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On Land and Labor Productivity
On Rice in Madagascar Highland

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Pierre Jean Claude Randrianarisoa

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**THE EFFECTS OF LAND QUALITY AND NATURAL SHOCKS
ON LAND AND LABOR PRODUCTIVITY
ON RICE IN MADAGASCAR HIGHLAND**

by

Pierre Jean Claude Randrianarisoa

A THESIS

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ABSTRACT

THE EFFECTS OF LAND QUALITY AND NATURAL SHOCKS ON LAND AND LABOR PRODUCTIVITY ON RICE IN MADAGASCAR HIGHLAND

By

Pierre Jean Claude Randrianarisoa

Despite economic reforms towards a more liberalized market, rice land and labor productivity remain low in Madagascar Highland. The purpose of this paper is to address the importance of the effects of land quality and natural shocks on land and labor productivity, and to explore the implication for agricultural policy actions.

Using data from 563 rice plots, the study finds that: (a) land quality and natural shocks do influence rice production in Madagascar and their omission in modeling efforts leads to a bias of the marginal effects of land, labor, and other factors; (b) return to land and labor varies across smallholder farms of different size. Smallholder farms of all size have low family labor productivity, and only medium and larger smallholder farms find interesting profit in using hired labor; and (c) improvement in Rice Seedling Transplantation seems to be a way to overcome bad land quality and to reduce production vulnerability from exogenous natural shocks. However, its negative effect on the return to labor seems to explain farmer's reluctance to adopt this technique.

Major implications to draw from this study the necessity are to include land quality and exogenous natural shocks in agricultural production analysis in developing countries. Also, one should look at the way to improve the return to labor as land productivity increases, for example, the use of mechanical small tools or the use of animal traction or a better allocation of family labor in order to increase its return.

To Tojo, Rojo, and Oly,

To my beloved father,

To my mother,

“Ny hazo no vanon-ko lakana, ny tany naniriany no tsara”.

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Introduction

During the last decades, the use of modern inputs and adoption of different new technologies were thought to be available to boost agricultural production in Sub-Saharan African countries. Experience from the Green Revolution in Eastern Asia was usually taken as an example of the successful effects of this kind of intensification on agricultural productivity. However, many African countries failed to attain the expected results. The case of rice in Madagascar falls under this situation. Agricultural land and labor productivity remain low, and adoption of new technologies is disappointing despite economic reforms towards a more liberalized market and a reduction of institutional constraints facing the agricultural sector (Minten et al, 2000; UPDR, 2000; USDA, 1999)

A better understanding of the return to inputs from rice production at the farm level is crucial to address agricultural policy adjustments. One needs to identify what factors of production offer the highest marginal returns to land and labor, on which agricultural development policy might thus focus.

Usually, researchers use inputs and conditioner variables to assess the determinants of agricultural production. Land quality and natural shocks are sometimes overlooked, with the assumption that farmers are facing homogenous land characteristics and the same production risks. Thus, farmer's decisions are independent from these exogenous factors (Kelly et al, 1996; Frisvold, 1994; Bernier and Dorosh, 1993; Tshibaka, 1989; Hossain, 1988).

In reality, farmer's choice variables are likely to be correlated with land quality, hence a mutation of the parameter estimates of the variable inputs. Consequently the

effects of variable inputs on agricultural production partially depend on the characteristics of land quality.

Moreover, the magnitude of natural shocks during the agricultural season affects also output level (Sherlund et al, 2001; Reardon et al, 1996). It was shown for example that annual change in rainfall, which caused drought or flood, leads to a different level of production. This paper will then examine whether omitting land quality and natural shocks in the estimation of the production function will lead to a bias in the importance of the effects of common farmer's choice variables on agricultural production.

It is also important to know to what extent there are different returns among different farm size of smallholders. Can such results help to better understand the low rate of adoption of chemical fertilizer or adoption of improved production technology on rice production in Madagascar? Consequently, the objective of this paper is to give decision-maker additional information in order to better identify policy interventions that might foster greater uptake.

These kinds of research can be addressed by the analysis of the production function relating the use of physical inputs with output. We will use rice data from households in Madagascar highland for the analysis. Our analytical method is based on econometric models that explain observed production, as a function of biophysical characteristics of land units, exogenous natural shocks, farmer's choice, and some conditioner variables.

