7

Forest Preservation, Flooding and Soil Fertility: Evidence from Madagascar

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1. Introduction

In several developing countries, forest preservation programs have been put in place with an economic justification based on the local ecological services that they provide (Pagiola et al., 2002). It is argued that the presence of forests preserve the hydrological balance; reduce soil erosion due to increased soil stability; reduce flooding and regulate flows (Perrot-Maitre and Davis, 2001; Johnson et al., 2002; Pattanayak and Kramer, 2001a,b). However, other authors dispute the domestic benefits of forests and state that natural scientists often overvalue forests (Chomitz and Kumari, 1998; Aylward and Echeverria, 2001; Calder, 1999). Assuming that an externality costs of deforestation exists, policy makers have started to look at how to correct for this and how a workable system can be put in place to pay for ecological services locally. Increasing attention is going towards the direct payment for environmental services (Ferraro and Simpson, 2002; Durbin, 2002; Pagiola et al., 2002).

We look at this issue in a case study in Madagascar. Multiple studies have shown the high and accelerating deforestation rate in Madagascar (McConnell, 2002). Causes of deforestation are multiple and have been linked to poverty (Zeller et al., 2000), conversion of forest land to pastures (McConnel, 2002), use of wood for charcoal (Casse et al., 2004), wood exports or household fuel consumption (Minten and Moser, 2003), slash-and burn agriculture (Barrett, 1999; Keck et al., 1994; FOFIFA, 2001; Casse et al., 2004; Terretany, 1997), rural insecurity (Minten and Moser, 2003), and land tenure problems (Freudenberger, 1999). While deforestation threatens the unique eco-system of Madagascar, it has also been linked to higher incidences of flooding and greater soil erosion and damages therefore the agricultural resource base domestically (Freudenberger, 1999, Kramer et al., 1997). Overall, it is estimated that the damage of soil erosion in Madagascar is high (Kramer et al., 1997; World Bank, 2005) although the numbers that have been suggested might have been exaggerated (see f.ex., Larson, 1994).

In this analysis, we study the potential domestic benefits of forests on lowland agriculture. While we do not try to establish explicit linkages between deforestation and sedimentation off-site, we do look at the effects of flooding and sedimentation downstream as perceived by rice farmers. The analysis is based on a small-scale survey in Northern Madagascar where we try to monetize the cost to farmers of flooding and sedimentation on their rice fields downstream.[1] If the link between forest cover and flooding would exist in this area and if the link is strong, a positive willingness to pay might then justify investments in conservation measures upstream.

We contribute to the literature in two ways. First, we show that an important percentage of rice farmers benefit from flooding and sedimentation (as shown in higher land values after sedimentation and refusal for contribution towards conservation) and that current economic returns to investment in forest preservation, largely beneficial because of averted rice productivity declines, might thus be overestimated.[2] Second, in the rural scarcely monetized settings of developing countries where land transactions are rare, we develop an alternative to the hedonic price analysis of land values using willingness-to-accept scenario's explicitly allowing for uncertainty.

The structure of the paper is as follows. First, we discuss the conceptual framework. Second, the methodology, data sources and the structure of the survey are presented. Third, we look at descriptive statistics describing households as well as sedimentation and flooding incidence. Fourth, the determinants of land values, incorporating the impact of sedimentation, and the results of a willingness to pay question to avoid flooding and sedimentation are discussed. We finish with the conclusions.

2. Conceptual framework

Assume an expenditure minimization problem where expenditures are minimized subject to the constraint that utility equal or exceed some stated level, U^0. The solution to this minimization problem is the restricted expenditure function

$$e = e(p^0, T^0, U^0, \varepsilon^0)$$

where p^0 can be thought of as a vector of prices, T^0 is land availability to the household and ε^0 represents uncertain factors not reflected in p^0, T^0 and U^0.

In a first offer, the household is asked to sell land for a total payment of P^1. In a second offer, the household is asked to pay for conservation for a total payment of P^2. The change from T^0 to T^i in either of the two scenarios will result in a new expenditure function with a new set of prices and environmental and resource flows, i.e. $e = e(p^1, T^1, U^0, \varepsilon^1)$ in the first scenario and $e = e(p^2, T^2, U^0, \varepsilon^2)$ in the second scenario. It seems reasonable if you take away land or income, and given imperfect markets, that the shadow prices and wages are likely to change, i.e. we do not assume the price vector to be independent in the two scenarios.

In such a set-up, the welfare change - the Hicksian compensating surplus - is defined as the difference between the two expenditure functions,

$$e(p^i, T^i, U^0, \varepsilon^i) - e(p^0, T^0, U^0, \varepsilon^0)$$

where i is 1 (scenario 1) or 2 (scenario 2). The value of the welfare change is established by using contingent valuation measures and the Willingness to Accept/Pay (W) at the farm household level might be represented by W_j for household j

$$W_j = e(p^i, T_j^i, U_j^0, \varepsilon_j^i, X_j) - e(p^0, T_j^0, U_j^0, \varepsilon_j^0, X_j) + \eta_j$$

[1] While there is some rice cultivation on upland, the majority happens in the lowlands.

