Poverty and Degradation: What is the Real Linkage? Evidence from Madagascar and the Sahel

T J Wyatt International Crop Research Institute for the Semi-Arid Tropics B.P. 12 404 Niamey, Niger

> (227) 72-25-29 (227) 75-43-29 (fax)

t.wyatt@cgiar.org

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Abstract

Poverty and resource degradation are closely linked in the minds of many policy makers and researchers. However, economics would suggest that poor households have as much or more incentive to engage in resource conservation as their wealthier neighbors. Differences might arise if the poor have higher discount rates or are unable to make necessary investments. This paper presents the results of two studies which show that resource poor farmers are still willing to forego immediate income and production in order to protect their soil resources. The means by which they accomplish this must be cost-effective however. Farmers in the Sahel continue to leave land in fallow, despite the loss in immediate production because soil amendments, particularly chemical fertilizer, are too expensive in relation to the benefits; not because the are too expensive. Farmers in Madagascar make investments in soil conservation if those investments provide sufficient returns. It is the availability of alternative investments, often open to wealthier households, that may detract from soil conservation.

The author is an Associate Scientist in the Socio-Economic and Policy Program, International Crop Research Institute for the Semi-Arid Tropics and is based in Niamey, Niger. Grateful appreciation is expressed to Jim Wilen, Garth Holloway, Niek van Duivenbooden, Odiaba Samaké, Jean-Pierre Tiendrébéogo and the other members of the DMP/ORU research teams. All errors, however, are the fault of the author alone.

Poverty and Degradation: Madagascar and the Sahel.

Poverty and Degradation: What is the Real Linkage?

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Introduction

Poverty and resource degradation have long been linked in the minds of policy-makers and researchers. Indeed, the linkage seems almost too obvious to be questioned. Low-income households will overuse their resources in an attempt to improve their living standards and, in the process, reduce their ability to meet future needs. One need only consider the recent 'greening' of North American and Western European countries where higher incomes have induced greater effort at improving the environment to see the reverse phenomenon. Moreover, the hypothesis appears to explain the degradation of many resources in developing countries.

Efforts in more developed countries, however, have focused on public goods such as clean air and water. Indeed, degradation of open access resources continues in areas such as fisheries, often in spite of regulations. In the management of communal resources, institutional arrangements seem to be more important than the division between the wealthy and the poor. When it comes to the management of private resources, there is also some doubt as to the impact of poverty. Economic theory suggests that agents maximize their utility over some time horizon. It is the future impact on income of immediate decisions which provides the incentive to maintain resources. Therefore, poor households can be expected to engage in resource conservation to the extent that is economically justified, just like their wealthier neighbors.

We seem to face a paradox. Households, rich and poor alike should be considering the future costs to current actions and yet we observe significant losses of soil nutrients from overuse and high rates of erosion. In the Sahel of West Africa, more key nutrients like nitrogen, phosphorus and potassium, are exported from farmers' fields than are returned through soil amendments or natural regeneration (Bationo, *et al.*, 1998). Sedimentation, largely from agricultural fields, is an astonishing 12 to 50 million tons of soil per year in each of the three major rivers of Madagascar (Helfert and Wood, 1986). Why do farmers appear to be degrading the land upon which they depend? Is poverty constraining conservation activities that they would otherwise wish to undertake?

To examine more closely the linkage between poverty and environmental degradation, this paper presents the results of two studies. The first study uses a mathematical programming model to examine the means by which farmers in Mali manage the fertility of their soils. Results indicate that chemical fertilizer is not economical given high transport costs and the low value of the output. Rather, farmers continue to rely on application of manure and on fallow. The second study is a statistical analysis of the decision to terrace hillside fields in the highlands of Madagascar to control soil erosion. It is found that access to other resources that

provide a greater return has a larger influence on the decision to terrace than does income.

