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Analysis

Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries

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ABSTRACT

This paper examines the role of direct compensation payments for agrobiodiversity conservation, using minor millet landraces in India as an example. The cost of farmer participation in a hypothetical 'payments for agrobiodiversity conservation services' (PACS) scheme is estimated using a stated preference valuation approach. Significant inter-crop and inter-varietal differences are observed with respect to consumption values, upon which the compensation demanded by farm households is shown to primarily depend. Drawing on a categorisation of consumption values and farmer preferences, the paper points to the importance of simultaneously considering a range of potential interventions in order to conserve a priority portfolio of agrobiodiverse resources in predominantly subsistence-based agricultural systems.

1. Introduction

A vital subset of biodiversity, agricultural biodiversity (or agrobiodiversity) is the result of natural and human selection processes, with the latter driven by the needs and motivations of farmers, herders and fishers over millennia (FAO, 2004). Agrobiodiversity encompasses the full diversity of living organisms, of which the precise utilitarian function of many is largely unknown, yet closely associated with the basis of human survival and wellbeing (FAO, 2009; Jackson et al., 2007). From an economic point of view, agrobiodiversity is a component of natural capital, and the flow of services it provides proxies the interest on this capital (Perrings et al., 2006). It can also be seen as a form of natural insurance, as the portfolio of genes, species, communities and agricultural habitats can be used to ameliorate a wide range of environmental and economic risks (Pascual et al., forthcoming). However, despite the existence of a scientific consensus relating to the importance of maintaining genetic diversity within farming systems (Brush, 2004; Pascual et al., forthcoming), research and policy dialogues have tended to consider only to a limited extent the ecosystem services specifically associated with the maintenance of agrobiodiversity, the importance of their values or the incentive mechanisms required to ensure that these services continue to be maintained at socially desirable levels. Such public good ecosystem services include supporting landscape-level agroecosystem resilience (Hajjar et al., 2008; Heisey et al., 1997; Narloch et al., 2011a), maintaining socio-cultural traditions, local identities and traditional knowledge (Nautiyal et al., 2008), as well as the maintenance of evolutionary processes, gene flow and global option values (Bellon, 2009). Furthermore, while the deployment of diversity can be an effective mechanism for smallholder farmers to manage risk (Di Falco and Chavas, 2008, 2009), farmers will not in general consider the implications of their choices for the overall pattern of diversity and the implications that society as a whole faces. It is against this backdrop that external incentives that permit farmers to capture such non-market and public good components of the total economic value associated with the maintenance of agrobiodiversity are of particular relevance (Narloch et al., 2011a; Pascual et al., forthcoming).

External financial incentives may play a key role in ensuring the maintenance of socially desirable levels of agrobiodiversity, as poor smallholder farmers cannot be expected, nor be able to afford, to maintain such diversity where significant opportunity costs exist relative to the cultivation of improved crops/varieties. Arguably, in

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many instances, it is the constrained availability of agricultural inputs (including modern high yielding crop species/varieties and livestock breeds) and production technologies that form the main external constraint leading to the continued cultivation of many traditional plant and animal genetic resources (PAGR) on-farm (Hammer, 2003). However, not all *de facto* conservation of genetic resources in farmers' fields is possible as a sustainable conservation approach, given the current rapid economic development and cultural change in rural regions (Bellon, 2009). Alternatively other conservation (through use) approaches can be sought, for instance through the development of niche product markets. This approach can be seen as a potentially powerful tool for providing positive incentives to farmers to conserve and sustainably use threatened PAGR (Krishna et al., 2010). However, the degree to which such an approach can be successfully implemented in order to fully cover a strategic portfolio of diverse crop species/varieties or livestock breeds is questionable, as not every genetic resource in such a portfolio has a current market potential. In such a context, complementary incentive mechanisms, such as payments for agrobiodiversity conservation services (PACS), may emerge as being of particular significance (Narloch et al., 2011a).

PACS is one type of potential incentive mechanism and a variant or sub-category of payment for ecosystem services (PES) which focuses on the on-farm conservation of socially-valuable and threatened PAGR by providing rewards to the farmers (Narloch et al., 2011a, 2011b; Pascual and Perrings, 2007). Such schemes have been experimentally shown to be effective instrument for promoting the cost-effective maintenance of threatened PAGR (Narloch et al., 2011a, 2011b). Although the concept of PES has been hailed by some observers as "the most promising innovation in conservation since Rio 1992" (Wunder, 2005), to date, PES schemes have largely been limited to applications in the context of forest ecosystems, carbon sequestration, wild biodiversity conservation and water management (e.g., Engel et al., 2008; Landell-Mills and Porras, 2002; Muradian et al., 2010; and Wunder et al., 2008). Nevertheless, in the face of the rapid and unprecedented loss of agrobiodiversity across the world (FAO, 2007a, 2009), there is an emerging need to continue to evaluate the opportunities and constraints of PACS-like schemes to conserve threatened PAGR. Such schemes have recently been evaluated in terms of their effect on collective action and the potential impact of incentives for crowding-in or crowding-out social preferences (Narloch et al., 2012), as well as in terms of their capacity to take pro-poor/social equity trade-offs into account (Narloch et al., 2011b).

This paper aims to further contribute to this literature by exploring the potential for PACS to sustain the on-farm utilization of valuable-but-threatened crops based on farmers' own preferences, since this can offer valuable insights as to farmers' willingness to participate in such schemes. The paper uses a stated preference method applied at the individual farm-household level to elicit farmers' preferences and hypothetical compensation levels for the conservation of agrobiodiverse resources. Although there are a number of existing studies which value agrobiodiversity by estimating farmers' willingness to pay (WTP) for traditional crop varieties (e.g., Asrat et al., 2010) or livestock traits (e.g., Zander and Drucker, 2008), there remains only limited evidence regarding the link between farmers' subjective valuation of the genetic resource in question and the appropriateness of different *ex situ* and *in situ* agrobiodiversity conservation interventions. The feasibility of a direct payment scheme is examined for the conservation of threatened minor millet landraces using microeconomic data from the Kolli Hills, Tamil Nadu, India. The critical role of consumption preferences associated with the conservation of specific crop genetic resources (CGR) and their associated conservation costs that are borne by farmers are examined.

In the next section, we develop the conceptual framework that underpins the valuation analysis. Section 3 describes the sampling framework and study area, as well as presents the empirical analysis. Production system and socio-economic characteristics, together with the results of the contingent valuation exercise are provided in Section 4, while Section 5 discusses the major findings. Concluding remarks are provided in the final section.

2. Conceptual Framework

The private values accrued by farmers through the maintenance of on-farm agrobiodiversity are often less than the total benefits generated once public good values are also accounted for, resulting in sub-optimal levels of resource provision. Where high public good values exist, external incentives for agrobiodiversity conservation may be required. With agricultural intensification and monoculture, *improved* PAGR become more productive and profitable in the short-run for individual households, owing largely to their higher responsiveness to external capital inputs (Drucker and Rodriguez, 2009; Narloch et al., 2011a). The difference between the average gross margin of improved/intensified production systems and traditional systems create conservation opportunity costs for farmers. Ideally, PACS schemes would compensate for these opportunity costs. However, calculation of such opportunity costs is hampered by the existence of a multitude of non-market values related to the maintenance of agrobiodiversity, the heterogeneity of the production systems (caused by differences in farm-size, soil fertility etc.), and information asymmetries.

The stated preference of farm households' stated willingness to accept (WTA) compensation for the conservation of CGR can be used as a relevant measure of the opportunity cost of undertaking such an activity. The minimum compensation required to motivate a farm household to accept a PACS contract involving the cultivation of a fixed acreage of a given threatened CGR is assumed to signal the farmer's real opportunity cost of *in situ* agrobiodiversity conservation. Under asymmetric information, PES schemes could create perverse incentives and reduce the effectiveness of the compensation mechanisms (Pascual and Perrings, 2007), although such concerns may be overcome by introducing competitive tender approaches, with beneficiary selection based on (least) compensation demanded (Ferraro, 2008; Jack et al., 2009; Latacz-Lohmann and Van der Hamsvoort, 1998; Narloch et al., 2011b). Here we assume that under a fixed endowment of land, soil fertility and other inputs, there will be a declining marginal value product of the managerial time allocated by farming households to grow a specific crop or variety. If the household can allocate land to a second crop, it will do so until the marginal value products from its managerial time are equated between the two activities determining an endogenous (shadow) wage (Aslan and Taylor, 2009; Krishna et al., 2010; Van Dusen and Taylor, 2005).

