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Ecological Economics 57 (2006) 30–44

ECOLOGICAL ECONOMICS

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ANALYSIS

Local identification and valuation of ecosystem goods and services from Opuntia scrublands of Ayacucho, Peru

Luis C. Rodríguez[a], Unai Pascual[b,*], Hermann M. Niemeyer[c]

[a]*International Livestock Research Institute. P.O. Box 30709. Nairobi, Kenya*
[b]*Department of Land Economy, University of Cambridge, 19 Silver Street, Cambridge, CB3 9EP, UK*
[c]*Departamento de Ciencias Ecológicas, Facultad de Ciencias. Universidad de Chile, Casilla 653, Santiago, Chile*

Received 8 October 2004; received in revised form 24 February 2005; accepted 21 March 2005
Available online 13 June 2005

Abstract

Opuntia scrublands are important ecological–economic systems in the Andean area. They perform a major role protecting slopes against erosion, improving the soil properties and providing a variety of products employed in the human diet, and in animal feeding, as well as cochineal insects, a highly valued source of dyes. The collection of the insects has represented an important economic activity for the local communities since pre-Columbian times. Current Peruvian production represents between 85% and 90% of the global market, and is mainly based on collection of the insect in natural Opuntia scrublands located in the poorest Andean areas of Ayacucho. Although much is known about the financial benefits of cochineal for exporters and dye manufacturers, information about the value of standing Opuntia scrubs to collectors and the relative contribution of Opuntia scrubs to their household economies is scarce. Here we contribute to the estimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the cultural domain of Opuntia in order to identify the ecosystem goods and services recognized by peasants, and later presenting empirical estimates of their importance to annual household income.
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Keywords: Cochineal; Peru; Ecosystem services; Cultural domain; Valuation

1. Introduction

Ecosystem services is a concept that has gained much attention in diverse scientific circles in recent years, emphasizing their importance for human societies. Nevertheless, some of the ecosystem services could be very difficult to be understood and recognized by the widespread public due to the abstract nature of some of them, impossibility to be perceived with the senses, or the need of empirical knowledge or theoretical learning (Lewan and Söderqvuist, 2002). Most ecosystem valuation research is too focused on the question of 'what is the value' and not enough on what, in particular, people value (Swallow et al.,

* Corresponding author.
E-mail addresses: l.c.rodriguez@cgiar.org (L.C. Rodríguez), up211@cam.ac.uk (U. Pascual).

0921-8009/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2005.03.022

1998). The latter requires to find out how people actually use or recognize the current and future benefits provided by nature. One such example, that has received little attention, is provided by the Opuntia scrublands, one of the most important Andean socio-ecosystems in terms of the social and ecological functions that they provide.

Opuntia scrublands perform a major environmental role protecting slopes against erosion and flooding, as well as rehabilitating marginal lands by improving the levels of humidity and soil retention capabilities. Opuntia scrubs are also used for animal grazing all year round and can become an emergency feedstock in case of drought. In addition, its fruits and young cladodes have a considerable nutritional value and provide food for Andean peasants. In fact, the fruit can be eaten fresh or used for the preparation of syrup, as well as fermented and non-fermented beverages. Opuntia plants have a broad range of other uses, from living fences for protecting crops to organic material for composting and building material for adobe making. The plant mucilage flocculates turbid water and is a good adherent for wall painting, while the wood is used to some extent in the manufacture of ornamental and rustic work such as picture frames or lamps (Le Houérou, 1996).

Opuntia scrubs are especially important because they are host for cochineal insects. These insects are the source of carminic acid, a natural dye used in the food, textile, and pharmaceutical industries. The collection of the insect has represented an important economic activity for local communities in the Andean area and Mesoamerica since pre-Columbian times. Current Peruvian production represents between 85% and 90% of the global market, and is mainly based on recollection of the insect in natural Opuntia scrublands located in the Andean area of Ayacucho (Flores-Flores and Tekelemburg, 1995). Due to the favorable environment for both the insect and its host plant, cochineal collection in Peru has a considerable social and economic importance, representing a source of income for some 100,000 peasant households. These families inhabit poor communities exposed to social vulnerability, disruption of livelihoods and loss of security as a consequence of 12 years of violence derived from the actions of groups such as Shining Path, and armed peasant patrols and of the Peruvian army (Fumerton, 2001).

Although we know much about the financial benefits of cochineal exports and dye manufactures (PRA, 2002), we know much less about the economic value of standing Opuntia scrubs to local user and the relative contribution of the Opuntia scrubs to household consumption and household income. Additionally an appraisal of the relationships between the Opuntia scrubland and other economic and social systems in the area is still lacking. Without these assessments, it is not possible to evaluate alternative land use options or determine whether there are sufficient benefits from Opuntia scrubs to provide the incentives for local communities to participate in their protection and sustainable management.

Here we contribute to the estimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the 'cultural domain' of Opuntia in order to identify the ecosystem goods and services recognized by the communities themselves. Then, the local perception of the internal relationships among the goods and services provided by the scrubland is estimated, as well as the relationships between this socio-ecosystem and other social and economic systems existent in the region. This allows us to present empirical estimates of the importance of the goods and services provided by the Opuntia scrubland in relation to household income, valuing some of them as well as others not elicited in the cultural domain, but effectively used by the local communities.

The remainder of the paper is organized as follows. In the next section a background to the case study area is offered. Section 3 describes the cultural domain analysis. Then Section 4 describes the method used to derive the different components of the use value and offers an estimate of the aggregate use value of the scrubland. Lastly, the paper offers a discussion of the main results.

