Chapter 3

Valuation of Rice Diversity in Nepal: A Trait-based Approach

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Summary

Commercialization of valuable consumption traits (like aroma, taste and easy expansion in cooking) and production traits (like high yield and pest resistance) can make traditional crop varieties more attractive for local farmers, enhancing their on-farm conservation. Market-driven methods of conservation based on incentives and opportunity costs require a priori knowledge about farmers’ preferences for varieties and traits. This case study has attempted to value different useful traits of rice landraces grown in Nepal. A sample of randomly selected 200 Nepalese rice growers, 100 each from the hills and the plain, were surveyed on production of rice landraces and the market price fetched by each of them.

Two types of valuation methods were used: hedonic pricing and contingent valuation. The results of the hedonic pricing method (HPM) showed that consumers value aromatic and tasty traits of rice landraces close to NPR (Nepalese rupee) 11 billion ($148.6m) and NPR 2 billion ($27m), respectively. The contingent valuation method (CVM) was employed for estimating farmers’ derived demand for hypothetical seeds with different useful traits combined as desired by the farmers. The results showed that farmers were willing to pay nearly NPR 1 billion (close to $13.5m) for high-yielding landraces with aromatic traits and over NPR 1 billion for disease-resistant landraces highly suitable for cooking.

These values of unique traits of rice landraces are likely to exceed the costs of conservation. The estimates are indicative of the values of the rice traits embodied in the rice landraces that justify the need for their conservation. Therefore, it has been concluded that every dollar spent in conservation of such landraces makes the society better-off.
Background

Biodiversity on the earth is a reservoir of genetic resources (GRs) that have been used by humans for centuries and have vast potential for the production and manufacture of food, pharmaceutical and cosmetic products for the generations to come. Though biodiversity exists at the genetic (allelic variation), species and ecosystem levels (CBD, 1992), genetic level diversity is more important for food and agriculture as they are important for future crop breeding with conventional technology as well as modern biotechnology. The diversity of food plants consists of crop resources that are created and maintained as active components of agro-ecosystems (Brookfield and Padoch, 1994; Vandermeer et al, 1998) by the farmers.

As noted in Chapter 1, the need for the conservation of the biodiversity is indispensable. Conservation of GRs is important for future production of food that is needed for the sustenance of the human race on the earth. The literature suggests that the continued production of agro-biodiversity is dependent upon adequate supplies of farm resources among rural households (Brush et al, 1992; Mayer and Glave, 1999). A wealth of indigenous knowledge associated with the utilization of plants and animals exhibits the food and medicinal values of the GRs to local communities, including consumers, producers and other actors involved in the market value chain. Many of the farmers in developing countries are joint producers and consumers of the food, and both consumption traits and production traits of the crops are relevant for them.

Nepal has developed many modern varieties that, as expected, give higher yield in shorter duration than the landraces. There is a high rate of replacement of landraces by the modern varieties. The higher the profit gap from the modern varieties and landraces, the faster the replacement process. Thus, finding an effective strategy for conservation and sustainable utilization of crop GRs would involve enhancing the comparative advantage of the landraces, i.e. reduction in the profit from the modern varieties and/or increase in the profit from the landraces. The decrease in the profit from the modern varieties is not desired as it decreases the welfare of the people. That makes increasing the profitability of landraces the most plausible mechanism to improve their maintenance and slow down the replacement. Promoting the commercial use of GRs for increased profit to the farmers who grow them is emerging as one of the major strategies of effective in situ agro-biodiversity conservation. This approach of agro-biodiversity conservation is discussed in Chapter 6 in detail.

Sustainable use and conservation through commercial use of landraces builds on farmers’ self-interest and it is incentive-based rather than the ‘command and control’ approach. It is more suited to agro-biodiversity conservation that has larger direct use values on-farm. More specifically, the commercialization of GRs can generate income for the farmers and let them realize the economic importance of the resources for their livelihoods. However, the origin of new conflicts for dealing with biodiversity stems from the rules of division and appropriation of the benefits out of the commercial use of the genetic resources. As policy-makers
cannot fully understand the value of the landraces, it is likely that they are unable to negotiate with giant seed development companies (including biotechnology companies) for the best use of GRs and their effective conservation.

The future prospects of commercialization, however, crucially depend on the potential market value of the GRs. The market value, in turn, depends on three factors, namely:

1. How much one can commercialize it.
2. How much the breeding/seed development industry is willing to pay for the samples of GRs.
3. How much revenue a single provider can earn.

For GRs that have many potential suppliers and few seed development companies to buy them, the suppliers cannot expect revenue enough for their conservation as the market has a monopsonistic nature. Whether or not a market for GRs can effectively support the conservation of biodiversity essentially depends on the scarcity of the GRs. It is often assumed that the scarcity of the GRs, particularly those that control commercially important traits (such as cooking and production qualities), is rising as demand for them increases due to current advances and future prospects in the seed development sector.

Some crop GRs are found to be owned, managed and used by a few farmers or a limited number of communities. To the extent that benefits accrue to their users and owners, crop GRs are private goods. Their benefits are also public to the extent that they are accrued by all economic agents involved in the market value chain. Due to its public goods nature, the use of biodiversity by one person does not exclude others from using it. Therefore, as noted in Chapter 1, agro-biodiversity has both public and private goods features.

Replacement of the indigenous varieties by exotic high-yielding varieties and changes in farming practices and land use patterns are important causes of agro-biodiversity loss in Nepal (Upreti and Upreti, 2002). This is a typical case of market failure as the farmers fail to value the benefits to society from the conservation of the landraces. As noted in Chapter 1, farmers always maintain crop GRs to the extent that these resources address their household concerns. Thus, their conservation is not optimal as there are crop varieties that have little utility to address farmers' current concerns but have potential future public utility. Market failures, particularly its failure to account for the public goods values, are the major causes of loss in agro-biodiversity. Estimating the total economic value (TEV)\(^3\) of landraces by means of non-market valuation methods can help to develop policies that address the problem of market failures. The valuation of biodiversity can assist decision-makers with the development of mechanisms of equitable sharing of benefits from utilization of GRs, and help to justify investments in their conservation.