We take a simple two-crop model where it is assumed that a farmer with a fixed amount of land can choose, given a number of production and marketing constraints, to grow a traditional crop associated with relatively high public good value and a relatively lower private use value or a crop that is associated with higher private value and relatively lower public good value. Fig. 1 provides a stylized static framework illustrating the farm household's decision regarding which crop to grow. The vertical axis represents the marginal revenue (mr) from land cultivated under the CGR associated with a threatened landrace (indicated by subscript l) identified as a conservation priority by the conservation agency and the competing, modern (improved) crop variety (indicated by subscript c). The horizontal axis represents the share of land allocated to each of the two crops. Let's assume that the objective of the conservation agency designing the PACS scheme is to conserve the threatened CGR following a safe minimum standard (SMS) decision rule associated with achieving a cultivated acreage of L_l^*. We also assume for simplicity that the marginal revenue function of the improved competing crop is fixed (mr_c). The farm household would optimally allocate land to the threatened CGR where $mr_c = mr_l$.

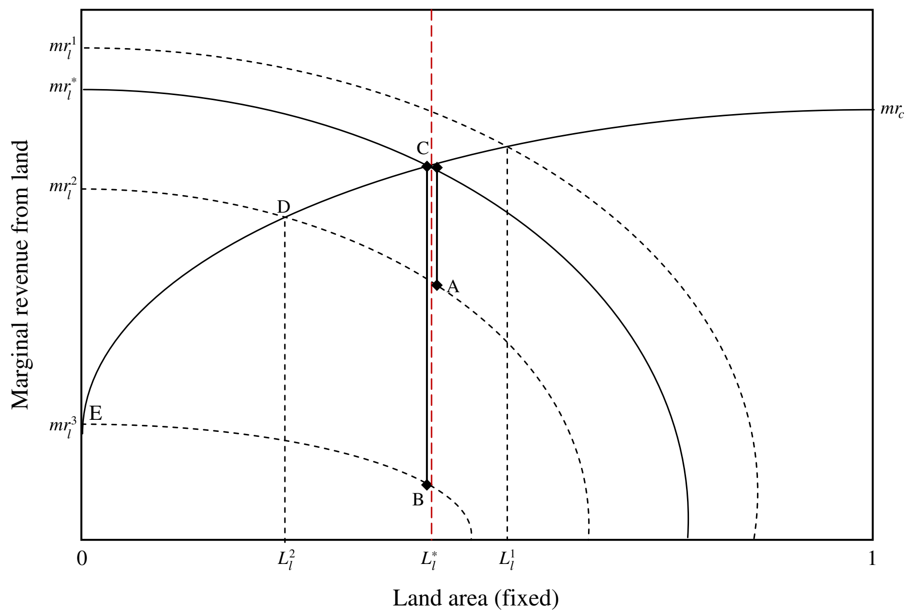

Fig. 1. Safe minimum standard-based PACS scheme agrobiodiversity conservation framework.

The minimum marginal revenue function of the threatened CGR that would result in cultivation of the SMS acreage L_l^* is mr_l^*.

The SMS implies that the population under consideration must be maintained at a level that makes it feasible to rebuild the genetic stock in the future (Drucker, 2006; Ready and Bishop, 1991) and/or exceeds a threshold beyond which desired ecosystem services are generated. The complexity in the application of a SMS approach lies in the difficulty of defining such a minimum PAGR population size. In the case of domesticated animals, the Food and Agricultural Organization (FAO) defines a livestock breed generally not to be at risk if there are 1000 breeding females and 20 males (FAO, 2007b). In the case of crop genetic resources, the estimation of a SMS is likely not only to be based on the cultivated area, but also on the amount of seeds available in local systems and their age, reproduction mode, the number of farmers of a specific CGR and the degree of local knowledge maintained. Additional criteria, such as geographical distribution of CGR and associated agro-ecological factors within those locations, existing seed distribution networks or breeding infrastructure, socio-cultural traditions and market integration could also be taken into account when establishing a workable SMS (Reist-Marti et al., 2003). Emerging examples of such an approach suggest that the area and farmer number criteria may be relatively modest; implying that the opportunity costs of a SMS approach may not necessarily be large (PSR, 2008).

The crop species being grown consists of a number of varieties, including landraces, which are heterogeneous with respect to their adaptability to local agro-climatic and soil conditions. This heterogeneity is reflected in their marginal revenue functions. Taking three *mr*-functions for three different landrace varieties of the crop (or alternatively three different crops or crop species) that need to be conserved, these can be represented as mr_l^1, mr_l^2, and mr_l^3, respectively. The CGR, whose mr_l function lies above mr_l^*, e.g., mr_l^1, determines an acreage that is superior to that required by the SMS rule and thus will not necessarily need to be conserved through a PACS approach. Since the private optimum acreage is larger than the safe minimum one and farmers may be assumed to have financial incentives not to replace such local CGR, *de facto* conservation would be sufficient. The other landraces, whose marginal revenue functions are represented by mr_l^2, and mr_l^3 respectively, however, face a situation where the replacement of the threatened landrace by improved crops/varieties would be financially justifiable from the farmer's perspective. In the case of a landrace associated with mr_l^2, the landrace is still cultivated but does not reach the SMS. In the case of a landrace associated with mr_l^3, such a landrace would already be extinct or on the verge of extinction. Consequently, active intervention, including those involving direct compensation such as PACS may be justified.

Given that the mr_l functions of landraces are household specific and that there are differences in perceived genetic resource utility and inter-farm productivity, the minimum compensation demanded by different households to increase acreage cultivated under the threatened landrace would also differ. In Fig. 1, for a given household growing landrace 2 associated with mr_l^2, the minimum compensation that would be required by the household to increase conserved land acreage to reach the SMS is represented by the area between points A, C and D. In case of a landrace associated with mr_l^3, the minimum compensation would be associated with the area between points B, C, and E. Similarly for a given landrace or CGR, three different farmers may have three different *mr*-functions, and the PACS scheme could use this information to ascertain the compensation to achieve the desired SMS at least cost.

Marginal utility (*mu*) functions are also appropriate functions with which to explain the land allocation decision. These functions may lie above or below the *mr*-functions, depending on how strong the production–consumption decisions of the farmer household are interlinked. We use farmers' subjective valuation of traditional crop varieties (millet landraces) to capture the consumption utility element associated with its production level. A farmer would cultivate a millet variety only if the compensation received to do so covers the marginal utility difference ($mu^c - mu_l$). By fixing the land acreage under traditional millet varieties in a hypothetical PACS scheme and by allowing the duration of the contract to change across households, the WTA or minimum compensation amount required to create the economic incentive to cultivate different landraces can be estimated. We develop the following three major hypotheses: (i) the current prevalence of existing minor millet landraces can be investigated by analyzing farm-households' preferences; (ii) the heterogeneity of such preferences across crop varieties would determine the cost-effectiveness of PACS as a conservation instrument; and (iii)

