondents were 300 pig farmers in 19 villages who produce for home consumption and sale. Markets are not well developed. All interviews were personal. Findings suggested that the most important attributes of pig varieties were weight, frequency of bathing, purchased feed requirements, and disease resistance. Farmers were presented with 6 sets of pair-wise choices that included only the main effects of the experimental design. In each, they were asked to choose one of two animal profiles or neither. Characteristics of the respondents' households were also

recorded, including the level of education and age of the respondent, number of members in the household, and number of pigs owned by the household. This information was used to draw inferences from the sample to a wider population and to demonstrate how farmers' choices depend on their social and economic characteristics. The findings from the choice experiment method were later compared with the results from the application of revealed preference methods, such as participatory rural appraisal techniques and conventional farmer, consumer and market surveys. Researchers concluded that the results of the choice experiment were compatible with shadow-cost computations obtained from revealed preference methods.

A second example is the study implemented by Kontoleon *et al.* (2002b), which investigated consumers' perceptions of genetically modified foods. The principal aim of this experiment was to estimate the social benefits of reducing GMO content in food to establish whether these benefits exceed the costs that the regulatory labelling scheme imposed by the EU will bring about. A questionnaire was mailed to 2000 households in the UK, with a response rate of 35%. Respondents were asked to choose between different levels of five attributes with direct effects on food safety and price of eggs: (1) living conditions of the chickens (free range or cage), (2) pesticides and fertilisers used in cultivation of feed (yes or no), (3) GMO content of the hen's feed (three different levels 0%, 1% and 5%), (4) a dummy variable indicating whether the eggs were certified by a food safety organization and/or an animal welfare organization or not, and (5) a price variable. An example of a choice set from this CE is shown in Table 1. Data were also elicited concerning each respondent's age, gender, income, level of education and whether or not there were young children in the household. Data were analysed using a multinomial logit model.

The overall outcome of this choice experiment was that higher production quality of eggs increases the probability of consumer purchase, suggesting that the individuals represented by the sample survey do value food safety as defined in the study. The findings support the European Commission's policy on compulsory GM content labeling of agricultural produce.

Information on consumer preferences of this type could assist in efficient targeting of niche markets for traditional varieties produced with less input-intensive methods. Such methods might also assist in the design of payment schemes to farmers for maintaining agricultural biodiversity in targeted 'hot spots' that are species rich or exhibit high levels of genetic variation.

Table 1. Example of a choice set from Kontoleon *et al.* (2002b).

	Option A	Option B	Option C	Option D
Living conditions	Cage	Cage	Free range	I wouldn't buy any eggs
Pesticides and fertilizers	No use	Use	No use	
GM content	1%	5%	0%	
Certified	No	No	Yes	
Price of 6 eggs	£0.98	£0.68	£1.45	
Tick one of these options:				
How many eggs do you consume weekly?	Eggs	Eggs	Eggs	

Conclusions

From the perspective of environmental economists, this presentation has argued that it is necessary to estimate the value of agricultural biodiversity. Only when the total economic

value of environmental goods like agricultural biodiversity is known can we justify any efforts to conserve them. The methods most commonly used to value environmental goods have been summarized, along with their advantages and limitations. There is scant evidence of their application in the case of agricultural biodiversity conservation on farms, in part because of the complexity of the processes involved. Perhaps more importantly, those farmers who maintain it tend to reside in isolated areas of lower-income economies where national priorities emphasize growth before biodiversity conservation. Still, these methods are likely to assume increasing importance for the design of efficient policies. Continued refinement and adaptation to developing-country contexts is therefore essential.

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Valuing variety traits or attributes with revealed and stated preference methods

Melinda Smale

This comment provides some examples from the agricultural economics literature of the application of revealed and stated preference methods described by Birol (Chapter 3). In these articles, hedonic price and conjoint utility analysis have been employed to value the traits or attributes of crop varieties and livestock types. Hedonic price analysis, a revealed preference method, can be used in this context only where markets are complete for the seed type, crop output or livestock type. Implicit values of traits are estimated indirectly through variation in seed or product price. Conjoint utility analysis is a stated preference method that can be employed where markets are complete or incomplete, since it relies directly on the consumer's rating of the seed, crop output or livestock types according to its attributes. Farmers are consumers of seed as inputs to crop production. When they produce for home consumption as well as for sale, they are also consumers of crop output.

Farmers and consumers (and farmer-consumers) make decisions based on the seed or production attributes that they observe. Some traits or attributes such as product health, grain colour, shape or form, or fragrance, are visible, or 'evident'. Others, such as protein content, dry volume or chemical content, are visible in a laboratory but not in a seed or grain sold in a marketplace. These have been called 'cryptic' traits (Von Oppen and Rao 1982).

The traits of crop or livestock products have technical determinants. These include the variety or genotype itself, production and harvesting conditions, and post-harvest handling, milling and marketing techniques. They also have economic determinants, such as consumer preferences. When these are transmitted through the marketing system, premia are an incentive for farmers to supply that trait. The cultural context, levels of education and income of the consumer form their preferences. If consumers derive utility or satisfaction from the characteristics of goods such as grain, Unnevehr (1986) has shown theoretically that:

$$P_y = \sum_{j=1}^m \beta_{yj} X_{rj}.$$

The price of grain P_y is equal to the linear sum of the products of the marginal value of each trait $j = 1, \dots, m$ and the amount of the trait supplied per unit of in the grain type (X_{rj}).

The steps involved in implementing hedonic price studies to value traits have also been described in detail by Von Oppen and Rao (1982). First, relevant evident and cryptic traits are identified through informal interviews with market participants and knowledgeable scientists. Next, samples are purchased from market retailers selected at random across sites as well as over time, to obtain a pooled time-series, cross-section data set. Prices are recorded when samples are purchased, and their characteristics measured in the laboratory with standardized methods. The data are then analysed econometrically. In studies investigating rice quality in Asia (Unnevehr *et al.* 1992), these implicit prices or marginal values β_{yj} were estimated by ordinary least squares (OLS) linear regression, though more advanced methods are possible, such as Box-Cox maximum likelihood estimation. The sign and significance of the regression coefficients indicate the extent to which consumers value quality characteristics. If the coefficients are statistically significant and meaningful in magnitude, we can conclude that there are market-based incentives for farmers to grow the varieties that supply this trait.

Some of the findings from these studies illustrate the importance of economic research about on-farm conservation of agricultural biodiversity. Sorghum prices in India were found to be associated with variation in both evident and cryptic traits (Von Oppen and Rao 1982). The marginal value of rice quality traits in Asia depended on region and income levels, as well as whether markets were located in rural or urban areas. Philippine rice given a traditional variety name in markets was typically a modern variety with preferred shape or cooking characteristics, and it earned a price premium (Unnevehr *et al.* 1992).

There is an obvious limitation to the use of this approach to estimate the value of traits found in traditional varieties, however. Gauchan *et al.* (2002) concluded that market incentives for rice in Nepal are better for modern rice varieties than traditional types, in part because of low volume and informal market structure. With the exception of traditional Basmati rice (which is of high aromatic quality), survey research in the Nepal project demonstrated that most rice landraces are traded through small-scale informal channels. Market signals for their superior qualities were weak relative to those expressed for modern varieties, and traders earned higher profits handling modern varieties than landraces.

An approach of potential use in cases where markets do not function well for the crop or livestock types is conjoint utility analysis, which is similar to the choice experiment method described by Birol (Chapter 3). Also based on the Lancaster theory of consumer choice, conjoint utility analysis is a survey-based valuation technique widely used in marketing research. In applications to farm household preferences over varieties with respect to the products consumed, variety choice is predicted by respondents' ratings concerning the extent to which each variety provides the product attributes they desire, controlling for their social and economic characteristics. The appropriate econometric estimation method appears to be ordered probit (Ndjeunga 2002; Hamath *et al.* 1997; Baidu-Forsen *et al.* 1997).

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III Ongoing applications of economics methods

On-farm conservation of rice genetic diversity in Nepal: farmers' and breeders' choices

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Introduction

On-farm conservation involves farmers' decisions to continue cultivating and managing traditional crop varieties in the agroecosystems where the crop varieties have evolved (Bellon *et al.* 1997). Farmers choose to conserve particular crop varieties by sowing the seed of the varieties they demand, selecting the seed and replanting. This choice is crucial since it determines whether a variety, which is a genetic resource stock, continues to evolve in farmers' fields.

Beyond the farm level, professional plant breeders also make decisions that affect the conservation of crop genetic diversity on farms. Professional plant breeders select, cross and utilize crop varieties in breeding programmes to develop new varieties and make them available to farmers. The choices made by breeders play a vital role in the maintenance of local crop diversity by influencing farmers' choices of the supply of new materials. Breeders can enhance the choices available to farmers by genetic stocks that may complement those they already grow or better meet their needs.

The challenge for government in Nepal is to create incentives for continued use and maintenance of genetic diversity by both farmers and professional plant breeders. National policies in agriculture and other related sectors need to support these goals. This paper outlines current economics research about on-farm conservation of rice genetic diversity in Nepal. The research attempts to address both farmers' and breeders' perspectives, which are described below. Policy trade-offs in the choices of materials to conserve are identified. Theoretical and econometric approaches are summarized. Working hypotheses are stated. Next, the theoretical and econometric approaches are outlined. Finally, variables measured in the sample survey research are listed.

The sample survey research and analysis envisaged here builds on several years of intensive, participatory research with farmers in the study sites of the national *in situ* conservation project. The findings from preceding social and economics research, as well as related research conducted by the project's biological scientists, are summarized in other proceedings and papers.

Farmers' choices

Farmers determine the survival of crop varieties or the maintenance of specific gene complexes in any given reference area by choosing whether or not to grow them and in what proportions. The choices they make today not only affect their welfare but can result in smaller plant populations and the loss of potentially valuable alleles.

Farmers choose which varieties of a crop to grow and how to allocate crop area among them based on their own objectives and constraints, and these vary among farmers. Depending on the length of their experience, and particularly with traditional varieties that they have grown for many years, they usually know the variety performance well, and can express their preferences with respect to agronomic traits (tolerance of biotic or abiotic stress,

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yield, maturity, storability). When farm households produce for both consumption and sale, farm women also express keen preferences with respect to consumption attributes (ease of processing, taste, cooking time).

Plant breeders' choices

Plant breeders choose varieties based on their perceptions, and these differ from those of farmers, as well as among breeders. Though the potential use value of any variety or group of varieties cannot be accurately predicted, plant breeders do employ decision-making criteria when they select materials for breeding or conservation purposes. Criteria may include diversity, distinctness or rarity of the adaptive traits relative to others found in the reference area. For example, they may identify varieties that are perceived to be morphologically or genetically diverse, have traits of unique or wide adaptation, or express tolerance to biotic or abiotic stress as potentially important for breeding programmes and hence, for genetic resource conservation.

On-farm conservation and policy trade-off

On-farm conservation is sustainable only when it is linked positively to farmers' livelihoods and the social fabric of farming communities. National decision-makers must also perceive some benefits from an economics, social or ecological point of view. Over the last five years, Nepal's *in situ* project has employed various strategies or policy instruments to support on-farm conservation efforts through enhancing the farmers' benefits from local crop diversity (Gauchan *et al.* 2002). These are of two types. The first type focuses on enhancing the competitiveness of local materials through participatory plant breeding and seed selection. The second is oriented toward increasing demand for local materials through market development, community awareness, diversity fairs or community biodiversity registers. While it appears that some benefits have accrued to farmers, experience has also indicated that certain traditional varieties have been promoted at the expense of others.