[2] For example, the World Bank (2005) estimates in its economic calculations that most of the benefits of the national environmental program (EP3) are obtained from avoiding productivity losses on rice fields.

where X_j is a vector of socio-economic characteristics for household j and η_j is an error term. Such a model can be further refined to allow for dynamic behavior (Holden and Shiferaw, 2002). If we let W_2 represent the subjective present value of future land productivity gains by switching from no interventions to conservation efforts in the uplands, the following equation holds in the case of the maximization of an expected intertemporal utility function:

$$U_j^0 (C_j^0) - U_j^0 (C_j^0 - W_j) = \sum_{t=1}^{\infty}(1+\delta_j)^{-t} EU_j^t(C_{1j}^t - C_{0j}^t)$$

Where δ_j is individual j time preference, EU_j^t is the expected utility for individual j in time t, and $U_j^t(C_{1j}^t - C_{0j}^t)$ is the utility gain in time t when switching from no interventions to conservation efforts in the uplands. Nonseparability in a dynamic context implies that intertemporal markets do not work well and that W would then vary over time with household discount rates that can be very high for poor liquidity constrained households.[3]
W can then be specified as a random variable which is a continuous function of observational variables that appear in the expenditure function such as farm, technology and socio-economic characteristics. W can thus be written as

$$W_j = Z_j\beta + \mu_j$$

$$\text{where } \mu_j \sim (0, \sigma^2)$$

where Z is a vector of explanatory variables, μ_i is the error term and σ is the standard deviation.

3. Methodology and data

An agricultural household survey was organized in November 2001 in an area northwest of Maroantsetra, in the northeast of Madagascar. The area was selected on the basis of the high diversity in watershed forms and areas and the perceived clear link between upstream activities and lowland impacts. First, a census of all the watersheds was done. In total, 65 watersheds were identified. Due to logistical reasons, only 52 watersheds were sampled. In each watershed, a stratified sample of rice plots was done. Rice plots were stratified based on the distance to the main river. In each watershed, around six fields were sampled, depending on the size of the watershed. In total, data on 268 rice farmers were obtained. The questionnaire that was implemented consisted of four parts. The first part dealt with plot characteristics (including a land valuation question), the second with questions on the rice harvest of last year on that plot, and the third on the overall structure of the agricultural firm. The final part described a willingness to pay scenario where households were asked to value their desire to avoid flooding and sedimentation in their rice fields.
Instead of the widely used and recommended dichotomous choice valuation question (Arrow et al., 1993), a stochastic payment card method (Wang and Whittington, 2005) was implemented for different reasons: (1) Given logistical constraints, a relatively small sample had to be relied upon. The payment card format gives the benefit of having extra information beyond the yes/no question (For papers that discuss the benefits of information

[3] Dasgupta (1993) has demonstrated this theoretically and Pender (1996) and Holden, Shifraw and Wik (1998) provide good empirical evidence on this.

beyond dichomotous choices, see Blamey et al. (1999) and Ready et al. (2001)). (2) Whittington (1998) and Wang and Whittington (2005) show that a main problem in contingent valuation studies is that the range that is offered is often not large enough to allow for a robust estimation of the valuation function. Moreover, as we had little a priori knowledge about the valuation function, we had to make sure that extreme levels were included in the bids on the payment card. Given the small sample, this could not have been achieved in the dichotomous choice variable format. (3) Uncertainty (for example on the future price evolution of agricultural products) and imperfect information (household chief had to answer immediately during the interview and could not consult with family members and/or village leaders) is allowed for in this format. Wang (1997), Wang and Whittington (2005) and Alberini et al. (2003) show the benefits of the explicit modeling of uncertain responses in contingent valuation data.

Two valuation questions were asked. The valuation questions were set up in such a way to reduce as much as possible the problem with starting point bias and with yea-saying: therefore, it started with an open-ended question (no starting point bais) followed by a payment card (additional information). In the case of the land valuation, a willingness to accept scenario was described where a certain monetary payment was given in exchange for the plot studied. As previous surveys in Madagascar had shown the reluctance of farmers to give a sales price for land - they would often report they would be unwilling to sell the plot whatever happened - it was made clear from the beginning that this was a hypothetical situation where we like to know their approximate financial value of the plot in their farming enterprise. The respondent was presented with a payment card in local currency but with references to values of local rice units, bikes, and value of livestock. On this payment card, the enumerator proceeded to fill in for every amount that was mentioned a code corresponding to 1. Accept to pay for sure; 2. A little bit in doubt but would say yes; 3. Not yes or no, do not know; 4. A little bit in doubt but would say no; 5. Will not pay for sure.

In the case of the question on willingness to pay for reduction in flooding and sedimentation, the valuation scenario was constructed as follows. Respondents were first asked if they thought if flooding and sediments had a negative, neutral or positive influence on rice productivity, in general and on the specific plot that was studied. A scenario was then described in the following way:

" Suppose that we leave the situation as it is and we leave damage as it is without any intervention to limit deposits on this rice field or to reduce the frequency of flooding on this field. In a second situation, actions will be undertaken in the watershed upstream of your fields. In this case, you will not suffer anymore from problems of flooding and sediments. However, you know that these actions will cost money. We would like to know how much you would be willing to pay for these actions, taking into account your possibilities. If you do not pay as much than what you would be really able to pay, actions will not be sufficient to reduce flooding and sedimentation. On the other hand, if you give a level that is higher than you can afford, functional interventions can not be agreed upon. How much would you be willing to pay? x sobika of rice?"

The question was formulated in local units of rice as this measure was easily recognizable by farmers. To finish the valuation section, a question was asked to the farmers on where they would get the rice from for the amount that they were willing to contribute. It was hoped that this would remind them of their budget constraint. Corrections on the payment card were allowed for afterwards.