We have opted to use the primal approach¹ for the analysis because of the following reasons. First, there is the difficulty to assess the relationship between market

¹ The primal approach here involves a maximization of an objective function (production) subject to physical constraints such as land, labor, capital, and other exogenous variables.

prices and smallholder's production decision especially in the case of developing countries. A second point is that with a cross-section data, prices have less variation than the volume of inputs, and this would provide less variability in the sample. Lastly, as farmers make decisions on input uses prior to realization of either output or output prices, these latter variables are almost surely not the ones over which farmers made their input decision.

For the organization of the report, we first present the rice situation in Madagascar, the analytical framework, the estimation method, and data explanation. Next we will demonstrate that the hypothesis of non-neutral impact of land quality and natural shocks holds for rice production in Madagascar highland. By the analysis of marginal products, we will show that omitting land quality and exogenous shocks in the analysis of agricultural production can mislead agricultural policy decisions. Then we will look at the differences in marginal value product by smallholder farm size, and draw some policy implications. And last, we will identify the farmer's decisions that result in highest land and labor marginal return under different land quality and natural shocks conditions.

1. Rice in Madagascar

1.1. Country Background

Agriculture represents 30 percent of Madagascar's Gross Domestic Production (GDP) while almost 78 percent of the total active population gets a livelihood out of it. Rice is the staple food and it occupies more than the half of total cultivated land. Its contribution to agricultural GDP is around 43 percent (UPDR, 2000, World Bank, 1998). Because rice is such an important staple food crop, it has long been central to any development strategy. Over the years, every government has implemented agricultural policies designed to encourage output increases.

The majority of rice production and thus marketed rice comes from smallholders. Large farms of more than 50 hectares represents less than 0.05 percent of total farms (SMTIS, 1989). Growing rice is part of the "cultural identity" of the rural community, as 92 percent of farmers are involved in rice cultivation. However, the average cultivated rice area per household among smallholders is only 0.8 hectare with important inter- and intra-regional differences. For example, in the North West and in the Lac Alaotra region, the average rice area per household exceeds 150 ares while in the Vakinankaratra and Fianarantsoa highland regions², it is only around 50 ares per household (SMTIS, 1989). The same study reports also a high intra-regional variability, with a coefficient of variation more than 100 percent on cultivated area of rice.

With only an average of 1.2 percent increase per year during the last 25 years, rice production is experiencing very little improvement, and is lagging far behind population

² The Vakinankaratra and Fianarantsoa highland regions are our study area.

growth³ (Minten et al, 2000; Roubaud, 1997; IFPRI, 1997). A liberalized economy and privatized market and production systems have not yet caused substantial changes to this trend. Findings from an IFPRI (1997) study showed that market reforms were still not enough to cause increases in rice production, and it was estimated that land and labor productivity in rice production remain low (UPDR, 2000; USDA, 1999).

Traditionally, rice is grown on narrow depressions ("bas-fonds") in lowland locations or on fields in terraces on the slope of hills. Besides these traditional rice fields, there are also some modern irrigated perimeters in flat areas. Natural exogenous shocks are frequent as illustrated by the incidences of numerous cyclones every year. These affect rice production seriously through the risk of long inundations⁴.

Rice is generally transplanted in Madagascar highland where the present study is focused. Direct seeding and "slash and burn" are rare. In the early 90's, a new technology "*Système de Riziculture Intensive*" (SRI) was promoted by extension services and various NGOs. This is a very labor intensive technology, which requires an almost permanent management of the rice field. It is based, among others, on (i) the use of young plants of 8 to 15 days for transplanting, (ii) several weeding cycles, i.e. from 3 to 4 times, (iii) a square transplantation allowing the use of small tools for weeding; and (iv) intensive water management practices by farmers. The SRI technology does not require the use of specific or improved rice varieties nor any fertilizer application. Expected yield are very high, reaching 12 to 18 tons per hectare⁵. Given farmer's difficulties for meeting all the required conditions for a complete SRI technology package, extension services started to

³ Madagascar demographic growth rate is 2.8 percent per year.

⁴ Inundation is defined as an entirely flooded plot during a few days that will affect negatively rice production.

