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Practical Alternatives to Estimate Opportunity Costs of Forest Conservation

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Abstract
Numerous studies have shown the merits of targeting the costs of conservation besides environmental benefits and aligning payments for ecosystem services with incurred costs. However, cost-effective and precise estimation of site specific opportunity costs is a major challenge. In this paper we test two approaches to estimate opportunity costs of conservation: One approach derives opportunity costs from annual land rents, and the other models regresses opportunity costs on easily obtainable and difficult to manipulate spatial and socio-economic independent variables such as soil quality. None of these approaches appeared to estimate opportunity costs sufficiently well. But since this judgment is based on how well the estimates compare to the reference opportunity costs, which were computed from farm budgets, we also considered potential flaws in the reference data and tested their plausibility. The tests confirmed the plausibility of data. Based on the results presented in this paper none of the two cost estimation approaches can be recommended for practical application in conservation programs. Yet, further research is necessary to confirm these findings giving special attention to the techniques that are applied to deliver reference point data on opportunity costs.

1 Introduction
In the allocation of scarce conservation funds, numerous studies have shown the merits of targeting the costs of conservation besides environmental benefits and aligning payments for ecosystem services to actually incurred costs (e.g. Alix-Garcia et al. 2008, Ferraro 2003, Wünscher et al. 2008). However, cost-effective and precise estimation of site specific opportunity costs is a major challenge. Ferraro (2008) describes three approaches that can be used to determine payment levels near the opportunity cost of environmental service provision: (i) gather information on observable landowner attributes that are correlated with opportunity costs, (ii) screening contracts (self-selection mechanisms) and (iii) procurement auctions. In this paper, two approaches are examined that fall into group (i): First, opportunity costs (per-hectare-returns) are estimated with the use of annual land rents ('Rent' approach). Second, opportunity costs are modeled using easily observable and difficult to manipulate spatial and socio-economic independent variables ('Model' approach). Our reference opportunity costs were computed from farm budgets using input and output flows ('Flow' approach). With data obtained in personal face to face interviews the Flow approach is likely to be too costly for real world PES programs and it also bears the risk of strategic bias by the interviewee. Yet, the computations from the Flow approach are believed to be relatively accurate and therefore serve as a reference point for the Rent and Model approaches. Both the Rent and the Model approach could be less costly alternatives to the Flow approach. The extent to which they are also cost-effective depends largely on how precisely they can estimate opportunity costs.

The paper is structured as follows. Section 2 describes how the reference opportunity costs were obtained. Sections 3 and 4 describe the Rent and Model approach and their results, respectively. We test the plausibility of the data in section 5 and conclude in section 6.

2 Reference Opportunity Costs (Flow Approach)
The data for our analysis was obtained in a field survey with 178 randomly selected landholders on the Nicoya Peninsula in the Northwest of Costa Rica. Opportunity costs of forest conservation refer here to the difference in income between the most profitable land use and forest conservation. For the calculation of opportunity costs, 'pastureland' is focused as the most likely alternative to natural forest. Natural forest itself is assumed to produce no commercial income. This is because logging and timber sales from natural forests are prohibited by law, unless a management plan has been certified by Costa Rican authorities, which in recent years has almost never occurred. Illegal logging and timber transport are risky, and very few rule violations seem to occur in the study area. Data of this study's field survey also show that non-timber benefits are close to zero. Though prohibited, gradual land-use change through the elimination of forest undergrowth and smaller trees towards pasture with scattered shading trees is somewhat more frequently observed in the Nicoya Peninsula. Thus, the opportunity cost of maintaining forest is equal to the foregone optional net return from pastures.

Micro level net returns of pastureland were calculated by subtracting from the sum of incoming monetary flows (e.g. from sales of cattle, milk, cheese, hay or renting out farm land) the sum of outgoing monetary flows (e.g. through purchase of farm inputs such as fertilizer, seed, herbicide, machinery, petrol). This approach is here referred to as the 'Flow' approach. The Flow approach is likely to deliver slight overestimates of opportunity costs for several reasons. First, the cost of land conversion is not considered (which, since timber is not commercialized, is always positive). Second, an average farm-specific opportunity cost based on existing pastures is calculated, ignoring that forests are generally found on economically marginal areas with lower potential pasture productivity. Third, family labor is not deducted from opportunity costs assuming there is no readily available income alternative. Treatments (i) to (iii) increase per-hectare-return (and thus opportunity cost) estimates and therefore lead to a conservative and careful interpretation of results. The annual mean opportunity cost computed from the surveys is US$ 55.23 per hectare (Min -363.31, Max 624.56, SD 120.19).