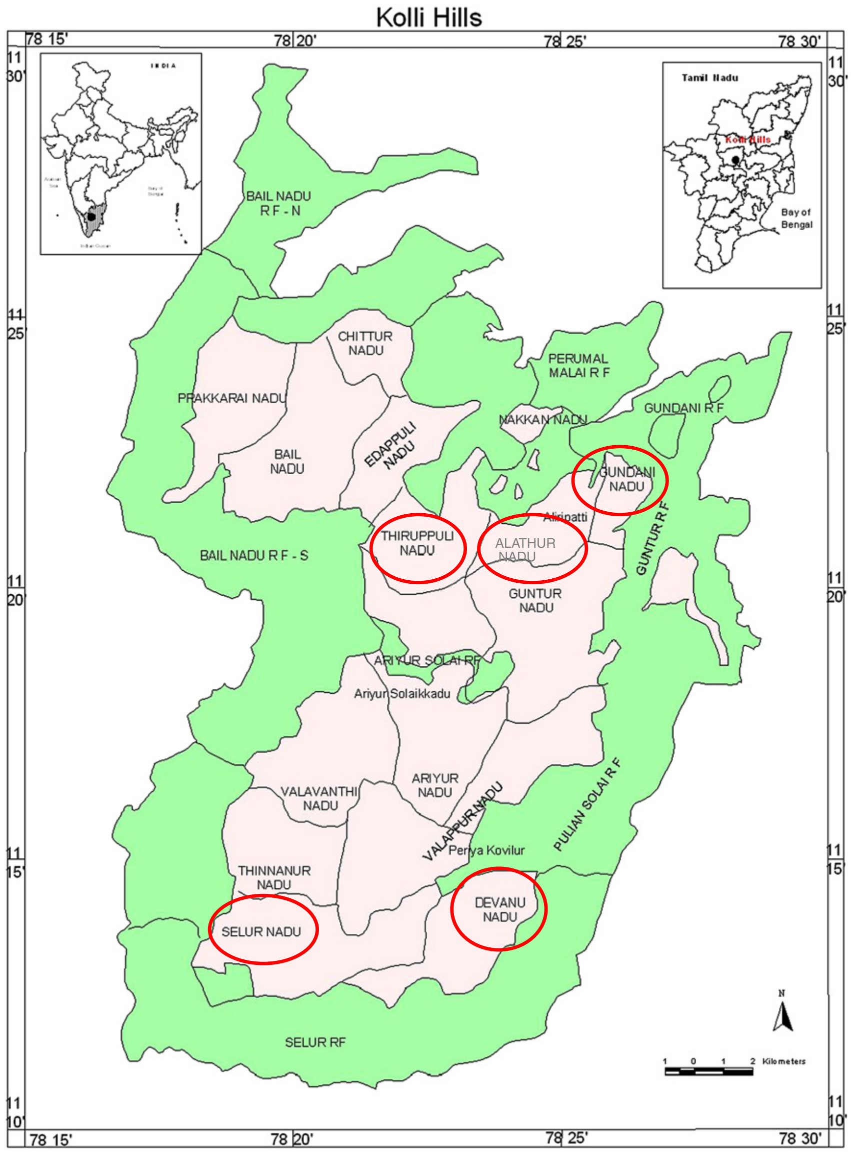

Fig. 2. Map of the study area.

households' preferred length of PACS contract is unaffected by the opportunity cost of conservation. The last hypothesis would imply that the duration of PACS schemes would not vary across crop varieties.

3. The Case Study: Minor Millets in the Kolli Hills, India

3.1. Study Area and Farming Systems

The Kolli Hill region of Tamil Nadu State (India) is characterized by significant *in situ* crop genetic diversity of minor millets (Jayakumar et al., 2002; King et al., 2008). This is a mountainous area that forms part of the Eastern Ghats of India, located at an altitude of 1100–1300 m, covering a geographical area of 503 km^2 (Fig. 2). In this region, land is mostly devoted to agriculture or forestry, and most of the inhabitants belong to the Malayali tribal community (MSSRF and FAO, 2002). Two crops of rice are commonly cultivated annually in the spring-fed valley lands, while cassava (*Manihot esculenta* Crantz) and millets are cultivated in areas where water scarcity is severe (Kumaran, 2004).

A genetically diverse pool of minor millet varieties have long been cultivated by the tribal households under subsistence farming systems. These comprise finger millet or *ragi* (*Eleusine coracana* L. Gaerth.), Italian millet or *thinai* (*Setaria italica* L. Beauv.), little millet or *samai* (*Panicum sumatrense* L. Roth ex Roem. et Schult), common millet or *panivaragu* (*Panicum miliaceum* L.) and kodo millet or *varagu* (*Paspalum scrobiculatum* L.). Each of the millet species is represented by several landraces or varieties that display diverse morphological and agronomic characteristics, and thereby contribute significantly to the unique agrobiodiversity status of the location. Despite the high cultural and consumption value of these millet landraces for the local population, there is an increasing threat from cash crops. Minor millet cultivation in the Kolli Hills started declining in the mid-1980s and has been progressively replaced by cassava (King et al., 2008). By 2001–02, cassava covered 56% of the total cultivated area, while millets represented only 11% (Gruere et al., 2009). Focus group discussions with community members have shown that the introduction of cash crops like cassava coupled with external financial support (such as crop loans provided in advance by merchants and contractors), the drudgery involved in the processing of millets, the lack of market linkages for minor millets, and the availability of alternative food grains—especially rice—at subsidized cost through the public distribution system, have all led to the large-scale expansion of cassava cultivation in upland areas that were traditionally under millets. Since the major threat to minor millet acreage and diversity originates from its relative economic performance, the consideration of incentive mechanisms to encourage its continued existence on-farm is of special relevance.

3.2. Sampling, Questionnaire and Data Collection

In cooperation with the M.S. Swaminathan Research Foundation (MSSRF), a non-governmental organization (NGO) with headquarters in Chennai (India), household-level surveys were conducted. Farm-households were selected in five zones (*Panchayats*), namely Devanur, Alathur, Thiruppuli, Gundani and Selur, as these zones are considered to encompass a wide range of the minor millet diversity found in the Kolli Hills. Through an initial transit walk, participatory appraisal as well as discussions with key informants, preliminary information was gathered *inter alia*, regarding the approximate number of minor millet-growing households, the extent of the cultivated area and the trends and reasons for decline in importance of individual millet species/varieties. A pilot survey was also administered among 50 randomly selected households (10 per zone) in 2009. Following further stakeholder consultation, the survey instrument was modified prior to its full implementation and a sample containing 50% of the households per selected zone was found to be adequately representative for the present study. Based on this strategy, a total of 454 households (84 to 96 households per zone) were covered in the final survey, of which 69% were found to be cultivating at least one millet variety.

Using a semi-random sampling approach (to ensure adequate representation of minor millet farmers in the survey), a structured questionnaire was administered over 5 months between January and June 2010.[1] Five enumerators were trained to interview household heads. Along with questions regarding the socio-demographic characteristics of households and farming practices, a close-ended contingent valuation survey instrument was included, aimed at better understanding farmer preferences for different landraces and to elicit the minimum compensation level households in the region would demand for entering into a contract with a hypothetical conservation agency. Compensation was elicited for cultivating both the household's most- and least-preferred millet landraces while accounting for the characteristics of the variety as well as the existing and expected agro-ecological and market conditions. The information gathered through piloting was employed to derive appropriate bid-levels, as well as to minimize the potential biases typically associated with contingent valuation studies.

3.3. Compensation Estimation: Methodology

An exploration of the potential of a PACS scheme to conserve *in situ* agrobiodiversity requires estimation of the compensation that would be demanded by the farm households for participation in the on-farm conservation of threatened crop species/varieties. Based on the opportunity cost principle, the compensation would depend on the difference in value of the associated marginal utility (and under a more restrictive assumption, farm profitability) when land is converted from the most profitable crop to a millet landrace. This value is likely to vary across households and across the millet species/varieties meant to be conserved.

Given the existence of significant diversity in farmer preferences for different minor millet landraces, farmers' minimum compensation requirements were separately recorded in a closed-ended WTA format for their most preferred variety (MPV) and their least preferred variety (LPV). The associated values would be expected to form the lower and upper bounds, respectively, of the compensation that would be demanded by households for committing to conserve different landraces in their farm plots.