2. Background

The Huamanga province was selected for the study because it is one of the most important areas of cochineal collection in Ayacucho. Six villages sharing similar agro-ecological and socio-economic conditions were included in the study. These villages are located in an area ca. 2500 m of altitude with mean

monthly temperatures ranging from 11 to 24 °C and yearly average rainfall of 754 mm distributed from October to March. The vegetation cover consists of a variety of grasses of the genera *Bouteloua*, *Heteropogon*, *Pappophorum* and *Aristida*. Isolated specimens of *Schinus molle* (Anacardiaceae), *Caesalpina tinctoria* (Caesalpinaceae), *Agave americana* (Agaveaceae) and cacti of the genera *Cleistocereus* and *Azureocereus* contrast with the abundance of Opuntias, which are predominant as the slope increases and reach stand densities over 2000 plants/ha (Piña-Lujan, 1981).

As regards socioeconomic characteristics, similarly to other communities all along the Andes, nuclear households are predominant, with about five members living at home and often more than one member migrating outside the community. Quechua is the native language of the inhabitants of the villages. Although most of them are fluent in Spanish, all conversations among themselves occur in their mother language. Farmers in the Andes do not constitute a homogenous social group. Processes of internal differentiation occur within villages as a consequence of uneven distribution of local resources and on different articulations within the larger economy (Bianco and Sachs, 1998).

The rural economy is highly diversified although agriculture is the main activity. While land is communally owned and communally farmed in an obligatory basis, individual household plots abound for production purposes using family labor and reciprocity relationships in the communal network. Household land plots are fragmented and holdings undergo constant division because of demographic pressure and inheritance practices. Hence, land tenure follows a process of accumulation and release along the individual life cycle, a pattern shared with most communities in Ayacucho (Ossio, 1992). Because of shortage of pastureland there is a limited opportunity to raise cattle. In fact, ownership of livestock is suggested as one of the principal basis of differentiation among families in the Andean communities (Montoya, 1982). However, this is not necessarily correlated with land tenure due to the use of crop byproducts as corn stalks for animal husbandry as well as weeds and vegetation growing in Opuntia scrublands (Gade, 1999). These animals are rarely consumed; instead they are kept as capital asset that can be liquidized when the need arises.

In an ecological context characterized by limited space available for agriculture, steep slopes, marginal soil fertility, and seasonal weather, Andean people have developed a rather complex farming system to meet their subsistence needs. Andean peasant communities usually practice an agro-pastoralism that takes advantage of environmental diversity in order to minimize risk. That behavior is reflected in the existence of a great variety of crops for subsistence, and a cash crop or cattle raising for the market. The Andean idiosyncrasy is also evident in community levels of social capital, long-standing patterns of mobility, reciprocity of obligation, and duality of spatial organization (Rodríguez and Pascual, 2004). Land uses typically overlap. Cochineal is harvested in Ayacucho from Opuntia scrublands, locally known as tunales, thus making productive use of communal lands and supplementing peasants' livelihood (Gade, 1999).

3. Local identification and valuation of ecosystem goods and services

3.1. The general framework

For tractability, the economic valuation of the Opuntia scrublands requires to translate the ecological complexity of structures and processes into a short number of ecosystem functions, which in turn provide environmental goods and services. The types of ecosystem functions resulting from natural processes of the Opuntia scrubland can be characterized, following De Groot et al. (2002), as: (i) production function, (ii) habitat function, (iii) regulation function, and (iv) information function. An overview of the functions relevant to Opuntia scrublands grouped in the four mentioned categories, as well as the ecological structure and processes occurring in that system and some of the goods and services provided is presented in Table 1.

Semi-structured surveys were used in the field to gather information from 113 households in 2002. This information was both qualitative and quantitative. The selection of the surveyed households responded to simple random sampling requirements under a voluntary participation scheme. Among the quantitative information, data were obtained about the frequency

Table 1
Functions, goods and services of Opuntia scrublands*

Functions	Ecosystem processes and components involved	Goods and services/references
Production functions	*Provision of natural resources*	
Food	Conversion of solar energy into edible plants and animals	Fruit and young cladodes for human consumption (Pimienta-Barrios, 1994). Fodder for cattle (Guevara et al., 1996). Traditional fermented and non-fermented beverages, syrups, and conserves (Vigueras and Portillo, 2001).
Raw materials	Conversion of solar energy into biomass diverse uses	Fuelwood source (Pardo, 2002). Cladodes employed for biogas obtention (Contreras and Toha, 1984). Cladodes used for obtaining organic fertilizer by composting process (García de Cortázar et al., 2001). Building material (adobe making) (Pardo, 2002).
Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for handicraft, lamps decoration (Yasseen et al., 1996). Fruits are used as dye sources (Vigueras and Portillo, 2001). Opuntia mucilage is used as base for traditional paint mixed with colored powders (Pardo, 2002).
Habitat functions	*Providing habitat (suitable living space) for wild plant and animal species*	
Refugium function	Opuntia scrublands cladodes provide breeding and nursery areas to cochineal insects that later are collected for commercial purposes	Maintenance of cochineal stock. Avoids the cost of manual infestation of Opuntia plants (Flores-Flores and Tekelemburg, 1995).
Regulation functions	*Maintenance of essential ecological processes and life support systems*	
Disturbance prevention	Opuntia scrubland biomass prevents drastic famine events	Prevention of drought effects (Nefzoui and Salem, 2001).
Water regulation	The vegetation cover provided by Opuntia scrubland regulates runoff	Runoff regulation (Le Houérou, 1996).
Water supply	Opuntia increases the capability of soils to retain and store water	Increase rain use efficiency (Le Houérou, 1996).
Soil retention	Role of vegetation root matrix and soil biota in soil retention	Land rehabilitation, prevention of damage from erosion (Le Houérou, 1996).
Nutrient regulation	Opuntia scrubland increases the organic matter (40%) and nitrogen content (200%) of the soils compared with open field	Maintenance of soil fertility (Monjauze and Le Houérou, 1965).
Information functions	*Providing opportunities for cognitive development*	
Cultural and artistic information	Variety of natural features with cultural and artistic value	Many lyrics of Pumpin music, a traditional genre in Ayacucho are inspired by the Opuntia. Lyrics represent advices, rules and norms for the sustainable use of the goods and services provided by Opuntia scrublands (fieldwork in 2002 Ayacucho).