⁵ This is an extrapolated yield from small plots. Moreover, in most of the cases, the average area cultivated with the SRI technology is below 10 ares.

recommend a less labor-intensive technology called “*Système de Riziculture Améliorée*” (SRA). This consists of using one or two parts of SRI, such as rice seedling transplantation along more traditional use of organic or mineral fertilizers. In this study, we will use the “*Improved Rice Seedling Transplantation*” (IRST) as the improved technology. This is the innovation related to SRI and SRA that farmers mostly retained.

1.2. Prior Studies on Rice Productivity in Madagascar

Using farm-level data, Bernier and Dorosh (1993) observed an average yield of 17.7 kg per are in the highland among smallholders⁶. They found that chemical fertilizer affects positively rice production in Madagascar with a marginal physical return of 6.2 kg of paddy for one additional kg of fertilizer at 90 kg per hectare average rate of application. However, the limitation of this study is that the region boundary does not follow the agro-ecological zones in Madagascar, leading to a higher variability in the sample, specifically for the highland region. Actually, the highland agro-ecological zone is a mountainous area situated above 1,000 meters of altitude. Average farm size is small. The Lac Alaotra area is part of the Middle East agro-ecological zone, situated in a lower altitude of less than 800 meters, and characterized by the dominance of larger farms established in some large irrigated perimeter. While the highland area is deficient in rice, the Lac Alaotra is surplus and is the primary rice supplier for the country. Another important drawback is the neglect of land quality and natural shocks in the analysis that might lead to a bias on the effect of input variables on productivity.

⁶ This yield corresponds to the category small farms in Plateau Central area in the Bernier and Dorosh Study.

A second set of analyses, particularly focused on the impact of market reform on agricultural productivity, showing that farmers who have the opportunity to increase their landholding are likely to have less incentive to intensify rice production (Zeller et al, 2000). Their yield is lower than the average farm in the area. First, farmer might apply less input per land unit when cultivated area increases, thus resulting in lower productivity. Second is that land quality may differ between existing plots and new additional plots, leading to a productivity difference. Without considering land quality and natural shocks, one can attribute the change in productivity to only the change in input use, which might be misleading. In their study in Brazil, Nerlove and Vosti (1996) found similar results. Application of the "Green Revolution" technical packages in marginal land resulted in lower increases associated with higher variances in the yield compared to the same technology applied on high-potential land.

Using a recursive model⁷, Minten et al (2000) found that input expenditures affect positively rice production. Irrigation, which is one variable used to control for land quality, had a significant and positive effect on production, but its magnitude was relatively low. Irrigation only contributed up to a 7 percent increase in yield.

Also, the effect of extension service and higher education were found to be insignificant. The advantage of this study is the introduction of land quality and natural shocks in the analysis, although they acknowledged that there were not enough variables that would control for these factors. Land quality was represented by irrigation and land prices while two indexes of climatic and disease risks were used to control for natural shocks.

⁷ The recursive model consists in considering cultivated land, input expenditures, and yield as endogenous in a system of regression equations.

However, the limitation of the Minten et al (2000) study is that the use of aggregation in input expenditures does not permit identifying the individual effect of each input on rice production. For example, one cannot observe the difference between the return from the use of chemical fertilizer from hired labor use. Also for the econometric estimation, the functional form used (Cobb-Douglas) precludes the analysis of the interaction terms between pair of variables separately.

The current study tries to improve the estimation of the effect of inputs on rice productivity by considering land quality and natural shocks variables, combined with the use of flexible functional form.

2. Analytical Framework, Estimation Method, and Research Design

2.1. Analytical Framework

The production function represents the physical relationship between inputs and output. Farmers are assumed to maximize production subject to constraints on land, labor, capital availability, and technology.

The level of production y might be affected:

- (1) by farmer's decision -- choice variables -- in determining the quantity of available labor, land, and capital allocated to each plot;
- (2) by fixed and quasi-fixed factors at the farm or regional level that act as conditioner variables;
- (3) by land quality and natural shocks variables.