3 Rent Approach

In the Rent approach, returns were approximated using annual land rents. Since land is not normally rented but owned by the farmers, hypothetical land rents had to be estimated. Land is only occasionally rented in order to balance seasonal shortages of feed supply. Rent is then paid per animal and month and was treated in this study merely as feed supplement. Annual rents were therefore derived from land sale market values which were in turn estimated applying a valuation tool ("Valoracion Comparativa") developed and provided by the Costa Rican Ministry of Finance (Ministerio de Hacienda). The Ministry of Finance applies this valuation technique to determine land taxes, the level of which is based on land value. The technique is based on a comparison of 'to be estimated land parcels' with 'reference land parcels' within 'homogenous zones'. Homogenous zones are areas within which land parcels with identical characteristics have identical market prices, while between homogenous zones land parcels with identical characteristics normally have differing market prices. The valuation tool is, after all, a linear land value regression model. The ministry obtains market prices for the reference land parcels from field observations. The most reliable type of observation is actual market transactions. The data base is complemented with observations of land sale offers and land value estimates by the National Insurance Institute (Instituto Nacional de Seguros), the Central Bank (Banco Nacional) and other governmental institutions. Depending on the type of observation, adjustments are made to the observed land value. Sale offers, for example, are multiplied with a factor smaller than one to adjust to the expected difference between offered price and actual selling price.

For this study, the ministry kindly provided the required prices for the 'reference land parcels' and the geographically referenced extension of associated 'homogenous zones'. The 178 land properties of the survey sample fell into a total of 24 homogenous zones. Differences in land characteristics increase or decrease the land value. The following land characteristics were solicited during the survey and then fed into the model:

a) Size of the property in hectares.
b) Length of the part of the property that runs along a public road in meters.
c) Average slope in percentages.
d) Availability of public services (electricity, telephone, canalization and street lighting) applying dummies.
e) Type and quality of road which gives access to property in 11 categories.
f) A measure of soil use capacity as a classification of land by its agricultural and forestry potential from one (worst) to eight (best).
g) Categories (one to five) representing access and availability of water on property.

The obtained land market values needed to be adjusted for bias and inflation. According to employees of the Finance Ministry and other land value experts of the Center of Tropical Agricultural Research and Higher Education (CATIE) the "Valoracion Comparativa" consistently underestimates land values. With the help of these experts it was determined that the estimated land values had to be increased by 20% to compensate for the underestimation. Further, adjustments were necessary as the

latest determination of reference properties was made in 1997. This was acknowledged by multiplying each estimated land value with the inflation rates of the years 1998-2004. These were determined to be 11.7% (1998), 10.0% (1999), 11.0% (2000), 11.3% (2001), 9.2% (2002), 9.4% (2003) and 11.5% (2004) (IMF 2006). Eventually, the annual rental value was estimated using the capitalization formula:

[Land Rental Value] = [Land Market Value] x [Capitalization Rate] (1)

The terms are defined as follows: (i) Land Rental Value is the annual fee individuals pay for the exclusive right to use a land site. (ii) Capitalization Rate is a market determined rate of return that attracts individuals to invest in the use of land, considering all the risks and benefits which could be realized. (iii) Land Market Value is the price paid for the land when sold on the market (Gwartney 1999). While the land market value is estimated using the 'Valoración Comparativa', the capitalization rate has to be taken from literature. As no appropriate data could be found for the Peninsula Nicoya, figures for Minnesota, USA, are used instead. Capitalization rates in Minnesota reached a historic maximum of 8.3% in 1975 and a minimum of 5.0% in 1981 (Lazarus 2000). For the Peninsula Nicoya a conservative estimate of 5.0% is used. As we use an identical capitalization rate for all sites, its level will affect absolute but not relative land rental values between sites. The estimated land rental values could later be calibrated using field observations of rental rates. In case any of the assumptions were wrong, the calibration corrects (i) the adjustments that were made to compensate for consistent underestimation of the "Valoración Comparativa", (ii) the adjustments that were made to account for inflation, (iii) the estimated capitalization rate and (iv) the adjustments to obtain breakeven rents as explained below.