While non-responses were not a problem in the plot valuation question, about one third of the respondents did not answer the willingness to pay question to avoid flooding or sedimentation. The characteristics of the respondents that refused to answer are not randomly distributed and might therefore cause inconsistency and inefficiency in the estimation of the coefficients in the regression of the willingness to pay question. A common method to control for non-responses to the willingness to pay question is to estimate a sample selection model (Messonier et al., 2000; Mekkonen, 2001), usually referred to as the Heckman two stage approach (Heckman, 1997). In this case, we estimate:

$$Y^*=\beta' X+\varepsilon$$

$$Y=0 \text{ if } Y^*\leq 0$$

$$\text{and } Y=Y^* \text{ otherwise}$$

$$Z=\alpha' V+\mu$$

$$Z=1 \text{ if } Z^*>0$$

$$\text{and } Z=0 \text{ if } Z^*\leq 0$$

where Y is willingness to pay (censored at 0); X is a vector of explanatory exogenous variables that explain Y; Z is 1 when there is a valid response and 0 otherwise; V is vector of explanatory exogenous that influence the probability of giving a valid response; α and β are parameters to be estimated; ε and μ are disturbances; Y^* and Z^* are latent variables.

4. Descriptive statistics

The Maroantsetra area in the Northeast of Madagascar is a humid area characterized by two types of agriculture: slash-and-burn cultivation ("tavy") on the hillsides and lowland rice cultivation. The area is isolated from the rest of Madagascar and is highly dependent on agriculture for income. The region is also still highly forested and is one of the largely untouched areas in Madagascar. Table 1 shows the basic descriptive statistics of the households in the survey. The head of households have a low average level of education, i.e. only three years. 10% of the households are female headed and these are mostly poorer households (Razafindravonona et al., 2000). The average size of the household is six members. Almost all the households are natives from the region and all the households report to depend on agriculture for their livelihood.

An average household in the sample possesses 62 ares[4] of lowland and 73 ares of upland. As in most of Madagascar, the main staple is rice. The average production is just below 1 ton which is estimated to be sufficient for subsistence by almost 70% of the population. However, most households - even some that declare to be self-sufficient in rice - reduce overall consumption during the lean period. The average length of this lean period is estimated to be three months. A household possesses on average 2 zebus. Total annual monetary household income is estimated at 2.7 M Fmg[5], i.e. around 415$US, i.e. low but

[4] 1 are = 0.01 ha

[5] Malagasy Franc; 1 USD$ = 6500 Fmg at the time of the survey

consistent with the high poverty levels and the low GNP of Madagascar (Razafindravonona et al., 2001).
Tables 2 presents the descriptive statistics of the rice plots that will be analyzed in more detail later on. The average plot size is small, 2.1 ares, with a range between 1 and 25 ares. Most of the plots are reported to be irrigated through a dam (96%). When asked about production problems in the last agricultural year, 28% of the farmers complained of droughts, 21% of sedimentation problems, and 14% of floods. Average yields during the previous agricultural year were estimated at 3.3 ton per hectare, high compared to the rest of the country but consistent with the excellent country-wide production conditions in 2001.[6]

variable	Unit	N	mean	median	min	max
size of household	number of people	268	5,65	5	1	14
education level head of hh	years	268	3,13	3	0	12
age	years	268	45,55	44	15	81
gender	man=1	268	0,90	1	0	1
native of region	yes=1	268	0,99	1	0	1
lowland	ares	268	61,87	50	0	340
upland	ares	268	73,40	50	0	1000
forest savoka	ares	268	33,09	0	0	500
primary forest	ares	268	30,06	0	0	600
zebus	number	268	1,75	0	0	18
total production of rice	kg	268	913,46	720	60	4500
total income	1000 Fmg	268	2695,57	1635	0	30100
rice production is enough	yes=1	268	0,27	0	0	1
length of lean period	number of months	268	2,81	3	0	10
potential access to credit	1000 Fmg	268	706,03	100	0	25000

Table 1. Descriptive statistics of household variables

Two major cyclones hit the area in the last five years: Huddah in 2000 and Gloria in 1997. The majority of the farmers state that production of plots was not affected by these events. Even when plots were affected, the perceived impact was reported to be small. Only 12% and 3% of the farmers declare that these cyclones had an impact on their rice yields in 2000 and 1997 respectively. Of these farmers, only 3% and 1% state that the impact on rice yield had been very high. Hence, it seems that the direct overall impact of these cyclones has been very small. This might be because the cyclones normally hit outside the regular growing period in Maroantsetra.[7]

[6] However, few farmers use modern inputs yet.
[7] The reported median harvest month is around November – in contrast to the rest of the country where main harvest are in April/May - while cyclones often hit in the beginning of the year.

variable	Unit	N	mean	median	min	max
Parcel characteristics						
area	ares	268	2,16	1,2	0,1	25
distance from house	minutes	268	15,40	10	1	90
isolated parcel	yes=1	268	0,04	0	0	1
parcel along river	yes=1	268	0,14	0	0	1
traditional perimetre	yes=1	268	0,82	1	0	1
parcel far from river	yes=1	268	0,57	1	0	1
parcel in terras	yes=1	268	0,17	0	0	1
parcel close to river (<100m)	yes=1	268	0,15	0	0	1
parcel between 100 and 200m of river	yes=1	268	0,10	0	0	1
interior of bend of river	yes=1	268	0,04	0	0	1
exterior of bend of river	yes=1	268	0,19	0	0	1
parallel to river	yes=1	268	0,56	1	0	1
irrigated by rainfall	yes=1	268	0,04	0	0	1
irrigated by dam	yes=1	268	0,96	1	0	1
distance river parcel	meters	268	103,45	40	0,2	1200
height difference parcel river	meters	266	2,51	2	0,2	20
order in irrigation (rank)	number	268	9,51	5	1	99
soil depth	cm	267	26,34	20	3	120
Sedimentation and flooding						
no deposits	yes=1	268	0,44	0	0	1
deposits of clay	yes=1	268	0,26	0	0	1
deposits of sand	yes=1	268	0,30	0	0	1
Cyclone Huddah 2000						
length flooding	days	218	1,66	1	0	30
maximal depth of water	cm	202	116,46	100	0	600
no impact on yields	yes=1	268	0,56	1	0	1
little impact on yields	yes=1	268	0,05	0	0	1
medium impact on yields	yes=1	268	0,04	0	0	1
strong impact on yields	yes=1	268	0,03	0	0	1
Cyclone Gloria 1997						
length flooding	days	144	1,31	1	0	17
maximal depth of water	cm	122	117,37	100	0	500
no impact on yields	yes=1	268	0,41	0	0	1