*Adapted from De Groot et al. (2002).

and quantity of different goods collected from the scrubland on an annual basis as well as the labor input used in collecting these goods. In addition, with the aim to explore the participation of Opuntia scrublands in the structure of households' income, information concerning agricultural outputs, cattle raising, remittances, and other productive activities was also collected.

Because not all ecological services provided by Nature are known or are sometimes ignored by external agencies, in many instances they are not properly assessed when analyzing local users' land conservation incentives. For this reason, we initially explored the cultural domain of the goods and services provided by the Opuntia scrublands. A total of 26 voluntary stakeholders were involved in this investigation. In

contrast with standard valuation, which represents choices or preferences, the cultural domain represents perceptions, and provides a complementary point of view to the understanding of internal relationships among the goods and services and between the ecosystem and the social systems.

3.2. Local identification of goods and services provided by Opuntia scrubland

In spite of the anthropocentric importance of ecosystem services with regard to social well-being, not enough is known about their recognition and identification by local users themselves (Kaplowitz, 2000; Lewan and Söderqvuist, 2002). Social sciences have a set of qualitative methods, which constitute comprehensive tools for that assessment. Cultural Domain (Weller and Romney, 1988) is an organized collection of items that in some sense go together or refers to the same concept, in this case the ecosystem goods and services provided by the Opuntia scrublands.

Cultural domain analysis provides a set of techniques to investigate knowledge structure. Following Borgatti (1998) the freelisting and triad techniques were applied to elicit the elements of the cultural domain and the attributes that local households use to distinguish among the items. Through semi-structured interviews, a list of uses and benefits provided by Opuntia scrubland were identified (Table 2). Then, in order to elicit from the respondents judgements of similarity among these items in the cultural domain, 30 triads were created. This was done by employing a balanced incomplete block design with lambda 2, using the ten most frequent elements obtained in the freelist, i.e., the core of the domain. The triad results were transformed into a similarity matrix and submitted to multidimensional scaling, MDS and cluster analysis (Fig. 1) in order to generate a two-dimensional representation of the relationships between the core elements of the cultural domain of the Opuntia.

3.3. Valuation of ecosystem goods and services provided by Opuntia scrubland

As explained above, the ecological goods and services provided by Opuntia scrublands are very diverse in the structures and functions involved in their supply, in their level of integration to diverse markets, and with regard to their contribution to peasant well-being. Some goods and services supplied by the Opuntia scrublands are not considered in the cultural domain since they provide global benefits which the local population is not aware of, i.e., gas regulation by CO_2 sequestration. Other goods and services effectively included in the cultural domain represent the outcome of extension activities rather than local use, i.e., young cladodes for cooking. While on the other hand, there are some goods and services used by the local communities which were not elicited in the cultural domain of Opuntia due to its abstract nature or incapability to be dissociated from natural cycles, i.e. the refugium service. Since we aim to assess the use value of Opuntia scrublands, this study covers the ecosystem goods and services effectively used by local population in Ayacucho, elicited in the cultural domain appraisal or identified in the fieldwork.

Table 2
Elements of the cultural domain of Opuntia scrublands

Elements of the cultural domain of Opuntia	Frequency (*n* of households)	% (of total)
Cochineal	126	100
Fruit	126	100
Cattle	126	100
Fences[a]	104	82.5
Food[b]	45	35.7
Chicha[c]	44	34.9
Fertilizer[d]	39	30.9
Marmalade	24	19.0
Salad[e]	16	12.6
Soil[f]	14	11.1
Wine[c]	13	10.3
Land[f]	8	6.34
Adobe	4	3.17
Erosion	2	1.58
Paint	1	0.79
Fumigate[g]	1	0.79

[a] The term refers to living fences made with Opuntia plants.
[b] This generic term refers to cocked meals.
[c] Chicha and wine are fermented beverages obtained from Opuntia fruits; they differ in preparation and alcoholic content.
[d] Opuntia cladodes are a source of biomass for composting. Although this element was elicited, it does not correspond to a common practice.
[e] Young Opuntia cladodes are chopped and used as vegetables.
[f] When these terms were elicited they referred to the effect of Opuntia over them.
[g] The plant mucilage is employed as adherent for fumigation.