As noted in Chapter 1, environmental values can be estimated using revealed and stated preference methods. The revealed preference methods use the market data as revealed by the respondent (consumer, farmer, etc.) while the stated
preference methods are based on the preferences stated by respondents under hypothetical market situations. The discussion of stated preference methods in resource and environmental economics dates back to the 1940s (Ciriacy-Wantrup, 1947). Extension of these valuation techniques to agricultural biodiversity is, however, a recent phenomenon (see e.g. Hoyos, 2010).

This chapter aims to evaluate the genetic diversity of traditional rice varieties in Nepal, using both revealed and stated preference methods. The outcome of this case study is expected to help in designing cost- and benefit-sharing approaches for the conservation and use of rice GRs. Information about the values of traditional rice varieties will be valuable to prioritize their on-farm conservation. Hedonic pricing method was used to find the value given by consumers for each trait of rice landraces and contingent valuation method was used to estimate the bidding price of a new variety of rice with useful desirable traits required by farmers.

**Approaches for measuring economic value of genetic diversity**

Human decision-making (in natural resource use and agricultural technology adoption) involves a series of trade-offs such as between environmental concerns (e.g. biodiversity protection) and meeting the immediate economic needs (e.g. income generation and food security). If traditional crop varieties are low yielding, on-farm conservation of these resources will involve opportunity costs in terms of food production and productivity. Economic principles of valuation can offer mechanisms to estimate the value of agro-biodiversity and make sound decisions aimed at internalizing the trade-offs, while contributing to both objectives of agro-biodiversity conservation and enhancing agricultural productivity.

Measuring the value of biodiversity is a great challenge. Reid et al (1993) observed that even though the debates on the measurement of biodiversity started in the 1950s, there is still no clear consensus about how the value of biodiversity should be measured. Pearce and Moran (1994) examined some aspects of measurement of biodiversity at genetic, species and ecosystem levels. Accordingly, the genetic differences can be measured in terms of phenotypic traits, allelic frequencies or deoxyribonucleic acid (DNA) sequences. The measurements of allelic diversity and DNA sequence require high-level technical information which is out of the scope of this paper. This study relies on the phenotypic characteristics of the products. The consumers and farmers (i.e. the users) can observe the consumption and production characteristics of rice at the grocery store and decide which ones to buy. Most of the characteristics can only be known after the product has been used as a consumer good and/or production input. For example, the consumption characteristics of rice will be known after cooking and eating whereas the production characteristics of the seed will be known to the farmers during their experience with the seed from its storability as an input all
the way through post-harvest traits (germination, early maturity, pest/disease resistance, tolerance to water stress, yield, marketability, perishability, post-harvest loss, etc.).

In this case study, rice consumers are surveyed to capture their preferences for different combinations of consumption traits of rice and the demand for seeds by the farmers is taken as the derived demand. Use values are assumed to be the most important part of the values of rice GRs from a consumer point of view and, by applying hedonic pricing, these use values can be assessed. The application of the contingent valuation method, on the other hand, allows the assessment of the TEV of rice GRs.

Methodology

The sources of data, sampling designs and analytical procedures underlying the empirical analysis are discussed in this section.

Data and sources

For valuation of GRs, two districts, namely, Kaski from the hills and Bara from Terai (the plains at the base of the Himalayas), were selected purposively in consideration of the richness of rice diversity. From each district, two village development committees (called villages hereafter) with a high concentration of the rice landraces have been identified by a survey of key informants including professionals, researchers in agro-biodiversity and extension officers in agriculture, all working in the district. Key informants were asked to rank five villages in the district with the highest diversity of rice landraces. Data were collected on accessibility (to markets, roads and transport services), area characteristics and rural development interventions in place. The area characteristics include the number of farm households, total geographic area, distance from district headquarter, area under paddy and total irrigated area. These statistics were scored and aggregated. The two villages with the highest aggregate scores were selected for the survey. On this basis, Lekhnath and Lumle villages were selected from Kaski district (Begnas area) and Kacharba and Maheshpur villages were selected from Bara district (Kacharwa area).

Considering the situation of the villages and the farm households, a checklist of questions for focus group discussions was prepared. From the discussions with the relevant stakeholders, a draft questionnaire for household surveys was drawn. More focus group discussions were conducted to refine the draft questionnaire. The questionnaire was then pre-tested on 30 farm households in each survey district.

A household was the sampling unit. The farm households cultivating the rice landraces formed the sampling frame. The sample households were selected using a simple random sampling method without replacement. A sample of 50 farm households was drawn from each of the four selected villages. Thus, 200 sampled households were surveyed altogether for estimating the value of
important traits of rice varieties. A team of two well-trained research assistants was deployed for the survey. The pre-tested questionnaire was administered by trained enumerators.

According to the survey data, the price of rice varieties varies from NPR 725 ($10) (for Chaite and Janaki varieties) to NPR 1622 ($22) (for Basmati varieties). The sampled 200 farmers were found growing 78 rice varieties altogether. Nearly 50 per cent of the farmers were found growing a high-yielding variety (BG-1442). Over 30 per cent of them were growing Basmati rice. Four varieties, namely BG-1442, Basmati, Sona Masuli and Anadhi, were the most popularly grown varieties. Most of the landraces were grown by less than 10 per cent of the farmers. If one is to take relative abundance and continuous use of traditional rice varieties as an index for on-farm conservation, those landraces grown by a small number of households are more likely to be lost easily if some conservation measures are not applied. The relative abundance of each of the variety is presented in Table 3.1.