The rest of the paper is organized as follows. We first consider theoretically the case of soil

fertility management through the use of inputs. The results are then illustrated using the results of the Malian study. We then consider the case of an investment in soil conservation and the impact of poverty on farmers ability to make such investments. Finally, a concluding section provides an interpretation of the results.

Soil Fertility Management

Theoretical considerations

Economic theory assumes that farm households maximize utility over a time horizon, which is essentially infinite as most households expect to pass on their assets to following generations. Where markets are functioning perfectly, consumption and production decisions can be separated (Singh, *et al.*, 1980). De Janvry, *et al.*, (1991) demonstrate that where markets are missing, exogenous prices are replaced by household shadow prices that are functions of parameters of the utility function. To simplify the modeling, we assume that farmers develop their expectations on the value of the output, including the likelihood of marketing a surplus or purchasing in case of a shortfall, before making their planting decisions. This assumption makes the model recursive and permits us to separate and focus on the production decisions.

Output is a function of inputs and soil quality, which evolves over time depending on the export of nutrients in the output and the restoration of nutrients through soil amendments or by natural processes. Thus, some inputs can have a beneficial impact on soil quality while others may be depleting through their effect on production. The farmer's problem is thus,

$$\max_{\mathbf{v}(t),\mathbf{x}(t)} \mathbf{J} = \int_{0}^{\infty} [\mathbf{E}[\mathbf{P}] \mathbf{Q}(t) - \mathbf{w} \mathbf{v}(t) - \mathbf{c}\mathbf{x}(t)] \, \mathrm{e}^{-\mathbf{r} t} \, \mathrm{d}t$$
$$\mathrm{s.t.} \mathbf{Q}(t) = \mathbf{f}(\mathbf{v}(t), \, \mathbf{x}(t), \, \mathbf{s}(t))$$
$$\mathrm{\dot{s}}(t) = \mathbf{g}(\mathbf{Q}(t), \, \mathbf{x}(t))$$

where E[P] is expected price, Q(t) is output in time t and is a function of inputs, v(t) and x(t), and of soil fertility, s(t), ? and c are input prices, ? is the discount rate, and \dot{s} is the rate of change of soil fertility, ds(t)/dt. Production is strictly concave in all inputs and increasing over the relevant range, *i.e.*, $f_i > 0$, $f_{ii} \le 0$, for all i = v, x, s, where subscript indicates partial derivative. The quality of the soil is decreasing (worsening) in output and increasing (improving) in the use of input x, which can be interpreted as soil amendments such as chemical or organic fertilizer. Input v does not directly influence soil fertility, but contributes to yields. For simplicity, let us consider v as labor and that the technology is Leontieff so that $v(t) = \overline{v}$.

The Hamiltonian of problem (1) is

$$= E[P] f(\overline{v}, x, s) - w\overline{v} - cx + l g(f(\overline{v}, x, s), x)$$

where ? is the co-state variable and is interpreted as the opportunity cost of the soil. The firstorder necessary conditions for a maximum are

$$\frac{\partial_{-}}{\partial x} = \mathbf{E}[\mathbf{P}] \mathbf{f}_{x} - \mathbf{c} + \mathbf{I}[\mathbf{g}_{Q} \mathbf{f}_{x} + \mathbf{g}_{x}] = 0$$
$$\frac{\partial_{-}}{\partial s} = \mathbf{E}[\mathbf{P}] \mathbf{f}_{s} + \mathbf{I} \mathbf{g}_{Q} \mathbf{f}_{s} = \mathbf{r}\mathbf{I} - \mathbf{I}$$

(Seierstad and Sydeaeter, 1987). Let s* denote the steady-state where $\dot{s} = \dot{I} = 0$. We can

then examine the impact of the parameters of the problem on the steady-state level of soil fertility to determine the impact of poverty. Under the assumption that $f_xg_Q + g_x \ge 0$ in the region around the steady-state, which implies that the use of input x at least counteracts the impact on soil quality of the additional production due to input x, the following qualitative responses characterize the farmer's problem.