Land rental values show a long term correlation to more volatile breakeven rents which are defined as the amount of money that remains from the sale of products minus the cash operating costs, depreciation and the opportunity cost of operator labor and management, i.e. the amount which remains to pay the rent in a particular year (Lazarus 2000). For the land parcels in our sample the breakeven rent is equal to the estimated net returns (and thus the opportunity cost of forest conservation). The breakeven rent's long term average normally lies above the land rental value which means that our estimates for land rental values will have to be corrected upwards. Without calibration the adjustments (i) to (iv) only affect absolute but not relative land rental values between sites.

The Rent approach revealed mean values (US$109.26) that are substantially higher than those of the Flow approach (US$55.23) (Table 1). After identification and exclusion of extreme outliers within each approach[1], the mean opportunity costs of the Flow (50.49$) and Rent (96.60$) approaches came slightly closer. An analysis of variance (ANOVA[2]) shows the means of the Flow and Rent approaches to be significantly different with and without extreme values. While the Rent approach revealed strictly positive values, several negative values were obtained in the Flow approach.

Table 1 Per hectare returns (in US$) according to Flow and Rent approaches

Estimation Approach	N	Mean	S.D.	Var. (-1)	Min.	Max.	Range
Flow	178	55.23	123.47	15,243.81	-363.31	624.56	987.87
Flow (adjusted)*	176	50.49	109.88	12,074.09	-363.31	532.72	896.03
Rent	178	109.26	146.16	21,362.82	13.35	980.26	966.91
Rent (adjusted)*	175	96.60	109.60	12,011.98	13.35	562.92	549.57

*Adjusted refers to the values obtained after the exclusion of outliers

Even though the absolute mean per hectare returns differ between approaches, it is possible that the approaches deliver estimates that are correlated, i.e. land plots with relatively high value estimates in one approach also tend to have relatively high estimates in the other approach and vice versa. In case such correlation exists, a bias that causes consistently different estimates could be corrected. However, Table 2 presents the results of a correlation analysis and shows that the Flow and Rent approaches are

[1] Outliers were identified as such if their z-standardized value was larger than 4 or smaller than -4 (Hair et al. 1995).

[2] According to the three tests Tukey, Duncan and LSD Fisher.

not significantly correlated. By omitting outliers from the analysis (indicated with 'adjusted') the Pearson correlation coefficient only slightly improved while the Spearman correlation coefficient even worsened. Given these results, the Rent approach does not appear to be a potential estimation alternative (based on the assumption that the Flow approach delivers a relatively precise reference point). Yet, since the correctness of Flow approach estimates is not guaranteed no final judgment can be made over the Rent estimates.

Table 2 Correlation analyses of opportunity cost estimates between approaches

Variables	n	Pearson	Signif.	Spearman	Signif.
Flow/Rent	178	-0.04	0.56	-0.05	0.53
Flow/Rent (adjusted)*	173	-0.06	0.46	-0.03	0.68

*Adjusted refers to the values obtained after exclusion of outliers

4 The 'Model' Approach

In this approach per-hectare returns are regressed on independent variables that are easy to elicit and difficult to manipulate (Ferraro 2008, Tattenbach et al. 2006). A similar approach has been used by Moore et al. (2004) to estimate conservation costs in Africa. The variables were either taken directly from the field survey, were determined by overlaying the geographic position of sampled land properties with secondary digital maps e.g. for soil quality, soil type or slope, or were calculated from these variables if so indicated in Table 3 and Table 4.

Table 3 and Table 4 show a list of the explanatory spatial and socio-economic variables available for the model. They were selected on the criteria of being easy to elicit and difficult to manipulate in a real PES program setting. The spatial variables are clearly difficult to manipulate and easy to elicit with the use of digital maps provided that correct geographical coordinates of the land parcel in question are available. Most of the socio-economic variables would also be relatively easy to obtain in a real PES program by making the PES applicant reveal specific personal details in the program application form such as age and number of property owners. Some of the socio-economic variables are, however, easier to manipulate, the risk of which could be reduced by cross checking information, e.g. with personal identification documents.