<table>
<thead>
<tr>
<th>Relative abundance (%)</th>
<th>Name of the Variety</th>
<th>No of varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>41 to 50</td>
<td>BG-1442*</td>
<td>1</td>
</tr>
<tr>
<td>31 to 40</td>
<td>Basmati</td>
<td>1</td>
</tr>
<tr>
<td>21 to 30</td>
<td>Sona Masuli* and Anadhi</td>
<td>2</td>
</tr>
<tr>
<td>10 to 20</td>
<td>Kathe, Anga, Meghdoott, Jetho Budho, Pahele, Mansuli*, China-4*, Sabitri*, Setwa, Rekshali, Ekde, Dhudhraj and Harinkar</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

Notes: *The relative abundance is measured as the percentage of the households growing that variety. The list of the varieties and landraces are in the descending order of relative abundance, BG-1442 being the most abundant and Bhalu being the least. The asterisks "*" at the end of the name of the varieties designate modern rice varieties and those without indicate a landrace.
Source: 2006 household survey, Nepal

Table 3.1 Relative abundance of rice landraces and varieties in the farmers' fields
Farmers’ knowledge of different traits of rice varieties can be used as an input in the sustainable use and conservation of agro-biodiversity. Their knowledge is the accumulation of the inherited experiences, updated by the observations in the field (Berkes et al, 1995; de Boef, 2000). They understand the connection between organisms and their surrounding environment (Perrings et al, 1995; Wood and Lenne, 1999). As a result, they grow different landraces of rice that are better suited to their farming systems (taking the seeds as production input) and their cooking preferences (taking rice as consumption good).

Hedonic pricing model

One of the widely used environmental valuation methods as a subset of the revealed preference approach is the hedonic pricing method. The philosophy behind hedonic pricing is that people pay for a product by valuing the embedded bundles of attributes of this product. The conceptual and analytical basis of this valuation technique emanate from Lancaster’s characteristics model (Lancaster, 1966). The early applications of this method, however, started in the 1920s. The first application of hedonic modelling is found in fresh vegetables. Though Waugh (1928) first used hedonic pricing on land characteristics, Ridker (1967) was the first to use this method on environmental goods for estimating the marginal value of air quality in residential areas.

Rosen (1974) used the hedonic price theory to interpret the derivative of hedonic property price function with respect to air pollution as a marginal implicit price and, therefore, the marginal willingness-to-pay (MWTP) of individuals for air pollution reduction. Rosen’s model starts with a distribution of utility-maximizing buyers and a distribution of profit-maximizing sellers. The equilibrium is achieved when the variation in price reflects the variation in the attributes under the condition of full information. Price (p) of a house, say, with a vector of attributes (z) and a vector (α) of parameters (Haab and McConnell, 2002) can be written as:

\[ p = h(z, \alpha) \]  
(Eqn 3.1)

The equilibrium will exist when the buyer maximizes the utility from consumption of a composite bundle of commodities (x) with a vector of household preference function (β). The utility function is \( u(x, z, \beta) \) and budget constraint with income \( y = h(z) + x \). Maximizing the utility subject to the budget constraint, we get optimal condition for each attribute.

\[ \frac{\delta u(x, z, \beta)}{\delta z_i} = \lambda \frac{\delta h(z)}{\delta z_i}, i = 1, \ldots, n \]  
(Eqn 3.2)

where the Lagrangian multiplier, \( \lambda \), is the marginal utility of the income. From Equation 3.2, MWTP for the i-th attribute can be calculated as \( \frac{\delta h(z)}{\delta z_i} \).
The hedonic price method has emerged as a powerful tool for the valuation of environmental goods that can be extended for valuation of newly recognized environmental amenities like biological diversity.

Dalton (2003) estimated a nonseparable household hedonic pricing model of upland rice attributes combining both production and consumption traits. Accordingly, yield was not a significant attribute in determining farmers’ WTP for new varieties. However, this trait has served as the defining factor for promoting a new variety for official release. What amount the farmers are paying for a particular new variety that comprises different gene combinations can be taken as the revealed preference of the farmers for genetic resources.

The value of major rice traits established by the Nepalese market can be estimated using hedonic pricing method based on the market price of varieties. It is assumed that the price the farmers pay for the rice depends on the variety attributes of rice, i.e. consumers pay more for the more useful variety attributes. Using this principle of price determination on the basis of the attributes of the product, the following model is used for estimating the use value established by the consumers on rice that are attributable to major traits of rice landraces.

\[
PP = \alpha + \beta_1 T + \beta_2 A + \beta_3 BR + \beta_4 LS + \beta_5 Md + \beta_6 Ce + \beta_7 Ex + \\
\beta_8 ST + \beta_9 MP + \beta_{10} TA + \beta_{11} Ms + v
\]

(Eqn 3.3)

where \(PP\), \(T\), \(A\), \(BR\), \(LS\), \(Md\), \(Ce\), \(Ex\), \(ST\), \(MP\), \(TA\), \(Ms\) and \(v\) refer to the price of paddy rice, tasty trait, aromatic trait, quality for bitten rice, quality for ‘latte’ and ‘siroula’, medicinal uses, uses in ceremony, expansion in cooking, good storage quality, milling per cent, Terai area, season and the error term respectively (a more complete description of all these variables is given in Table 3.3). \(\beta_1\) to \(\beta_{11}\) are coefficients to be estimated.