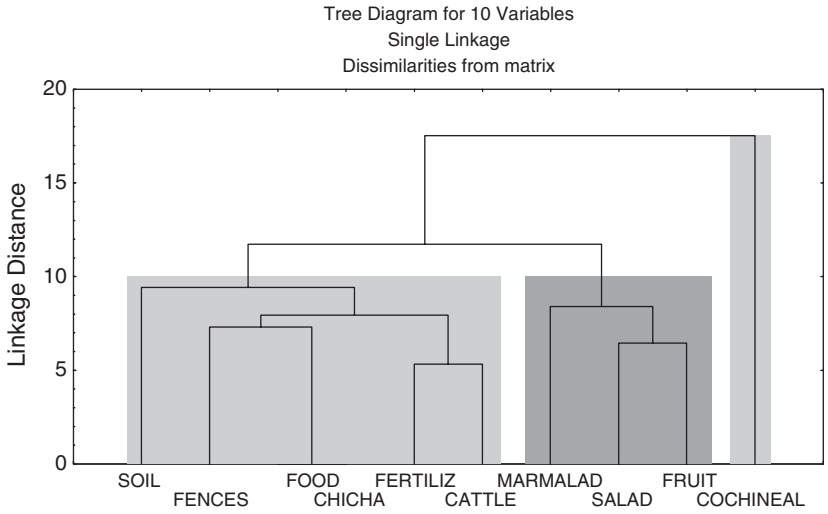

Fig. 1. Cluster analysis of the elements of the cultural domain.

Firstly the direct use value of Opuntias in terms of their production of food, fruit, cochineal, fodder, fuel and ornamental goods is estimated using direct market prices and when required, the value of the closest substitute goods. Then, an attempt is made to assess the habitat function value through its nursery and refugium services, based on an avoided cost approach, and lastly an estimate of the indirect use value regarding the regulation function of the on-farm erosion control service is provided through contingent valuation. Due to limited data and the complexity of natural systems, we are able to estimate only partially the value of some key goods and services (see Boumans, 2002).

3.4. Value of production function

Peasants are regularly visited by traders involved in the commerce of cochineal. These traders buy cochineal and develop arrangements for future transactions in order to accumulate cochineal stocks and dispatch them to more wealthy traders who later transport and sell the larger amount of insects demanded by export companies. The supply of fruit largely exceeds the local demand of the product and since its quality does not always fit well the requirements of markets, most fruit is not harvested.

After quantifying the yearly harvest of scrubland products, such as cochineal and fruit, and controlling for product quality (i.e., first or second quality fruit, dry or fresh cochineal) and the area used in the collection, market prices were used to derive the use value of the products collected in a given year. These prices were obtained from a representative selection of stakeholders and traders in order to be employed in the valuation approach.

Peasants usually buy young cattle and sell it after a year of stocking. Although Opuntia plants can be used as fodder by harvesting cladodes and including them in the diet, plants are more often directly browsed by livestock. The share of Opuntia browsed by cattle depends on herd size and season (Guevara et al., 1996). To properly evaluate cattle diet composition through the year, field observations and reports from peasants have been used. The value of Opuntia scrublands as provider of feedstock is calculated by multiplying the yearly livestock profits by the percentage of Opuntias (30%) of the total feedstock intake used in the diet of the cattle. This conservative percentage is concordant with empirical studies of browse consumption for low stocking rates in other Andean areas (Guevara et al., 1996).

Wood is the main energetic resource used by peasants for cooking, often collected by elderly people and children. The vegetation removed as a result of Opuntia scrubland habilitation is usually employed for firewood and normally collected by the head of the household. Besides family labor there is a market for hired labor under a salaried basis (Cotlear, 1989). The value of

Opuntia scrublands and the associated vegetation as sources of fuel was thus quantified considering the wage rate as a broad approximation of the opportunity cost of time employed by households in periodic labors such as taking out grasses and fallen branches after habilitating the scrublands that generate supply of fuel.

Columnar cacti are occasionally collected and sold to artisans for the confection of handicrafts. The value of the vegetation as a source of ornamental resources is calculated based on the market value of the raw material and the area searched for specific items. This approach tends to overvalue the benefits of the activity because there is no guarantee that the demand for the collected cacti will match the supply at any given year, implying that not all the scrubland area is valued for this service. Assuming that the total demand for ornamental resources is supplied, a conservative assessment can be estimated (Table 3).

3.5. Value of habitat function

Cochineal is a sessile parasitic insect living on Opuntia plants. First instar nymphs are the only mobile life stage. These nymphs crawl and disperse along the host plant searching for a place to settle or are transported by the wind to other potential hosts, thus colonizing distant areas. Once settled, nymphs become sessile and develop to adult insects. Due to their lack of mobility, cochineals are easily collected by peasants using soft brushes or spoons to withdraw them from their host plants. In most cases, only the less accessible insects or plants are left untouched. These cochineals, settled in so-called refugium areas, later re-colonize the scrubland. The value of the service of nursery and refugium is quantified based on the costs avoided by peasants if the host plants should be infested by hand, a common practice in commercial cochineal exploitations where adult female cochineals are artificially attached to uninfested plants in order to create new colonies and increase the density of the already existent colonies (Table 3).

3.6. Value of regulation function

The regulation function of Opuntia scrubland can have an important indirect use value for local communities, especially the one corresponding to erosion control, which has been explored further as it appears important in the Andean context. Erosion remains a major problem in the Peruvian Andes. Over 80% of the land is eroded, and much of the erosion is typified as laminar and consequently is not evidenced immediately (Alfaro and Cárdenas, 1988).