We have then the following model for our production function:

$$y = g(x, z, a; \beta) + \varepsilon \quad (1)$$

where y is rice output per plot in kg;

x is a vector of the farmer's choice variables;

z is a vector of conditioning variables;

a is a vector representing land quality and natural shocks;

β are parameters and ε is the stochastic disturbance term.

The z and a variables are exogenous factors and cannot be changed by farmers at least in the medium term. Researchers usually account for the z factors in agricultural productivity analysis. However, the a factors are sometimes overlooked either because of

missing data or because of insufficient observations precluding the estimation of large number of parameters.

If land quality and exogenous shocks do not affect agricultural production, the entire coefficient estimates of the α variables will be equal to zero, so:

$$y = g(x, z, \alpha) = f(x, z).$$

However, if the α variables affect the level of y , which means $Cov(y, \alpha) \neq 0$, and the x and the α variables are not correlated at all i.e $Cov(x, \alpha) = 0$, we would deduce that $y = g(x, z, \alpha) = f(x, z) + h(\alpha)$ under assumption of strong separability. This is indeed too strong an assumption to be true in the real world. Our hypothesis is that the α variables do have significant effect on the production level, and are correlated to x , which means $Cov(y, \alpha) \neq 0$ and $Cov(x, \alpha) \neq 0$. Therefore, the coefficient estimates of x and the marginal productivity of the input variables will be affected by the omission of the α variables in the analysis. In order to test this hypothesis, we will use a model integrating proxy variables that control for land quality and natural shocks variables.

To assess the potential biases introduced by omitting land quality and exogenous shocks, we will estimate two models. The first one includes variables that control for land quality and exogenous shocks, called "full specification model" and the second one, the "short specification model" excludes this set of variables.

The differences will be estimated by the relative change between the MPPs from the two models, and computed such that:

$$\%Change = \frac{MPP_{xi}^{full} - MPP_{xi}^{short}}{MPP_{xi}^{full}} * 100 \quad (2a)$$

If the percent change is statistically equal to zero, there is no bias in using the short model specification. Otherwise, the short specification model gives biased estimates of the marginal values of different factors of production.

Suppose that the farmer is seeking to maximize his profit without constraints and with the assumption of a competitive market where the farmer is a price taker in both inputs and outputs.

If w is a vector of prices of inputs and p a vector of prices of output, $y = f(x)$ is the quantity of outputs, and if we assume that (1) farmer would maximize his profit, and (2) for the sake of simplification, farmer produces only one output, then:

$$\pi(p, w) = \max p f(x) - wx$$

The first order condition for the single output profit maximization is:

$$p \frac{\partial f(x^*)}{\partial x_i} = w_i \quad i = 1, 2, \dots, n$$

which mean that the marginal value product (MVP) of each factor must be equal to its marginal factor price (MVP = MFP) for a profit maximization. Marginal Value Product is computed from the MPP and the average output price. It represents the expected monetary return from the use of one more unit of a given input x_i .

The benefit of allocating more or less input, say x_i depends on the value of MVP related to MFP, with the assumption that the production function is concave to the origin.

- If $MVP > MFP$: There is an under-use of input x_i . Farmers can still apply more inputs and having higher MPP of x_i ;
- If $MVP = MFP$: This is the point of profit maximum that farmer should seek;

- If $MVP < MFP$: There is an over-use of input x_i resulting in a lower value of the MVP of x_i compared to the price of x_i .

However, changes in land and labor productivity can be thought of as a combination of two phenomena:

1. The direct change due to the difference in the use of the inputs and;
2. The indirect effect of land quality and natural shocks.

To clarify the idea, we will present a couple of examples. We assume that the changes in the input use are related to the adoption or not of a given new technology, e.g. in the use of improved rice seedling transplantation.

If a farmer decides to adopt a given new technology on the same plot, it will affect land and labor Marginal Physical Product (MPP)⁸, by the direct effect of the impact of the technology use.

- If a farmer applies the same technology in two plots with different land quality, land or labor MPP would differ from the difference in land quality, with the hypothesis that land quality affects agricultural production.
- If a farmer opts to adopt the new technology on good quality land and not to use on bad land quality, the total MPP change between the two plots would be the sum of the change from the land quality difference plus the change from the new technology adoption (1) + (2).