**Contingent valuation method**

Revealed preference methods of environmental valuation are preferred over the stated preference methods like the contingent valuation method (CVM). However, the revealed preference methods cannot always be employed, particularly when the values of the resources have not yet been realized. The diversity of landraces has immense future potentials from breeding high-yielding varieties with useful traits available in the landraces. Therefore, the potential future values of those varieties can be valued using only stated preference methods. The CVM relies on a questionnaire survey about WTP of individuals for conservation of a certain environmental resource. Pearce and Moran (1994) have argued that CVM is a promising option for biodiversity valuation in general because of the potential for information provision and exchange during the survey process, which offers scope to experiment with respondent knowledge and understanding of biodiversity. A variation of this approach has been used by Brown and Goldstein (1984) in order to value *ex situ* (plant) collections. They used a model where the benefits of
reducing expected future production losses are weighed against gene-bank operating costs and searches, arguing that all varieties should be conserved for which the marginal benefit of preservation exceeds marginal cost. Oldfield (1989) focuses on actual crop losses (in this case related to southern corn leaf blight) as a measure of value of the genetic improvement efforts used to eventually overcome such losses. A recent study by Poudel and Johnsen (2009) has also applied CVM to assess rice landraces in Nepal.

In this study, two basic steps were followed to estimate the value of useful traits in the landraces:

1. A hypothetical description (scenario) of the new rice varieties, with combinations of different traits available in landraces, was presented to the farmers. This included the combination of different useful traits into a single variety. The farmers were asked to bundle the different useful traits of rice into a single variety.
2. The farmers were asked questions to determine how much they would be willing to pay for 1kg of seed of the new variety combining the useful traits they have chosen. These questions took the form of asking how much a farmer was willing to pay for some new variety that contains a desired mix of the useful traits. Depending on the preferred elicitation format, econometric models are then used to infer a WTP for the change. An aggregate welfare measure was calculated by multiplying the mean with the relevant population of users.

The values put by the farmers on the rice seeds with different traits were estimated based on farmers’ bid for a price of a hypothetical rice variety with a combination of traits they desire to have in a single variety. The following mathematical model was used for empirical estimation of the value the farmers attach to different combinations of the traits.

\[
PS = \alpha + \beta_1 HA + \beta_2 T + \beta_3 Ex + \beta_4 SL + \beta_5 DrR + \beta_6 LF + \beta_7 DsR + \\
\beta_8 TA + \beta_9 A + \beta_{10} FR + \beta_{11} F + \beta_{12} PT + \beta_{13} RA + \beta_{14} I + \epsilon
\]

(Eqn 3.4)

where \( PS \), \( HA \), \( T \), \( Ex \), \( SL \), \( DrR \), \( LF \), \( DsR \), \( TA \), \( A \), \( FR \), \( F \), \( PT \), \( RA \), \( I \) and \( \epsilon \) refer to price of hypothetical seed, high-yielding and aromatic traits, tasty trait, cooking expansion trait, suitability to be sown late, drought resistance, suitability for less fertile land, disease resistance, Terai area, age of the household head, gender, number of family members, number of plots of paddy land, ownership of radio, non-agriculture income and the error term respectively (a more complete description of all these variables is given in Table 3.5). \( \beta_1 \) to \( \beta_{14} \) are coefficients to be estimated.
Farmers planted each variety separately on different plots or sometimes in different parts of the same plot. On average, each farmer grew 4.62 varieties of rice every year, each on small areas. For example, the average area under the most popular variety (grown by over 44 per cent of the households), modern variety BG-1442, was 0.26ha followed by the landrace Basmati 0.16ha (Table 3.2). Though Basmati was grown by a larger proportion of the households (nearly 38 per cent) than Sona Masuli (nearly 30 per cent), the area commanded by these two varieties showed the opposite. This was more distinct in the case of Anadhi. Though this long grain aromatic landrace was grown by over one-fourth of the total households, the average area under this landrace per household was very small. These precious landraces (like Basmati and Anadhi) are unable to compete with other commercially grown modern varieties. They are thriving in the farmers’ field only due to their special and desirable pheno-type characteristics.

The reason for the small area of land under Anadhi was its low price and productivity. It is clear that the gross return from Anadhi is about one-third of the gross return from the competing modern rice varieties. It showed that the typical landraces with unique genes are unlikely to survive in situ under business as usual situations. The options are either to go for ex situ conservation or to make the society understand the value of these landraces and find market-based in situ conservation mechanisms to benefit farmers and generate better consumption outcomes.

The descriptive statistics of rice traits used for the hedonic pricing model are presented in Table 3.3. Though some of the traits appeared to be not mutually exclusive, they were used separately as long as there was no problem of multi-collinearity.

These variables were fitted to a regression model to estimate the contribution of different traits to the price of the type of rice purchased. Many phenotypic properties like taste, aroma, expansion in cooking, storage quality and suitability to various dishes (bitten rice, latte and siroula, and ceremonial dishes), and

### Table 3.2 The most popular four varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type</th>
<th>Relative abundance (%)</th>
<th>Average area (ha)</th>
<th>Productivity (qt/ha)</th>
<th>Price (NPR/qt)</th>
<th>Gross return (NPR/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG-1442</td>
<td>Improved</td>
<td>44.5</td>
<td>0.26</td>
<td>41</td>
<td>1074</td>
<td>44,034</td>
</tr>
<tr>
<td>Basmati</td>
<td>Landrace</td>
<td>37.5</td>
<td>0.16</td>
<td>30</td>
<td>1622</td>
<td>48,660</td>
</tr>
<tr>
<td>Sona Masuli</td>
<td>Improved</td>
<td>29.5</td>
<td>0.23</td>
<td>49</td>
<td>1126</td>
<td>55,174</td>
</tr>
<tr>
<td>Anadhi</td>
<td>Landrace</td>
<td>26.5</td>
<td>0.02</td>
<td>14</td>
<td>1168</td>
<td>16,352</td>
</tr>
</tbody>
</table>

Note: * qt stands for quintal, 1 qt = 100kg.
Source: 2006 household survey, Nepal