variable	Unit	N	mean	median	min	max
little impact on yields	yes=1	268	0,01	0	0	1
medium impact on yields	yes=1	268	0,01	0	0	1
strong impact on yields	yes=1	268	0,01	0	0	1
This harvest						
problems with flooding	yes=1	268	0,14	0	0	1
problems with drought	yes=1	268	0,28	0	0	1
problems with deposit sand	yes=1	268	0,21	0	0	1

Table 2. Descriptive statistics parcel, flooding, and sedimentation

Runoff and erosion happen often during rare events such as cyclones and heavy, intense rainfall (Kaimowitz, 2000; Brand et al., 2002). While direct impact on productivity might be small, long-term impacts through increased sedimentation might be large. In the next section, we will evaluate the values these rice farmers attach to sedimentation and flooding. We will estimate these through well-established methods in environmental economics: (1) an indirect valuation method using the hedonic pricing methodology and (2) a direct valuation method using the contingent valuation technique.

5. Regression results

5.1. Land valuation

To evaluate to what extent farmers incorporate physical and environmental amenities in land valuation, a modified hedonic pricing analysis was done. Given that land sales are rare in the region and good land valuations are therefore more difficult to get at, a stochastic payment card method was implemented to arrive at approximate land valuations of the rice plot in the sample. The stated price at which households are willing to sell their plot for sure is used as dependent variable in the regression analysis. The results of this regression are shown in Table 3.

The results illustrate that farmers are well aware of the effect of the physical characteristics on the value of their plots. As expected, area is shown to be a significant determinant of value (see Figure 1). A doubling in area increases the value of the plot by only 0.54, i.e. significantly different from one. This result indicates that larger plots are relatively less valuable than smaller plots, controlling for physical characteristics. On first sight, this implies that there are potential profits to be made by repacking plots in smaller units.[8] While returns to scale would result in relatively higher values for larger plots, a potential explanation might be that farmers prefer different smaller plots compared to one big plot as in this way, farmers are able to diversify their risk.[9] The likelihood that small plots, that are spatially segregated, are all hit by calamities at the same time - such as flooding, drought, sedimentation problems or plant diseases - is less than for one big plot. This risk averseness, typical for poor small farmers, might be an important explanation of the concave land price relationship.

[8] Similar results have been found in other countries as mentioned by Lin and Evans (2000).
[9] Blarel et al. (1992) study this phenomena in depth in Ghana and Rwanda.

variables	Unit	Coefficient	t-value	P>|t|
plot characteristics				
area	log(ares)	0,503	**7,590**	**0,000**
parcel in terras	yes=1	-0,343	**-1,840**	**0,067**
parcel along river	yes=1	-0,617	-1,470	0,142
tradional perimeter	yes=1	-0,215	-0,530	0,596
interior bend of river	yes=1	-0,371	-1,600	0,111
exterior bend of river	yes=1	-0,045	-0,300	0,765
distance river parcel	log(meters)	0,027	0,700	0,488
height difference parcel river	log(meters)	0,040	0,300	0,762
soil depth	log(cm)	0,260	**2,140**	**0,034**
irrgation directly from river	yes=1	0,216	**1,700**	**0,091**
irrigated by dam	yes=1	-0,305	-1,000	0,320
clay deposit after cyclones	yes=1	0,299	**1,990**	**0,048**
sandy deposits after cyclones	yes=1	0,429	**2,980**	**0,003**
household characteristics				
education head of household	years	0,016	0,740	0,463
age of head of household	years	0,001	0,130	0,893
gender head of household	man=1	-0,237	-1,110	0,267
annual monetary income	log(Fmg)	0,041	1,330	0,185
length of lean period	months	0,017	0,690	0,492
potential access to credit	log(Fmg)	-0,010	-0,870	0,384
owned number of zebus	log(number)	0,300	**3,460**	**0,001**
owned agricultural land	log(ares)	-0,070	-0,950	0,341
intercept		12,248	**14,700**	**0,000**
Number of observations	256			
F(21, 234)	9,62			
Prob > F	0			
R-squared	0,3929			
Root MSE	0,9256			

Table 3. Hedonic price regression
(dep. var. = log (value of land); robust standard errors)

Most of the physical variables turn out not significant at the conventional statistical levels, indicating that these are not major determinants of sales prices. However, there are a few exceptions. Plots in terraces, at the top of the river, are less valuable. This might be because these plots are more likely to be affected by drought. The impact is shown to reduce the value of the plot by around 34%. The perceived cultivable soil depth is a highly important determinant of land prices. A doubling of soil depth increases the value of rice land by 26%. Agronomic evidence suggests that soil depth is crucial for root development which has been shown to be an important constraint on rice production in Madagascar.