Value elicitation in a WTA format is relatively less popular in the CV literature, due to the widespread belief that the format is not incentive-compatible for stated preference approaches (Haab and McConnell, 2002).[2] However, in the case of potential compensation elicitation, given that the property rights of land for minor millet cultivation reside with the farmers, the WTA format is the more appropriate as it provides a "rent-out" price, relevant for valuing a proposed relinquishment of certain rights (Brown and Gregory, 1999). In order to make the responses incentive compatible, competitive bidding was introduced by framing the accompanying explanatory introduction in the context of a competitive tender approach. In this context, it was indicated that, due to budget limitation, only a limited number of farmers from each location would be selected for participation in the PACS scheme given the objective of reaching a SMS for each of the various landraces through the selection of least-cost providers. In the closed-ended format, this corresponds to the respondent answering in the affirmative until the bid offers proposed by the interviewer become lower than the perceived opportunity cost of cultivating the particular landrace. The contingent valuation questions were phrased as follows:

> *You can help to ensure that a small amount of minor millets will continue to be grown in farmers' fields throughout the Kolli Hills. You can do this by telling us what would be needed to help you guarantee that you would plant millet landraces on your farm over the coming years. That information will be used to help us estimate the total cost of establishing a conservation programme to ensure the continued growing of millet in the Kolli Hills.*
>
> [Field assistant instruction: Show the farmer Bid Card 1 and say "I am going to ask you if a minor millet conservation programme were established in the future, whether you would be willing to participate in the programme based on the conditions shown on (bid) card no. 1?"]
>
> *You only need to decide whether you want to participate or not. However, before you answer, please note that only a limited number of households in the Kolli Hills would be selected to participate in this scheme, as the amount of funding for the scheme would be limited. Therefore the smaller the amount of support you would require to participate in the programme, the higher are your chances of being selected.*

An example of a pictorial bid card, shown to the farmers along with the CV question, is presented in Appendix A. The first set of questions was about the most-preferred millet variety of the household and later repeated for the least preferred one; both in a double-bounded dichotomous choice (DBDC) framework with follow-up questions. This approach was selected due to being generally superior to an open-ended format as it confronts respondents with a more market-like situation (Bateman et al., 2002). Respondents were presented with initial bid offers and, following their initial response, they were presented with a new offer. Lower bids were offered if their initial response had been "yes" and higher ones offered if their initial response had been "no".

[1] Field assistants began by randomly interviewing farming households regardless of whether they were minor millet growers or not. Subsequently, if it looked like the 50:50 ratio would not be achieved, they then purposefully selected millet-growing households. Most (80%) of the sample farmers, however, ended up being selected randomly.

[2] An allocative mechanism is said to be incentive compatible if it provides individuals with incentives to truthfully and fully reveal their preferences (Cummings et al., 1997).

The chosen DBDC model has been shown to be statistically more efficient than a single bounded approach (Hanemann et al., 1991). Nevertheless, there are certain framing effects frequently associated with DBDC formats. Shift effects or shifts in respondents' answers between the two CV questions can be particularly problematic (Whitehead, 2002). Analysis of the pilot survey data showed that a negative shift indeed existed and respondents were found more likely to answer "no" to the follow-up question when they had answered "yes" to the initial question. Discussion with interviewers and farmers revealed that reducing the bid amount in the follow-up WTA question once they had accepted the contract at a higher (initial) bid level, created a feeling of "being cheated" amongst the respondents. In order to address this issue in the final survey, more detailed explanations regarding the conservation funding limitations and the associated competitive nature of the process were provided to farmers.

Before running the interval regression model with responses from the DBDC model and carrying out an estimation of farmer and variety specific WTA values, the possibility of the existence of a shift effect was tested using a Seemingly Unrelated Bivariate Probit (SUBP), a maximum likelihood two equation model (Cameron and Quiggen, 1994). The dependent variables of the two equations of SUBP are dummy variables, representing yes/no responses obtained for the initial and follow-up bids, respectively. The dichotomous choice responses to the first and follow-up bids were included as dependent variables, and upon finding an insignificant correlation between the two equation error terms ($\rho=0$), the DBDC model was estimated using an interval regression method.

Additionally, due to the possibility of a hypothetical bias associated with the CV method, due care was taken during the surveys to emphasize the possibility of actually implementing the PACS scheme in the near future. The nature of the question was made simple, through repeated modifications, to be understandable to all farmers, among which many are illiterate. The familiarity of the local NGO in the study location and the past history of project implementation by this organization are considered to also contribute to limiting such hypothetical bias. The respondents were told that half of the total requested compensation would be provided at the beginning of the season and the rest after cultivation of the landraces had taken place. An additional condition was that farmers would be expected to save 3 kg of quality seed (which represents about 9% of the millet production from 0.10 acre, based on the productivity levels of the 2009/10 season) at home for following production seasons.

In the pilot surveys, the initial bid of the CV questions ranged from Rs. 100 to 1320 per year (1 US$ = Rs. 46.64 on average between March and June, 2010) to cultivate 0.10 acre of minor millets under a pure cropping system or 0.15 acre under a mixed cropping system. The duration of the hypothetical PACS contract was comprised of three values: 1, 2, or 3 years, which were assigned randomly across households, independently of the bid amount. Table 1 shows the bid structure and frequencies.

The mean WTA was estimated, employing interval regression and using the zone dummies alone as the explanatory variables (see explanation below). Mean WTA estimates for the MPV and LPV were found to be Rs. 286 and 578, respectively. Following piloting, the frequencies of the bids for the main survey were lowered for the extreme bid values. This was done without introducing bias by approximately framing these around the mean WTA values derived. For the MPV, the initial bid ranged from Rs. 100 to 750 and for the LPV from Rs. 250 to 1000. An equal number of respondents were allocated to each of the initial bids. Based on the responses to the bid values, the range of WTA values were estimated; for "yes"–"yes" responses the range being $(0, A_{i2})$, for "yes"–"no" (A_{i2}, A_{i1}), for "no"–"yes" (A_{i1}, A_{i2}), and for "no"–"no" $(A_{i2}, +\infty)$, where A_{i1} and A_{i2} stand for the initial and follow-up bids. The probabilities of respondents' answers to the first and second bids are as follows:

$$\begin{aligned}
p(\text{"yes"}-\text{"yes"}) &= p[I_i(A_{i1})=1; I_i(A_{i2})=1] = p(\text{WTA}_i < A_{i2})\\
p(\text{"yes"}-\text{"no"}) &= p[I_i(A_{i1})=1; I_i(A_{i2})=0] = p(A_{i2} < \text{WTA}_i < A_{i1})\\
p(\text{"no"}-\text{"yes"}) &= p[I_i(A_{i1})=0; I_i(A_{i2})=1] = p(A_{i1} < \text{WTA}_i < A_{i2})\\
p(\text{"no"}-\text{"no"}) &= p[I_i(A_{i1})=0; I_i(A_{i2})=0] = p(A_{i2} < \text{WTA}_i).
\end{aligned} \quad (1)$$

Under the assumption of normally distributed error terms, these probabilities can be estimated using the log-likelihood function (Cameron, 1988):

$$\begin{aligned}
\ell = \sum_{i=1}^{n} & I^{\text{"yes"}-\text{"yes"}} \ln\left[\phi\left(\frac{A_{i2}-\beta' x}{\sigma}\right)\right] + I^{\text{"yes"}-\text{"no"}} \ln\left[\phi\left(\frac{A_{i1}-\beta' x}{\sigma}\right) - \phi\left(\frac{A_{i2}-\beta' x}{\sigma}\right)\right]\\
&+ I^{\text{"no"}-\text{"yes"}} \ln\left[\phi\left(\frac{A_{i2}-\beta' x}{\sigma}\right) - \phi\left(\frac{A_{i1}-\beta' x}{\sigma}\right)\right] + I^{\text{"no"}-\text{"no"}} \ln\left[1-\phi\left(\frac{A_{i2}-\beta' x}{\sigma}\right)\right]
\end{aligned} \quad [2]$$

where I denotes binary indicator variables for the four response groups. Such coding of the likelihood model allows one to estimate β directly, and the coefficients can be interpreted as the marginal effects of the x variables in monetary terms. The lower bound of "yes"–"yes" responses is set at zero, to restrict the WTA to being positive values. The explanatory variables included a CV-specific attribute (duration of the contract), household characteristics (gender, age and education of household head, landholding and household size) and zone dummies (Table 2). A single equation is estimated, pooling the responses to the proposed bids regarding the MPV and LPV using an intercept dummy and interaction terms with the explanatory variables.

4. Results

4.1. Farmer Characteristics

The sample farmers are found to be mostly middle-aged (45 years old) and illiterate (57%), reflecting the general pattern of the tribal

Table 1
Bid structure for WTA elicitation.

	Pilot survey (N = 50)				Main survey (N = 454)			
	MPV		LPV		MPV		LPV	
	Initial bid[a]	% households	Initial bid[a]	% households	Initial bid[a]	% households	Initial bid[a]	% households
	100	6	120	6	100	25		
	300	22	360	22	250	25	250	25
	500	24	600	24	500	25	500	25
	700	30	840	30	750	25	750	25
	900	10	1080	10			1000	25
	1100	8	1320	8				
Est. mean WTA[a]	286.12		578.34					

[a] Note: measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under a mixed cropping system.