Estimation of the value consumers put on rice landraces

Farmers planted each variety separately on different plots or sometimes in different parts of the same plot. On average, each farmer grew 4.62 varieties of rice every year, each on small areas. For example, the average area under the most popular variety (grown by over 44 per cent of the households), modern variety BG-1442, was 0.26ha followed by the landrace Basmati 0.16ha (Table 3.2). Though Basmati was grown by a larger proportion of the households (nearly 38 per cent) than Sona Masuli (nearly 30 per cent), the area commanded by these two varieties showed the opposite. This was more distinct in the case of Anadhi. Though this long grain aromatic landrace was grown by over one-fourth of the total households, the average area under this landrace per household was very small. These precious landraces (like Basmati and Anadhi) are unable to compete with other commercially grown modern varieties. They are thriving in the farmers’ field only due to their special and desirable pheno-type characteristics.

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These variables were fitted to a regression model to estimate the contribution of different traits to the price of the type of rice purchased. Many phenotypic properties like taste, aroma, expansion in cooking, storage quality and suitability to various dishes (bitten rice, latte and siroula, and ceremonial dishes), and
medicinal values were preferred by the consumers. These results were expected a priori.

Some undesirable traits were also identified. The undesirable traits included coarse grain (beside medium grain) and lack of taste (beside medium taste). The undesirable traits were hypothesized to bear negative prices in the bundle of properties. As the price was taken for fresh harvest of paddy rice, the milling percentage was also a concern for the buyer. It was assumed that the higher the milling percentage, the higher the amount the buyer would pay, keeping all other traits constant (all else being equal). The geographical area ‘Terai’ was fitted to catch the fixed effects of hills and plains.

### Table 3.3 Descriptive statistics of rice traits and price (n = 932)

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Variable description</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Expected sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Tasty</td>
<td>Dummy variable showing presence of tasty trait (1 if tasty and 0 otherwise)</td>
<td>0.61</td>
<td>0.49</td>
<td>+</td>
</tr>
<tr>
<td>2 Aromatic</td>
<td>Dummy variable showing presence of aromatic trait (1 aromatic and 0 otherwise)</td>
<td>0.19</td>
<td>0.39</td>
<td>+</td>
</tr>
<tr>
<td>3 Bitten</td>
<td>Dummy variable for bitten rice (1 good for bitten rice and 0 otherwise)</td>
<td>0.19</td>
<td>0.39</td>
<td>+</td>
</tr>
<tr>
<td>4 LateSiro</td>
<td>Dummy variable for Latte and Siroula (1 good for Latte and Siroula and 0 otherwise)</td>
<td>0.08</td>
<td>0.27</td>
<td>+</td>
</tr>
<tr>
<td>5 Medicine</td>
<td>Dummy variable for medicinal properties (1 good for medicinal uses and 0 otherwise)</td>
<td>0.10</td>
<td>0.30</td>
<td>+</td>
</tr>
<tr>
<td>6 Ceremony</td>
<td>Dummy variable for special ceremonies (1 good for special ceremonies and 0 otherwise)</td>
<td>0.18</td>
<td>0.39</td>
<td>+</td>
</tr>
<tr>
<td>7 Expansion</td>
<td>Dummy variable for expansion (1 good for expansion in cooking and 0 otherwise)</td>
<td>0.20</td>
<td>0.40</td>
<td>+</td>
</tr>
<tr>
<td>8 Storage</td>
<td>Dummy variable for storability (1 good for storability and 0 otherwise)</td>
<td>0.28</td>
<td>0.45</td>
<td>+</td>
</tr>
<tr>
<td>9 Milling</td>
<td>Percentage of rice flour recovered in milling</td>
<td>62.43</td>
<td>5.82</td>
<td>+</td>
</tr>
<tr>
<td>10 Terai</td>
<td>Dummy variable for geographic area (1 for plain area and 0 for hill)</td>
<td>0.48</td>
<td>0.50</td>
<td>–</td>
</tr>
<tr>
<td>11 Season</td>
<td>Dummy variable for season (1 for main season and 0 for summer season)</td>
<td>0.92</td>
<td>0.27</td>
<td>+</td>
</tr>
<tr>
<td>12 PadyPric</td>
<td>Price of paddy rice (NPR per 100kg)</td>
<td>1033.87</td>
<td>278.54</td>
<td></td>
</tr>
</tbody>
</table>

Source: 2006 household survey, Nepal
The average price paid by the market to the fresh harvest of paddy was NPR 1034 ($14), ranging from NPR 500 ($7) to NPR 2,400 ($32). If we assume that all farmers obtain equal market opportunities, the variation in the price is due to the difference in the quality, taking quality as the bundle of desirable traits.

The results of the linear hedonic model fitted to the above data are presented in Table 3.4 along with the 95 per cent confidence interval of the coefficients estimated. The model explained over 40 per cent variations in the price of the paddy. To the extent that the model faces omission of the relevant explanatory variables, the marginal value of each trait was overstated. It is also important to bear in mind that the non-use values of rice landraces are not included in this analysis.

The estimates showed that consumers paid NPR 36 ($0.5) per quintal for a tasty trait. This coefficient was on average about 3.5 per cent of average price of paddy. The estimate was highly significant. It can be inferred that by conserving the landrace with this trait and keeping alive the potential of incorporating this trait to other rice varieties in the world, it is possible to maintain the potential benefits of increasing the value of global rice production by over 3 per cent.

Similarly, for the aromatic trait, the consumers were willing to pay NPR 293 ($4) per quintal. This was over 28 per cent of the average price of the rice. If we were to lose this trait, the potential financial loss to society would be 28 per cent of the total value of rice produced globally. This is a value large enough to warrant investing in the required conservation measures.