One type of trade-off may occur when policy instruments promote one form of diversity (such as richness) at the expense of another (such as evenness). *Richness* refers to the count of varieties and *evenness* refers to the equitability in the area shares distribution among varieties. For example, Aguirre *et al.* (2000) found that 'development' (market integration) contributed to evenness but detracted from richness among maize landraces grown in Southeastern Guanajuato, Mexico. Market integration may contribute to dominance or richness but detract from evenness, as suggested by the field observation of the project team in the Kaski ecosite. Here, linking farmers to markets increased the area of the *Anadi* rice landrace but reduced the area cultivated in other rice landraces grown in similar environments.

The second type of trade-off involves differences in the choice criterion used by plant breeders to select core subsets of varieties or landraces for conservation. The choice criterion might be diversity, rarity or distinctness. These may be measured by isoenzyme techniques, molecular methods, or analysis of agromorphological traits. Breeders choose from among these criteria according to their own objectives. Each choice is associated with a unique set of varieties targeted for conservation. Increasing the likelihood that farmers will maintain varieties that are members of one core subset may decrease the prospects that varieties in core subsets associated with alternative choice criteria continue to be grown. If so, policies designed to attain one objective might have serious consequences for another.

The aim of the current economics research in the Nepal project is to investigate two types of **policy trade-offs** that may occur in supporting on-farm conservation of rice genetic diversity:

1. Diversity trade-off: A policy promotes the maintenance on farms of one form of diversity (such as richness) at the expense of another (such as evenness).
2. Trade-off between core subsets: A policy that promotes the maintenance of a core subset defined according to one choice criterion (such as diversity) reduces the likelihood that a core subset defined according to another choice criterion (such as rarity or adaptive potential) is maintained.

Working hypothesis

Empirical research in the Nepal project sites (Gauchan 2000; Gauchan *et al.* 2001) provides strong evidence to support the hypothesis that:

- Variety traits are important to farmers and consumers
- Markets for at least some of these traits are missing
- Farmers' production decisions are not separable from their consumption decisions.

Structure of the model

When markets are missing and farmers care about variety traits, then the characteristics model of consumer choice invoked by Lancaster (1966) may be appropriate. Given that, we would postulate that the farm (and consumer) household maximizes utility over the attributes of varieties rather than the varieties themselves.

Each variety represents a bundle of these attributes expressed in different proportions that are fixed for that variety. For example, one variety yields more fodder and less grain, while another yields more grain and less fodder. Farm households can vary the total quantity of attributes they have to consume only by changing the relative share of rice area they allocate among them.

This leads to a slightly different specification of the theoretical approach presented by Van Dusen (Chapter 2), though it is also based on the farm household model. The choice of levels of variety attributes or traits (\mathbf{q}) maps into a set of seed amounts for each variety, and given a fixed land endowment, an allocation of rice area among varieties (Smale *et al.* 2001). It is assumed that land-allocation decisions among crops are decided before the decision to allocate rice areas among varieties.

$$\text{Max}_{\alpha} V(\mathbf{q}, Y; \Omega_{hh}) \quad (1)$$

The choice variable is a vector of area shares planted to varieties $i=1,2,\dots,m$. The cash constraint can be represented simply as the sum of expected net income from rice production and income that is exogenous to the variety choice decision at planting time (Y^0):

$$Y = L \sum_i (p_i \mu_i - c_i) \alpha_i + Y^0 \quad (2)$$

The expected net income from rice production is the area-weighted sum of the expected yields by variety (μ_i) valued by grain prices, less per unit costs of production. The farm technology constraint shown in equation (1) above still holds, though the specification implies constant marginal costs in the observable range. By definition,

$$\sum_i \alpha_i = 1 \quad (3)$$

This problem yields reduced form equations for the non-separable model where optimal area shares are determined by vectors \mathbf{p} , \mathbf{c} , and $\boldsymbol{\mu}$, and other variety-specific characteristics, as well as the vectors of household, market and farm factors:

$$\alpha^* = \alpha^* (\mathbf{p}, L, \Omega_{\text{Var}}, \Omega_{\text{Farm}}, \Omega_{\text{HH}}, \Omega_{\text{Market}}) \quad (4)$$

Diversity outcomes are expressed similarly:

$$D = D(\mathbf{p}, \Omega_{\text{Var}}, \Omega_{\text{Farm}}, \Omega_{\text{HH}}, \Omega_{\text{Market}}) \quad (5)$$

The yields of rice varieties, as well as other variety-specific traits that might be determinants in a trait model, are in fact determined by genotype by environment interactions, where the environment includes farmer management practices. For example, expected yields could be estimated as instrumental variables in a separate regression as:

$$E(\mu_i) = a_0 + \mathbf{D}'\beta_1 + \Omega_{\text{HH}}'\beta_2 + \Omega_{\text{Farm}}'\beta_3 + e \quad (6)$$

where \mathbf{D} is a vector of 0-1 variables for variety-specific effects.

The two types of policy trade-offs can be investigated through the estimation of equations (4)–(6). These are explained next.

Econometric tests for diversity trade-offs

The first set of econometric tests investigates which explanatory factors specified in the farm household decision-making model affect changes in different types of rice diversity (richness, dominance and evenness) measured at the household level. For example, diversity may be measured by the variety count (richness), variety percent of rice area (dominance) and a Shannon index constructed from variety area shares (evenness). Statistical tests on regression coefficients provide information about the following:

- Which factors (market and price, variety-specific attributes, household characteristics, farm production characteristics, ecosite) significantly increase or decrease the expected level of rice intervarietal diversity in the household?
- Do the factors and their effects differ by diversity measure?
- What are the average market, household, farm and ecosite characteristics associated with high and low levels of diversity?

Tests are implemented by specifying regressions with different dependent variables (diversity indices) and the same independent variables. Signs and significance of regression coefficients are compared. The equations are likely to be run as a SUR model or set of OLS regressions.

The second set of econometric tests investigates which explanatory factors specified in the farm household decision-making model affect changes in the likelihood that different core subsets (selected with different choice criteria, such as rarity or diversity) are grown. Statistical tests on regression coefficients provide information about:

- Which factors (market and price, variety-specific attributes, household characteristics, farm production characteristics, ecosite) significantly increase the likelihood that farmers continue to grow varieties identified as members of core subset A?
- How do these factors affect the likelihood that farmers continue to grow varieties identified as members of core subset B?

Tests are implemented by specifying regressions with different dependent variables (all varieties that are members of core subset group A, 0 otherwise; all varieties that are members of core subset B, 0 otherwise) and the same independent variables. Signs and significance of regressions coefficients are compared. The equations are likely to be run as probit regressions (see Van Dusen, Chapter 2).

Variable measurement

Variables to be measured are given by equations [4]–[6]:

1. Dependent variables: Area shares, diversity indices based on areas shares, expected yields computed from subjective yield distributions elicited from farmers.
2. Independent variables: Household, market and farm characteristics; variety attributes, ecosite.
 - **Household characteristics:** human capital (age, education, experience), household assets
 - **Market characteristics:** distance of plot to market, farmers' participation in market, prices
 - **Farm characteristics:** land types, rice area, land fragmentation, irrigation systems
 - **Variety attributes:** production, consumption, subjective triangular yield distribution
 - **Ecosite:** dummy variables for ecosite, representing agroecological and economic factors at the site level.

Acknowledgements

This paper is a part of the author's PhD research on the economics of on-farm conservation of rice genetic diversity in Nepal, at the University of Birmingham, U.K. The support and insight of Dr Bhuwon Sthapit, Scientist, IPGRI-APO, and Dr M.P. Upadhyaya including the members of the National Multidisciplinary Group (NMDG) of the Nepal component of the *in situ* project are gratefully acknowledged. The guidance of advisors Melinda Smale (IPGRI/IFPRI), Nigel Maxted and Matthew Cole (University of Birmingham), and the insights and support of Toby Hodgkin and Devra Jarvis (IPGRI) are also acknowledged.

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Managing millet diversity on farms in India: farmers' choices, seed systems and genetic resource policy

Latha Nagarajan³

Introduction

International Agricultural Research Centers (IARCs) and other organizations have aided crop breeding programmes in developing countries to incorporate sources of genetic diversity from beyond national boundaries into the modern cultivars grown locally (Evenson and Gollin 1997; Smale *et al.* 2002). In recent years, large private firms have dominated biotechnology research particularly in crops such as maize, cotton, soyabeans and canola. Since these firms need to earn profits, they may have little interest in solving problems specific to developing countries. They require a stable, large, commercial market for their seed products. Consequently, they are not likely to be able to serve the seed needs of large numbers of the developing world's small farmers.

In highly variable environments that are often marginal for crop growth, subsistence-oriented farming systems dominate. Such systems are particularly common in the semi-arid tropics. Many of the principal crops grown in such environments are not globally important staple crops but 'poor people's' crops, including lentil, chickpea, pigeon pea, pearl millet and minor millets. Millets contribute almost 100 million t of grain to the global food budget each year. It is not likely that millets will diminish in importance to subsistence farmers, because other crops will not grow under the harsh conditions where millets grow. There are other desirable attributes associated with millets, including higher value of micronutrients compared with major cereals, as well as greater tolerance to pests and diseases and extreme soil conditions.

Production and consumption of millets in certain states of India and Africa (the largest growers of these crops) are decreasing owing to the replacement of other major cereal crops, rising incomes, changing food preferences, and/or cheap food imports (Seetharam *et al.* 1989). These millet farming systems are undergoing profound changes due to increased population pressure, economic and environmental changes. However, with the latest advancements in biotechnology research combined with the diversity found on farms, it may be possible to develop millet varieties that are both more productive and provide other attractive attributes. Millets may provide a good case for on-farm conservation if they can be improved to better meet the food and feed needs of the farmers in *less favoured economic or physical environments*.

Research objectives

The proposed research will study in depth the varietal diversity of millet crops at the farm household level and in community seed markets in two regions of India. These detailed analyses based on primary data collection will be placed in the context of historical use patterns for modern and traditional millets at regional and national levels. Historical use patterns will be summarized from secondary data. The study is intended to develop implications for genetic resource policy in three areas.

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- Characterize biological diversity at different spatial scales and assess its variability over time at the household, community, district and regional levels
- Empirically examine the determinants of diversity at household and community levels in the context of existing seed systems
- Draw out implications for genetic resource policy, seed market development, and public-private institutional roles.

Research methods

Household survey

- farmer trait preferences and practices
- seed flows and exchange norms among farmers
- econometric estimation of a farmer decision-making model of millet variety and species choice—a theoretical model of the farm household, in which farmers choose among millet varieties and species (intra- and interspecies diversity).

Community survey

- markets for millet seed and variety traits

Market and intellectual property analysis

- secondary-level information from various sources (private and public seed companies)
- seed market trends
- interaction with international research institutions
- review of secondary literature

Proposed sites for the research

One proposed study area will be selected either in Karnataka or Andhra Pradesh because of the relative economic importance of millets in terms of area and production (nearly 10% of the total area in Andhra Pradesh and 24% in Karnataka).

Millets are grown mainly for subsistence in these regions, as mixed crops with other types of millets (such as minor millets). Diversity is therefore observable within the same millet types or across millet types. The major factors leading to simultaneous cultivation of a combination of millets appear to be consumption preferences for food or feed. For example, people from Karnataka prefer foods derived from 'ragi' (finger millet) and pearl millet as a part of their diet, using sorghum and maize as feed. By contrast, people from Andhra Pradesh prefer sorghum derivatives for consumption.

Among the numerous crop combinations found in small farmers' fields in Karnataka, the most frequently grown combinations are: finger millet (ragi) and mustard; groundnut, sorghum (jowar), pigeon pea (a pulse, also known as red gram), cowpea; finger millet, field bean and amaranth (two pulses), castor (for oil purpose), sorghum, chilies. In the Deccan Plateau, these crops serve to meet the family consumption and they ensure a fairly balanced diet. Millet is the staple food. In the case of major millets such as sorghum and pearl millet, modern varieties are visible only in irrigated areas. These are sometimes cultivated alongside landraces of traditional varieties in the system described above.