Table 2
Farmer cultivation of and preference toward different millet varieties.

Crop and variety	Share of households growing this varieties in				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Finger millet					
Arisikaizhvaragu	0.32 [0.46; 0.00]				0.02 [0.00; 0.00]
Karakaizhvaragu		0.13 [0.23; 0.08]			
Karunguliyankaizhvaragu		0.38 [0.67; 0.10]		0.04 [0.00; 0.00]	
Perunkaizhvaragu				0.08 [0.00; 0.00]	0.34 [0.45; 0.14]
Sattaikaizhvaragu	0.28 [0.44; 0.00]				0.28 [0.00; 0.00]
Sundangikaizhvaragu		0.09 [0.00; 0.00]	0.65 [0.97; 0.00]	0.25 [0.00; 0.00]	
Little millet					
Karumsamai		0.08 [0.09; 0.36]			
Kattavettisamai				0.06 [0.12; 0.00]	
Malliasamai					0.02 [0.18; 0.29]
Sadansamai			0.00 [0.00; 0.41]		
Vellaperumsamai	0.14 [0.10; 0.01]	0.08 [0.00; 0.00]	0.02 [0.00; 0.00]	0.46 [0.87; 0.00]	0.04 [0.00; 0.00]
Thirigulasamai			0.04 [0.00; 0.11]		
Italian millet					
Koranthinai			0.07 [0.03; 0.48]		
Mookkanthinai		0.05 [0.01; 0.45]			
Palanthinai					0.00 [0.26; 0.15]
Senthinai				0.02 [0.01; 0.20]	
Perunthinai	0.03 [0.00; 0.00]		0.01 [0.00; 0.00]		0.00 [0.11; 0.43]
Common millet					
Panivaragu			0.03 [0.00; 0.00]	0.00 [0.00; 0.80]	
Kodo millet					
Thirivaragu	0.00 [0.00; 0.99]				

Note: figures in parentheses indicate share of sample households identifying the particular variety as MPV and LPV [HH_{MPV}; HH_{LPV}].

population in Tamil Nadu (Narloch, 2010). Households comprising four to five members are common. Significant variation is observed across zones with respect to household wealth, although in general the households in the Kolli Hills are asset-poor with limited ownership of durable assets—especially agricultural implements. Most households complement their crop farming activities with livestock and to a limited extent with non-agricultural wage employment. Affiliation with organizations is largely limited to Large-sized Adivasi Multipurpose Cooperative Societies (LAMPS), which were set up in the late 1970s to cover large tribal areas, giving more emphasis to the procurement of minor forest products and surplus agricultural produce, as well as providing people with long-term loans (Karmakar, 2002). Farmer-based organizations are the second most popular type of formal organizations. Millet farmers' self-help groups seemed to play a key role only in certain locations. Village level seed banks also play only a limited role, with an average of only 7% of households having access to them.

4.2. Land-use Patterns and In situ Conservation of Minor Millets

Agricultural land-use in the Kolli Hills can be classified into three types: (i) spring-fed valley lands, mainly under paddy, (ii) rainfed lands, allocated for millets and cassava, and (iii) land on the valley fringes, under pineapple, coffee, pepper and other crops (Gruere et al., 2009; Kumaran, 2004). Analysis of the primary data provides further insights into the farming system, co-existence of millets with competing crops (especially cassava), and the changing importance of millets in the farming system. The data indicate that most farm production takes place on land owned by the household, with leasing-in and out being rare. Land ownership appears to have been stagnant over the years, but with significant inter-year variation regarding cultivated area. Also, in a particular year, the land distribution across different crop species varies across zones. Jackfruit (*Artocarpus heterophyllus* Lam.) is the most prominent crop in the region. Cassava is the next most important crop and production is mainly purchased by starch factories. Regarding millet, finger millet is the most important millet crop in the Kolli Hills cultivated by approximately 69% of the sample households, followed by little and Italian millets. Only limited acreage is dedicated to common millet, while kodo millet had completely disappeared from the production systems by 2009. It was observed that millets are produced mainly for subsistence needs, as is the case of rice. All other crop outputs are often sold in the market, with no cassava production being used for home consumption.

About 69% of the sample farmers were cultivating at least one of the minor millet varieties in the survey year. However, about 20% of the sample households stopped growing millet between 2008/09 and 2009/10, while at the same time the number of farmers cultivating cassava increased (25% increase in acreage during the 2008–09 period). Cassava, as a cash-crop of growing importance, is found to compete directly with minor millets in many parts of Kolli Hills.[3] The share of land area allocated under millets varied significantly with the scale of operation. Small farmers allocated about 18% of their land to millets, while large farmers (>5 acres cultivated land) allocated less than 8%. In other words, smallholders bear a relatively higher opportunity cost for cultivating millets on-farm, leading to the hypothesis that it would be easier to convince larger farmers to participate in a PACS scheme.

Across the five selected case study zones, the consumption value of minor millets and their key role in farmers' livelihoods as the traditional staple food appear to be the main reasons for farmers still retaining and in some cases increasing millet acreage. Analysis at the plot-level indicates that, although the land area left under minor millets as a whole is rather small and most of the varieties are grown by a few farmers, some millet landraces enjoy relatively high popularity among farmers. An analysis of the total cultivated areas of the 19 millet landraces studied reveals nine of those to be cultivated on less than five acres of land each (and by under 30 farmers).

[3] The relationship does not, however, hold with respect to changes in land area under these crops: as more farmers switch to cassava but grow the crop on a smaller area, fewer farmers now cultivate millets but on larger areas.

Table 3
Descriptive statistics of explanatory variables of the contingent valuation model.

Variable	Description	Mean (Std. deviation)	Range	
			Minimum	Maximum
Duration	Duration of contract, as indicated to the respondent (years)	2.01 (0.83)	1.00	3.00
Landholding	Land-holding size (acres)	2.60 (1.68)	0.25	20
Household	No. of household members	4.37 (1.69)	1.00	11.00
Gender	Sex of the household head (dummy, 1: female; 0: male)	0.13	0.00	1.00
Age	Age of the household head (years)	44.59 (11.31)	22.00	75.00
Education	Years of formal education obtained by the head (years)	2.70 (3.57)	0.00	15.00
Zones:	(Dummy variables)			
Z_1	Zone 1 (Devanur)	0.20	0.00	1.00
Z_2	Zone 2 (Alathur)	0.19	0.00	1.00
Z_3	Zone 3 (Thirupuli)	0.21	0.00	1.00
Z_4	Zone 4 (Gundani)	0.19	0.00	1.00
Z_5	Zone 5 (Selur)	0.21	0.00	1.00

The preference and prevalence of landraces in the region appear in Table 2, together with farmers' subjective perceptions regarding the superior attributes of these varieties (see Appendix B). Given the availability of cereal grains at subsidized price in the market, the continued prevalence of these millets is a strong indication of the fact that the market does not provide a perfect substitute from a consumption perspective. Millet varieties with inferior consumption value (e.g. *Panivaragu*) are found to be cultivated by fewer farmers and on limited acreage, while the varieties which are less productive but have significant consumption values (e.g., *Kattavettisamai*) are more widely cultivated. In sum, in the subsistence farming systems of the Kolli Hills, it is the consumption value of the millets that determine its prevalence, while productivity is only a secondary reason (Table 2; Appendix B). Hence, the cost of conserving millet varieties through a PACS scheme is likely to be directly linked to the consumption value rather than its productivity.[4] To further analyze this aspect, farmer preferences are translated in monetary terms by means of a CV model. This allows us to estimate the cost of conservation of each of these millet varieties under the proposed PACS scheme.

4.3. Farmers' Willingness to Participate in a PACS Scheme

The summary statistics of the explanatory variables of the CV model are shown in Table 3 and the bivariate probit model estimates to test for the shift effect in Appendix C. The model parameter, ρ, is found to be statistically insignificant, showing no significant shift-effect in the function, allowing us to proceed with the estimation of the DBDC interval regression model. The estimates of the DBDC model are provided in Table 4.