$$\frac{\partial s^{*}}{\partial E[P]} = \frac{\mathbf{r} f_{x} + f_{s} g_{x}}{f_{s} g_{Q} - \mathbf{r}} / \sum_{xs} > 0$$
$$\frac{\partial s^{*}}{\partial c} = 1 / \sum_{xs} < 0$$
$$\frac{\partial s^{*}}{\partial r} = \frac{E[P] f_{s} (f_{x} g_{Q} + g_{x})}{(f_{s} g_{Q} - \mathbf{r})^{2}} / \sum_{xs} < 0$$

that is, the steady-state level of soil fertility responds positively to increases in the expected value of the output and negatively to increases in the cost of the fertility-enhancing input and the discount rate.

It is not immediately obvious how these factors relate poverty to land degradation. If lowincome households are more likely to be self-sufficient in or net purchasers of the staples they also produce, rather than net sellers, they may place a higher value on their own output. This would imply that poorer households are more likely to maintain soil fertility for future production than net sellers, who may be wealthier. This supports the results of Pagiola (1995) who showed that subsistence households were more likely to conserve their resources than households with alternatives to agriculture. On the other hand, low-income households are thought to have higher discount rates as their focus is on immediate survival. In that case, poorer households are likely to degrade their soils to a greater extent than wealthier households. The difficulty is that such relationships between household characteristics do not necessarily hold. Wealthy households may not rely solely on agriculture and may therefore be net buyers. The household discount rate is likely to be a function of multiple factors, among which is the opportunity for alternative investments. This suggests the need for an empirical examination of how these multiple factors contribute to land use decisions.

Fertilizer Use in the Malian Sahel

Rainfall in the West African Sahel is low and highly variable, but agronomic studies suggest that low soil fertility is the primary limiting factor to agricultural production (van Keulen and Bremen, 1990). Farmers have traditionally used two methods for maintaining soil fertility: fallow and the application of manure. Increasing population pressure has led to a decrease in the fallow period and the extensive grazing practices make collection of sufficient fertilizer difficult (Tiendrébéogo, 1999). Inorganic fertilizer, including imported chemical fertilizer, appears to be the best means of maintaining the nutrient balance while increasing crop yields (Bationo, *et al.*, 1998). Use of inorganic fertilizer is extremely low, however, especially since the devaluation of the franc CFA in 1993. One common hypothesis for this is that farmers lack the necessary capital to purchase fertilizers; in other words, poverty constrains farmers from using the appropriate input.

This section presents the results of a whole village, non-linear programming model of a typical

Sahel environment to examine the factors that influence farmers' decision regarding soil fertility management. The major difference between this model over previous efforts (Shapiro and Sanders, 1998; Coulibaly, *et al.*, 1998) is that decisions regarding the crop and livestock systems are not separated. Manure is an important input into crop production and depends on the number of animals and the management of the herd. Stocking rates and management depend on forage availability, particularly crop residues. The two systems also compete for the same resources, especially land and family labor. Cash investments will therefore flow to the activity with the highest return, not merely a positive return. Sales of livestock to fund purchases of monetary inputs, for example, must weigh future losses in terms of meat, milk and manure production against the benefits of increased grain and fodder production. In addition, the marketing system is modeled in some detail to account for the burden of transport that falls upon the producer to obtain inputs or to bring his or her produce to market.

The primary source of data for the model is a multi-scale land-use characterization carried out as part of a project to develop a multi-scale decision support system for policy analysis (DMP, 1997). The system will cover household, village and district levels. The data consists of detailed biophysical descriptions, including soil types distinguished by local cultivators, production systems and socioeconomic information. The key village for this analysis is Lagassagou, situated in the north of Mali between the Niger river and the border of Burkina Faso.