Endogenous variables were excluded from the list of regressors by testing logical endogeneity for correlations. If these were not significant, the variables were maintained. For example, 'Off-FarmWork' could, theoretically, be explained in part with 'Area' because smaller farms require less labor and earn less income and therefore make 'Off-FarmWork' more likely and necessary. But since the two variables were not significantly correlated they were both maintained. The same is true for 'ProductionFocus' which could depend on 'Capacity' because the soil use capacity theoretically explains a focus on beef or dairy production. As no significant correlation could be detected also these two variables were maintained. If the correlation was significant, as for example between 'Family Labor' and 'Household Size', the variable which was thought to be endogenous, in this case 'Family Labor', was deleted from the list of regressors.

Table 3 List of easily obtainable spatial variables

Variable	Meaning	Type	Sign
DistAuction	Distance in meters to nearest cattle auction center. Distance measured "as the crow flies". Longer distance is expected to decrease per-hectare-returns because of higher transport costs or increased use of intermediaries.	Metric	(-)
DistCommerce	Distance in meters to nearest commercial center. Distance measured "as the crow flies". Longer distance is expected to decrease per-hectare-returns because of higher transport costs and less access to spare parts and repairs.	Metric	(-)
Slope	Average slope of land in %. Steeper slopes are expected to decrease per-hectare-returns.	Metric	(-)
Precipitation	Precipitation in mm per year. Higher rainfall is expected to increase per-hectare-returns.	Metric	(+)

SocialIndex	Average index for level of social development of a region ranging from 0 to 100. Advanced social development (higher index) is expected to increase per-hectare-returns.	Metric	(+)
DryMonths	Average number of annual dry months. Higher number of dry months is expected to decrease per-hectare-returns.	metric	(-)
Altitude	Altitude in meters above sea level. Higher elevation is expected to increase per-hectare-returns because of more moderate temperatures.	metric	(+)
Area	Size of property in hectares. Large properties are expected to have higher per-hectare-returns because of economies of scale.	metric	(+)
Life zone	Holdridge life zone on property. Seven categories. Bh-P6 (humid premontane forest in transition to basal) is used as reference category and assumed to be the most favorable life zone for agricultural production. All other life zones are expected to decrease per-hectare-returns as they offer either too humid, too dry or too hot conditions: Bh-T (Humid Tropical Forest), Bh-T10 (Humid Tropical Forest in transition to dry), Bh-T2 (Humid Tropical Forest in transition to perhumid), Bmh-P (Very humid premontane tropical forest), Bmh-P6 (Very humid premontane forest in transition to basal), Bs-T (Tropical Dry Forest), Bs-T2 (Tropical Dry Forest in transition to humid).	categorical	(-)
Soil	Soil type. 13 categories. Ah-e (Alfisole, very steep slope) is reference category. All other categories expected to increase per-hectare-returns because soil type and/or slope are more favorable for production. Other soil types are Ah-fo (Alfisole, steep slope), Ah-mo (Alfisole, moderate slope), Ah-so (Alfisole, light slope), Ah-p (Alfisole, flat), Eu-e (Entisole, very steep slope), Id-so (Inceptisole, Dystropept, light slope), It-p (Inceptisole, Tropaquept, flat), Iw-p (Inceptisole, Ustropept, flat), Iw-so (Inceptisole, Ustropept, light slope), Mt-p (Mollisol, flat), Vi-p (Vertisol, Pelludert, flat), Vm-p (Vertisol, Pellustert, flat)	categorical	(+)
Road	Type and quality of road leading to property. Categories from 1 to 5 with decreasing quality. Reference category is Type 1. Types 2-5 are expected to decrease per hectare returns because of increased transport costs.	categorical	(-)
Canton	Canton to which land parcel belongs to (canton is an administrative unit in the order, from small to large: (i) municipality, (ii) district, (iii) canton, (iv) province. Six categories. Canton Carrillo is reference category. All other cantons of the study area (Hojancha, Nandayure, Nicoya, Puntarenas, Santa Cruz) are expected to decrease per-hectare-returns. This is because all observations in Carillo lie on good and even soils with favorable production conditions and high per-hectare-returns.	categorical	(-)
Well	Existence of wells on property. 1=yes, 0=no.	binomial	(+)