The second study site will be located in Bhuj, Gujarat. After Maharashtra and Rajasthan, Gujarat occupies the major area under pearl millets (around 11% of the total area). Millets are grown in mixed cropping with bean, castor, sesame, guar and fodder sorghum. Seed security is the major issue in this system and farmers' preference for traditional varieties results from extreme agroecological conditions. Half of the district is covered by desert and the region is characterized by frequent droughts. The adoption of improved varieties by farmers is low because these perform well only when rains are good. The main source of stable income to farmers comes from animal husbandry. Dairying is the major economic activity of the region.

Millets, which are grown in the mixed cropping system (which represents nearly 14% of the total area), are primarily intended for fodder.

Methodology

Test which factors (household, market, farm characteristics; variety attributes; agroecology of the region) affect the cultivation of diversity millets on farms

The role of millet diversity in farm household consumption and income will be characterized. Farmer decision-making will be analysed using a theoretical model of the farm household, in which farmers choose among millet varieties and species (intra- and interspecies diversity), as presented by Van Dusen (Chapter 2). Explanatory variables, as defined by the household model, will be tested for separability of production and consumption decisions. These variables include: human capital, assets, income sources, farm characteristics such as soil types or access to irrigation, price and market-related variables reflecting the farmer-specific costs of transactions. Trait preferences for millets will also be elicited, as well as information on seed flow and norms of seed exchange among farmers. Dependent variables are diversity indices.

The household sample will be stratified by regional level variables that represent market access and agroecosystems. One regional site is Andhra Pradesh/Karnataka, where millets are grown as crops for subsistence. Hence the factors affecting millet variety and species choice are hypothesized to vary by region as well as among communities and household, depending on agroecology, market conditions and farmer preferences over consumption and agronomic traits as these relate to their farming objectives.

The proposed method will involve a household survey including a crop and variety inventory based in the first instance on local taxonomies and nomenclature, and in the second, on the characterization of genetic diversity based on analysis of agromorphological variation within and among seed samples from millet types grown by farmers. The second phase will be conducted and supervised by partners in IPGRI and ICRISAT in India.

The econometric model enables the identification of factors that are associated with higher and lower predicted levels of millet diversity on farms as the economy of the region develops, with implications for policy interventions related to education, infrastructure and access.

Determine the extent to which local millet seed markets supply the traits that are demanded by farmers within a context of historical diffusion patterns and trends in the millet seed industry

This component of the research will consist of an assessment of formal and informal seed markets in the study areas. Its purpose is to identify potential entry points for crop improvement and seed system innovations to address the needs of farmers in ways that support the maintenance of millet diversity.

Data collection will entail some questions in the household survey and a separate trader study in the nearest local markets. The purpose of this exercise will be to identify the extent to which the traits demanded by farmers are or are not satisfied by supply in local markets. When combined with the results of the on-farm analysis, this analysis will help pinpoint the problems that might be addressed by specific germplasm improvement of seed system innovations. In particular, the work seeks to identify policy instruments or strategies that can enhance farmer welfare or seed security while contributing to the maintenance of millet diversity on farms.

Expected research outputs

Findings will lead to policy discussion concerning the following three areas:

- What is the nature and degree of millet diversity (at different spatial scales) and how has that changed over time?
- What is the influence of household characteristics such as human capital and assets, market development and infrastructure, farm physical characteristics, and agroecological factors on the diversity of millets maintained on farms and in communities?
- What is the likely impact of seed policy changes on the structure of formal and informal seed markets, and implications for the diversity of millets maintained in communities?

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Safeguarding agricultural biodiversity on farms in Hungary

István Már

Summary

In preparation for Hungary's entry into the European Union, a consortium of Hungarian universities and research institutes have developed the National Agri-environment Programme. Recently accepted by the Ministry of Agriculture and Regional Development, the programme calls for the development of 'multifunctional', community-based agriculture. 'Multifunctional' refers to the satisfaction of cultural, social and environmental amenities as well as economic needs. The degree of intensity of agricultural production (level of mechanization and use of purchased inputs) will depend on the biological and human resource endowments of an area. The social, economic and cultural role of landraces in this complex system, as well as relevant policies concerning their potential use, have not yet been elaborated. The on-farm project will contribute scientific understanding about the role of locally grown landraces in Hungary's multifunctional agriculture.

Introduction

The actual Hungarian agricultural system is in a transitional phase from centrally planned to market economy, and is characterized by continuous structural reorganization. From the early 1960s, the concept of modern agriculture in Hungary was based on the principles of modern plant breeding activities. The main objective of this concept has been to increase productivity by using species and cultivars with high-yielding potential in environmental conditions modified by human intervention. In most cases these activities have focused on quantitative traits rather than qualitative traits of species. The unique qualitative traits of non- or partially improved plant genetic resources include specific adaptation to local environmental conditions, resistance to local pests and diseases, yield stability and higher nutritional value. These traits not only make them potentially suitable for sustainable agricultural programmes, but may also serve as the basis of initiatives to secure new market opportunities.

The landraces still cultivated by farmers in home gardens or on their small plots are an integral part of the plant genetic resources for agriculture held nationally. The conservation and use of local germplasm has importance for the future breeding activities to satisfy special local needs concerning ecosystem health and ecosystem services. In the modern system that today dominates Hungary's agricultural landscape, landraces of field and vegetable crops survive only in areas that are marginal for production and in home gardens, where they are adapted to specific conditions and there is a demand for high-quality products, both by the farmers who produce them and by other consumers. Within the framework of IPGRI's Global Project 'Strengthening the scientific basis of *in situ* conservation of agricultural biodiversity on-farm' Hungary's national project has a particular role to play. The interdisciplinary research envisaged in this project aims to identify the policy mechanisms that favour the survival of landraces in an advanced economy.

Integration of on-farm conservation activities into the National Agri-Environment Programme

Economic theory and historical patterns generally lead us to hypothesize that the changes associated with economic development reduce the interest farmers have in growing diverse crops and varieties. As agriculture intensifies and becomes commercialized, producers and consumers trade on more formal, impersonal markets, and they tend to specialize.

Farmers have 'incentives' to grow varieties when they possess the traits and characteristics that satisfy the farmers' objectives. In advanced economies, in the absence of special government programmes, economists would tend to hypothesize that landraces will

only be grown when: (1) production of the landraces for the market is profitable, (2) they have unique qualities that urban consumers value or that are valuable for export, and (3) only if these same qualities cannot be easily transferred or are not possessed by modern varieties (Smale 2001). If these conditions held, there would be *market-based* incentives for conserving landraces on farms. Market-based incentives are generally considered to be less costly than publicly funded programmes or subsidies.

Hungarian universities and research institutes have developed a proposal for a National Agri-Environment Programme. The programme calls for the development of 'multifunctional,' community-based agriculture. 'Multifunctional' refers to the satisfaction of cultural, social and environmental amenities as well as economic needs. The degree of intensity of agricultural production (level of mechanization and use of purchased inputs) will depend on the biological and human resource endowments of an area. In certain areas of the country the programme will be targeted for heavier labour utilization relative to machinery and purchased inputs in order to reduce unemployment rates and reliance on certain types of capital and external inputs. Cultivation of landraces, among other practices, plays an obvious role in this agricultural strategy. However, the social, economic and cultural role of landraces in this complex system, as well as relevant policies that might enhance their role, have not yet been elaborated. The Hungarian national on-farm conservation project will be able to contribute to scientific understanding of the role of crop genetic resources in Hungary's National Agri-Environment Programme.

The national on-farm conservation project also has the potential to improve the livelihoods of local farmers, if it increases farmers' access to useful germplasm held in national genebanks or by other farmers. Local crop genetic resources may serve as a basis for the market development initiatives, or niche markets. Farmers may also benefit from continued agricultural biodiversity and ecosystem health. The research of the project aims to investigate these potential benefits with a combination of biological and economics research.

Purpose of the On-farm Conservation Project and home gardens

In a total population of roughly 10 million, there are an estimated 2 million Hungarian households producing agricultural goods for their own consumption or as a source of additional revenue. In Hungary the 800 000 home gardens, ranging in size up to 1 ha, involve the labour of about 1.5–2 million people. In rural areas these have evolved from the plots that households were permitted to cultivate privately during the period in which agriculture was collectivized (1960–89). Throughout that period, home gardens are believed to have played a significant role in meeting the subsistence needs of many peri-urban and rural households.

Home gardeners have specialized in labour-intensive production such as horticulture and animal husbandry, while field crops have been generally grown on large-scale, fully mechanized farms. These small repositories of genetic diversity are cultivated almost entirely with family labour. The 1996 Microcensus indicates that among persons aged 14 and over, 33% had been engaged in auxiliary agricultural work—though relatively few rely on agriculture as a main occupation. Part-time agricultural activity and home gardens continue to play a critical role in assuring the livelihoods of rural Hungarian households (Hungarian Statistical Monitor 2000).

One of the purposes of the Hungarian On-farm Conservation Project is to assess the social, cultural and economic role of the biodiversity found in these local gardens. A second is to recommend policies that support the broadened use of crop genetic diversity in Hungary within the frame of a multifunctional agriculture system.

The On-Farm Conservation Project is built on six different research activities:

1. Analyse ecologies of the targeted sites.
2. Assess the genetic diversity for landraces grown in household plots (agromorphological characterization on farmers' fields and on experimental plots, biochemical and molecular characterization).

3. Evaluate the criteria/traits farmers use to distinguish and select different 'farmer units of diversity' and/or named local cultivars.
4. Assess the product quality of landraces as feed or foodstuffs.
5. Evaluate the actual and potential social and economic role of landraces and home gardens in multifunctional agriculture, including the provision of social, cultural and environmental amenities.
6. Study the national seed regulatory and institutional framework for on-farm conservation.

Current status of On-farm Conservation Project

Since 1997, collection missions have been conducted across sites in Hungary in order to appraise the extent to which landraces are still cultivated in farmers' fields. The major finding of these missions was that only maize and bean varieties were identified in large numbers across sites. For this reason, the On-Farm Conservation Project targets these two crops.

Biological research is currently underway in three different regions of the country: Nyírség-Tiszahát, Körös-mellék and Örség. Each region includes microregions that are considered to be environmentally sensitive areas (ESA), as identified by the National Agri-Environmental Programme. Because of funding constraints, only two of the six main research activities have been initiated: (1) assessment of genetic diversity, and (2) evaluation of the social and economic role of landraces (maize and bean) and biodiversity in home gardens.

The genetic analyses focuses on: (1) the characterization of the genetic diversity within species, (2) the assessment of the genetic distinctiveness among varieties, and (3) the identification of the most important and stable agromorphological traits which make them suitable for local production. Small-scale farmers who produce for their own or local consumption typically have a range of objectives and constraints and they care about many different aspects of a variety—not only those related to how well the variety grows under certain soil, disease and rainfall conditions, but also those associated with how well the grain and stover serves for feed, fodder, staple foods and special dishes prepared for special occasions. The processes used to maintain landraces should also be better understood by first documenting farmers' knowledge concerning the traits they use to distinguish varieties, select and manage seed, and then measuring the impact of these practices on the genetic diversity of targeted populations over time.

The evaluation of the actual and potential costs and benefits of maize and bean landrace production in multifunctional agriculture will be conducted through in-depth household and community baseline surveys of various types in the study regions. Data will be collected concerning resource use, income, expenditure and consumption using samples stratified by appropriate indicators (i.e. intensity, endowments, or type of land use). The initial sampling frame and methods planned for this research are described next (see following chapters). Since the research is in progress, however, these are continually being revised.