⁸ MPP is the physical amount of production given by one additional unit of an input. The advantage of its use is that it permits the analysis of the allocation efficiency of each input, thus allowing farmers to stop or to continue using the given input.

Hence, if one wants to know the effect of the adoption of a new technology on the productivity, it might be useful to look at the characteristics of land and eventual natural shocks.

To see the effect of land quality and exogenous shocks on the use of factor x_i , the objective is then to look at the magnitude Δ :

$$\Delta = \frac{(\frac{\partial y}{\partial x_i} | t = 1, a_k = 1, \bar{x}_j, \bar{z}) - (\frac{\partial y}{\partial x_i} | t = 0, a_k = 0, \bar{x}_j, \bar{z})}{(\frac{\partial y}{\partial x_i} | t = 0, a_k = 0, \bar{x}_j, \bar{z})} \quad (2b)$$

Where t is the technology to be analyzed, t is equal to 1 if farmer adopt the technology and is equal to zero if there is no adoption;

x_j is the specific farmer's land or labor variable,

x_j are other choice variables influencing productivity,

the a_k are different categorical variables representing land quality and natural shocks. The value 1 represents a good state of land and a value 0 a bad state, for example $a_k=1$ is for irrigated land while $a_k=0$ is for rainfed;

and z other conditioner variables such as dummy villages, localization etc.

- If $\Delta > 0$: The adoption of technology t gives farmer greater profit in using the factor of production x_i ;

- If $\Delta = 0$: Farmers will be indifferent in adopting or not t because it does not have impact on the MPP of the factor of production x_j . The cost minimizing theory should then influence farmer's decision;
- If $\Delta < 0$: The adoption of technology t does not pay off farmer's expenditures on adopting technology t .

Therefore, besides the presentation of the marginal return for each input, we will also show the changes in land and labor marginal returns when both the crop growing conditions change, for example from rainfed to irrigated land.

2.2. Estimation Method

2.2.1. Regression estimation

The analysis is conducted by using econometric estimation. However with data from a cross-section survey, heteroskedasticity issues are likely to be present because of the similarity between farmer's behavior and input use per village (Deaton, 1997). Hence, the choice of the econometric estimation method becomes crucial because Ordinary Least Square (OLS) does not anymore give efficient estimators. With heteroskedasticity, the variance σ^2 is not constant over the explanatory variables, then obviously the magnitude of which y will depend on σ_x^2 should not be weighted equally. Therefore, the points for which σ_x^2 is comparatively large should be down-weighted.

Using the test for heteroskedasticity suggested by Wooldridge (2000), we found that our sample exhibits heteroskedastic properties⁹. We will then do the estimation by allowing the conditional variance, as well as the conditional mean, to vary with the explanatory variables by using the Feasible Generalized Least Square (GLS) method.

Feasible GLS weights each variable by the inverse of the conditional variance of the residual from an original equation. As we do not know the value of the variances, we have to model the heteroskedasticity form from an original equation.

Suppose we have the original model:

$$y_i = \alpha_0 + \sum_{i=1}^k \alpha_i x_i + \varepsilon_i \quad (3)$$

where α 's are the coefficient parameters to be estimated, x_i 's are the explanatory variables, and ε the error terms. With OLS, we assume that ε is *i.i.d*(0, σ^2). However, if ε exhibits heteroskedasticity i.e. ε is $N\sim(0, \sigma_i^2)$, the approach is to estimate the model allowing the variance of ε to change.

The method we are using relies heavily on the work of Maddala (1971) and Wooldridge (2000).

First, we estimate equation (3), disregarding heteroskedasticity. The objective is to get the estimated disturbances $\hat{\varepsilon}$ which represent the heteroskedastic error terms of the model.

$$\text{Suppose that } Var(\varepsilon/x) = \sigma_i^2 = \sigma^2 h(x)$$

⁹ Wooldridge (2000), page 276 presents a specific case of White test for heteroskedasticity using predicted fitted value of the dependent variables and their squared terms. We got a **r squared** of 0.015 and a Lagrangean Multiplier (LM) value of 8.45, which indicates heteroskedasticity at 5 percent of significance level.

where $h(x)$ is some functions of the explanatory variables that determine the heteroskedasticity. In our case, we use an exponential model for $h(x)$ in order to get positive expected values which represent the conditional variances¹⁰.

$$Var(\varepsilon | x) = \sigma_e^2 e^{(\delta_0 + \sum_{i=1}^k \delta_i x_i)} \quad (4)$$

where x_i are the RHS in equation (3), δ_i 's are unknown parameters.