The village is located on a sandy plain in an important millet-producing region. Millet is the

main staple, grown both for home consumption and for sale. Groundnuts and cowpea are the main cash crop and their residue is valued as livestock feed. Sorghum, fonio, bambara groundnut and sorrel are minor crops. The cropping season begins in June or July with the onset of the rainy season. The main input into the production system is labor. The timing of different cropping activities varies somewhat by crop. Other inputs are manure, crop residues, chemical fertilizer and pesticide. The most common fertilizers are mixtures of nitrogen, phosphorus and potassium (NPK), but the exact type and quality are highly variable. Few farmers use chemical fertilizer on their fields; only 102 kg were used in the entire village in 1998 (Samaké, *et al.*, 1998).

Soils are fairly uniform in terms of physical characteristics (Samaké, *et al.*, 1998). Fields are distinguished by distance from the village. *Lara* fields are close to the household while fields far from the village are called *baracoum*. The distance increases labor time for agricultural activities, particularly for the application of organic material. Animals are usually kept near the household compound at night and manure is deposited directly on the fields. To apply significant quantities of manure to the *baracoum* requires collecting the manure from around the compound and transporting it to the fields. For this reason, the generally observed pattern is that the *lara* is cultivated almost continually while fields in the *baracoum* are periodically left fallow.

The model maximizes net village revenue which is divided between 33 production units grouped into three categories based on land holdings and household population. Consumption

requirements are specified for cereal and dairy products, allowing for substitutability between grains (millet, sorghum, fonio and cowpea) and between types of milk (cow and goat). Table 1 shows household and village requirements and resources. Production functions are generated based on on-station and on-farm trials conducted by local scientists. Because farmers may lack complementary inputs and access to the same fertilizers as researchers, yield responses to fertilizer were reduced by 20%.

Soil fertility is measured as an index ranging from 1 to 100 and includes measures such as nutrient content and organic matter. Yields are a logarithmic function of soil fertility. The export of nutrients in harvested material reduces nutrients in the following year. Except for pesticide, inputs restore nutrients to the soil as well as having a positive impact on yields but with differential effects. Fertility can also be restored by means of fallow. The model solves the yield and soil fertility equations simultaneously to determine the level of soil fertility that would be maintained in the steady state. Results are shown in Table 2.

These results are tentative. A better calibrated model is currently in operation, but these results are quite indicative. According to the model, all the production units engage in groundnut cultivation, with only a small amount of land cultivated in millet. The households sell the groundnuts and purchase their food supplies. This is due to a misspecification in the livestock market which allows households to restock each year. Thus the households largely engage in feeding out cattle on existing range and forage, purchasing new stock every year and selling off following a period of fattening. The problem is that such stock for fattening is

unavailable, particularly if everyone in the village engages in the same activity. It also explains some of the extra value placed on groundnut production; it is valued as a source of fodder. It may be that the model is overoptimistic in expected groundnut yields. While yields can often be spectacular, groundnuts are also quite sensitive to drought and are therefore a risky crop.

The wealthiest household, in terms of income per capita, is the production unit A, which also has the most land and labor resources. Producer B has the lowest per capita income, though nearly as much land as A, with C, the smallest household in the middle. If the poverty hypothesis is correct, B should face the most difficult time in maintaining soil fertility and this is, in fact, correct. In both the fields closest to the village, the *lara*, and the out-lying fields, the *baracoum*, Household B maintains their fields at a lower steady-state level of fertility than either of the other households. However, there is not a clear cut distinction between the other households. Though C is closer to B in terms of income per capita and is the poorest household in terms of land holdings, they maintain their *lara* fields at a much higher level than does Household A. The *baracoum* fields are less fertile than are A's, but the difference in these outlying fields is slight.