Rice varieties suitable for bitten rice attracted lower prices (negative coefficient). This finding suggests that this trait had negative impact on utility for

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Tasty</td>
<td>36.55**</td>
<td>17.75</td>
<td>1.72 71.37</td>
</tr>
<tr>
<td>2 Aromatic</td>
<td>293.44***</td>
<td>21.20</td>
<td>1.72 71.37</td>
</tr>
<tr>
<td>3 Bitten</td>
<td>–50.65***</td>
<td>18.72</td>
<td>–87.38 –13.92</td>
</tr>
<tr>
<td>4 LateSiro</td>
<td>122.20***</td>
<td>29.00</td>
<td>65.29 179.11</td>
</tr>
<tr>
<td>5 Medicine</td>
<td>48.24*</td>
<td>28.94</td>
<td>–8.55 105.04</td>
</tr>
<tr>
<td>6 Ceremony</td>
<td>124.80***</td>
<td>21.52</td>
<td>82.57 167.03</td>
</tr>
<tr>
<td>7 Expansion</td>
<td>–2.84</td>
<td>19.63</td>
<td>–41.37 35.69</td>
</tr>
<tr>
<td>8 Storage</td>
<td>15.13</td>
<td>17.62</td>
<td>–19.45 49.71</td>
</tr>
<tr>
<td>9 Milling</td>
<td>–5.68***</td>
<td>1.36</td>
<td>–8.36 –3.01</td>
</tr>
<tr>
<td>10 Terai</td>
<td>152.10***</td>
<td>18.76</td>
<td>115.27 188.92</td>
</tr>
<tr>
<td>11 Season</td>
<td>85.31***</td>
<td>26.81</td>
<td>32.70 137.92</td>
</tr>
<tr>
<td>12 Constant</td>
<td>1129.07***</td>
<td>92.01</td>
<td>948.51 1309.64</td>
</tr>
</tbody>
</table>

N = 93  F(11, 920) = 57.99***  Prob > F = 0.000  Adjusted R² = 0.402

Notes: * qt stands for quintal, 1qt = 100kg, *** significant at 1% level; ** significant at 5% level; * significant at 10% level.
Source: 2006 household survey, Nepal
consumers relative to other traits. This is because rice varieties just harvested with poor quality and higher moisture content are more suitable for bitten rice. Such varieties are less storable and less preferred for steam rice and hence fetch a lower price. However, the rice varieties with traits suitable for other snacks like latte and siroula can fetch a higher price by NPR 122 per quintal. Similarly, the traits suitable for traditional healing purposes and for use in ceremonies are valued higher than other varieties.

As expected, the varieties with traits that make the rice coarse were valued negatively by the consumers as compared to the medium coarse. The result suggests that the higher the milling percentage, the lower the consumers were willing to pay. This is against *a priori* expectation. This might be because the consumers generally buy milled rice (not paddy rice) and hence the milling per cent is the concern of millers, not consumers. Even if some consumers buy paddy rice to mill it themselves, the milling per cent is not known to the buyers at the time of bidding a price. It is a trait that buyers know through experience. The farmers in the plain region are getting higher price of paddy for similar quality as compared to the farmers in the hill region. This can be because of the fixed effects factors, such as better transportation and communication facilities for better market connectivity in the plain areas.

Rice in Nepal accounts for more than half of the principal food crops. On average, 4 million tons of rice are produced every year (GON, 2007) with an estimated value of NPR 41.4 billion ($559.5m). This means that the aromatic traits of rice generate an extra NPR 11 billion ($148.6m) per annum for Nepal and tasty traits over NPR 2 billion ($27m). However, there are different landraces with different degrees of aroma and different levels of taste. A separate study is worthwhile to quantify and understand the importance of such traits and to value each specific aroma and taste trait.

The analysis apportions the price paid by the consumers to the value given to the different traits. Accordingly, protecting each of the preferred traits roughly increases the value to the society by the respective values.

**Estimation of producers’ (farmers’) values of rice traits**

Since it is unlikely that one rice variety will supply all of the attributes that the farmers value, they demand varietal diversity (Joshi and Bauer, 2005). In general, the producers’ demand for certain traits is the consumers’ derived demand for the traits. Moreover, some traits like high yield and disease (pest) resistance are additional concerns to the producers. If one is to follow the contingent valuation to estimate the producers’ valuation of the preferred rice traits, a contingent market has to be created in the minds of the farmers and they would be asked how much they are willing to pay.

Some preferred major traits like aroma, taste, high-milling percentage, expansion in cooking and good storage quality are highly demanded by consumers. In
addition, producers also put value on high-yielding traits, the variety that can be late sown, drought resistance, suitability for less fertile land and disease resistance. Considering that access to suitable seed is a priority issue for in situ agrobiodiversity conservation (Cleveland et al, 1994; Cleveland and Soleri, 2002; Rhoades and Nazarea, 1999; Zimmerer, 2002), the willingness to pay for new type of seeds is analysed. Each sample household was asked to select three combi-

Table 3.5 Descriptive statistics of the traits preferred and combined by the farmers 
(n = 600)