Table 4 Socio-Economic Variables

Variable	Meaning	Type	Sign
PriceIndex	Index for product prices in %. Built from various individual prices collected in the field survey. The population's average is 100%. Higher prices (i.e. higher index values) are expected to increase per-hectare-returns.	Metric	(+)
FactorIndex	Index for factor costs in %. Built from various individual factor costs collected in the field survey. The population's average is 100%. Higher factor prices (i.e. higher index values) are expected to decrease per-hectare-returns.	Metric	(-)

NumberLandlords	Number of property owners. It is expected that a higher number of owners decreases per-hectare-returns because management decisions are more difficult to take.	count	(-)
HouseholdSize	Number of household members. A high number of household members is expected to increase per-hectare-returns because of availability of labor.	count	(+)
Off-FarmWork	Dedication to farm activities only (1) or also to off-farm activities (0). It is expected that off-farm activities contribute to income and thus increase per-hectare-returns as farm investments may be made possible.	binomial	(+)
Accessibility	All year accessibility of property with 4x2 automobile. 1=yes, 0=no. All year accessibility is expected to increase per-hectare-returns because it reflects good road conditions and lower transport costs.	binomial	(+)
ProductionFocus	Main production focus: 1=principally milk, 2=principally meat, 3=milk and meat. Category 2 is used as a reference dummy. Both categories 1 and 3 are expected to be associated with higher per-hectare returns.	binomial	(+)
EducationalLevel	Educational level of farm owner. Eight categories from 'never went to school (0)' to 'University degree (8). Reference Dummy is category 1. Higher educational levels are expected to improve farm management capabilities and therefore per-hectare-returns. Signs for categories 2-8 are therefore expected to bear a positive, category 0 is expected to bear a negative sign.	categorical	(-) (+)
Age	Age of landowner in years. Per-hectare returns are expected to decrease with age.	metric	(-)
Capital	The amount of capital ($/ha/year) that was put into production on pasture land. Higher capital amounts are expected to increase per-hectare-returns.	metric	(+)

To see whether the variables fulfilled the assumptions of normal distribution, homoscedasticity and linearity each variable underwent appropriate tests. Normality was tested applying a QQ-plot to the metric variables, where the R as a measure of normal distribution has to be larger than 0.94 to be considered normally distributed. Variables with R smaller than 0.94 and/or with a distribution that appeared to be skewed or irregular were transformed taking a log, square root or inverse. If the transformation did not raise the R above 0.94 the variables were omitted, although two exceptions were made for variables that turned out to be rather categorical than metric, namely 'Precipitation' and 'DryMonths'. As the assumption of normality applies less strictly to categorical variables they were not omitted. The variables 'Altitude' and 'NumberLandlords', however, were excluded from further analysis.

Homoscedasticity was tested using an F-test for equal variance. Variables or categories which showed to be heteroscedastic were excluded from further analysis. As a result 'off-farm-work' and 'accessibility' were excluded. Finally, all metric variables or their transformations were tested for linearity. This was done using simple regressions with "Per-hectareReturns" as the dependent variable. The standardized residuals were plotted against the predicted values and where no pattern could be identified the variable was classified to be linear. This was the case for all tested variables.

This section analyses the potential of linear regression models to estimate per hectare returns with the variables presented in the previous section. Two different models are constructed:

(i) The 'AllVariable' model with all the variables which were presented in Table 3 and Table 4 as long as they fulfill the assumptions of normality, homoscedasticity and linearity.
(ii) The 'AutoSelection' model with an automatic selection of the variables used in the AllVariable model applying a backward elimination technique.

Table 5 presents the AllVariable model. Because of the high number of variables the difference between the R^2 (0.34) and the adjusted R^2 (0.15) is large. This model has only six significant variables: 'DryMonths',_'LifeZone(bh-T2)', 'Soil(Ah-fo)', 'Soil(Ah-so)', 'ProductionFocus' and 'EducationalLevel(0)'. The estimators of four of these carry signs as expected in Table 3 and Table 4. The coefficient for 'DryMonths' and 'EducationalLevel(0)' do not carry the expected signs. 'DryMonths' has a positive sign and increasing number of dry months therefore is associated with increasing per-hectare returns. Even though this relation would make sense for other parts of Costa Rica where an excess of rain may cause production problems, it is surprising to find this result on the Nicoya Peninsula where the number of dry months is relatively high (mean: 4.6). Therefore no immediate logical explanation for this finding can be offered. For 'EducationalLevel(0)' a negative sign was expected since no formal education at all is generally associated with an lower economic performance. In the field survey, however, there happened to be 'EducationalLevel(0)' landowners (n=10) with per-hectare returns (mean 78.58$) higher than those of the 'EducationalLevel(1)' landowners (n=72) who had a mean of 36.63$.