What is interesting is the methods by which these households maintain the fertility of their soils. Household C, although poorest in terms of land area, relies totally on the use of fallow, rather than soil amendments. Like the other production units, C engages in livestock production, but theirs is exclusively a transhumance system of entrusting their cattle to professional herders. This precludes the collection of manure. While the reliance on fallow could indicate that low

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income is constraining their use of purchased or otherwise costly inputs, it also indicates a willingness to forego immediate production in order to maintain productive capacity in the future. In fact, all the production units rely to some extent on fallow, with only limited use of manure. Fertilizer use is non-existent. The problem is not lack of resources with which to make purchase, but the fact that it is not economically feasible given the value of the output and the cost of the fertilizer. The major component of cost is transportation, which can add a third to the effective price that farmers face.

Investments in Soil Conservation

Let us now consider an issue that most closely concerns the poverty and resource degradation link. Conventional wisdom suggests that poorer households lack the financial capacity to undertake investments in resource conservation. This is not addressed in problem (1) where the technology, a fertility-enhancing input, is easily divisible. Technologies that have large fixed costs or are not divisible may lead to different results. Terraces to control erosion is one such technology. In this case, the question is not how much of an input to use in every time period, but whether to install the terraces¹. The decision would normally be based on an analysis of net present value (NPV).

Let output be a function of conventional inputs, terraces, and soil depth, Q = f(v, x, s), where x now represents the presence of terraces ($x_0 = 0$). The function *f* is increasing in v and s, but decreasing in x, since terraces reduce the area of cultivation and may increase labor

requirements (*e.g.*, for maintenance). Soil erodes away at an average annual rate of g = g(a, x) where a denotes fixed topographical or climatic features such as slope and $g_a > 0$. The NPV of the investment is the difference in the income stream obtained from the field with the terraces in place less the cost of investment and the income stream from the field without terraces. Let us assume that the investment entails the construction of terraces <u>x</u> such that $g(a, \underline{x}) = 0$ at a cost of I(a, d) where a determines construction costs and d represents non-construction or fixed costs; $I_a > 0$ and $I_d > 0$. Therefore,

$$NPV = \int_{0}^{\infty} \left[PQ(\overline{v}, \overline{x}, s_{0}) - \overline{wv} \right] e^{-rt} dt - I(\mathbf{a}, \mathbf{d})$$
$$- \int_{0}^{\infty} \left[PQ(v(t), x_{0}, s(t)) - \overline{wv}(t) \right] e^{-rt} dt$$

 $s.t.s(t) = s_0 - t g(\mathbf{a}, x)$

where P is the expected price of the output, s_0 is the initial soil depth, \underline{v} is the optimal input level in the presence of terraces and v(t) is chosen optimally in the absence of terraces and declining soil depth, that is, the farmer may be able to offset the impact of erosion with additional inputs. For a given field, if the NPV of terraces were greater than zero, we would expect to see farmers constructing the terraces, if they were not already present.

The probability of observing an investment in terraces, given that NPV > 0, may depend on other factors, however, including measures of wealth or poverty. That is,

$$Prob[T = 1 | NPV > 0] = f(Z)$$

where Z is a vector of household and field characteristics. In particular, if an outside observer calculated the NPV based on some constant discount rate across household and fields, Z might include such direct influences as the size of the investment and the accessibility of credit

as well as factors that influence the household's individual discount rate including wealth, alternative investment opportunities and the security of the land tenure. If poverty is an important factor, we would expect the size of the investment and other measures of wealth to have a significant influence on the decision.

Investments by Malagasy farmers

In this section we examine the impact of various measures of wealth on the decision of farmers in the highlands of Madagascar to terrace their hillside fields. Data for this estimation comes from detailed household and plot surveys in four areas in the province of Antananarivo, near the escarpment that parallels the east coast of the island (Wyatt, 1998). The agricultural system is primarily rainfed. Rice is the main staple and is grown in lowland valleys under flood irrigation. Hillsides are cultivated in cassava, maize, beans and sweet potato. The area is characterized by sharp relief and intense rainfall which contributes to a dramatic rate of erosion that can be as high as 250 kg/ha/year (Randrianarijaona, 1983).