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Variable description constructed</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Expected sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 YieldAroma</td>
<td>Dummy for high yielding and aromatic traits (1 good for yield and aroma and 0 otherwise)</td>
<td>0.33</td>
<td>0.47</td>
<td>+</td>
</tr>
<tr>
<td>2 Tasty</td>
<td>Dummy for taste (1 good for taste and 0 otherwise)</td>
<td>0.23</td>
<td>0.42</td>
<td>+</td>
</tr>
<tr>
<td>3 Expansion</td>
<td>Dummy for expansion (1 good for expansion in cooking and 0 otherwise)</td>
<td>0.11</td>
<td>0.32</td>
<td>+</td>
</tr>
<tr>
<td>4 SowLate</td>
<td>Dummy for late sowing (1 good even if sown late and 0 otherwise)</td>
<td>0.21</td>
<td>0.41</td>
<td>+</td>
</tr>
<tr>
<td>5 Drought</td>
<td>Dummy for drought resistance (1 good for drought resistance and 0 otherwise)</td>
<td>0.18</td>
<td>0.39</td>
<td>+</td>
</tr>
<tr>
<td>6 Land</td>
<td>Dummy for soil quality (1 productive under poor soil quality and 0 otherwise)</td>
<td>0.11</td>
<td>0.31</td>
<td>+</td>
</tr>
<tr>
<td>7 Disease</td>
<td>Dummy for disease resistance (1 good for disease resistance and 0 otherwise)</td>
<td>0.17</td>
<td>0.38</td>
<td>+</td>
</tr>
<tr>
<td>8 Terai</td>
<td>Dummy for geographic areas (1 plain and 0 hill)</td>
<td>0.50</td>
<td>0.50</td>
<td>–</td>
</tr>
<tr>
<td>9 Age</td>
<td>Age of the household head (in years)</td>
<td>49.38</td>
<td>9.00</td>
<td>–</td>
</tr>
<tr>
<td>10 Gender</td>
<td>Dummy for gender (1 female and 0 male)</td>
<td>0.17</td>
<td>0.38</td>
<td>+</td>
</tr>
<tr>
<td>11 Family</td>
<td>Number of family members</td>
<td>7.03</td>
<td>1.98</td>
<td>–</td>
</tr>
<tr>
<td>12 PlotPady</td>
<td>Number of plots of paddy land</td>
<td>4.49</td>
<td>2.74</td>
<td>+</td>
</tr>
<tr>
<td>13 Radio</td>
<td>Dummy for ownership of a radio set (1 if household owns radio set and 0 otherwise)</td>
<td>0.96</td>
<td>0.20</td>
<td>+</td>
</tr>
<tr>
<td>14 Non-farm</td>
<td>Non-agricultural income (in NPR 1000)</td>
<td>79.74</td>
<td>226.94</td>
<td>–</td>
</tr>
<tr>
<td>15 Price</td>
<td>Price of the hypothetical seed quoted by the farmers (NPR per kg)</td>
<td>59.69</td>
<td>28.08</td>
<td>–</td>
</tr>
</tbody>
</table>

Source: 2006 household survey, Nepal

Considering that access to suitable seed is a priority issue for in situ agrobiodiversity conservation (Cleveland et al, 1994; Cleveland and Soleri, 2002; Rhoades and Nazarea, 1999; Zimmerer, 2002), the willingness to pay for new type of seeds is analysed. Each sample household was asked to select three combi-
nations (X, Y, Z) of desirable traits they prefer in new rice varieties. The traits are considered as fully separable and combinable. The only exception is that the high-yielding and aromatic traits are inseparable for the farmers because the farmers who prefer high-yielding varieties also prefer aromatic ones. The correlation between these two traits is 0.95. The most popular traits selected by the farmers to be incorporated into a new variety are found to be high yield and aroma combined, high milling percentage, taste and a variety that can be sown late (Table 3.5).

To estimate farmers’ WTP for different traits, each respondent was asked to bid a maximum price for 1kg of rice seeds with different combinations (X, Y, Z) of desirable traits. Under the condition that the combinations they made are available in the market, the farmers on average are willing to pay NPR 60 ($0.80) per kg of such rice seed.

Farmers’ WTP for the hypothetical traits they combined was fitted with the desirable traits they selected, a geographical dummy for catching fixed effects, the age and gender of the respondents, family size, the number of the plots the farmer is operating for rice cultivation, radio set ownership, non-farm income and farmers’ quoted price of seed.

The coefficients of different variables that explain farmers’ WTP for the rice seed are presented in Table 3.6. The farmers valued NPR 19 per kg extra for high-
yielding aromatic traits. The farmers were willing to pay NPR 6 more for tasty trait. One of the major cooking characteristics, the expansion in cooking, was also highly valued by the farmers. For the rice variety that leads to expansion in cooking, the farmers were ready to pay NPR 22 extra for 1kg of improved seed.

The farmers as producers also positively valued the traits that make the landrace suitable for less fertile land. For these seeds, the farmers were willing to pay nearly NPR 11 per kg extra. This reduces the fertilizer cost for the farmers and the environmental problems associated with fertilizer application. For disease-resistant traits, the farmers were willing to pay the most (NPR 22 extra per kg of seed). This reduces the loss of crop and costs of pesticides for the farmers on top of the ecological benefits to the society. In addition, it avoids human health problems due to the pesticide residue they consume with rice and health problems of animals that consume the straw. The result showed the importance of rice genetic resources that can be incorporated to other varieties for the development of new varieties with high-yielding and disease-resistant characteristics.

There were some biases on the part of the respondents, which have been captured. Older farm household heads bid slightly higher prices for the new seed than the younger farmers. Older farmers who knew the traditional food habits and culture could better understand the importance of the traits of landraces than younger farmers. Similarly, female farmers were ready to pay more than male farmers. This might be because the traditional dishes of rice are prepared mostly by women and they are in a better position to understand the values of the rice traits than their male counterparts. The women also have better understanding of their farm situations than men and can appreciate better the production traits of rice.

The farmers in the Terai (plain) areas were willing to pay less for the new varieties. This might be because they had better access to new varieties of rice in border towns of India. Similarly, the larger the number of plots the farmers had, the lower their WTP for the new varieties. This might be because the larger the number of plots they have, the more diverse their agro-ecology and thereby the better their chance to grow a larger number of varieties in their farm. Rana et al (2007) have found that on-farm landrace diversity is positively affected by the number of parcels of land that farmers manage. Unlike previous expectations, the farmers with radio sets (means higher access to the information and a higher living standard) were willing to pay less. This might need further study to disprove or explain it further. A similar result was found for farmers with higher non-farm income. For these farmers, the improved varieties were less important.