A single equation was estimated by including the variable MPV as an intercept dummy and its interaction terms with other explanatory variables. The estimates indicate a strong regional differentiation in terms of WTA, with households' demographic characteristics playing a lesser role. Households in Devanur (Zone 1) appear to demand the lowest compensation for cultivating their MPVs and the highest compensation for cultivating their LPVs. In this zone, where kodo millet was traditionally grown, farmers have indicated a strong dislike for the cultivation of the associated landrace, *Thirivaragu*. A significant share of households was not willing to cultivate this millet even at a compensation level of Rs. 1000/year. In other zones, farmers were more responsive to the increasing bid structure. The observed variety-specific (strong difference in the perceived consumption values between MPVs and LPVs) and zone-specific factors (relatively wealthier households with a long history of organization participation) could be the reasons for this regional heterogeneity of preferences.

The duration of the contract is found to have a significant impact only in the case of LPVs, resulting in an increase in the annual compensation demanded under longer contracts. The impact of the duration of the contract on WTA for MPVs is not found to be significantly different than that for LPVs. Thus the hypothesis that the preferred contractual duration of the PACS scheme is unaffected by the opportunity cost of conservation cannot be rejected.

Although small and marginal farmers are more dependent on minor millet crops, as they devote a higher share of their cultivable land to millet production, the CV model (Table 4; Model I) shows that land size does not play a significant role in determining the compensation demanded by millet farmers, and hence the hypothesis that large farmers might have a relatively higher willingness to participate in the PACS scheme is not supported by the data. This may be considered a positive finding as the inclusiveness of PACS schemes vis-à-vis smaller farmers may be desirable from both a social equity perspective (for example, see Narloch et al., 2011b) as well as due to their crucial role of such farmers in the de facto conservation of landraces. Women appear to demand higher compensation for cultivating LPVs, possibly due to their increased awareness regarding the lower consumption value of such varieties. The age of the respondents, which acts as a proxy for household experience relating to millet farming, is also found to increase the compensation demanded for LPVs, although it reduces it for MPVs.

Table 4
WTA interval regression estimation results.

	Model I: overall			Model II: excluding Zone 1		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
Model intercept	792.37	92.61	0.00	394.15	94.04	0.00
Duration	56.78	16.32	0.00	40.95	16.17	0.01
Landholding	−7.41	9.55	0.44	−8.26	10.43	0.43
Household	−1.13	8.26	0.89	−0.67	8.15	0.93
Gender	72.70	40.42	0.07	34.04	39.62	0.39
Age	2.46	1.29	0.06	2.58	1.33	0.05
Education	−3.77	4.24	0.37	2.29	4.34	0.60
Z_2	−443.87	47.32	0.00			
Z_3	−592.94	47.03	0.00	−143.82	37.64	0.00
Z_4	−475.43	48.19	0.00	−34.05	39.22	0.39
Z_5	−307.62	46.86	0.00	126.00	37.62	0.00
MPV	−633.47	126.01	0.00	−42.84	130.61	0.74
MPV∗Duration	−26.49	22.36	0.24	−5.85	22.60	0.80
MPV∗Landholding	−2.24	12.28	0.86	2.26	14.47	0.88
MPV∗Household	6.59	11.37	0.56	7.51	11.42	0.51
MPV∗Gender	−63.83	56.08	0.26	−8.70	55.23	0.88
MPV∗Age	−3.55	1.78	0.05	−3.78	1.85	0.04
MPV∗Education	5.57	5.80	0.34	−1.89	6.05	0.76
MPV∗Z_2	668.85	62.41	0.00			
MPV∗Z_3	597.17	61.22	0.00	−77.54	52.55	0.14
MPV∗Z_4	599.14	63.58	0.00	−65.29	55.12	0.24
MPV∗Z_5	438.99	61.50	0.00	−218.31	52.84	0.00
Number of observations	908			728		
Log likelihood	−1235.02			−961.92		
LR χ^2 [df]		546.61 [21]	0.00		290.08 [19]	0.00

Notes: dependent variable is the range in which household WTA would fall in and is measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under a mixed cropping system.

[4] This would be consistent with the high shadow prices that Aslan and Taylor (2009) identify in the face of market asymmetries, where specific consumption traits can be attained through subsistence cultivation but not through the market.

Table 5
WTA and share of farmers who would participate in a PACS scheme.

Farmer participation (%)	WTA for MPV conservation; with a duration of PACS scheme			WTA for LPV conservation; with a duration of PACS scheme		
	1 year	2 years	3 years	1 year	2 years	3 years
5	123.24	153.52	183.80	378.04	434.82	491.60
10	136.29	166.57	196.86	407.15	463.93	520.70
20	152.68	182.96	213.24	441.67	498.45	555.22
50 (Median WTA)	267.78	298.06	328.34	564.51	621.28	678.06
Mean WTA	247.20	277.48	307.77	623.04	679.81	736.59

Notes: WTA values are measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under a mixed cropping system.

As mentioned earlier in this section, the farmers of Zone 1 (Devanur) were found to have a severe aversion towards their stated LPV (*Thirivaragu*), with their willingness to cultivate this variety being relatively low even at high compensation levels. In order to understand the impact of such "almost lexicographic" preferences (i.e. these farmers prioritize varietal attributes almost always irrespectively of the hypothetical compensation offered) by farmers in the WTA estimation, an additional model was estimated, excluding the observations from this zone. These estimates are shown in Table 4 (Model II). The most pronounced impact of the exclusion of Zone 1 was a change in the coefficient of the dummy variable representing MPVs. The compensation demanded for LPVs declined by about 50%, while the difference between LPVs and MPVs became statistically insignificant. This shows that on-farm conservation of varieties of little, common and Italian millets through a PACS scheme may be less expensive than previously estimated and could be further minimized if the programme could choose least-cost providers up to the point where the SMS is reached.

The estimated WTA values for MPVs and LPVs, including the observations from Zone 1, are given in Table 5. These average figures, although providing a broad estimate of the approximate cost of conservation of minor millets in the Kolli Hills region, conceal a wide range of variety-specific compensation requirements demanded by the sample households for participating in the hypothetical PACS programme, as shown in Table 6. Farmer demand, in terms of the mean WTA, ranges from Rs. 1489 (for one of the popular finger millet varieties grown extensively in Zone 1 and Zone 5) to Rs. 9822 (for the kodo millet variety) per acre per year (assuming a contract length of 1 year). On-farm conservation of kodo millet thus appears to entail significant costs and hence might be better considered for *ex situ* conservation should overall funds be limited. Based on these results, Fig. 3 reveals households' willingness to cultivate MPVs and LPVs given alternative compensation levels. The resulting S-shaped probability distribution curve is akin to the diffusion logistic function of the conventional technology adoption literature (Rogers, 2003).

Table 6
Estimated farmer WTA compensation for different millet varieties.[a]

Crop and *variety*	Mean WTA (Rs./year)	Range of WTA (Rs./year)	
		Min.	Max.
Finger millet			
Arisikaizhvaragu	153.30	74.49	195.24
Karakaizhvaragu	407.99	340.60	540.41
Karunguliyankaizhvaragu	399.57	335.57	644.34
Perunkaizhvaragu	370.71	208.49	748.88
Sattaikaizhvaragu	148.85	0.00	201.16
Sundangikaizhvaragu	152.33	87.79	197.60
Little millet			
Karumsamai	518.65	360.26	636.84
Kattavettisamai	280.53	256.90	316.07
Malliasamai	531.11	227.64	737.44
Sadansamai	406.71	316.41	455.02
Vellaperumsamai	274.75	103.05	957.20
Thirigulasamai	411.24	365.90	489.07
Italian millet			
Koranthinai	387.89	122.30	475.55
Mookkanthinai	546.02	367.77	629.83
Palanthinai	431.67	230.44	756.06
Senthinai	489.79	300.13	578.17
Perunthinai	599.62	257.20	736.31
Common millet			
Panivaragu	499.29	407.15	613.90
Kodo millet			
Thirivaragu	982.21	863.44	1084.50

[a] Note: assuming duration of contract is 1 year. WTA values are measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under mixed cropping.