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Site and sample selection for analysis of crop diversity on Hungarian small farms

Ágnes Gyovai

Introduction

The Hungarian component of the global project, 'Strengthening the scientific basis for *in situ* conservation of agricultural biodiversity on-farm' is at the stage of initiating in-depth household surveys to describe the economic role of and value of home gardens in conserving biodiversity. These surveys include identifying the factors influencing the likelihood that farmers will continue to grow maize and bean landraces. The scheme employed for site and sample selection is described below.

Site selection

In Hungary, sites for economics research were selected on several criteria. First, to link the on-farm conservation research of the global *in situ* project to the National Agri-environmental Programme (briefly called NAEP). Thus, sites needed to be located within the pilot sites of the NAEP. Sites were also located in areas where collection missions had been conducted and a number of landraces had been identified. Finally, all sites are considered as Environmentally Sensitive Areas (ESAs). Under these criteria, three sites were selected that represented major contrasts in terms of agroecology and market infrastructure, associated with differences in farming system and land-use intensity.

According to the strategy detailed in the NAEP, extensive (lower mechanization and purchased input use relative to labour) farming methods are considered the most appropriate practice for conserving traditional varieties of crops, or the landraces that are the research interest of the project. In the context of Hungary's agricultural system, home gardens and small farms in ESAs are the best locations for conserving agricultural biodiversity since these small-scale, labour-intensive systems do not compete for resources with the capital-intensive production of field crops in the higher potential areas.

Environmentally Sensitive Areas (ESAs) in the NAEP

Hungarian ESAs are areas with low agricultural productivity but high environmental value. In the context of the NAEP, the main goal of the ESA system is to protect natural areas, such as those inhabited by endangered plant and animal species, through supporting extensive production methods. In the three research sites, the ESA system provides opportunities for: (1) application of extensive production methods oriented toward environmental protection (Szatmár-Bereg region), (2) habitat development for endangered species (Dévaványa region), and (3) 'mosaic' farming with small plots (Örség-Vend region).

Farmers who have fields located within the ESA boundaries are eligible for support and payments according to the package of farm management rules tailored to the ecological potential and protection needs of each region. However, no support system as yet exists for conservation of landraces and agricultural biodiversity found in home gardens and on small farms. Biological and economics research on this project is therefore designed to investigate, document and analyse the ecological, social and economic importance of this diversity to those involved in policy formulation.

Study sites

Dévaványa region

Dévaványa region is located in the centre of the Hungarian Great Plain. The area is flat and the natural conditions (climate, soil) are generally suitable for intensive crop production. One can find a mosaic of cultivated lands and grasslands where the soil conditions are less suitable for cultivation. These differing soil conditions justify a combination of both intensive agriculture and extensive grazing at the same site. In Dévaványa region the goal of NAEP is the protection of the rich wildlife with special emphasis on the bustard population.

This region is the most urbanized among the sites selected. With one exception, each of the five settlements included in the site represents a town with an area of 12 387 up to 30 398 ha. The population size of the settlements ranges from 5334 to 15 874 inhabitants. Here migration is not an important factor, but the number of inhabitants is stagnating. The infrastructure is well-developed.

Szatmár-Bereg region

Szatmár-Bereg is in the northeast of Hungary, on the Ukrainian border. The characteristics of the area are similar to Dévaványa region. The landscape is a mosaic of grasslands, forests, arable lands and moors. Aside from the beautiful landscape, the region has several important natural endowments. There are plans for the future establishment of a national park. Today the NAEP promotes nature conservation in this ESA.

In Szatmár-Bereg, villages are relatively small, both in area (1600–2819 ha), and population sizes (488–939 inhabitants). All of the six villages face a declining and aging population. The explanation for this pattern is straightforward. The region is a less-favoured area for agricultural production and is located far from the economic centre of the country. There have been few investments in infrastructure or employment-generation, and the unemployment rate is high (15–30%). A particular disadvantage for economic development of the region is its low road density.

Őrség-Vend region

Őrség-Vend region is located in the southeast of Hungary, on the Slovenian border. This region differs from the other two sites in many ways. The agricultural landscape is heterogeneous, including knolls, valleys, forests, grasslands and arable lands. Poor soil conditions render intensive agricultural production methods impossible. Here, NAEP supports extensive production methods to preserve the landscape for future generations.

In this study site the 11 villages are extremely small (520–3356 ha), and the smallest villages have only 58 to 267 inhabitants. The problem of a declining and aging population is even greater in these communities than in Szatmár-Bereg. Moreover, the unique forms of settlement in this region—'szer' and 'szórvány'—make it difficult to design the public utilities necessary to support villages. Most villages are far from towns, and road density is very low.

Selection of households

The first step in selecting households was to determine a sampling frame. Village authorities were unwilling to provide a list of households in the settlements because of concerns for personal privacy. Existing databases from the Ministry of the Interior were too costly to obtain. The list was therefore compiled by combining information from detailed maps drawn by the NAEP, telephone books and the Hungarian Central Statistical Office TSTAR database. Since little was known about the characteristics of the households in the survey sites and the extent of their involvement in agricultural production and home gardens, a brief screening questionnaire was designed in order to better target the sample in a second stage. Since a minimum final sample of 100 per site was thought necessary for data analysis, and the

response rate to a mail survey was expected to be low, the team decided to include 600 households per site (1800) in the first stage. All administrative units within the sites were sorted based on population sizes and the initial sample was distributed proportionally.

Letters were sent out to explain the purpose of the forthcoming survey, and the background and description of the national on-farm conservation project. Attached to the letter were the following questions:

- Do you currently cultivate a home garden that is owned by your family?
- Do you currently cultivate land other than that in the home garden?
- Do you grow any traditional varieties of the following crops in the home garden or your fields?

Please complete the following table:

Crop	Local name of variety	In home garden	In fields
Maize			
Beans			
Others			

Results

The response rate for the initial screening survey was extremely low, as indicated in Table 1.

Table 1. Response rate for screening survey by study site.

Region	Letters sent	No. of responses	Response rate (%)
Déaványa	615	119	19.34
Szatmár-Bereg	600	60	10.00
Örség-Vend	580	55	9.48
Total	1795	234	13.03

The overall response rate was about a third of the level that might be considered acceptable for a mail survey in a developed country. The low response rate (13.03%) may be explained in part by the growing amounts of unsolicited mail received by Hungarian residents today (advertisements, political statements, etc.). On the other hand, many of those who did respond expressed interest in the letter and attached detailed descriptions of their gardens and varieties in their reply.

On the basis of responses, respondents can be divided into four groups, as indicated in Table 2.

Table 2. Percentage distribution of respondents by type of agricultural participation.

Region	Home garden only (%)	Field only (%)	Home garden and field (%)	No home garden, no field (%)	Landrace growing (%)
Déaványa	49.57	4.2	21.84	24.36	32.77
Szatmár-Bereg	45	1.66	46.66	6.66	50.00
Örség-Vend	30.9	1.81	54.54	12.72	35.18
Average	41.82	2.55	41.01	14.58	39.31

In Déaványa region, which is the most urbanized site, about one-quarter of respondents have neither home garden nor field. Despite this, Déaványa region has the highest rate of respondents who have only fields, which implies that they are engaged in agriculture on a larger, commercial scale.

The percentage distribution of respondents among farm types is similar between Szatmár-

Bereg and Örség-Vend regions. Roughly half of the respondents in each site own both home gardens and fields. In each of the two sites, only a minority of respondents stated that they owned neither home garden nor field (6.66 and 12.72%).

Concerning landrace cultivation, on average 40% of respondents reported that they grow traditional varieties, and most of these were maize and beans as expected from the collection missions. This implies that our total sample of landrace growers is about 90 farmers.

Clearly the full sample of respondents to the screening survey will be visited in conducting household interviews, and there will be no second-stage sampling. In addition, the response rate will be augmented through the use of 'key informants' (such as agricultural agents) or by enlisting the assistance of local people to locate those who did not initially respond. This will also serve the purpose of involving communities in the survey and better introducing the national on-farm conservation project, which is an important ingredient for its future success.

Conserving agricultural biodiversity on Hungarian small farms: economics research tools

Ekin Birol, Györgyi Bela, Ágnes Gyovai, György Pataki and Melinda Smale

Objectives

The goal of economics research in the Hungarian country component of the Global IPGRI *In Situ* Conservation On-farm Project is to define the role of agricultural biodiversity in the NAEP and to provide information to decision-makers for the design of appropriate policies. To address this goal, the research has several specific objectives. The first is to estimate the contribution of home gardens and components of home gardens, such as maize and bean landraces, to the consumption and income of farmers located in ESAs. The second is to identify the factors that influence the variety choices of these farmers in their home gardens and fields, and profile those most likely to continue to maintain higher levels of diversity. The third is to estimate the total economic value and value of specific attributes of home gardens. The fourth is to value specific attributes of maize and bean landraces. A final objective is to evaluate the institutional context for conservation of agricultural biodiversity on farms in Hungary.

The team plans to employ a combination of methods to meet their objectives. These are: (1) econometric application of a farm household model of choices affecting diversity of crop species and varieties grown on small farms; (2) a choice experiment on home gardens to detect the home garden attributes most significant to farmers and their attributes; (3) a conjoint analysis (and perhaps a hedonic analysis) to estimate the marginal value of attributes of bean and maize landraces, and (4) an analysis of the institutions, actors, and legislation affecting the potential for conserving agricultural biodiversity on farms. Methods 1-4 are discussed in detail in Section I of this volume. Applications planned for the research to be implemented in Hungary are described below.

Survey methods

The survey methods planned for the Hungarian project include several tools, though these have not occurred in the ideal sequence. The institutional analysis involves group discussions and focus group interviews with key stakeholders in agricultural biodiversity conservation. The conjoint utility analysis will involve focus group interviews to identify attributes, followed by a more controlled exercise that enables farmers to score or rank varieties with respect to attributes. The choice experiment and farm household model have begun with informal, semi-structured interviews in each of the study sites.

Gyovai (Chapter 8) has described the sample design for the formal survey of farm households. Personal interviews will be conducted based on a pre-tested, structured questionnaire. The formal survey of farm households serves multiple purposes. First, it generates data for the application of the farm household model. Second, it reveals the subsample for the choice experiment, which will be conducted only with farmers who have home gardens. A third, and important purpose is to provide essential statistics to decision-makers. For example, the data will be used to demonstrate the frequency of use of home gardens and cultivation of landraces and enable the team to estimate the value of production from home gardens as a proportion of total consumption. The features of home gardens can be described statistically, such as the mean and mode of species and varieties managed, by intensity of land use and market access.

Fourth, the survey serves as a diagnostic for the design of policies to support conservation of agricultural biodiversity on farms. The data enable the team to profile the farmers (and sites) with the highest *ex ante* probability of maintaining agricultural biodiversity. This information may be of use for targeting conservation programmes. In principle, these

households and sites would require the minimum amount of public funds to continue conserving. However, they may be the oldest farmers in the community. If so, programmes must be devised to transfer their knowledge and responsibilities to younger farms, while stemming the migration of youth from these communities. Finally, the survey provides a baseline against which any future policy interventions directed toward the conservation of agricultural biodiversity in the study sites might be assessed.

The formal questionnaire consists of several sections: (1) a field and garden inventory of crops and varieties, and farm land quantity and quality; (2) human capital (education, experience), employment patterns, and asset position of farm households; (3) indicators of value of farm production, total consumption and income levels, and (4) basic market information for seed and products.