Table 3
Economic values of ecosystem goods and services of production and habitat functions provided by Opuntia scrubland in Ayacucho

Collected product from Opuntia scrubland		Annual average market value/ha (NS)[a]
Production Function		
Cochineal production		
Harvested cochineal (kg/ha)	65.73 (41.67)	690.20
Price of cochineal (NS/kg)	10.5	
Fruit production		
High quality fruit (boxes/ha)	34.82 (36.79)	322.06
High quality fruit price (NS/box)	7	
Lower quality fruit (boxes/ha)	17.40 (16.3)	
Lower quality fruit price (NS/box)	4.5	
Fodder production		
Total cattle profits (NS)	537.30 (648.95) × 0.3	235.58
Fuel production		
Area of habilitated scrubland per household (ha)	0.97 (0.71)	188.97
Labor (days employed collecting fuel/ha)	18.89 (9.05)	
Daily wage rate (NS)	10	
Ornamental production		
Average income from handicraft sale[b] (NS)	50.62	39.71
Area used for collection of raw material for craft making (ha)	1.38 (0.46)	
Total Production Function		1476.52
Habitat Function		
Infestation		
Labor (days employed in infestation/ha)[c]	52.95 (46.13)	529.95
Daily wage rate (NS)	10	
Total Habitat Function (3 infestations per year)		1589.85

[a] NS: Nuevos Soles.
[b] This corresponds to eight households that reported some handicraft activity.
[c] This corresponds to 13 households that reported having infested Opuntia scrublands.

Opuntia scrublands are not interspersed among the crops. Any approach to measure the service of erosion control based on the change in fruit production and cochineal collection will be biased due to the extraordinary resistance to soil degradation by the plant. As any change in productivity will be evident only after many years of severe soil loss differences in the perception of erosion and its impacts can be observed in diverse community sectors (Korshing et al., 2001). Peasants' interest in soil erosion is primarily concerned with on-farm impacts such as increased production costs, decreased profitability owing to soil fertility decline, and financial costs of implementing needed soil conservation measures. Cochineal collectors are in close contact to the markets, even in remote communities in Ayacucho. This high level of integration to the markets, lead us to explore the possibility of developing a Contingent Valuation study with the aim to get a broad monetary idea of the households' willingness to pay (WTP) for the service of soil erosion control provided by the Opuntia scrubland.

A conservative single-bounded dichotomous choice WTP elicitation format is adopted based on Hanne-mann's (1984) Random Utility Maximization (RUM) model.[1] Focal group meetings were developed to define five bid options: 0.5, 0.75, 1, 1.5, and 2 nuevos soles (NS) per month/ha, equally divided amongst respondents. We tried to adapt the study to the local conditions and idiosyncrasy of the respondents so the payment vehicle selected was a contribution to communal funds, particularly in view of the lack of other realistic means of payment such as taxes or services bills, and because communal institutions have experience in collecting and managing funds.

Since households' potential WTP for lower soil erosion is expected to be small relative to their available income, it is not likely that the marginal utility of income varies with the income of a given respondent. One practical way to incorporate the effect of income, and at the same time allow the marginal utility of income to vary across households is to use income categories and to let the coefficients vary according to income category (Haab and McConnell, 2002).

The approach considers a linear model for the indirect utility (V_j) of household j in scenario i: $V_{ij}=\alpha_i \boldsymbol{z}_j+\beta_i y_j+\varepsilon_{ij}$, where, y_j is household j's discretionary income, $\boldsymbol{z}_j$ is the vector of variables related to household j; $\boldsymbol{\alpha}_i$ is a vector of parameters and ε_{ij} is the unobservable error term. Letting the marginal utility of income vary across individuals with different income levels such that $\beta=\delta \boldsymbol{w}_j$, where $\boldsymbol{w}_j=\{1, \boldsymbol{w}_{1j},\ldots \boldsymbol{w}_{Kj}\}$ is a vector of individual specific covariates associated to the parameter bid vector $\boldsymbol{t}$. In our case, $\boldsymbol{w}_j$ represents a vector of variables indicating if income belongs to a specific income stratum. Hence, income y_j is classified as a categorical variable such that a household in each stratum has a different marginal utility of income. We define $\boldsymbol{w}_{ij}=1$ if $y_j<c$; 0 otherwise, and $\boldsymbol{w}_{2j}=1$ if $y_j>c$; 0 otherwise, where the threshold c represents the subjective extreme poverty line in the case study area.[2] Hence, the sample is divided into two subsamples according whether the household is above or below the poverty line. Following Park et al. (1991), under a RUM framework the indirect utility function for each respondent can be expressed as a random variable and the utility model becomes $u_{ij}=\boldsymbol{\alpha}_i \boldsymbol{z}_j+\delta_1 \boldsymbol{w}_{1j} y_j+\delta_2 \boldsymbol{w}_{2j} y_j+\varepsilon_{ij}$.

The variables in vector $\boldsymbol{z}$ are presented in Table 4 and include several socio-demographic household characteristics such as dependency relationships (labor force / family size ratio, and presence or absence of dependents within the household) as well as gender and age of the head of the household. The former are proxies for household labor capacity, while the age of the head of the household is included due to its relation with physical capital level and land tenure. A set of education related variables as proxies for human capital, are also considered in $\boldsymbol{z}$. These included years of formal education and literacy since it is not uncommon that in spite of school attendance many persons are functional illiterates; the number of elicited elements of the Opuntia cultural domain as a proxy for traditional knowledge of the system is also included. Finally, since the perceptions of community problems and actions toward their solution are mainly determined by peasant embeddedness and the per-

[1] It has been suggested recently that the single- and double-bound CVM models yield similarly efficient point estimates when the sample size is large and when the former is informed by a pretest conducted on a small population (Calia and Strazzera, 2000).