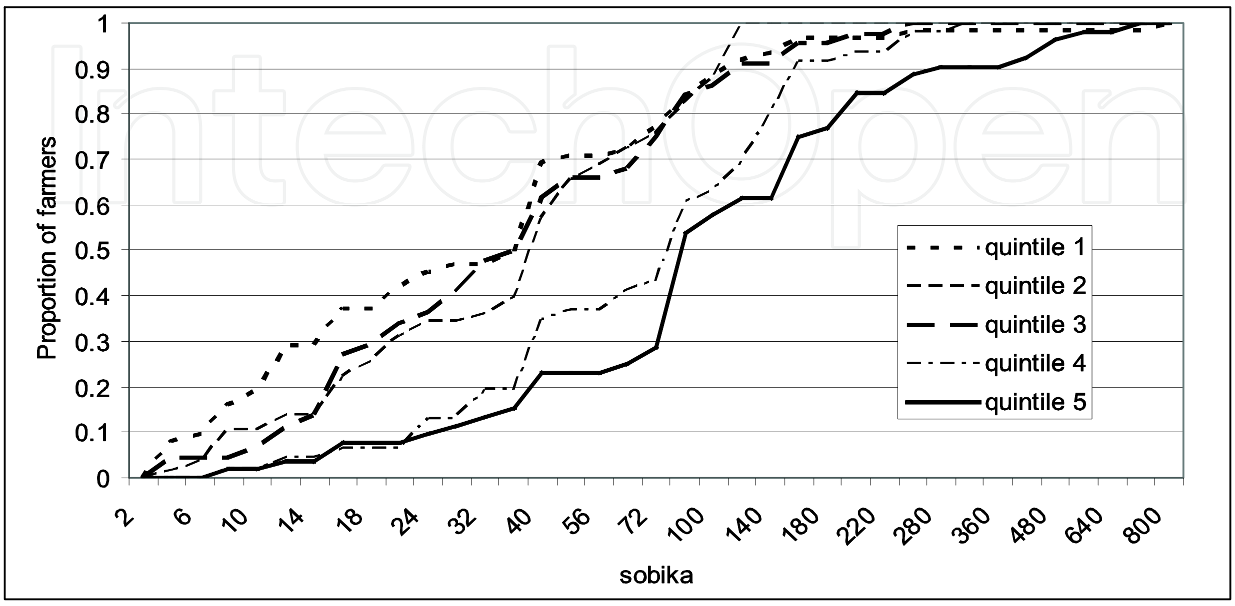

Fig. 1. Willingness-to-accept the sales price 'for sure' (by plot size quintile)

In line with de Janvry et al. (1991), we assume imperfect or missing markets where farm households are the decision makers and production and consumption decision are not separable. This implies that land prices would also depend on household characteristics and they were thus included in the regression. Few of these variables come out significant. Only the ownership of cattle leads to significant higher land values. This seems linked to the importance of ownership of cattle to access to manure, an important lasting fertility and land quality enhancing input in these environments (Minten et al., 2007; Barrett et al., 2002).

To measure the effect of sedimentation, we created dummies for clay and sand deposits during recent floods. Compared to soils without deposits during floods, these plots are estimated to be significantly more valuable. The plots affected by soil and sand deposits are estimated to be respectively 30% and 43% more valuable. The latter results might seem surprising at first sight. However, sand deposits come usually together with organic material that might significantly improve the fertility of soils. Farmers also often remove the more damaging sand from the plot. These results indicate overall that sedimentation does not reduce the value of the plot per se, ceteris paribus. We discuss this in more detail below.

5.2 Willingness-to-pay to avoid sedimentation and flooding

All sedimentation is not perceived to be bad for rice productivity. In fact, erosion and heavy rainfall might induce runoff of the good topsoil of the uplands that ends up in the lowland ricefields (Chomitz and Kumari, 1998). This seems also to be the case in the lowlands of the Maroantsetra region. When asked about the perceived effect of flooding and sedimentation on rice yields overall, 53% of the farmers reported that they thought this relation was negative (Table 4). However, 38% of the farmers thought that it was actually good for rice yields (while 9% thought its effect was neutral). In a follow-up question, it was asked what the rice farmers expected of the effect of sedimentation and flooding on the rice plot in the sample. Farmers were evenly divided on the question: 37% thought that the effect would be negative, 38% expected a positive effect and 26% reported to expect a neutral effect.

variable	Unit	N	mean
Overall effect sediment/flooding on rice yield…			
positive	yes=1	268	0,38
neutral	yes=1	268	0,09
negative	yes=1	268	0,53
Effect on studied parcel of sediments/flooding on rice yield…			
positive	yes=1	268	0,37
neutral	yes=1	268	0,26
negative	yes=1	268	0,38

Table 4. Perceived effect of sedimentation/flooding

Finally, farmers were asked what they were willing to pay to avoid flooding and sedimentation. Figure 2 illustrates, for the respondents that were willing to pay, how the willingness to pay varies for the different levels that were offered to the respondent. We see that the median willingness to pay (at 95% for sure) to avoid flooding is just over 2 sobika, the local unit for a rice basket containing 12 kgs on average per household per year. This amounts to around 4$. This implies that if a vote would be held in the region, more than 4$ would not be accepted by a majority of the population. 50% of the farmers would refuse to pay more than 4.5 sobika for sure. On average, this corresponds to 7% of their total rice production of last year.

The number of farmers that were undecided about accepting or refusing the offer is largest in the middle of the graph, as could be expected (see Wang (1997; p. 223)). For some bids, the indecision domain contains up to 15% of the farmers. This high number indicates the importance of allowing farmers to convey information beyond the simple yes/no format in contingent valuation studies as has been shown by other authors (Blamey et al., 1999; Ready et al., 2001; Alberini et al., 2003).