Application of farm household model

A set of research questions is of potential interest in applying the econometric model of the farm household outlined by Van Dusen (Chapter 9). These include:

1. Which factors predict that farmers will grow landraces of maize and beans?
2. Which factors predict that farmers will have (i) home gardens, (ii) farm fields, and (iii) both home gardens and farm fields?
3. Which factors predict higher levels of diversity on Hungarian small farms?
4. Do these factors differ according to whether the farmer has (i) home gardens only, (ii) farm fields only, and (iii) both home gardens and farm fields?
5. Which households and sites have the highest ex ante probability of maintaining agricultural biodiversity?

Factors are broadly categorized as household characteristics, physical characteristics of farms and sites, market access of household members and infrastructure conditions in sites.

Data collected in the formal survey of farm households will be analysed first descriptively, in order to refine the underlying theoretical model and specify the econometric models, as well as generate baseline summary statistics by site. For research question (1), a probit or logit with sample selection would be appropriate, while question (2) might be addressed with a multinomial logit model. The specification of (3) will depend on how the team decides to measure diversity, taking into account the genetics analyses undertaken by the biological scientists. Hypothesis tests involve the application of individual t-tests on regression coefficients as well as tests of joint hypotheses, for questions such as (4). Selection or mixture models will probably be required given that some households in each study site have neither farms nor home gardens. Question number (5) is answered through examination of predicted values of the independent variable and mean levels of independent variables. Estimated regression equations can also be employed for simulations.

Application of choice experiment to value Hungarian home gardens

The choice experiment method for valuing environmental goods is discussed in detail by Birol (Chapter 3). The purposes of applying this method in Hungary are to: (1) identify those attributes of home gardens that farmers (who are also consumers) consider most valuable, and (2) determine the monetary value of these attributes, which can be interpreted as the amount farmers would be willing to accept in compensation for their loss.

Informal interviews were conducted with approximately 40 farmers who cultivate home gardens in the three study areas during the initial phases of the economics research of the project. The biological scientist who heads the project and implemented the previous collection missions led these interviews. Attributes were selected for inclusion in the choice experiment based on review of the notes from these discussions. They consist of the following:

1. **Diversity attribute:** Intra- and interspecies diversity of plants in the garden. The levels chosen for these attributes being 6, 13, 20, 25, with 13 being the average (i.e. status quo).
2. **Organic farming:** Whether any chemicals (fertilizers and pesticides) are used in production or not. The attribute is dichotomous (Yes; No).
3. **Agrodiversity variable:** Whether the agricultural system is mixed or specialized. This attribute has two levels: crops only; crops, livestock and orchards versus crops only.
4. **Cultural heritage variable:** Whether the home gardens contain any heirloom varieties or not. The attribute is dichotomous (Yes; No).
5. **Monetary variable:** Percentage of annual household consumption most frequently obtained from the home garden, which will be translated into forints using secondary data. There are four levels to this attribute 15%, 45%, 60%, 75%. 60% is the most frequent (i.e. status quo).

Hypothesis tests on estimated regression coefficients will reveal the significance and relative magnitude of value farmers place on these attributes of home gardens. Each coefficient is an estimated marginal value of the attribute in terms of the monetary variable. The total economic value of the home garden to farmers in the study sites can also be inferred from the results, including both use and non-use benefits. The data on the characteristics of the households that will be collected alongside the experimental data will be used to extrapolate the values estimated from the sample to the population represented by the sample. This information is essential for the design of effective policies to promote different attributes of home gardens or support their continued management by farmers. Moreover, the results of this experiment (a stated preference method) can be compared with those from the farm household analysis (a revealed preference method) to check the validity of the experiment.

Conjoint and hedonic analyses of bean and maize landraces

A conjoint analysis, as well as possibly a hedonic analysis, will be implemented in order to estimate the significance and marginal value of bean and maize landrace attributes to consumers. Smale describes similar applications of these methods briefly (see Chapter 4). Conjoint analysis is akin to the choice experiments method. Developed for marketing research, it relies on consumers' stated preferences over the levels of attributes provided by a set of goods, controlling for their demographic, social and economic characteristics. Conjoint utility analysis can be employed whether there are markets for maize and bean landraces or not. Although markets for maize and bean landraces exist, they are informal and limited in volumes sold. However, since preferences are expressed in terms of scores or ranks that refer to consumer satisfaction or utility, monetary values cannot be assigned to attributes through conjoint analysis. Hedonic analysis does permit the estimation of marginal value of each attribute, including both those perceived by consumers ('evident' attributes) and those observable only in a laboratory ('cryptic' attributes). The coefficients of the linear regression of the price charged for a sample of maize or beans purchased in the market on the sample's attributes represent partial derivatives. The partial derivative of the market price with respect to an attribute is its marginal value.

Results from the application of either method have clear implications for plant breeders who seek to improve landraces, by identifying traits that consumers consider important. Similarly, either may provide evidence on the potential for niche markets or market-based incentives for landrace cultivation. Neither generates information about diversity per se. Furthermore, markets may provide an incentive to specialize in one landrace or another, which does not imply that diverse landraces are maintained. Nevertheless, in Hungary, where modern methods of production dominate the agricultural landscape, the continued

survival of landraces in farmers' gardens and fields creates some diversity in the system. In any case, there is some challenge in choosing the appropriate format as well as correctly interpreting results, given the informal nature and limited size of markets for landraces in Hungary. The design of this component of the research awaits additional focus group interviews and group discussions.

Institutional analysis

The analysis of institutions involves the study of how rules shape human behaviour. These rules or institutions can be formal and codified as law, or they may be informal and exist as rules-in-use or norms. Related research focuses on how individuals and groups construct institutions, how institutions operate, and the outcomes generated. An institutional analysis will be conducted in order to understand the perspectives of each stakeholder involved in conserving agricultural biodiversity on small farms in Hungary. The design of this analysis is currently underway, though it would have been preferable from a standpoint of research process to initiate it earlier.

Conclusions

Economics research on the On-Farm Conservation Project in Hungary is unique in that it is the first effort in IPGRI's global project to combine tools from different fields of inquiry: microeconomic theory of the farm household, from the field of agricultural economics; choice experiment and hedonic valuation methods, from the field of environmental economics; conjoint analysis, from marketing research, and the field of institutional economics. It is hoped that by combining tools from these fields, the policy relevance of economics research about the conservation of agricultural biodiversity on farms can be made more relevant. In some instances, applications reveal different estimates of the same economics concept, which can be compared to assess their validity. A major advance in methodology may be attained if the research is successful.

IV Social analysis

Social and economic research in the Burkina Faso country component of IPGRI's Global *In Situ* Conservation On-farm Project: methods and results

Ram Christophe Sawadogo

Introduction

Dans le cadre du projet « Renforcement de la base scientifique de la conservation *in situ* de la Diversité Biologique Agricole », la composante burkinabé du Projet global de l'IPGRI, implantée au Burkina Faso depuis 1997, s'est principalement souciee de l'implication directe des populations rurales, paysannes et pastorales. Le projet, impliquant une dizaine d'équipes, poursuit quatre objectifs principaux :

- accroître les connaissances sur les processus de prise de décision des paysans dont l'intervention influence la conservation *in situ* de la diversité biologique agricole
- renforcer les capacités des institutions nationales chargées de la planification et du développement des programmes de conservation de la diversité biologique agricole
- élargir la diversité biologique agricole par utilisation des cultivars traditionnels et promouvoir la participation des populations rurales et d'autres groupes sociaux à sa conservation
- atteindre l'efficacité de la gestion administrative et du suivi des évaluations.

Cet article présente plus spécifiquement quelques résultats d'une étude socio-économique articulée selon de trois axes :

- l'identification des niveaux de connaissance et le recensement des facteurs sociaux, culturels, économiques et écologiques qui, chez les paysans, interviennent dans les choix de diversité biologique agricole et les stratégies de leur réalisation
- l'étude, sous l'angle économique, des niveaux des productions et des principales affectations des produits
- l'étude, sous l'angle socio-économique, des corrélations entre les variables économiques, d'une part, et les caractéristiques socio-démographiques et les statuts sociaux et familiaux des répondants, d'autre part.

Méthodologie

Un questionnaire a été soumis à la population ciblée afin d'évaluer les connaissances relatives aux espèces cultivées et aux conditions optimales de culture. Il a été construit pour aborder les questions générales suivantes :

- Quels sont les éléments constitutifs de ce capital de connaissance ?
- A quels référents culturels, économiques, écologiques et humains se rapportent les choix qu'opère le producteur pour une campagne ou pour une culture donnée ?
- Quels sont les moyens mis en œuvre pour réaliser les choix décidés ?
- Le producteur se donne-t-il des perspectives d'amélioration de l'utilisation ou d'exploitation de la diversité biologique agricole ?

Ces guides-entretiens ont été complétés par l'observation directe et par des entretiens collectifs.

La population ciblée était constituée des producteurs des villages des trois sites du projet (Ouahigouya, Tougouri et Thiougou) avec pour chaque village, au moins trois familles et dans chaque famille, quatre personnes (le chef de concession, un chef de ménage, une femme et un célibataire rattaché au chef de concession).

L'échantillon global des entretiens individuels a été de 180 personnes, dont 60 chefs et 120 autres membres des unités domestiques.

Les variables discriminantes retenues ont été le sexe, l'âge, la religion, les activités économiques, le statut migratoire, le niveau d'instruction et l'ethnie.

Les données quantitatives et qualitatives ont nécessité un double traitement informatique sur les logiciels Excel et SPSS 10.0.

Dans le cas spécifique des données relatives à la production (quantités globales, moyennes selon les statuts sociaux familiaux) et à la distribution selon les destinations (consommation familiale, vente, dons et sacrifices), seules les moyennes au niveau des unités domestiques ont été présentées.

Résultats

Tout d'abord, il s'est avéré que les données chiffrées obtenues auprès des seuls chefs d'unités domestiques conduisaient à une sous-estimation des quantités réelles des productions et de leurs affectations. Le chef d'unité domestique, qui ne connaît avec certitude que les données relatives aux produits issus du seul champ familial et de ses propres champs personnels, à l'exclusion des produits des champs individuels des autres membres de l'unité domestique, a préféré, dans de nombreux cas, plutôt s'abstenir que de livrer des données hasardeuses. Ce biais a surtout affecté les produits spécifiques aux champs cultivés par les femmes comme le gombo, l'arachide, le petit pois et le fonio avec une invalidation touchant respectivement 179, 125, 169 et 177 des 180 unités domestiques de l'étude. Par contre, le mil, production majeure des champs familiaux, a présenté le plus faible taux d'invalidation (79 sur 180), soit une couverture de 56,1%.

Connaissance de la biodiversité agricole et logique du comportement des producteurs

L'analyse des données a montré que les paysans possédaient une bonne connaissance de la biodiversité génétique agricole :

- Un répertoire de 81 espèces différentes a pu être dressé, distinguant les arbres, les plantes et les herbes. 53 espèces ont été déclarées utiles dans un champ, sur la base d'au moins sept critères positifs. L'identification a reposé sur des repères précis : pour les ligneux, la taille, le caractère épineux, la couleur et la forme du tronc, la forme des feuilles, la couleur et la forme des fruits ; pour les herbacées, la taille et la forme.
- 70% des paysans utilisent des critères précis pour justifier le maintien de certaines plantes à l'état sauvage : l'abondance de l'espèce, son caractère inhabituel, l'ignorance des conditions d'une domestication de l'espèce, la faible valeur attribuée à l'espèce et le manque de moyens pour réussir sa domestication.
- Au moins 51,4% des paysans reconnaissent les parties utiles des plantes et 71,7% d'entre eux en précisent les domaines d'usages actuels.
- 94,3% et 94,1% des paysans identifient le lieu et la période propices à la germination des espèces végétales.
- 98,8% des répondants définissent clairement les problèmes de l'agriculture et 67,9% ceux de l'élevage, citant dans le cas de l'agriculture : la sécheresse, la divagation des animaux, l'absence d'arbres, le manque de moyens, la croissance de la population, la surexploitation des champs et l'absence d'accès au crédit.