5. Discussion: Implications for a PACS Scheme Implementation

The cost of running a PACS scheme would primarily be a function of the compensation level demanded by farmers in the form of direct payment in addition to implementation (e.g., administrative) and transaction costs (e.g., costs related to raising awareness regarding the existence of the scheme, supporting farmers to develop realistic bids, selecting beneficiaries, monitoring and verification, etc.). What the analysis shows is that the selection of landraces for inclusion in a PACS scheme would strongly depend on their consumption values and current threat level (measured broadly in terms of prevalence). As shown in Fig. 4, there is a strong negative correlation between farmers' WTA compensation level for the different varieties of millet and their associated consumption preferences. This association is stronger (in absolute terms) than the association between the WTA compensation and varietal productivity levels. This may be considered to be largely due to the subsistence nature of farming in the study area and to the difficulty in finding perfect substitutes for such consumption traits in the market.

The relationship between the current prevalence of varieties, as indicated by the number of households cultivating them, and the corresponding compensation demanded by households to continue cultivating them is shown in Fig. 5. Based on the preferences and compensation demanded, we can group the varieties into three categories. The varieties in Group I were conserved *de facto* during the study period (i.e., all finger millet varieties except *Karakaizhvaragu*, and the little millet variety *Vellaperumsamai*). In general, these varieties have high consumption utility and low conservation costs in terms of required compensation to farmers. As most of them are already popular with the farmers and there is only a low risk of extinction, these varieties may not need to be included in a PACS scheme. This might not be the case with the other groups. For Group II, the farmer demand for compensation is low, but cultivation is limited at present. The relatively low cost of conservation of these rare varieties is thus indicative of the impact that relatively modest conservation funding could achieve. This group includes most of the little millets and Italian millet varieties, one finger millet and the common millet variety. The reasons for low farmer adoption of these varieties vary from seed market imperfections to agronomic disadvantages. The Group-III (kodo millet) variety is strongly disliked by farmers, having low consumption values and consequently being more expensive to conserve on-farm than any of the other.

To maintain the ecosystem services arising from the *in situ* conservation of crop diversity, such as the maintenance of agroecosystem resilience, evolutionary processes and gene flow, traditional knowledge and future option values, criteria other than just land area

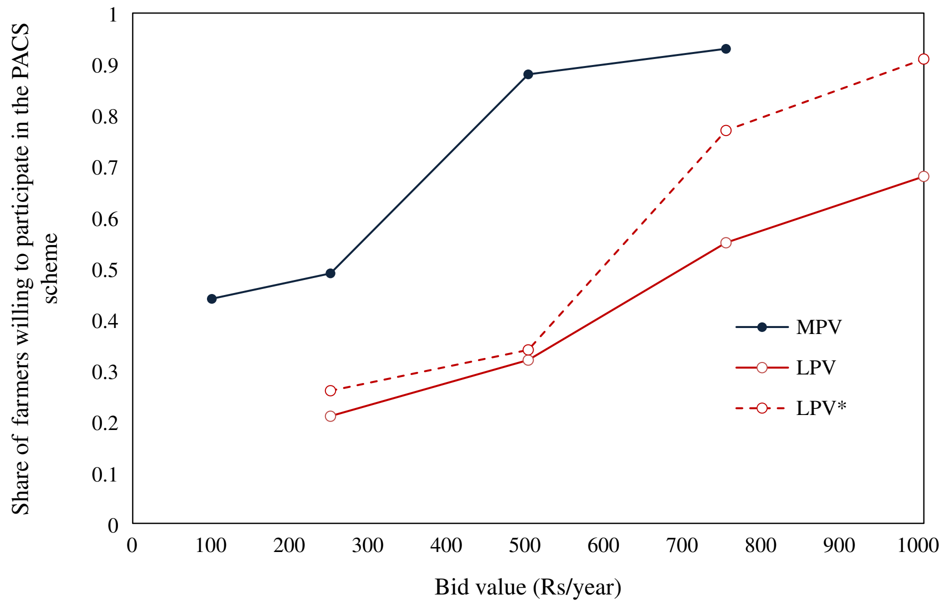

Fig. 3. Probability of accepting the PACS contract under varying WTA compensation levels for MPV and LPV. Notes: LPV*: calculated excluding Zone 1. Bid values are measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under mixed cropping.

under cultivation may well need to be taken into account. For example, as noted previously, consideration should be given to such factors as, *inter alia*, number of farmers cultivating the variety, the spatial distribution of communities involved in conservation activities, the functionality of the seed system, and the amount and age of seed stored (Narloch et al., 2011a). While the choice and weighting of such factors in order to link them with the provision of the specific ecosystem services in question remains to be empirically determined, it would nonetheless appear that there are indeed significant public good benefits from CGR conservation potentially accruing to a large number of subsistence farm households due to improved landscape-level resilience, as well as through the enhanced supply of nutritionally

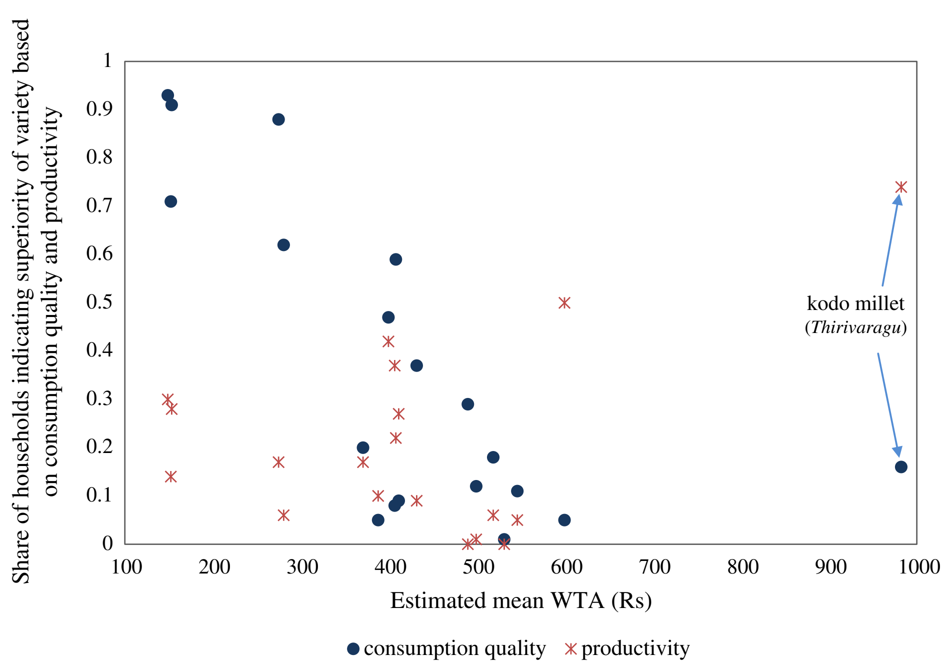

Fig. 4. Farmer perception on millet variety attributes and the estimated WTA. Notes: WTA values are measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under mixed cropping. WTA estimates are derived from Model I of Table 4. Each of the asterisks/dots represents a millet variety. Correlation coefficient between % households considering a variety superior due to consumption quality and WTA is −0.70 (excluding kodo millet −0.85). Correlation coefficient between % households considering a variety that is highly productive and WTA is +0.39 (excluding kodo millet −0.15).

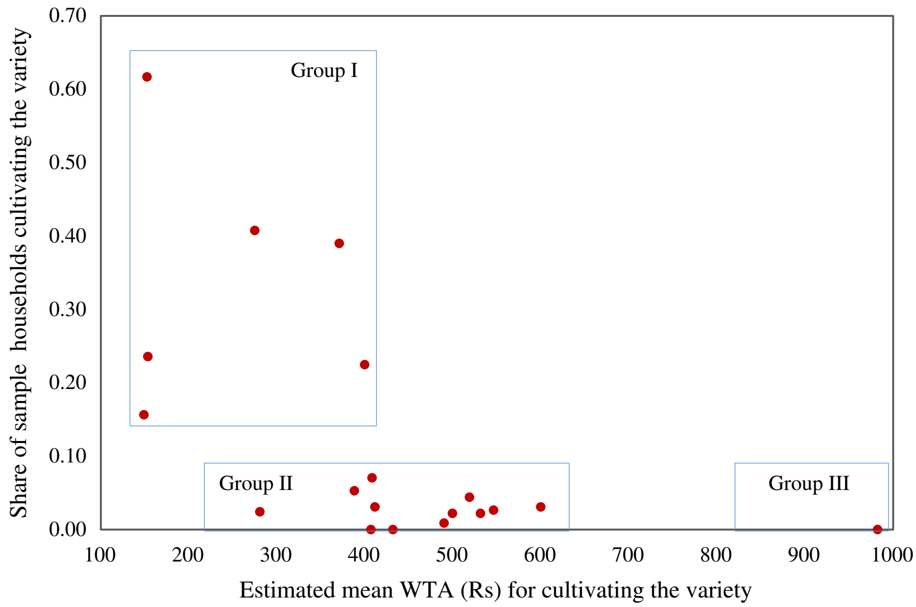

Fig. 5. Prevalence of millet varieties and estimated WTA to cultivate them. Notes: WTA values are measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) per year for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under mixed cropping. WTA estimates are derived from Model I of Table 4. Each of the dots represents a millet variety.

superior foods (especially if the Group-II varieties are conserved on-farm).