[2] The subjective extreme poverty line is based on the perception of the minimum income level that the household considers necessary to live, and was estimated in 76.5 nuevos soles per month (Herrera, 2002).

Table 4
Definition and sample descriptive statistics of variables used in the CV analysis regarding the regulation functions provided by the Opuntia scrubland

Variable	Definition of variable	Mean	Standard deviation	Min	Max
DEPEN	Ratio members aged (15–60)/household size	0.66	0.23	0.25	1
HEADAGE	Age of the head of the household	40.57	11.57	22.00	72.00
SCHOOL	Number of years of formal education.	3.97	2.11	0.10	9.00
CULTDOM	Number of elicited elements of the Opuntia cultural domain	5.73	1.42	3.00	9.00
FARMINC	Income obtained from farming activities	82.76	11.75	41.01	94.80
Categorical variables					
W1.bid	The bid multiplicated by the poverty dummy (1 if the household is below the subjective poverty line; 0 otherwise).	0.77	0.69	0	2.00
W2.bid	The bid multiplicated by the poverty dummy (1 if the household is above the subjective poverty line; 0 otherwise).	0.33	0.58	0	2.00
Dummy variables					
LITERACY	Dummy variable: 1 if the head of household is able to read dependent; 0 otherwise	0.08	0.27	0	1
NODEPEN	Dummy variable: 1 if the household has no dependent; 0 otherwise	0.22	0.42	0	1
MIGRATION	Dummy variable: 1 if the head of the household is migrant; 0 otherwise	0.27	0.44	0	1
GENDER	Gender of the head of the household. 1 if male; 0 if female	0.86	0.35	0	1
EROSION	Perception of erosion: 1 if the head of household has perceived erosion; 0 otherwise.	0.35	0.48	0	1

Sample size: 113 households.

ceived benefits and costs of the problem and solution, variables such as migration experience, the share of farming income, and erosion perception are considered as covariates in the analysis.

The results of the binomial logit model to estimate the effects of the z and income variables on WTP are presented in Table 5.[3] Following Haab and McConnell (2002) the mean WTP is given by:[4] $E(WTP) = -\frac{\delta}{\beta}$, where β is the value of the coefficient of the cost variable in the estimated logit equation, and δ is the sum of all other terms in the equation evaluated at the mean values of the explanatory variables. The analysis reveals a mean monthly WTP of 1.33 NS/ha (15.96 NS/year). This is a relatively low value partly on account of households' low incomes and also because the identification of physical damage due to soil loss is complicated by spatial and temporal discontinuities. The low WTP could be interpreted as if peasant households have little incentive to control off-farm costs of soil erosion (Crosson, 1986). However, the estimated yearly WTP for the service of erosion control from the Opuntia scrublands correspond to approximately 3% of the value of cochineal collected. In spite of the differences in inputs and activities, this result is in the same order of magnitude of the environmental damages from agriculture in most regions of the United States (Smith, 1992).

The results indicate that the likelihood for peasants agreeing to pay the proposed amount decreases as the

[3] The Lagrange Multiplier test suggested that the error term is not normally distributed and therefore a binomial logit was used instead of a Probit model (Greene, 1993). The generalized likelihood ratio statistic, 91.99 distributed as Chi-squared with 12 degrees of freedom shows that the model explains the variability in the acceptance of bids satisfactorily.

[4] From a theoretical viewpoint, the mean WTP is often preferred over median WTP as a measure of welfare (Johansson et al., 1989).

Table 5
Parametric binary logit model of the determinants of the WTP for erosion control service by Opuntia scrubland

Variable	Coefficient	Marginal effect	*t*-ratio
Constant	−32.66	−7.19***	−3.44
Gender	−1.49	−0.33	−1.14
Depen	6.96	1.53**	2.40
Nodepen	−3.45	−0.76**	−2.16
Migration	2.94	0.65*	1.85
Headage	−0.03	−0.01	−0.48
Literacy	2.04	0.45	1.14
School	0.36	0.08	1.32
Erosion	2.35	0.52**	2.22
Cultdom	0.16	0.03	0.55
Farminc	0.38	0.08***	3.90
W1	−3.33	−0.73***	−3.90
W2	−3.81	−0.84***	−3.57
Log likelihood function	29.54		
Restricted log likelihood	75.54		

***Statistically significant at $P<0.01$; **Statistically significant at $P<0.05$; *Statistically significant at $P<0.10$.

bid increases. In addition, as expected, the likelihood of accepting the bid significantly increases if the household effectively perceives soil erosion or obtains a high proportion of income from farming. Additionally, households with no dependents are more likely to reject the proposed bid. Due to the cyclic phenomenon of land accumulation and release that characterize land tenure system dynamics in Ayacucho (Ossio, 1992), households without dependents mainly correspond to either young or mature couples, and in both cases these households possess smaller land extensions, their income levels are lower, and consequently the likelihood to accept the bid decreases.

The likelihood of accepting the bid increases significantly as the ratio labor force/household size increases. This could be explained because households with lower dependency ratios normally have a higher per capita income, allowing them to reallocate resources out of the family subsistence sphere towards investment in human or physical capital to enhance household production and reduce social vulnerability (Bianco and Sachs, 1998; Locke et al., 2000).