Estimation of the decision to install terraces is based on 130 different households with 415 fields, 131 of which were recently terraced. Fields terraced more than five years previously are not included as price expectations could have changed in the intervening period. Most terraces were constructed within the past three years. Older terraces often dated to the colonial period; few terraces were constructed during the 1970s or 1980s. Field-level data include topographical features that influence erosion, soil depth, type of crop cultivated, inputs used, and the tenure regime. Household data include demographic variables, crop sales and

purchases along with the price received or paid, and income from other activities.

Profit functions were estimated as a function of household-specific prices and physical features of the field. The long-term annual erosion rate was estimated for each field given the slope and length. Future profits were calculated given the impact of soil depth on profits and the erosion rate. Labor is the primary input into the construction of terraces. Labor time was estimated as a function of field size and the slope to obtain installation costs. From these components, the NPV of terraces on each field was calculated (Wyatt, 1998). Given a discount rate of 25%, the calculations indicate that about 76% of the fields in the sample have a positive NPV to an investment in terraces. Of these, farmers have terraced approximately 35% of the fields. Of the remaining 24%, which reported a negative NPV, 27.5% had been terraced (Wyatt, 1998).

The presence of terraces on a field is explained by the imputed value of the terraces and other field and household specific variables to determine the impact, if any, of poverty on farmers' decision to engage in soil conservation. Field specific variables are the calculated NPV, the cost of construction and the tenure regime. Summary statistics for these field specific variables are shown in Table 3. The tenure regimes consist of titled land, land privately owned under traditional regulations, land owned by a parent and land owned by the extended family. Land in the latter category can be reallocated to other family members as needs arise. Household-level variables include demographic variables, non-crop income and other asset holdings. Summary statistics for these variables are shown in Table 4.

The decision to install terraces is estimated as a probit where the dependent variable takes on a value of one if the field was terraced and zero otherwise. The marginal effect of the explanatory variables, calculated at the sample mean, are shown in Table 5. The results are instructive. Certainly the economic rationale of soil conservation is demonstrated. An increase of 1000 malagasy francs (Fmg) - about US\$0.25 or half the daily wage rate - in the value of the terraces increases the probability of investment by almost two-tenths of one percent and is highly significant.

On the other hand, the impact of poverty is not clear. Construction costs do not appear to be a major constraint to Malagasy farmers' decision to invest in terraces. Indeed, construction costs are positively related to the presence of terraces. This relationship probably stems from two causes. Construction costs were estimated as a function of the amount of labor required to build the terraces and they are positively related to the size of the field and its slope. Steeper slopes are more vulnerable to erosion, not merely on average but also to sudden, extreme losses. Thus, farmers may be motivated by risk to preferentially terrace steeper fields, everything else being equal. Second, if there are fixed costs associated with construction, including organizing a work party, the preference might be given to larger fields. The positive coefficient on the number of men in the family indicates that a pool of labor from which to draw is important and may also indicate a lower opportunity cost of labor.

While the positive sign on construction costs tends to discount the importance of liquidity

constraints impeding soil conservation, the positive signs on both non-crop income and credit activity suggest that households need alternative sources of income in order to finance agricultural investments. Credit in particular has a major influence, despite the fact that the majority of these loans are small, of short duration and primarily for consumption. Most are informal loans between family and friends and carry no interest. The importance of credit, however, indicates that institutional arrangements may be as or more important influence on natural resource management than the level of poverty per se.

The coefficients on other wealth-indicators point to the ambiguous role played by poverty. Family size is negatively associated with terracing, everything else equal, which certainly lends credence to the theory that the poor must sacrifice their resources in order to support immediate consumption needs. The total amount of land controlled by the household, holding the amount of low land constant, has a significant and positive impact on terracing. This does not explain whether it is the additional asset that makes the investment possible, or if it indicates an emphasis by the household on agriculture that increases the incentive to invest in soil conservation.