The farmers highly valued the production traits and cooking characteristics of rice varieties. Older people in hill areas with a smaller number of plots were willing to pay more for seeds of new varieties with multiple traits than farmers with the opposite features. The farmers, on average, were willing to pay 23 to 62 per cent higher prices for different traits of rice.

In Nepal, more than 1.5 million hectares of land are planted with rice every year (MOAC, 2006). Given that the recommended seed rate for rice is 30kg per ha, the total rice seed planted every year is about 46,500 tons. The farmers were
ready to pay NPR 19 per kg extra for seeds of high yielding aromatic traits combined. It means, in total, farmers value NPR 0.88 billion ($11.9m) for high-yielding aromatic traits. Similarly, the farmers on aggregate give a value of NPR 1.03 billion ($13.9m) for each trait of expansion in cooking and disease resistance.

The Green Revolution in Nepal is still considered as a cause for concern through the displacement of landraces by high-yielding and fertilizer-responsive modern varieties. As the market supplies high-yielding modern varieties of rice, the profit-maximizing and risk-taking farmers generally replace the more diverse landraces by more uniform modern varieties. Consequently, a few genetically uniform high-yielding varieties have replaced genetically variable crop landraces over the longer term.

About 53 per cent of the farm households in Nepal continue to grow both modern varieties and landraces side by side. Their demand for both types is clearly shaped by markets, land and soil heterogeneity, and the consumption preferences of their families (Joshi and Bauer, 2006). Other authors have emphasized the development approaches that can value, conserve, develop and market agro-biodiversity to alleviate the extreme poverty (Bardsley and Thomas, 2005).

To conclude, commercialization of the valuable consumption traits (like aroma, taste and expansion in cooking) and production traits (like yield and pest resistance) can increase the importance of the landraces among the farmers. This approach can help conservation of rice diversity in the farmers’ fields.

Conclusions and implications for policy

Understanding the values that users (producers and consumers) put on the specific traits of rice landraces grown by smallholder farmers will be helpful to the design of market-based conservation strategies. With this motivation, this case study has focused on the valuation of genetic diversity of rice landraces in Nepal. The valuation is required not only for developing mechanisms for the equitable sharing of benefits from its utilization but also for the justification of added investment for conservation and bio-prospecting. The study uses both revealed and stated preference methods. Hedonic pricing method was used to find the value given by the consumers for each trait and contingent valuation method was used to value new variety seeds with a combination of traits that they consider useful.

The hedonic analysis apportioned the price paid by the consumers to the value they give to different traits. The study concludes that protecting each of the preferred traits increases their value to society. For instance, the value of the aromatic trait of Basmati or other local landraces can be about one-fourth of the value of rice produced globally.

For Nepal alone, the aromatic traits of rice have values of about NPR 11 billion ($148.6m) and tasty traits over NPR 2 billion ($27m) per annum. These estimates include only the use values of rice that arise from the actual use consisting of the direct use value from consumption by the households and option values generated by an individual’s WTP to protect rice production against any future
risks. The value given by the farmers to use seeds of aromatic landraces was derived from the value given by the consumers. Other use values (like the ecosystem functions of paddy field) and non-use values are also important elements but are not captured here. For all these reasons, the estimates were indications of the lower bounds. As the estimates showed, the values of different unique traits of rice landraces were assumed to be larger than the costs of conservation. The conservation costs will become even more justified and appealing when the total economic values are accounted by including their non-excludable and non-rival use (like ecosystem functions) and non-use values.

As expected, consumers valued more consumption traits (such as aroma and taste) that can maximize their utility. In contrast, farmers as producers valued more production traits (such as high yield and disease resistance) that increase their income.

Market-driven methods of conservation are effective and efficient as they are based on incentives and opportunity costs. Efforts are needed to establish new markets for the conservation of landraces with unique traits. Commercialization of the valuable consumption and production traits can make landraces more attractive for local farmers. This will decrease the income gap between the modern rice varieties and landraces, decreasing the rate of replacement of landraces by the modern varieties. Market-driven methods of conservation are plausible to all actors involved as they are implemented based on incentives and opportunity costs. For both moral and equity reasons, it is essential either to compensate local poor farmers for maintaining low-productive rice landraces or to enhance the comparative advantages of these landraces so that farmers can earn better incomes. From a moral perspective, the poor cannot afford to bear the opportunity costs of agro-biodiversity conservation on behalf of society.9

Notes

1 The landraces include the farmers’ traditional varieties produced and maintained by them for many generations, and even high-yielding varieties that have been bred and released for more than 15 years have since become incorporated into farmers’ own seed production systems (Almekinders and Louwaars, 1999; Cleveland and Soleri, 2002).
2 There are other strategies to protect biodiversity, including in situ conservation through protected area conservation, and ex situ conservation through zoos, aquaria, botanical gardens, seed banks and gene banks.
3 The concept of TEV states that an environmental good or resource consists of two broad categories of values: use and non-use values (Bateman et al, 2002). Use values are further classified into direct and indirect use values while non-use values consist of existence and bequest values.
4 The key informants include a senior district agricultural development officer, a senior agronomist in the district, a senior extension officer, researchers working on local landraces at the National Agriculture Research Council (NARC), farmers knowledgeable about local agro-biodiversity, and community leaders.
5 Exchange rate May 2010: 1 US$ = 74 NPR.
6 Bitten rice is flattened, dry rice used for snacks.
7 Latte and siroula are local snacks popular on particular occasions.
8 Non-farm income was considered since it affects rice income.
9 The authors duly acknowledge comments and suggestions from anonymous reviewers.

References


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