The effects of migration on the environment are largely undetermined and as Curran and Agardy (2002) and Noronha et al. (2002) argue, selective migration can change social relationships and the value of ecosystem services to the local population and consequently modifies ecosystem management. In this study, the coefficient related to migration experience exhibits a positive and statistically significant sign. This seems unexpected at first sight since it could be assumed that migrant peasants might be involved in a disembedding process from Nature, and consequently they might be less concerned about the level of damage to natural systems (Borgström and Wackernagel, 1999). However, in Ayacucho, temporal migration as well as the cyclic process of land tenure and the endogamy characteristic of the mechanisms of land accumulation and release do not facilitate the disembedding process. By contrast, this type of migration and the fact that in these communities, land is scarce may create incentives to promote investment in physical capital (Locke et al., 2000; Adger et al., 2002).

Labor shortage is considered the cause of the inadequate attention to agriculture and environmental deg-

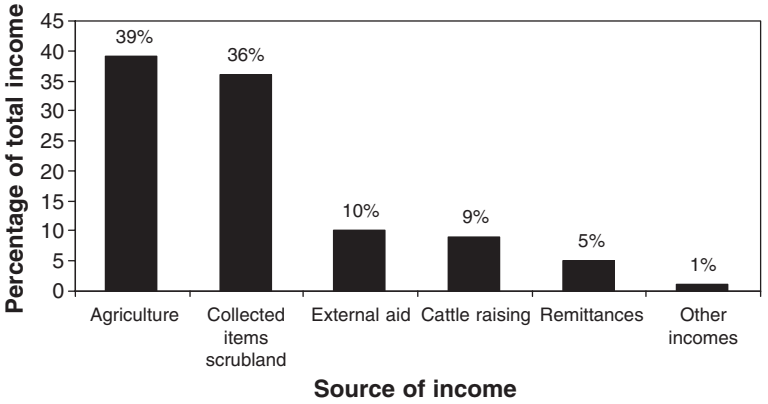

Fig. 2. Households' income share of collected items from scrubland.

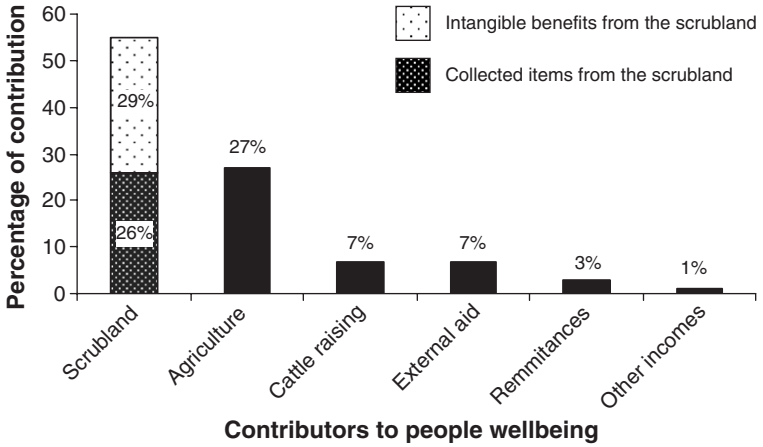

Fig. 3. Participation of goods and services provided by the Opuntia scrubland on peasants' well-being.

radation, as well as the negative effects on cultural and social organization in emigration areas (Zimmerer, 1993). However, in these communities, similarly to other places in the Peruvian Andes, migration processes only take place after the labor force is sold within the community; hence, the labor shortage reasoning for environmental degradation may be weak. The exposed arguments referred to the kind of migration, land scarcity and lack of labor shortage may explain the disposition of migrant peasants to accept the bid.

The analysis of fieldwork data shows that for the selected communities the income of collected items from the scrubland is as high as 36% (Fig. 2). When considering both the collected items and the valuated ecosystem services, the Opuntia scrubland accounts over 55% of peasants' income, and the value of the selected ecosystem services themselves is higher than the income obtained from agriculture (Fig. 3).

4. Discussion

4.1. Local identification of scrubland goods and services: the linkages with the agro-pastoral and other socio-economic systems

Regarding the identification of goods and services provided by Opuntia scrublands, the Cultural Domain appraisal provided us with a departure point to understand the local perception of the internal relationships among these goods and services, as well as the relationships between the scrubland and other social and economic systems.

The MDS and the complementary cluster analysis show two clusters conformed by i) marmalade, salad, fruit; ii) cattle, fences, fertilizer, soil, food and chicha; and an isolated element, cochineal. The first cluster shows the direct relationship between the fruit and its processed products such as marmalades and salads. The second one is related to croplands and subsistence, and includes elements such as fences, soil, fertilizer and cattle, as well as food and "chicha". The existence of an isolated element and the associations inside the second cluster may be explained on the basis of the recurrent Andean strategy of crop production mainly for subsistence, while simultaneously having another activity as source of cash such as cattle raising or in Ayacucho, cochineal collection (Gade, 1999). Thus, the second cluster includes a series of food security, where cattle manure and Opuntia compost supply organic fertilizer to the soils increasing crop production, while fences provide crop protection by reducing the loss of crops from animal grazing. Furthermore, livestock supplies animal force, which can be used in the family cropland or interchanged with human labor for certain tasks, thus maintaining the relations of cooperation and reciprocity in the community (Cotlear, 1989). These goods and services link the elements of the cultural domain of the Opuntia to the agro-pastoral system, to risk reduction and to coping strategies such as soil improvements and crop protection that are usually