D'autre part, l'étude des comportements a montré aussi une conscience claire de ce qui est souhaitable ou à proscrire pour la préservation et la promotion de l'environnement. Ainsi 84,9% des paysans citent le reboisement, la sauvegarde de la nature, la lutte contre le ruissellement des eaux, etc. Ces pratiques préconisées s'appuient sur des justifications précises. Par exemple, ils connaissent le rôle positif des arbres sur la pluie et sur la fertilisation des sols. Ils sont aussi conscients des menaces que font peser les feux de brousse tout comme la surexploitation du bois de chauffe sur cette ressource.

Gestion territoriale des cultures

Sur la question des motifs d'abandon des champs, posée aux chefs d'unités domestiques, 27,3% citent un sol infertile (ou sol pauvre) (13,9%), le vieillissement du sol (7,2%), le mauvais rendement du champ (6,2%) et l'exode rural (1,4%).

Les motifs d'aménagements des champs s'inscrivent dans la même logique que ceux de déplacements de champs et sont principalement d'ordre environnemental.

De même, le classement par ordre d'importance des cultures actuellement pratiquées répond à une logique contextuelle donnant la priorité successivement aux produits de base de l'alimentation, puis aux produits secondaires et enfin à ceux destinés à la commercialisation.

Activités économiques des répondants

- Sur l'échantillon de 539 paysans soumis à l'enquête de terrain, 263 ont exercé, dans le passé, dans 32 localités et 6 pays différents, des activités aujourd'hui abandonnées. La nature de ces activités, leur période d'exercice, les circonstances de leur apprentissage, leurs avantages et inconvénients et enfin les raisons de leur abandon, ont tous été précisés.
- les producteurs ont effectué le classement des activités et ont spécifié les conditions nécessaires à leur prospérité.

Stratégies des choix variétaux des paysans

Au cours des trente dernières années, une centaine de tentatives d'introduction de nouvelles cultures ont été faites et les principales stratégies identifiées sont les suivantes :

- Le statut des acteurs sociaux qui influencent les choix : Contrairement à l'attente, c'est à des éléments extérieurs, à savoir les agents du ministère de l'agriculture, que les initiateurs de choix génétiques préfèrent se référer, avant de consulter les détenteurs de l'autorité coutumière, en raison de leur influence et de leur meilleure connaissance des méthodes culturales.
- Les moyens techniques de culture (semences sélectionnées choisies sur la base de critères techniques, outillage transformé, recours aux fertilisants et leurs justifications), sont utilisés par une majorité d'exploitants.
- Les moyens organisationnels au sein des unités familiales précisent les tâches qui incombent à chaque membre ; les regroupements extra-familiaux, par souci d'entraide, de facilité d'équipement et d'autres formes d'assistances, évoquent également les obligations des adhérents.

En outre, il convient de signaler qu'une étude a été effectuée sur les éléments de prévision des campagnes agricoles, utilisés par les paysans pour connaître, de manière globale, le succès ou l'échec de la campagne et, de manière spécifique, la satisfaction des besoins pluviométriques d'une culture. Les résultats en ont été présentés à l'équipe des évaluateurs externes venus au Burkina Faso en 2001 et lors d'une rencontre internationale tenue la même année.

Tous ces éléments de stratégie prévisionnelle et de gestion des situations contextuelles montrent que le paysan, contrairement à l'opinion naguère répandue, dispose bien d'une connaissance certaine de la biodiversité agricole et d'un répertoire de choix stratégiques obéissant à une rationalité interne objective.

Etude économique

Les aspects économiques analysés ont intéressé les niveaux de production et de distribution selon les quatre destinations principales rencontrées dans la zone de l'étude (consommation, vente, dons et sacrifices).

Production

Au total, douze produits de base ont été identifiés par notre étude auprès des 60 chefs d'unités domestiques. Le tableau 1 présente les quantités totales et les moyennes de production.

Tableau 1. Rendement des productions domestiques

Espèces	Nbre de réponses valides	Nbre de réponses manquantes	Moyenne de production (kg)	Production totale (kg)
Mil	101	49	177,32	17909
Sorgho blanc	64	116	114,11	7303
Sorgho rouge	38	142	69,58	2644
Maïs	66	114	7,06 [†]	466 [†]
Riz	26	154	81,79	2127
Niébé	32	148	132,44	4238
Arachide	55	125	70,81	3895
Pois de terre	11	169	68,18	750
Igname	0	180	—	—
Gombo	1	179	3,00	3
Sésame	9	171	33,56	302
Fonio	3	177	57,33	172

[†]Les données pour le maïs sont exprimées en unités de mesure spécifique à cette culture.

Pour la période d'observation, les valeurs moyennes des revenus agricoles correspondants aux différents produits répertoriés ont été calculés mais leur conversion en revenu monétaire se fait de manière indirecte en prenant plutôt en compte les dépenses réelles du ménage.

Destination

Les résultats de la répartition des productions globales selon les grandes destinations trouvées dans la zone de l'étude sont présentés dans les figures 1 à 5 pour les principales cultures. On constate que la consommation absorbe toujours la plus grande partie des produits des cultures. Par ailleurs, il a été demandé aux enquêtés d'établir eux-mêmes les proportions des produits de cultures qu'ils affectent respectivement à la consommation et à la commercialisation. Les résultats de cette seconde approche montrent que 39,1% des producteurs destinent la totalité de leurs produits à la consommation contre 4,2% à la commercialisation.

Cette dominante met en évidence le caractère d'autosubsistance de l'économie locale.

Commercialisation

Les données sur la commercialisation ont été obtenues à partir d'un effectif de 896 réponses enregistrées. Les résultats suivants apparaissent :

- les produits commercialisés sont, pour 96,4% des réponses:
 - les vivres (79,7%)
 - autres produits (11,4)%
 - les animaux (5,4%)
- les lieux de vente sont, pour 85,2% des réponses :
 - le marché du village (73,2%)
 - le village voisin ou un marché régional (18%)
 - à domicile (3%)
 - entre le marché du village et le domicile (1%)
- les acheteurs, pour 95,1% des réponses, sont :

- les commerçants (58,5%)
- autres combinaisons (16,7%)
- les habitants du village (11,8%)
- autres personnes (8,1%)
- cette activité de commerce trouve ses justifications, pour 95,3% des réponses, dans les besoins de parvenir à :
 - un gain d'argent (80,4%)
 - combinaisons diverses (22,7%)
 - autres destinations (5,6%)
 - résoudre les problèmes de santé (1,5%)
 - l'acquisition de matériel agricole (1,2%)
 - l'acquisition de produits phytosanitaires (0,7%)
- les difficultés d'écoulement qui handicapent l'activité sont, pour 77,3% des réponses :
 - autres facteurs (44,8%)
 - la mévente (22,8%)
 - l'absence d'étalon de mesure convenable (6,8%)
 - l'enclavement ou les mauvaises pistes (4,5%)
- au regard de certaines de ces difficultés, les producteurs pensent savoir que les exigences du marché sont, pour 94,2% des réponses :
 - la quête de la bonne qualité (54,5%)
 - autres exigences (36,9%)
 - la recherche de la graine débarrassée des cailloux (2,9%)

Les populations pratiquent essentiellement une agriculture d'autosubsistance. La part modeste des produits affectés à la commercialisation est absorbée principalement par l'environnement proche et a pour but de procurer un revenu numéraire. Les producteurs identifient certains facteurs limitants du système commercial et sont conscients des exigences des consommateurs.

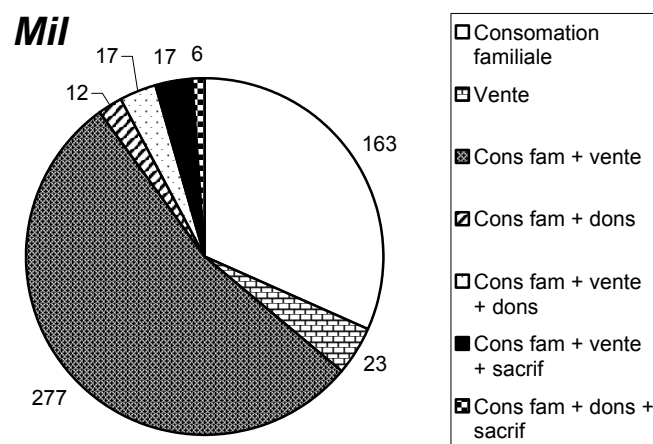


Figure 1. Répartition de la production de mil.

Sorgho blanc

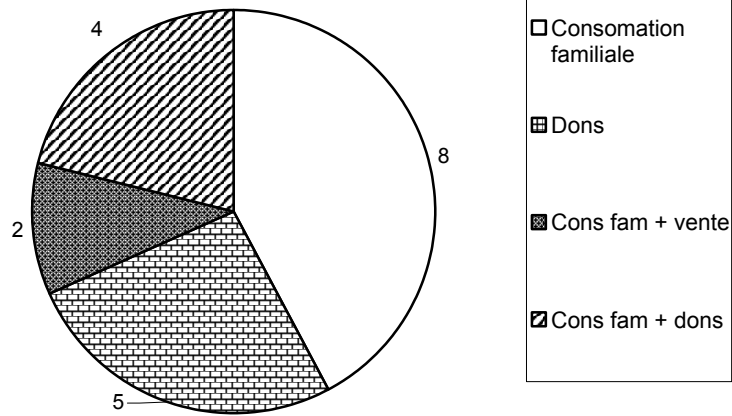


Figure 2. Répartition de la production de sorgho blanc.

Sorgho rouge

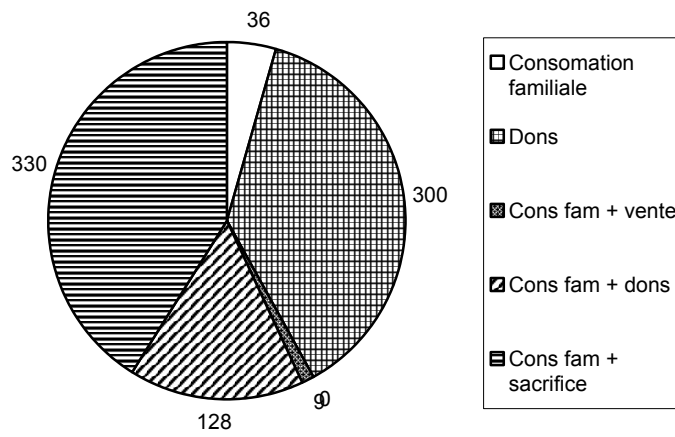


Figure 3. Répartition de la production de sorgho rouge.

Arachide

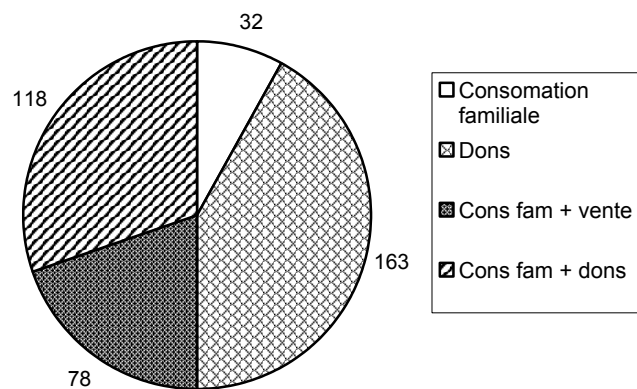


Figure 4. Répartition de la production d'arachide.