Table 5 Model 1 (AllVariable)

Dependent Variable	**N**	**R^2**	**R^2 Adj.**	
Per-hectare-returns	176	0.34	0.15	
Independent Variables	**Estimator**	**S.E.**	**T**	**p**
Constant	-1262.96	632.34	-2.00	*0.048
LOG_PriceIndex	22.02	77.33	0.29	0.776
ROOT_FactorIndex	-10.67	7.66	-1.39	0.166
LOG_DistAuction	67.55	71.01	0.95	0.343
ROOT_DistCommerce	-0.11	0.36	-0.30	0.766
Slope	11.27	10.05	1.12	0.264
Precipitation	0.03	0.04	0.86	0.393
SocialIndex	9.34	8.96	1.04	0.299
DryMonths	96.77	44.33	2.18	*0.031
LOG_Area	24.27	18.88	1.29	0.201
HouseholdSize	-6.12	5.78	-1.06	0.291
LOG_Capital	33.19	16.93	1.96	0.052
LifeZone (bh-T)	44.58	43.69	1.02	0.309
LifeZone (bh-T10)	14.43	30.13	0.48	0.633
LifeZone (bh-T2)	-200.00	79.24	-2.52	*0.013
LifeZone (bmh-P)	80.62	54.95	1.47	0.145
LifeZone (bs-T2)	-3.44	45.57	-0.08	0.940
Soil (Ah-fo)	69.09	33.36	2.07	*0.040
Soil (Ah-mo)	45.52	35.39	1.29	0.201
Soil (Ah-p)	-32.78	113.36	-0.29	0.773
Soil (Ah-so)	109.65	43.31	2.53	*0.012
Soil (It-p)	170.65	115.08	1.48	0.140
Soil (Iw-p)	26.67	32.43	0.82	0.412
Soil (Iw-so)	74.89	50.29	1.49	0.139
Soil (Mt-p)	56.68	49.23	1.15	0.252
Soil (Vi-p)	-12.53	112.32	-0.11	0.911
Soil (Vm-p)	21.50	32.10	0.67	0.504
Road (2)	-33.56	27.45	-1.22	0.224
Road (3)	6.72	30.45	0.22	0.826
Road (4)	0.54	35.76	0.02	0.988
Canton (Hojancha)	-148.14	85.02	-1.74	0.084
Canton (Nandayure)	-101.13	63.48	-1.59	0.113
Canton (Puntarenas)	-114.32	79.15	-1.44	0.151
Canton (Santa Cruz)	-46.99	45.58	-1.03	0.304

Wells	-13.93	19.95	-0.70	0.486
ProductionFocus	59.89	21.51	2.78	*0.006
EducationalLevel (0)	85.96	39.21	2.19	*0.030
EducationalLevel (2)	27.81	19.19	1.45	0.150
EducationalLevel (8)	1.96	34.80	0.06	0.955

Finding so few variables to be significant in the AllVariable model raises the question whether simple significant relations between the dependent and explanatory variables become suppressed due to correlations between the explanatory variables. To shed some light on this it was analyzed whether significant simple relations do exist between the dependent and independent variables. There are only five significant simple correlations, one less than significant variables in the AllVariable model. Consequently, the low number of significant variables in the AllVariable model is not caused by intercorrelation, but rather there do not exist significant relations between the explanatory variables and per-hectare-returns in the first place. Three variables are significant in both the AllVariable model and simple correlation, namely 'DryMonths', 'LifeZone(bh-T2)' and 'ProductionFocus', each in both cases with the same sign. The two variables 'PriceIndex' and 'CantonHojaancha' are significant in the simple correlations (and carry expected signs) but not in the AllVariable model, possibly because intercorrelations suppress their significance in the model. The three variables Soil(Ah-fo), Soil(Ah-so) and Education(0) which are not significant in simple correlations attain significant roles in the AllVariable model, possibly because of mediator effects.