Regressions were run to look at the determinants of the willingness to pay to avoid flooding and sedimentation on the plot in the sample. These results serve to validate the WTP answers. A two-step approach was used. In a first step, a selection equation was run to explain the characteristics of the households that are willing to contribute to avoid flooding and sedimentation. In this step, variables are included that are potential determinants of the likelihood of the plot to be subject to flooding and sedimentation. In a second step - controlling for the characteristics of the plot and the household which explain if it is willing to contribute - economic variables are included in the regression to measure to what extent they are able to contribute, taking into account their socio-economic background. A selectivity coefficient was then included in the second-stage willingness to pay regression.

This set-up would allow us to obtain efficient and unbiased estimates in the second stage regression.

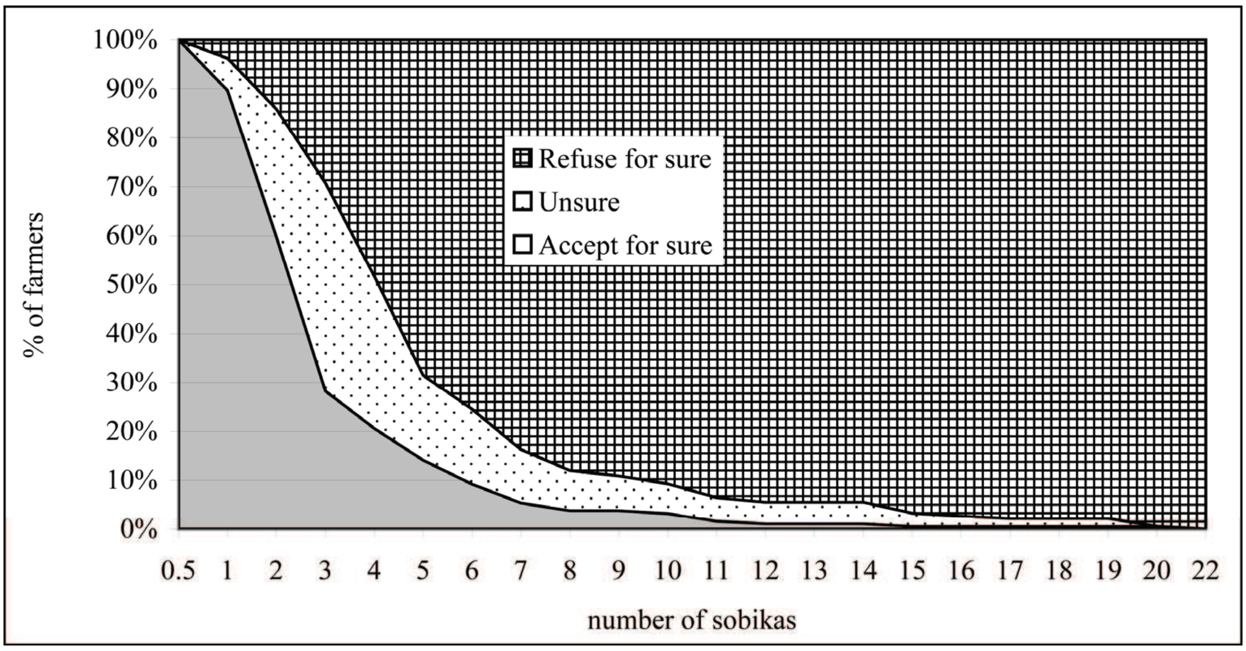

Fig. 2. Willingness to pay to avoid flooding/sedimentation

The results are largely conforming to expectations. The coefficient that measures the expected effect of sedimentation and flooding on the plot and the household perceived effect of sedimentation are significant determinants of the probability that the household is willing to contribute.[10] Households with plots on the exterior bend of the river, bigger soil depth and irrigated by dams are significantly more willing to contribute. These plots might be more exposed to risk or are more valuable. It is interesting to note that negative experiences with the last two cyclones make the household less likely to contribute. These households might believe that there is not much that can be done or, alternatively, that this type of adversity might easily be overcome.

The results on the amount that households are willing to contribute – the second stage regression - suggest that wealthier households are willing to pay more. Different measures of wealth were included. A doubling of the area of lowland in possession would increase the willingness to pay significantly by 11%. A lean period that lasts one month longer as measured by the period that they do not have sufficient rice, an indicator of poverty of the household (Barrett and Dorosh, 1998; Minten and Zeller, 2000), reduces the willingness to pay of the household by 6%. Potential access to credit increases the willingness to pay significantly. However, its coefficient is small. Overall income and the number of zebus owned by the household show the expected positive sign but are not significant at the 10% level. Household characteristics, such as level of education, gender and age of the head of household, do not influence the willingness to pay significantly.

[10] However, the match is not perfect. 72% of the households that expected a positive impact were not willing to pay to participate. This compares to 91% of the households that expected a neutral impact and 8% of the households that expected a negative impact.