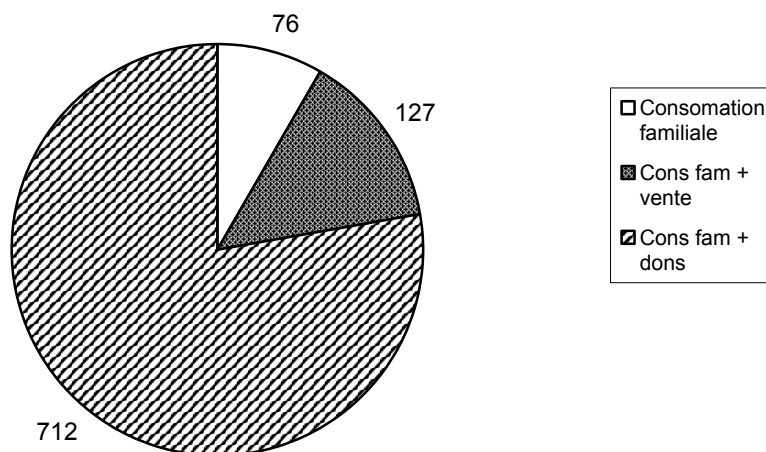
Maïs

Figure 5. Répartition de la production de maïs.

Résultats socio-économiques

Les aspects socio-économiques sont constitués par l'établissement des corrélations entre, d'une part, les variables économiques et d'autre part, les caractéristiques socio-démographiques (âge, sexe, niveau d'instruction, religion, etc.) et les statuts sociaux et familiaux des répondants (situation matrimoniale, relation au chef de ménage : chef de ménage, épouse, fils/filles, collatéral, etc.), qui sont, sous l'angle sociologique, à la base des comportements économiques ; s'y ajoutent également ce qui, dans l'étude, se présente comme les stratégies des producteurs en matière de choix de variétés.

La répartition des productions globales selon le sexe, la religion et le niveau d'instruction révèle une seule dominante remarquable, à savoir que les hommes détiennent des proportions de loin supérieures à celles des femmes pour les produits agricoles de base de l'alimentation, (mil et sorgho blanc). Les écarts sont respectivement de 1 à 9 pour le mil et de 1 à 2 pour le sorgho blanc, alors que les rapports s'inversent pour des produits de moindre importance alimentaire, comme l'arachide où le rapport est environ de 1 à 2 en faveur des femmes. Il apparaît donc que les hommes soucieux de leur rôle connu de chef de famille, tiennent à conserver leurs prérogatives en matière de contrôle de la base de l'alimentation des ménages.

Par ailleurs, il est montré que les hommes ayant le plus faible niveau d'instruction (analphabètes) détiennent les meilleurs niveaux de production. Conscients de l'absence d'autres perspectives d'emploi et de moyens de subsistance, ils accordent plus d'intérêt aux instructions des agents d'encadrement agricole. Les statuts des chefs de ménage et le type d'activité principale du cultivateur viennent renforcer ces conclusions.

Conclusion

Dans cet article sont présentés plusieurs résultats de l'étude des aspects socio-économiques de base du Projet IPGRI. Il apparaît que les paysans possèdent un bon niveau de connaissance de la biodiversité agricole. Leurs savoirs concernent quatre-vingt espèces cultivées, de nombreuses plantes utiles, leurs usages et les conditions propices à leur culture. Ils sont conscients des problèmes de l'agriculture et des comportements à préconiser pour la préservation des ressources. Ils disposent d'un répertoire de choix stratégiques pour atteindre les conditions d'une meilleure productivité au regard par exemple des techniques culturales, de l'outillage technique ou des types de sols.

L'évaluation de l'aspect économique a porté sur la production et la ventilation selon diverses utilisations de douze cultures majeures. La part réservée à la consommation se révèle dominante pour les cinq cultures principales que sont le mil, le sorgho blanc, le sorgho

rouge, l'arachide et le maïs. Ceci souligne le caractère d'autosubsistance de l'économie locale. La commercialisation des productions s'effectue dans l'environnement proche (commerçants et marché du village) et se pratique principalement pour obtenir un revenu monétaire.

L'étude des aspects socio-économiques souligne le rôle des hommes comme détenteurs majoritaires des productions principales. Ils gardent le contrôle de la base de l'alimentation, conformément à leur statut de chef de famille. Il est à noter que le degré d'instruction des hommes est corrélé négativement aux rendements de production obtenus. Les hommes analphabètes se montrant les plus attentifs aux conseils des agents d'encadrement agricole.

Toutefois, l'entretien avec les seuls chefs d'unités domestiques a créé un biais pour les productions qui ne dépendent pas directement d'eux, en particulier les productions cultivées par les femmes. Il sera donc judicieux d'interroger, au moment de la collecte des données de terrain, l'ensemble des acteurs individuels des unités domestiques.

D'autres aspects mériteraient de retenir l'attention comme une évaluation des résultats économiques liés au choix d'une nouvelle variété, dans un ensemble de données contextuelles (prévisions pluviométriques, technologies disponibles, ressources humaines, etc.) De même, il serait intéressant de procéder à une évaluation des risques et des résultats réels au niveau du paysan, des stratégies individuelles et collectives mises en place pour gérer ces risques. Ainsi, serait atteinte une meilleure connaissance des cycles complets de choix d'une campagne agricole, allant des choix stratégiques du début de la campagne aux résultats finaux et à l'appréciation qu'en fait le producteur.

Par ailleurs, la conscience de l'apport des formations déjà reçues et celle de besoins de nouveaux apprentissages peuvent, si ces attentes rencontrent une offre de formation et de suivi suffisants, entretenir l'espoir d'un engagement collectif pour la réalisation de l'autosuffisance alimentaire, grâce à une diversité biologique agricole effective, assumée et gérée à bon escient.

L'élaboration de stratégies à long terme pour un développement durable de l'agriculture doit passer par une approche participative soutenue accompagnant de telles orientations de la recherche.

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The participation of farm women in the *milpa* system of the Yucatán, Mexico: production spaces and agricultural biodiversity

Diana Lope-Alzina

Introduction

The Mexican national component of IPGRI's Global *In Situ* Conservation On-Farm Project includes research on the role of farm women in the *milpa* system of the Yucatán. The work summarized here addresses the relationships among the extent of different production areas in which farm women actively participate, the number of varieties maintained by the household in which they reside, and the numbers of varieties whose seed was managed or exchanged by women. The analysis focuses on the principal crops of the *milpa* system—maize, beans, chile and squash. Social and economic characteristics of the farm women are also presented.

The Yucatán is characterized as a centre of origin and diversity of maize (*Zea mays*), bean (*Phaseolus vulgaris*, *P. lunatus*, *Vigna unguiculata*), squash (*Cucurbita moschata*, *C. argyrosperma*), and chile (*Capsicum annuum*, *C. chinense*). The agricultural system developed by the ancient *Maya* civilization has survived for centuries despite the massive social and technical changes experienced by farming communities in this region. The agricultural system locally known as the *milpa* system was traditionally composed of two principal production spaces.

The first major production space, known as the *milpa* field, consists of intercropped maize (*Z. mays*), bean (*P. vulgaris*, *P. lunatus*, *V. unguiculata*), squash (*C. moschata*, *C. argyrosperma*), and sometimes chile (*C. annuum*, *C. chinense*). Fields may also include a *pach pakal*, which is a horticultural area. The second major production space is the *solar* or home garden. This area is located next to the dwelling, and includes horticulture, arboriculture and livestock rearing, along with some wild plants. In addition to these two major production spaces, the system includes a *hubché* or *monte*, which consists of the non-cultivated area or forest. These areas are the source of gathered products such as construction material, fibers, medicinal plants, tanning agents, fuel wood, tints, edible wild plants and work tools. *Montes* are also used for beekeeping.

In *Mayan* society, women play a role as important as their husbands in assuring the survival of the family and household. Although women in this study community reveal a degree of authority and participation in family decision-making, they face constraints. For example, as will be shown here, they have limited access to production spaces other than the *solar*.

Objective and research questions

The objective of the analysis presented here was to assess the extent to which women participate in the production spaces of the *solar* and *milpa* fields, and relate their participation to the diversity of maize, beans, squash, and chile maintained on farms. Diversity is indicated here by numbers of varieties managed by the household, and the number of varieties whose seed was managed and exchanged by women. Management of seed refers to sowing, asking to have sown, or selecting seed. Exchanges refer to purchase, sales or interchanges of seed.

Research questions

To meet this objective, the study addressed the following questions:

- What is the extent (land area) of the production spaces in which women participate?
- What are the socioeconomic characteristics of the women who actively participate in production spaces?

- Is there a difference in the number of varieties *maintained* by households in which women participate at the *solar* and those in which women participate in both *solar* and *milpa* fields?
- Is there a difference in the number of varieties *managed* (sown, asked to sow, selected) by women who only participate in the *solar* and those who participate in both the *solar* and *milpa* fields?
- Is there a difference in the number of varieties *whose seed was exchanged* (purchased, sold and interchanged) by women who only participate in the *solar* and those who participate in both the *solar* and *milpa* fields?

Hypotheses

The following specific hypotheses were advanced:

- Women participate little in crop production systems or spaces outside the *solar*.
- Between women who participate in the *solar*, and those who participate in both the *solar* and *milpa* fields, there are no differences with respect to: (1) number of varieties maintained by households, (2) number of varieties managed by women, and (3) number of varieties whose seed is exchanged by women.
- Because maize, bean and squash are mainly cultivated in the *milpa* fields, the number of landraces whose seed is managed and exchanged by women is lower in these crops than in chile, the crop cultivated mainly in the *solar*.

Study site

The *Yaxcaba ejido* covers an area of 11 021 ha held by 450 *ejidatarios*. This town is connected to important urban centres such as Merida, Valladolid and Cancun through one of the main interstate roads of the Yucatán Peninsula. This town was selected for study because: (1) it is located within the heart of the Yucatán maize belt, (2) the traditional *milpa* system persists as the main economic activity, and (3) a great deal of background social and botanical research had been conducted. In *Yaxcaba ejido*, current land-use patterns consist of *milpa* and *solar* agriculture, horticulture, irrigated fruit tree production, extensive livestock production, and exploitation of forests for fuel and building materials.

Sample selection

The sample of households included in this study is the same as that used by previous social science researchers in the project (1999, 2000). The community is organized in four sectors. A sample was drawn at random from each sector with probability of selection proportional to the population (roughly 600 households in 1999), and an overall sampling fraction of 10%. The sample is therefore relatively small (60 households).

Survey instrument

A questionnaire was formulated in Spanish and interviews were conducted primarily in *Maya*. Information elicited in this survey was complemented with that obtained in the two previous household surveys.

Results

The social characteristics of farm women interviewed are shown in Table 1. Though subgroup numbers are limited given the relatively small overall sample size, some general relationships are discernible.

The first result was that the proportion of women identifying themselves as Spanish-speakers was greater among younger age groups than among older women. This is consistent with the fact that the mean number of years in school is also higher. Overall, the proportion of respondents claiming Spanish as their first language is only 28%. Mean years of education did not vary, however, by social group.

Respondents were asked to classify themselves by social status. Responses consisted of four categories: (1) *Co'ol ka'ab*, (2) *Co'ol nal*, (3) *Comerciante* or 'shop-keeper', and (4) *Parcelario*. The *Co'ol ka'ab* depend primarily on the *milpa* system for a living, while the *Co'ol nal* also sell labour and agricultural products. *Parcelarios* rely mainly on fruit trees and livestock production. Given the small overall sample size and our interest in agricultural production, those who rely primarily on the *milpa* system (*Co'ol ka'ab*) are compared with all other groups combined. Although the poorest, *Co'ol ka'ab* maintain the highest total number of maize, bean, squash and chile varieties. 'All others' may or may not have the agricultural production as their main activity but play important roles in local society.