Although this study has examined the structure and allocation of monetary compensation for the on-farm conservation of CGR (by contrast, see Narloch et al., 2011a, b for the use of an in-kind reward tender approach), focusing especially on the method used to estimate the level of compensation required to motivate conservation, there nonetheless exist a number of institutional issues that would need to be simultaneously addressed in the context of actually developing a PACS scheme of this kind. These include issues related to the potential role of government or other agencies (e.g. as an intermediary and/or regulator), the establishment of mechanisms to sustainably finance the flow of direct payments, the development of monitoring approaches, as well as the establishment of status information regarding threat levels and conservation goals. Policies that would promote change in the community, like information campaigns or consumption subsidies, that would increase the consumer base of minor millets, would also be considered to come under the purview of such institutional changes (Gruere et al., 2009).

India is a signatory of United Nations Convention on Biodiversity (CBD), and thereby undertakes to carry out in-depth reviews of its CBD-related programme of work on incentive measures (Decision IX/6), analyze “the effects of different incentive measures and the impact on biodiversity” (para 4e) and develop “methods for assessing the effectiveness of incentive measures” (para 4f) (CBD, 2008). The challenge nonetheless remains for PACS-type incentive mechanism schemes to be upscaled and widely adopted as part of wider *in situ* biodiversity conservation strategies.

6. Conclusions

Relatively few studies have examined the role of direct payments on agrobiodiversity conservation and the importance of consumption preferences on the *in situ* conservation of agrobiodiversity. This paper highlights the critical importance of the quality attributes of the crop genetic resources not only in ensuring *de facto* conservation, but also in determining the costs and potential impacts of external interventions, such as PACS schemes. It has been shown that the perceived traits of CGRs, associated farm household utilities, and conservation options (*ex situ*, *in situ* with PACS or *de facto*) are closely related to each other.

An appropriate PACS scheme and its underlying priority CGR portfolio could have both direct and complimentary impacts on the CGRs under threat. For example, such a scheme could ensure that farmer experimentation efforts and market development would be focused on priority threatened CGR. However, a range of additional issues would have to be addressed prior to such a PACS scheme being implemented in practice. These would include for instance, the definition of scientifically-informed conservation goals and safe minimum standards, assessing the degree to which the varieties identified are sufficiently dissimilar to merit inclusion in a priority conservation portfolio (Narloch et al., 2011b; Weitzman, 1998) and the potential impact of such incentive mechanisms on other threatened non-millet crop species not covered by the PACS schemes. Further work is also necessary with regard to identifying the potential complementarity of niche product market development instruments (aimed at enhancing the private good values accruing from the maintenance of threatened plant and animal genetic resources) and PACS schemes aimed at enhancing the capture of public good values.

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Appendix A. Example of Initial Bid Card Shown to the Farmers

		Bid card number:
Landrace (type/name)		Landrace Y ___________ (= most preferred variety)
Area to be planted with landrace		10 cents (if pure) (15 cents if mixed crop)
2 Vallam of quality seed to be donated to village seed bank		Yes
Length of contract		1 year
Type of support that farmer would receive		Rs. 100 (paid 50% at beginning of contract and 50% upon successful completion)
Decision of the farmer		Yes, I would participate ☐ No, I would not participate ☐

Appendix B. Farmer perspectives of millet landrace attributes

	Share of farmers recognizing millet landrace characteristic							
	Higher productivity	Consumption quality	Cultural traditions	Suited to soil conditions	Only lesser attention required	Pest/disease tolerance	Drought tolerance	Short duration
Finger millet								
Arisikelvaragu	0.28	0.91	–	0.01	–	–	–	–
Karakelvaragu	0.22	0.59	0.07	0.21	0.08	0.05	0.05	0.02
Karunguliyankelvaragu	0.42	0.47	0.10	0.16	0.01	0.07	0.05	0.01
Perungelvaragu	0.17	0.20	0.02	0.06	0.01	0.39	0.15	0.01
Sattaikelvaragu	0.30	0.93	–	–	–	–	–	–
Sundangaikelvaragu	0.14	0.71	–	–	0.01	0.03	–	0.12
Little millet								
Karumsamai	0.06	0.18	0.08	0.26	0.36	0.07	0.24	–
Kattavettisamai	0.06	0.62	0.21	0.63	0.14	0.20	0.14	0.07
Malliasamai	–	0.01	0.01	–	0.04	0.02	–	0.92
Sadansamai	0.37	0.08	0.15	0.30	0.04	–	0.03	0.03
Vellaperumsamai	0.17	0.88	0.12	0.25	0.04	0.11	0.02	0.01
Thirigulasamai	0.27	0.09	0.02	0.07	0.01	–	–	0.53

Appendix B (*continued*)

	Share of farmers recognizing millet landrace characteristic							
	Higher productivity	Consumption quality	Cultural traditions	Suited to soil conditions	Only lesser attention required	Pest/disease tolerance	Drought tolerance	Short duration
Italian millet								
Koranthinai	0.10	0.05	0.18	0.12	0.02	0.51	0.01	0.01
Mokkanthinai	0.05	0.11	0.06	0.17	0.34	0.19	0.30	0.05
Palanthinai	0.09	0.37	0.19	0.09	0.19	0.02	0.05	–
Senthinai	–	0.29	0.17	0.54	0.46	0.33	0.10	0.37
Perunthinai	0.50	0.05	–	0.09	0.24	0.03	0.08	–
Common millet								
Panivaragu	0.01	0.12	0.16	0.36	0.38	0.33	0.14	0.52
Kodo millet								
Thirivaragu	0.74	0.16	0.00	0.08	0.02	0.01	0.02	0.04

Source: Narloch (2010).

Appendix C. SUBP Model Regarding Responses to Initial and Follow-up WTA Questions

	Variables	Coef.	Std. Err.	p value
Eq. (1)	Initial bid (Rs./year)*	0.002	2.E−04	0.00
	Duration of contract (1, 2 or 3)	−0.169	0.075	0.03
	MPV (vs. LPV) (dummy)	0.637	0.290	0.03
	MPV∗initial bid (interaction)	0.001	4.E−04	0.00
	MPV∗duration of contract (interaction)	0.063	0.111	0.57
	Model intercept	−0.958	0.212	0.00
Estimated mean WTA*	MPV	147.50		
	LPV	627.32		
Eq. (2)	Follow-up bid (Rs./year)*	−2.E−04	3.E−04	0.48
	Duration of contract (1, 2 or 3)	0.007	0.072	0.93
	MPV (vs. LPV) (dummy)	0.279	0.273	0.31
	MPV∗follow-up bid (interaction)	0.001	4.E−04	0.02
	MPV∗duration of contract (Interaction)	−0.078	0.104	0.45
	Model intercept	0.149	0.224	0.51
Estimated mean WTA*	MPV	<0.00		
	LPV	795.17		
Model parameters	ρ	−0.026	0.090	0.77
	N	908		
	Log-likelihood ratio (LR)	−1097.50		
	Wald $\chi^2(10)$	222.18		0.00

*Measured in Indian rupees (Rs.; 1 US$ = Rs. 46.64 on average between March and June, 2010) for cultivating 0.10 acre of millets under monocropping or 0.15 acre of millets under a mixed cropping system, ass\uming length of contract as 1 year.

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