variables	Unit	Coef.	z	P>z
dep. var.: willingness to pay in log(Fmg)				
area of the plot	log(ares)	-0,014	-0,230	0,816
education head of household	years	-0,016	-0,820	0,410
age of head of household	years	-0,006	-1,320	0,187
gender head of household	man=1	-0,108	-0,610	0,542
owned lowland	log(ares)	0,112	**1,950**	**0,051**
annual monetary income	log(Fmg)	0,036	1,090	0,276
length of lean period	months	-0,058	**-2,460**	**0,014**
potential access to credit	log(Fmg)	0,021	**1,910**	**0,057**
owned number of zebus	log(number)	0,030	0,400	0,691
intercept		0,116	0,220	0,822
selection equation				
expected effect of sedimentation on plot	1=pos; 2=neutral; 3=neg.	0,683	**4,990**	**0,000**
area of the plot	log(ares)	-0,161	-1,440	0,150
parcel along river	yes=1	-1,074	-1,500	0,134
traditional perimetre	yes=1	-0,704	-1,060	0,287
parcel in terras	yes=1	-0,442	-1,460	0,144
parcel close to river (<100m)	yes=1	-0,448	-1,500	0,134
parcel between 100 and 200m of river	yes=1	-0,030	-0,070	0,943
interior of bend of river	yes=1	-0,216	-0,400	0,689
exterior of bend of river	yes=1	0,836	**3,200**	**0,001**
irrigated by dam	yes=1	0,970	**1,960**	**0,050**
distance river parcel	meters	0,005	0,080	0,939
height difference parcel river	meters	0,113	0,810	0,420
order in irrigation (rank)	number	-0,087	-0,910	0,362
slope (distance one sees w/o obstacle)	meters	0,056	0,640	0,525
soil depth	cm	0,464	**2,740**	**0,006**
estimated age of plot	years	-0,003	-0,410	0,680
little impact on yields of cyclone 1	yes=1	-0,087	-0,180	0,859
medium impact on yields of cyclone 1	yes=1	-1,182	**-1,780**	**0,075**
strong impact on yields of cyclone 1	yes=1	-1,642	**-2,510**	**0,012**
little impact on yields of cyclone 2	yes=1	-0,333	-0,390	0,695
medium impact on yields of cyclone 2	yes=1	-0,087	-0,060	0,949
strong impact on yields of cyclone 2	yes=1	0,434	0,290	0,770

variables	Unit	Coef.	z	P>z
overall perceived impact of sedimentation	1=pos; 2=neutral; 3=neg.	0,385	**2,580**	**0,010**
intercept		-3,186	1,018	-3,130
rho		-0,744	0,119	
sigma		0,778	0,050	
lambda		-0,578	0,118	
LR test of indep. eqns. (rho = 0): chi2(1) = 13.88 Prob > chi2 = 0.0002				
Number of obs		265		
Censored obs		82		
Uncensored obs		183		
Wald chi2(9)		21,33		
Prob > chi2		0,011		
Log likelihood		-296,3996		

Table 5. Willingness to pay to avoid flooding on rice plot (Heckman selection model)

The coefficients on the explanatory variables show that the stated amount is consistent with economic logic. Households with access to liquidity and who perceive to suffer from flooding are willing to pay more. To further test for robustness, regressions were run without the selectivity coefficient and with the refusal to pay for sure as dependent variable. The coefficients obtained - but not reported - confirm the results discussed earlier.

We end this section with a final note on the significance of these results at the national level. There are two main differences of the surveyed farmers with the rest of the country. First, the watersheds in this area are small and sedimentation downstream can easy be linked to upstream activities. This is however not the case in the rest of Madagascar and the link between sedimentation downstream and corrective measures upstream are more difficult to make as watersheds are larger.[11] Second, the rice harvest in the Maroantsetra region is at the end of the year, i.e. before major cyclones hit the country. This might reduce the willingness to pay for a reduction of floods. In the rest of the country, the main harvest is in the beginning of the year and it might thus more directly be affected by rice losses due to floods and submersion. The run-off of good soils might then only affect the subsequent harvests.

Based on the data of the national household survey of 2001, it is found that 15% of agricultural households cultivate lowland, 21% upland and 64% both. This compares to respectively 25% and 75% of the households that we interviewed in the Maroantsetra area (because of the study subject, only rice farmers were selected). The majority of the households in Madagascar and in our dataset cultivate thus both uplands and lowlands and

[11] Brand et al. (2002) show how the size and the shape of watersheds are important determinants for run-off.

it seems that farmers that might cause erosion and those that suffer from it are often the same households.[12] This makes a compensation mechanism cumbersome.

Secondary sources of information further seem to indicate that siltation and erosion might be a relatively minor problem in Malagasy agriculture overall and this despite the high recent deforestation rates in Madagascar.[13] The 2001 national household survey asked farmers about the biggest constraints they faced to improved agricultural productivity. The same question was asked in the 2004 national household survey, based on a different sampling frame and with a bigger sample. Respondents had to rank options from 'not important' to 'very important'. The results are presented in Table 6 ordered in decreasing percentage of households that identified the constraint as 'quite' or 'very' important. Answers were strikingly consistent between the two surveys, three years apart and with a different sample. The most and least frequently cited constraints were common to both surveys. Access to agricultural equipment, access to cattle for traction and transport and access to labor are ranked among the top four constraints in both surveys. The clear pattern in these answers is that inputs that complement labor and boost its productivity are most limiting in farmers' opinion (Minten et al., 2007). By contrast, less than 40 percent of households identify the siltation of land as an important constraint and it is more commonly identified as not a constraint on agricultural productivity. Farmers were further asked for each plot in the national household survey of 2001 about the production problems in the year preceding the survey. Siltation was mentioned as a problem on less than 1% of the rice plots.

6. Conclusions

Flooding and sedimentation downstream are often linked to deforestation upstream. While the debate is on-going and results seem to be variable and site specific (Chomitz and Kumari, 1998; Calder, 1999), policy makers are looking for ways to solve this externality problem to ensure sustainable financing for ecological services of conservation efforts such as reforestation and soil conservation measures. Based on interviews with almost 300 rice farmers - users of land downstream - in the Northeast of Madagascar, this paper tries to shed light on the willingness to pay for ecological services for forests, in this case to avoid flooding and sedimentation.