concerned with maintaining the assets and the capacity of the household to generate future-income and avoid social vulnerability (Watts and Bohle, 1993). The Andean organization considers a set of different production cycles in the community in order to promote the intensive use of available labor force. Cochineal collection occurs as an isolated element very distant and unrelated to the other elements of the cultural domain, because the insect is not consumed and it is not part of the production cycle for food security. Cochineal is a source of cash and the key element in the socio-ecosystem because it permanently links the natural system represented by Opuntia scrubland to the economic system evidenced by markets. The simultaneous existence of both subsistence crops and a product for the market has been considered a cause of differences in the access to resources, of modifications in the labor relations, and finally of changes in the social organization of Andean communities (Golte, 1980). Following the notion of embeddedness (cf. McCay and Jentoft, 1998), from which the man's economy and any productive activity is enmeshed in social relationships, and the fact that the social and ecological systems are indeed connected (Berkes and Folke, 1998), this analysis adds social and community dimensions into the framework of the cultural domain of Opuntia in Ayacucho, and makes evident the linkage between the scrubland and both the agro-pastoral and the socio-economic systems involved in peasants' livelihood.

4.2. The set of ecosystem services that people value is a dynamic construct

Some of the elements of the cultural domain of Opuntia elicited by respondents, may represent a result of the extension activities of NGOs but do not necessarily imply application of the provided knowledge. For example, generic terms such as food and chicha, appeared in the domain, although peasants in Ayacucho do not regularly prepare meals with Opuntia, neither do they ferment fruit for drinking chicha. The appearance of these elements is no doubt an outcome of tasting sessions and exhibitions organized by NGOs to promote Opuntia and cochineal. On the other hand, other uses and benefits of Opuntia previously reported by peasants, such as diabetes control, veterinary treatments or flocculation of turbid waters were not elicited, and some reported uses exhibited a lower frequency than the expected, based on the certainty that they were recognized since pre-Columbian times, such as adobe making and paint manufacture (Pardo, 2002). These findings clearly show that 'what people value' referred to ecosystem services is a dynamic construct defined by the users, and has an internal structure susceptible to modifications, as are elements of a cultural domain. Nature is not a pre-given thing, which everyone experiences in a similar way; it is always experienced as a localized phenomenon, and considered under particular and local frames of references. Nature is experienced by senses and through the senses new ways of apprehending Nature and the natural have been socially organized (Franklin, 2002). In this regard, the level of embodiment between Nature and society is an important concept for the recognition of the goods and services provided by natural systems. Ecosystem services is not an environmental issue imposed upon societies; rather it is in some way socially constructed based on ecosystem processes and components which may affect human well-being. Similarly to other environment related issues (Irwing, 2001), the kind of evidence and expertise upon which people draw when seeking to interpret and understand Nature may explain the great differences in how social groups select which set of ecosystem services to be concerned about.

4.3. Valuation of scrubland ecosystem services and their contribution to household income

It is undeniable that social groups are more concerned about those goods and services, which have use value. Among them, the non-timber forest products (NTFPs) have come to play an important role in large-scale commercial income generation and employment in many parts of the developing world due to the increased market demand (Sinha and Bawa, 2002).

In monetary terms, Godoy et al. (1993) in a review of about two dozen studies of the value of non-timber forest goods suggest a median annual value of about US$50/ha. In a worldwide review of the value of food and raw material collected from rainforest, Costanza et al. (1997) found average annual values of US$32/ha and US$315/ha, respectively. Nevertheless, in a panel data study in Bolivia and Honduras, the value of the goods collected from the forest was under US$10/ha/

year (Godoy et al., 2002). This value is below the lower end of the previous estimates, but in the same order of magnitude of the findings of Soren (2001) and Kvist et al. (2001) who report values of about US$15/ha/year for the local extraction of non-timber forest products from the Peruvian Amazon, and certainly a small fraction of the US$5702–11265/ha/year obtained from commercial extraction of non-timber products in areas where high value palm is the dominant species (Muñiz-Miret et al., 1996).

On a comparative basis, the total value of the NTFP collected from the Opuntia scrubland considered in the study represents over US$400/ha/year that is certainly in the range of magnitude of other natural systems such as tropical rainforest. This result underlines the view that generally the attention paid to tropical forest systems such as Amazon lowlands has been disproportionately high compared to the Andes (Mares, 1992; Young, 1997).

The importance of NTFPs to local economies is more evident in their contribution to household income. Some studies suggest that their sustainable harvest could be higher than timber income or income from agriculture (e.g. Peters et al., 1989). Some rural communities obtain about 40–63% of their income from collection of NTFP and in some cases the collection of a single specific product could represent as much as 40% of their income (Runk, 1998). In Ayacucho, where some communities obtain about 10% of their income from external aid agencies, the items collected from Opuntia scrubland represent as much as 36% of their total income, very close to the 39% obtained from agriculture and in line with the report of Escobal (2001) for the non-farm income levels in rural Peru.

Even if only some of the intangible benefits are considered, the value of these ecosystem services provided by Opuntia scrubland is relatively higher than the computable direct financial revenues from agriculture. This points towards the need to conserve the flow of values provided by the Opuntia as is a fundamental asset for Andean peasants. This is even more relevant especially since market prices rarely reflect the positive externalities generated by this ecosystem, and since if only left to the realm of market forces, this may lead to short-term over-exploitation of the scrubland, hence reducing local users' welfare levels.

Acknowledgements

This work has received financial support from Fondo de Innovación Agraria (FIA) Chile, Millennium Science Initiative, and Presidential Chair in Science awarded to HMN. We are also indebted to Andreas Kontoleon for his useful comments on an earlier draft of this article. The paper also benefited greatly from fruitful discussions at the 2004 ISEE conference in Montreal.

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