In an attempt to simplify the model, an automated backward elimination process is applied in the 'AutoSelection' model (Table 6). The AutoSelection model contains seven variables (categories) of which four significantly contribute to explaining the dependent's variable variance. The four significant variables are LifeZone(bh-T2), Canton(Hojaancha), ProductionFocus and EducationalLevel(0). The two variables LifeZone(bh-T2) and ProductionFocus stick out because they showed to be significant in the simple correlations and all three presented models. The only additional variable that was tested significant in the simple correlation and is also significant in the AutoSelection model is Canton(Hojaancha). It bears, as expected, a negative sign. EducationalLevel(0) reappears in the AutoSelection model as a significant variable after having been significant already in the AllVariable model. If the p-values were rounded to the second digit EducationalLevel(2) would also count as a significant variable bearing, as expected, a positive sign. With the exception of EducationalLevel(0) all remaining significant variables also bear signs as expected. The adjusted R-square of the AutoSelection model is 14% and thus only 1% below the AllVariable model.

Table 6 Model 3 (AutoSelection)

Dependent Variable	**N**	**R^2**	**R^2 Adj.**	
Per-HectareReturns	176	0.18	0.14	
Independent Variable	**Estimator**	**S.E.**	**T**	**p**
Constant	-8.36	25.84	-0.32	0.747
LOG_Capital	25.29	14.68	1.72	0.087
LifeZone (bh-T2)	-272.48	59.97	-4.54	*<0.001
Soil (It-p)	180.58	101.82	1.77	0.078
Canton (Hojaancha)	-74.30	27.82	-2.67	*0.008
ProductionFocus	49.81	18.31	2.72	*0.007
EducationalLevel (0)	82.90	34.06	2.43	*0.016
EducationalLevel (2)	33.19	16.92	1.96	0.051

Yet, although the number of variables could be reduced substantially in the latter model (AutoSelection), the R-square was too low to sufficiently estimate per hectare returns for the implementation of cost-aligned (flexible) payments in a real world PES program.

5 Testing Plausibility of Data

The poor results of the Rent and Model approaches to determine opportunity costs give reason to question the quality of the opportunity cost estimates from the Flow approach. In this section various plausibility tests are conducted. First, interviewees were asked to give a direct estimate of their perceived per-hectare-returns which are compared here to the Flow approach estimates. Second, the input and output data from the Flow approach is exposed to production functions.

4.1 Comparing Estimates from the Flow approach and Perceived returns

The principal results of the Fow approach and perceived returns are presented in Table 7. In terms of mean opportunity costs, the Flow approach reveals a smaller value (55.23$) than the perceived costs (84.11$). The results of an analysis of variance (ANOVA[3]) show the means of the Flow approach and perception to be not significantly different. After the identification and exclusion of extreme outliers within each approach[4] (indicated with 'adjusted' in Table 7) the mean opportunity costs of the Flow approach (50.49$) and perception (66.65$) come closer together and the analysis of variance (ANOVA) confirms the means to remain not significantly different.

Table 7 Opportunity Costs (in US$) according to different approaches

Approach	N	Mean	S.D.	Var. (-1)	Min.	Max.	Range
Flow	178	55.23	123.47	15,243.81	-363.31	624.56	987.87
Flow (adjusted)*	176	50.49	109.88	12,074.09	-363.31	532.72	896.03
Perception	120	84.11	161.28	26,011.00	0.00	1,428.57	1,428.57
Perception (adjusted)*	118	66.65	79.49	6,318.45	0.00	400.00	400.00

* Adjusted refers to the values obtained after exclusion of outliers

Not significantly different in their absolute mean values does not necessarily mean that the approaches are also consistent in their relative estimates, i.e. land plots with relatively high opportunity cost estimates in one approach also tend to have relatively high estimates in the other approach and vice versa. Table 8 shows the results of a correlation analysis and suggests that the opportunity cost estimates of the Flow and Perception approaches are significantly correlated. By omitting outliers from the analysis (indicated in Table 8 with 'adjusted') the Pearson correlation coefficient could be increased from 0.27 to 0.44 (which corresponds to an R^2 of 0.07 and 0.19, respectively) and the Spearman correlation coefficient could also be slightly increased from 0.50 to 0.53 (corresponding to an R^2 of 0.25 and 0.28, respectively). The results suggest that the estimates from the Flow approach are plausible, i.e. the land holders perceive their per hectare returns to be similar to the estimated per hectare returns.