From equation (4), we have:

$$\varepsilon^2 = \sigma_e^2 e^{(\delta_0 + \sum_{i=1}^k \delta_i x_i)} v \quad (5)$$

where v is the error term of the conditional variances.

Taking the natural logarithm of (5):

$$\ln(\varepsilon^2) = \gamma_0 + \sum_{i=1}^k \delta_i x_i + \mu \quad (6)$$

where $\mu = \ln(v)$ has a zero mean and independent of x , thus homoskedastic;

$$\text{and } \gamma_0 = \ln(\sigma_e^2) + \delta_0$$

Replacing ε by $\hat{\varepsilon}$, we run the conditional variance regression¹¹ in order to get the effect of each input on the variability of the outcomes y . The fitted values, let say $\hat{g}$ from equation (4) after few modifications, are the weights to be applied to the original model in order to have an unbiased estimator of the coefficient parameters and efficient standard errors. Because we used the natural logarithm in equation (4), the modification consists in taking the exponential of the expected value from equation (6) in order to restore the

¹⁰ Linear model for the heteroskedastic error term gave us negative values for some observations. The issue of the sign of the expected value is that we cannot use a negative weight with WLS method.

¹¹ OLS can be used in this case with the assumption that μ is i.i.d(0, σ^2)

original magnitude of the numbers. Then following the Weighted Least Square estimation method, we use the inverse of $e^{\hat{g}}$ as weight in the final equation.

2.2.2. Choice of functional forms

Several types of functional forms have been used to analyze agricultural productivity. Each of them has their advantage and drawback related to the simplicity of use and the behavior toward assumptions of microeconomic theory. For example, the linear form is relatively simple and easy to manipulate but violated some economic theories such as diminishing marginal return. The Cobb Douglas is also nicely behaved and easy to compute functional form but it does not allow looking at the pairwise interaction terms between two variables and leads to a zero output level when one of the variables input is zero. We have a high likelihood of having such case for example in fertilizer use. Therefore, we eliminate these two functional forms.

During the last three decades, the use of Quadratic, Translog, and generalized Leontief (GL) models has become more familiar in agricultural production analysis in developing countries (Sherlund et al, 2001; Byiringiro, 1995; Clay et al, 1995; Savadogo et al, 1994). They were chosen because of their flexibility, which allows an ability to provide second order approximations to any arbitrary function. They share the common characteristics of linearity in parameters and permit looking at the interaction terms between two independent variables. They also would fit most of the assumptions of economic theories on the analysis of agricultural production.

The Mackinnon White Davidson (MWD) test for non-linear non-nested models is used to identify the “best among the tested” functional form for our data. Pairwise tests

between three functional forms (quadratic, Translog, and square root generalized Leontief) indicated a better fit for square root generalized Leontief. Details of the tests are given in appendix 2.

Specifically, with the three sets of vectors representing farmer's variable choices, conditioners, and land quality – natural shocks variables presented in equation (1), square root GL model is of the form:

$$\sqrt{y_i} = \alpha_0 + \sum_{i=1}^n \alpha_i \sqrt{x_i} + \sum_{k=1}^m \delta_k z_k + \sum_{t=1}^l \delta_t a_t + \sum_{i=1}^n \sum_{j=1}^n \varphi_{ij} x_i + \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \sqrt{x_i x_j} + \sum_{i=1}^n \sum_{k=1}^m \delta_{ik} z_k \sqrt{x_i} + \sum_{i=1}^n \sum_{t=1}^l \gamma_{it} a_t \sqrt{x_i} + \mu \quad (7)$$

where $\mathbf{x}$ is a vector of variable inputs;

$\mathbf{z}$ a vector of conditioner variables;

$\mathbf{a}$ a vector of land quality and natural shocks variables;

$\alpha, \beta, \varphi, \delta, \gamma$ are parameters to be estimated;

and μ is i.i.d error term.

n is the number of input variables,

m the number of conditioner variables,

l the number of land quality and natural shocks variables.