The results of our analysis show that the rice farmers are clearly aware of the effect of sedimentation on production. Sedimentation is not perceived to be unambiguously bad for lowland productivity. Policy interventions that focus on only correcting the perceived negative relationship are therefore misguided. A hedonic pricing analysis on riceland

[12] Lowlands are further divided depending on the type of irrigation scheme. The World Bank (2005) estimates the total lowland area at 1.1 million hectares, representing 40% of the cultivated area. The bulk of these lowland areas, 800,000 hectares or 70 percent of the total irrigated lands, are very small in terms of average superficies (a few hectares), and are not equipped with improved irrigation infrastructure. 300,000 hectares is equipped with infrastructure meant to improve water management. Uplands can further be divided in uplands that are cultivated on a permanent basis and land that is cultivated for three to four years and is then followed by long fallow periods.

[13] It is estimated that Madagascar lost about 12 million ha of forest between 1960 and 2000, effectively reducing forest cover by 50% in just 40 years (World Bank, 2003).

values shows that farmers take sedimentation into consideration in the valuation of their rice plots but that rice plots with sedimentation are valued significantly higher, ceteris paribus.

	Percentage of households that state this constraint is … important			
Variables	**not**	**a bit**	**quite**	**very**
Constraints to overall agricultural productivity				
EPM 2001, 2470 agricultural households				
Access to agricultural equipment	19	18	27	35
Access to land	27	19	29	25
Access to cattle for traction and transport	24	23	29	24
Access to labor	22	28	30	20
Access to credit	36	19	23	22
Degradation of irrigation infrastructure due to environmental problems	29	31	22	18
Access to agricultural inputs (e.g. fertilizer)	34	26	19	21
Access to cattle for fertilizer	42	23	19	16
Land tenure insecurity	44	26	22	8
Silting of land	46	29	18	7
EPM 2004, 3543 agricultural households				
Access to agricultural equipment	11	14	32	43
Access to irrigation	13	21	29	37
Access to cattle for traction and transport	16	20	35	29
Access to labor	17	22	37	24
Avoid droughts	20	19	27	34
Access to agricultural inputs (e.g. fertilizer)	24	20	26	30
Phyto-sanitary diseases	19	25	30	26
Avoid flooding	25	20	26	29
Access to cattle for fertilizer	28	22	25	25
Access to credit	31	23	22	24
Silting of land	33	29	23	15
Land tenure insecurity	38	24	23	15

Table 6. Farm households' reported constraints on improved agricultural productivity

The results of the survey further show that, while 10% of the farmers believe that flooding and sedimentation has no effect, a significant part of the farmers (almost 40% of the rice farmers in the sample) feels that their plots actually benefit from flooding and sedimentation. This seems related to the fact that flooding occurs outside the main harvest period and thus therefore not seem to cause any large immediate production damage. Damage depends then on the type of deposits as flooding can actually cause valuable soils and organic material to be transported to the ricefield and to be beneficial for rice productivity. The negative or positive effect of flooding seems to depend on spatial determinants, i.e. location with respect to the main river that irrigates the rice fields matters.

However, a significant part of the farmers also realize the bad effects that sedimentation can have on their rice production. Therefore, they are willing to contribute to avoid flooding and sedimentation on their fields. These farmers are willing to contribute 4$ per household per year. The magnitude of the amount that they are willing to pay corresponds to spatial as well as economic rationales. Households that are richer, not credit constrained, and that suffer less from seasonality problems are willing to pay significantly more to avoid this flooding and sedimentation damage. Given beneficial effects of sedimentation for some farmers and small willingness to pay by other farmers, our results overall thus suggest that current economic rates of return on forest preservation projects in Madagascar, largely beneficial because of across-the-board domestic agricultural benefits on lowlands, might be overestimated.[14]

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[14] One caveat of the analysis is whether poor farmers' own high discount rates should be the basis for assessing the severity of this type of environmental problem or whether the perceived damage from society's perspective should be based on the much lower social discount rates. While this will change the overall end result, it can be expected, given positive and negative effects of sedimentation, that this is partly canceled out, no matter low or high discount rates. In any case, the objective of the analysis is not to do a full-blown cost-benefit analysis (in which case we would also have to value the loss of production on the uplands) but to show that some of the assumptions in the calculation of current economic rates of return might be questionable.

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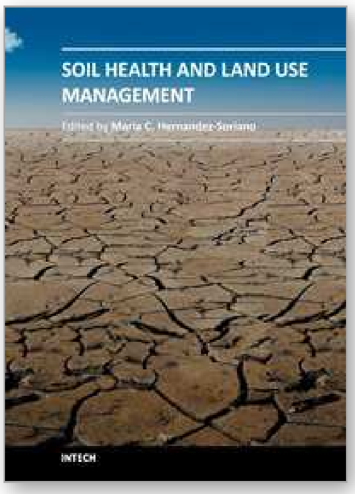

Soil Health and Land Use Management
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Soils play multiple roles in the quality of life throughout the world, not only as the resource for food production, but also as the support for our structures, the environment, the medium for waste disposal, water, and the storage of nutrients. A healthy soil can sustain biological productivity, maintain environmental quality, and promote plant and animal health. Understanding the impact of land management practices on soil properties and processes can provide useful indicators of economic and environmental sustainability. The sixteen chapters of this book orchestrate a multidisciplinary composition of current trends in soil health. Soil Health and Land Use Management provides a broad vision of the fundamental importance of soil health. In addition, the development of feasible management and remediation strategies to preserve and ameliorate the fitness of soils are discussed in this book. Strategies to improve land management and relevant case studies are covered, as well as the importance of characterizing soil properties to develop management and remediation strategies. Moreover, the current management of several environmental scenarios of high concern is presented, while the final chapters propose new methodologies for soil pollution assessment.

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