Other variables indicate that it is the incentive effect that dominates. Low land, which is used to produce rice, has a negative and very significant impact on investments on hillside fields.

The education level of the household head has a similarly negative and significant effect. These results suggest that households with alternative investment options, including rice production or skilled labor, and which therefore rely less on hillside production, may be the ones who fail to make what seem to be profitable land-improving investment. Alternative investments with a higher return increase the opportunity cost of capital and deter soil conservation investments.

While not directly linked to poverty, insecure land tenure is often associated with poorer households and it is often assumed that government titling programs would provide greater incentives to make improvements such as soil conservation measures. In this area of Madagascar, at least, land tenure does not seem to be an important issue. This analysis shows that the traditional land tenure system is at least as effective in providing incentives as government title. Titled land is, in fact, less likely to be terraced than private ownership without title (the default category), however this results must be interpreted with caution. Less than five percent of the sample fields were characterized as titled and all came from an area where farmers appeared to prefer agroforestry techniques to control erosion. More striking is the fact that land owned by the extended family is more likely to be terraced than private holdings. This may partly due to the fact that land improvement can be the basis of transferring rights from the family to the individual (personal communication). Thus, an expensive land titling program may prove to be ineffective in increasing investments, despite large costs and potential political problems.

V. Conclusions

The concerns over the impact of poverty on farmers' decisions regarding the use and misuse of their personal resources makes intuitive sense. When faced with a choice between immediate needs and long term benefits, it seems clear that the immediate needs would take priority. Economic theory, however, would say that only where the two are mutually exclusive, implying that there does not exist technology that is both agronomically sustainable and economically feasible, would the decisions on the part of low-income households differ from those of wealthier households. Rather, both groups would weigh the trade-off between the needs of the present and the future.

The studies presented here have shown that poverty is not without some influence on decisions regarding soil fertility management and soil conservation. That influence, however, is limited and seems to be as much a factor of the institutional arrangements and infrastructure than of poverty itself. Farmers in the Sahel of Mali do not use soil amendments to a great extent, mainly because of the high cost of the input. Imported fertilizer is costly, especially since the devaluation of the franc CFA, but it is the transport costs borne by the farmer, because of limited infrastructure that would permit easy market access, that appear to make the difference. However, we do observe farmers using local organic material, including manure from their livestock, to maintain fertility. Fallow, despite the immediate loss in production that comes from taking land out of production, continues to be practiced. Farmers may not maintain their soils at the maximum level of fertility possible, but there are not large differences between the practices of resource-poor households and the resource-rich.

Even making investments in soil conservation, which would seem to be subject to farmers' ability to generate sufficient resources, does not prove to be influenced to a great extent by the

wealth of the household. It is somewhat surprising how resourceful low-income households can be in arranging needed investments. The informal credit market, which is often used just to overcome consumption needs in the very short term, has been shown to have a significant influence on the decision of farmers to construct terraces. Again, institutional arrangements seem more important than the status of the household itself. In fact, poor households seem to be as willing if not more willing to undertake needed investments. The major influence on the discount rate with which households evaluate their investment options seems to be alternative investments, rather than consumption.

This is not to say that poor households do not have a difficult time of maintaining their resource base, nor to say that they are not under constant pressure to take what they can in the short term. But this is as much a reaction to the difficulty of agriculture in general and the continuing demographic shift toward urban areas, that is alternative investments, than it is poverty itself. There is every reason to think that focusing attention on enabling rural financial institutions to function smoothly, investing in infrastructure and implementing policies that are supporting of market growth and wise use of resources in general, will assist not just poor farmers, but their wealthy neighbors as well, to respond to the incentives already in place to plan for the future.

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Production units	(A)	(B)	(C)	Village
Number	15	12	6	33
Population	39	10	5	735
Monthly food requirements				
cereal (kg)	585	150	75	11,025
milk (l)	19.5	5.0	2.5	367.5
Resources				
labor (persons)				
men	7	2	1	135
women	8	2	1	150
boys	6	1	1	108
land (ha)				
lara	3.0	2.9	1.0	85.8
baracoum	16.7	12.0	3.9	417.9
total	19.7	14.9	4.9	503.7

Table 1. Household and village requirements and resources, Lagassagou, Mali.