Table 1. Social characteristics of respondents.

Social characteristics of farm women interviewed		Most used language		Mean years of schooling
		Maya (N)	Spanish (N)	
Age group	20-39 yrs old	6	7	3.3
	40-59 yrs old	26	10	1.91
	60+ yrs old	12	–	1.66
Social status	Co'ol ka'ab	28	7	2.09
	All others	16	10	2.27

Women reported activities only in *solar* and *milpa* production spaces. The activities conducted by women in the *solar* consist mainly of pre-seeding, seeding and care of livestock. In the *milpa* fields, women only participate in seeding and harvest. Figure 1 reveals that the focus of women's activities is the *solar*. The fact that the *solar* is the primary production space of women makes sense because it is located adjacent to the dwelling area where they are responsible for child care, food preparation and other domestic chores. The *milpa* fields can be widely dispersed.

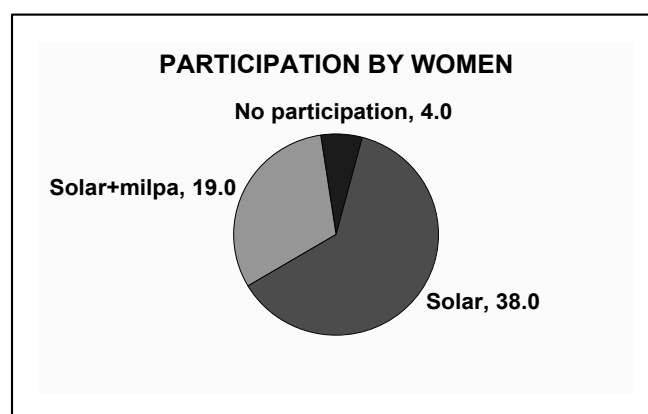


Figure 1. Women's participation in production spaces.

The average areas cultivated per household for the two types of production spaces where women participated were 4.19 ha for *milpa* and 0.11 ha for *solar*. The mean area for the *solar*, the production space in which women more often work (1.5 ha) is small compared with the average area cultivated by the household as a whole (4.29 ha), which includes both *solar* and *milpa* fields.

Table 2 shows mean areas where women participated according to their social and economic characteristics. There is no appreciable difference by language group. The tendency seems to be that *Co'ol ka'ab* women have access to a larger area (2 vs. 1 ha, average). This finding may reflect the fact that the social status of this group is so closely related to *milpa* production. Also, the extent of land area in which women participate appears to decline as they grow older, which is probably related to their life-cycle stage as well as the physical requirements of work in the *milpa* fields.

Table 2. Extent of participation (ha) by social characteristics.

Social characteristics		Women participants (N)	Mean of cultivated land area where women participated (ha)
Social status	Cool Ka	34	2.06
	All others	27	0.97
Language group	Spanish	17	1.40
	Maya	44	1.59
Age group	20-39 yrs old	13	1.94
	40-59 yrs old	36	1.73
	60+ yrs old	12	0.67

The percentage distribution of women's income is shown in Table 3, according to type of expenditure and participation in production spaces. Women earn cash income primarily through local sales of agricultural products, services provided to others, or sales of various artisan products. Clearly, there is no significant difference in expenditure allocations by the extent of women's participation in production spaces. However, there is a meaningful difference in the allocation of women's income among the three categories of expenditures. More than 70% of the income was allocated to basic human needs (consumption expenditures of various types), while around 20% was invested in the production system and a scant 6.5% of the income was invested in human capital (schooling and education).

Table 3. Allocation of women's income by type of expenditure.

Production spaces where women participate	Average percentage of women's income spent on:		
	Basic human needs	Human capital	Production system
<i>Solar</i>	73.14	4.86	22.00
<i>Solar + milpa</i> fields	72.94	8.24	18.82

Women were asked the number of varieties of maize, beans, squash and chile maintained by their households from 1999 to late 2000-early 2001, when the survey was conducted. Mean numbers by crop and category of women's participation are shown in Table 4. No differences are apparent between the number of crop varieties maintained by households in which women participated only in the *solar* and those in which they participated in both *solar* and *milpa* fields.

Table 4. Mean number of crop varieties maintained by household.

Production spaces where women participate	Mean number of crop varieties maintained by the household			
	Maize	Bean	Squash	Chile
<i>Solar</i>	2.2	2.1	1.2	1.3
<i>Solar + milpa</i> fields	2.3	2.7	1.1	1.2

Next, respondents were asked to list the varieties they themselves sowed, demanded to have sown, or for which they selected seed. Overall, the numbers are on average less than 1. Evidently, some respondents were not involved at all in the management of seed. To the extent that differences occur by extent of participation, they are most apparent for maize and squash (though the squash numbers are themselves the lowest) than for beans or chile. Mean numbers of bean and maize varieties managed are nearly identical between the two groups. Women are more involved in seed management for chile than for the other crops. This can be seen not only in the higher numbers for chile than for other crops in Table 5, but also by comparing the numbers for each crop in Table 5 with those in Table 4. The mean number of chile varieties for which women made variety choice or selection decisions was nearly 1, an average of 1.3 total varieties managed by the household. In contrast, they were involved in the choice of a far smaller proportion of maize varieties.

Table 5. Mean number of crop varieties for which women made variety choices or selected seed.

Production spaces where women participate	Mean number of crop varieties managed by women			
	Maize	Bean	Squash	Chile
<i>Solar</i>	0.2	0.6	0.2	0.9
<i>Solar + milpa</i> fields	0.6	0.5	0.1	0.8

Finally, women were asked to list the varieties for which they purchased seed, sold seed, gave or received seed as a gift. In terms of numbers of varieties, women's participation in seed exchange is even more limited than in seed management (Table 6). Only in chile seed exchange is their participation recognizable, and it is substantial relative to the total number of varieties maintained by the household. There are no differences in the level of seed exchange by production spaces in which women participate.

Table 6. Mean number of crop varieties for which women exchanged seed.

Production spaces where women participate	Mean number of crop varieties in seed exchange by women			
	Maize	Bean	Squash	Chile
<i>Solar</i>	0	0.2	0.1	0.7
<i>Solar + milpa</i> fields	0	0.3	0.0	0.7

Conclusions

Women participate little in *milpa* production, but participate intensively in the smaller, *solar* production space of the *Mayan* system. As a consequence, their involvement in seed management and exchange is very limited particularly for maize and squash, and less so for beans, which are principally *milpa* crops. Chile, frequently found in the *solar*, is the crop in which their involvement is most visible.

This finding has two implications. First, if we interpret numbers of named varieties as an indicator of diversity, it is only in chile that women's role is pronounced. Second, the *solar* represents the main tool that women have for assuring the livelihoods of their families. From this space, they obtain products for both home consumption and sale. To enhance women's capacity to invest in human capital and the production system itself, while at the same time contribute to maintaining diversity, chile would be the target crop.

Acknowledgements

To the women of Yaxcabá, Project partners and advisors, Donors (IDRC, Canada), and SDC (Switzerland).

Orientation and perspectives for social and economic research in the Morocco country component of the IPGRI Global *In Situ* Conservation On-farm Project

Larbi Zagdouni

La population actuelle du Maroc est estimée à quelques 30 millions d'habitants dont 47% de ruraux. Bien que sa part relative ne cesse de diminuer, la population rurale continuera à l'avenir à augmenter en valeur absolue.

L'agriculture reste l'un des piliers fondamentaux de l'économie du pays. Elle contribue à hauteur de 15 à 20% dans son Produit Intérieur Brut (PIB), elle procure à elle seule 80% de l'emploi rural et 40% à l'échelle nationale.

Selon les résultats de dernier Recensement Général de l'Agriculture (RGA) réalisé en 1996, ce secteur compte actuellement près de 1,5 millions d'exploitations agricoles disposant d'une Superficie Agricole Utile (SAU) totale de l'ordre de 8,7 millions d'hectares dont 14,3% irrigués et 85,7% en agriculture pluviale.

Outre la persistance de sa forte dépendance des conditions climatiques et de leur caractère hautement aléatoire, l'agriculture marocaine demeure par sa structure, un secteur très inégalitaire : les exploitations de moins de 5 ha représentent 71,1% du nombre total d'exploitations du pays, mais n'exploitent que 23,9% de sa SAU. Ce qui consacre son caractère fondamental d'une petite agriculture familiale.

Les résultats du RGA ont révélé aussi la persistance d'une agriculture qui reste insuffisamment pénétrée par le processus de modernisation des techniques de production. Le recours à la mécanisation des travaux du sol et des moissons ne se pratique respectivement que par 47% et 31% des exploitations du pays. Quant à l'utilisation des engrais, des produits phytosanitaires et des semences sélectionnées, elle ne concerne respectivement que 51%, 33% et 16% de celles-ci.

Tous ces indicateurs confirment le caractère familial, traditionnel et fragile d'une part très importante du secteur agricole au Maroc. Et le fait que l'économie rurale se réduise souvent à la seule activité agricole amplifie davantage les processus de surexploitation et de dégradation des ressources naturelles, ce qui risque à terme, de mettre en péril la durabilité du potentiel de production agricole et des écosystèmes.

Si cette problématique se pose au niveau des différentes zones rurales du pays, elle concerne, en premier lieu, ses zones oasiennes, montagnardes et pastorales du fait de leur plus grande fragilité écologique et de l'insuffisance des actions publiques de développement dont elles ont jusqu'à présent bénéficié. Dans ces zones, la survie des populations repose sur deux sources de revenus complémentaires : la pratique d'une agriculture de subsistance qui ne parvient pas toujours à couvrir à elle seule les besoins de consommation des populations concernées et les transferts générés par le recours à d'autres activités exercées localement ou à travers l'émigration.

A l'occasion de la préparation du Plan quinquennal de développement économique et social 2000-2004, la prise en compte de cette problématique a donné lieu à l'élaboration d'une vision et d'une stratégie à long terme pour un développement durable de l'agriculture et du monde rural dont les principes de base sont : la territorialisation des politiques, l'intégration des programmes de développement, la participation des bénéficiaires et la promotion du partenariat entre les différents opérateurs dans le choix et la mise en œuvre de ces programmes^(*).

^(*) « Stratégie 2020 de développement rural », Conseil Général du Développement Agricole, Ministère de l'Agriculture, du Développement Rural et des Pêches Maritimes, Royaume du Maroc, 1999.
« Pour une stratégie de développement à long terme de l'agriculture marocaine », Ministère de

Dans ce contexte, le Projet de conservation *in situ* de la diversité biologique agricole s'inscrit tout à fait dans le cadre des nouvelles orientations de la politique nationale à l'égard des zones à écologies fragiles telles les zones de montagnes et oasiennes dont le développement durable figure parmi les grandes priorités actuelles du pays. De par sa conception et les objectifs qui lui ont été fixés, ce projet est de nature à contribuer au développement de ces zones, notamment à travers la mise au point d'approches appropriées pour assurer une plus grande valorisation de leurs ressources phytogénétiques et permettre à leurs populations de tirer un meilleur profit de leur savoir-faire ancestral dans ce domaine.

Concernant la composante socio-économique du projet, elle devrait avoir pour finalité la contribution à l'identification des opportunités susceptibles de permettre aux populations des zones concernées d'améliorer et de diversifier les revenus qu'elles pourront tirer de la diversité biologique agricole dont elles disposent.

A cet effet, les investigations à entreprendre au titre de cette composante devront privilégier le traitement de deux thèmes complémentaires :

- l'analyse des pratiques de valorisation de la diversité biologique agricole disponible et l'évaluation économique de leurs performances
- l'identification des contraintes qui limitent ces performances et les alternatives pour les améliorer.

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