Table 8 Correlation analyses of opportunity cost estimates between approaches

Variables	n	Pearson	Signif.	Spearman	Signif.
Flow/Perception	120	0.27	*0.003	0.50	*<0.001
Flow/Perception (adjusted)*	116	0.44	*<0.001	0.53	*<0.001

*Adjusted refers to the values obtained after exclusion of outliers

4.2 Production Functions

Instead of looking directly at the plausibility of per hectare return estimates, a quadratic production function is used here to examine the relation between the input (x_i) and output (y) data (Fuss et al. 1978) of the production process. A significant positive relation would mean the input and output quantities that were determined as part of the field survey are plausible. Table 9 presents the output variable (y) and the input variables (x_i) that were used in the production function.

[3] According to the three tests Tukey, Duncan and LSD Fisher.

[4] Estimates were identified as outliers if their z-standardized value was larger than 4 or smaller than -4.

Table 9 List of variables and the expected relation (sign) of input to output variable

Output variable	**Description**	**type**	**sign**
TotalSales	Total annual sales in $.	metric	
Input variables			
Labor	Total labor in hours per year	metric	(+)
CircCapital	Total annual value of circulating capital in $	metric	(+)
Area	Land area in hectares	metric	(+)
Herd	Herd size in head of cattle	count	(+)

In a first step, a simple correlation matrix (not presented here) helps to give an overview of how the variables are related to each other. It turns out that all four input variables are significantly correlated to the output variable 'TotalSales'. However, nearly all input variables are significantly correlated with each other, with 'Area' and 'Labor' being the only exception. Therefore it is likely that some of these variables become suppressed in a multiple regression.

In the next step the data are used in a quadratic production function by Lau (1974, in: Fuss et al. 1978) which is a more flexible form than the Cobb-Douglas production function. All variables and cross products are expected to have positive signs. The quadratic production function as presented in Table 10 shows total sales to significantly increase, as expected, with 'circulating capital' and the cross products 'CirculatingCapital*Labor' as well as 'Area*Herd'. The cross product 'CirculatingCapital*Area' has, unexpectedly, a negative estimator. The R-square is exceptionally high and shows the model to explain 96.6% of the variance of total sales. It can be concluded that the elicited data on input and output quantities is plausible and gives no reason of concern.

Table 10 Quadratic Production Function

Dependent Variable	**N**	**R^2**	**R^2 (adj.)**	
Total Sales	176	96.8	96.6	
Coeff.	**Est.**	**S.E.**	**T**	**p**
Constant	184.229	450.984	0.409	0.683
Labor	-0.148	0.170	-0.869	0.386
CirculatingCapital	0.980	0.083	11.746	*<0.001
Area	6.827	7.612	0.897	0.371
Herd	23.481	14.402	1.630	0.105
CirculatingCapital*Labor	0.000	0.000	3.619	*<0.001
CirculatingCapital*Area	-0.004	0.001	-3.462	*0.001
CirculatingCapital*Herd	0.001	0.002	0.731	0.466
Labor*Area	0.000	0.002	0.160	0.873
Labor*Herd	0.000	0.003	0.160	0.873
Ha*Herd	0.123	0.045	2.741	*0.007

6 Conclusion

Payment differentiation might encounter several obstacles such as the identification of a reliable, sufficiently precise and cost-effective method to determine micro level participation costs. Two approaches to estimate opportunity costs of conservation were tested in this chapter: The 'Rent' approach which derives opportunity costs from annual land rents, and the 'Model' approach which regresses opportunity costs on easily obtainable and difficult to manipulate spatial and socio-economic independent variables such as soil quality. None of these approaches appeared to estimate opportunity costs sufficiently well. But since this judgment is based on how well the estimates compare to the Flow approach estimates (in the case of the Rent approach), or how well the independent variables model the Flow approach estimates (in the case of the Model approach), it is possible that the Rent and Model approaches did not perform well because of flaws in the Flow approach estimates. Therefore, the plausibility of the Flow approach estimates was tested by (i) comparing them to the per hectare returns as they were perceived by the land holders and (ii) using input and output quantities from the survey (on which the Flow approach estimates are based) in production functions. The tests confirmed the plausibility of data. Based on the presented results the two cost estimation approaches cannot be recommended for practical implementation in PES programs. Further research is necessary to confirm

these findings. In such efforts, special attention needs to be given to the techniques that are applied to deliver reference point data on opportunity costs.

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