Production units	(A)	(B)	(C)	Village
income per capita (\$USD)	1188	860	940	1124
lara				
groundnut (ha)	2.1	1.9	0.6	57.9
manure (ton/ha)	2.8	1.7	0.0	
fallow (ha)	0.9	1.0	0.4	27.9
percent	30.0	34.5	40.0	32.5
fertility index	70.1	67.2	86.5	
baracoum				
millet (ha)	0.0	0.0	0.3	1.8
groundnut (ha)	10.7	7.6	0.9	257.1
fallow (ha)	6.0	4.5	1.4	152.4
percent	35.9	54.0	35.9	36.5
fertility index	69.5	65.6	67.5	

Table 2. Results of village programming model, Lagassagou, Mali.

Table 3. Summary statistics of field specific variables, Madagascar.

Variable	mean	standard deviation
terraced $(1 = yes)$	33.25%	
value ¹ (1000 Fmg ²)	27.50	48.28
construction costs (1000 Fmg ²)	36.16	33.87
titled	4.10%	
household-owned ³	69.9%	
parent-owned	3.6%	
extended family ownership	22.4%	
n = 415		

¹Value is calculated as the net present value of immediate investment (discounted value of future production with no change in soil depth less construction costs) minus the net present value of not investing (discounted value of production given continued erosion).

²Franc malagasy. The exchange rate in 1996, when the data was collected was approximately 4000 Fmg to US\$1.00.

³Traditionally recognized tenure, but without official government documents.

Variable	mean	standard deviation
gender of household head (female = 1)	4.6%	
age of head (years)	45.3	13.1
education of head (years)	4.47	3.16
family size (persons)	6.15	2.73
men	2.03	1.23
non-crop income ¹ (millions of Fmg)	0.706	0.692
credit $access^2$ (participation = 1)	48.9%	
low land (ha)	0.598	0.920
cultivated hillside land	0.769	0.696
total land	2.153	2.746
conservation group ³ (member = 1)	58.9%	
n = 130		

Table 4. Summary statistics of household specific variables, Madagascar.

¹Non-crop income was estimated as a function of household human and physical assets and the predicted values was used in the estimation. ²Credit access was assumed if the household obtained money or loaned money from any source. Formal loans are rare, but informal networks are common.

³Several non-governmental organizations with a focus on natural resource management are active in the area. Terraces are not a specific target of any of these groups, however.

Variable	marginal effect	t-statistic
constant	-0.4198	-2.816
value of terrace (1000 Fmg)	0.0016	2.505
construction costs (1000 Fmg)	0.0031	3.138
gender of head (female = 1)	-0.0046	-0.041
age of head	-0.0002	-0.066
education of head	-0.0355	-2.071
men	0.0714	2.495
family size	-0.0223	-1.685
non-crop income (million Fmg)	0.0853	1.646
credit participation (yes = 1)	0.977	1.867
low land	-0.2117	-3.185
cultivated hillside land	-0.0406	-0.832
total land	0.0344	2.310
group membership (yes = 1)	0.2317	4.239
titled land	-0.5219	-2.809

Table 5. Marginal effects on the decision to terrace.

parent-owned	0.0344	0.244
extended family ownership	0.1377	2.090

n = 415

correct predictions = 73.7%

observations at one = 138

McFadden's $R^2 = 0.1572$

^{1.} In fact, the decision is *when* to make the investment. Farmers always have the option of investing at a later time in they choose not to do so immediately. Under certain conditions, it may be optimal to wait, even though the NPV is greater than zero. Simply put, it may be better to defray the costs it current benefits are small due to sufficient soil depth (Wyatt, 1998).