Square root GL exhibits diminishing marginal returns to factors of production. Its marginal productivity does have unrestricted sign, allowing it to represent all stages in the

production process. GL is linear in parameters, so it can be estimated with linear regression method.

A drawback of the squared root GL is that we cannot normalize the variables to have zero means¹². We then work with non-normalized variables; therefore we might not have exact second order approximation anywhere.

If land quality and natural shocks are not considered, we have the short specification model:

$$\sqrt{y_i} = \alpha_0 + \sum_{i=1}^n \alpha_i \sqrt{x_i} + \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \sqrt{x_i x_j} + \sum_{k=1}^m \beta_k z_k + \sum_{i=1}^n \sum_{k=1}^m \delta_{ik} z_k \sqrt{x_i} + \mu_i \quad (8)$$

From the equations 7 and 8, we have computed the marginal return of an input x_i and the elasticity of x_i to y by taking the partial derivative of y with respect to input x_i for the marginal return, and multiplying the result by $(x_i y^{-1})$ for the elasticity.

For the full specification, we have then:

$$MPP_{xi} = \frac{\partial y}{\partial x_i} = (\alpha_i + 2\beta_{ii} \sqrt{x_i} + \sum_{j=1}^{n-1} \beta_{ij} \sqrt{x_j} + \sum_{k=1}^m \delta_{ik} z_k + \sum_{t=1}^l \gamma_{it} a_t) \times \sqrt{\frac{x_i}{y}} \quad (9)$$

$$e_{y,xi} = \frac{\partial y}{\partial x_i} \frac{x_i}{y} = MPP_{xi} \frac{x_i}{y} \quad (10)$$

The MPP and elasticity for the short specification are obtained from equation (9) and (10) by dropping the term with the a 's variables.

¹² Negative values are not allowed by the square root function of the GL model. With normalization, one would expect to have exact approximation at any point of the curve.

2.3. Research Design

Theoretically, land quality and natural shocks variables differ in the sense that farmers have knowledge of their own land quality while natural shocks are truly stochastic. Farmer's input use decision might have then higher probability to be affected by land quality rather than natural shocks. An obvious example is that the quantity of fertilizer applied in a given plot can be thought as independent of the existence of drought that might occur during the agricultural cycle¹³. However, different irrigation quality may induce different fertilizer use decisions by farmers.

Therefore, to investigate the individual effect of these types of factors, two separate F-tests based (1) only on land quality -- irrigation, topography location, and soil texture -- and (2) only on natural shocks -- inundation and drought -- were performed. The null hypothesis is that all the parameter estimates for land quality or natural shocks are equal to zero.

2.3.1. Description of variables

a) Dependent variables

y , the dependent variable, represents the total quantity of paddy rice produced per plot. It is measured in kilograms.

b) Explanatory variables.

Plot area

Plot area is obvious in having a strong positive relationship with the level of production. Area is quantified in are (100 square meters). Data are obtained from

¹³ Notice that Malagasy farmer's generally applies fertilizers only at the beginning of the agricultural season.

farmer's estimation of their plot areas, cross-checked by various traditional area measurements.

Labor

There is an ongoing discussion of the homogeneity or not of family labor and hired labor. Results in the literature diverge but findings seem to indicate that they are not perfect substitute (Feder, 1985; Deolalikar and Vivjerberg, 1982; Rao and Chotigeat, 1981; Brown and Salkin, 1974). Frisvold (1988) attributed the difference between family labor and hired labor to the higher incentive of family labor to better execute agricultural tasks. However, he also demonstrated that hired labor efficiency depends on the level of supervision by family labor. Other findings showed that hired labor are more professional, more homogeneous, thus have the expectation to give higher output. Following these findings, we will separate family and hired labor in our analysis. Moreover, we will treat child labor as an independent and separate variable, avoiding weighting and aggregating issues¹⁴ and in order to get more homogeneous adult family labor composition.

Chemical Fertilizer

In general, we expect chemical fertilizer to have a positive relationship with agricultural production. In practice, some farmers use chemical fertilizer to accelerate the growth of the plants in the nursery plot. This constitutes an indirect effect of fertilizer use in agricultural production, providing healthier plants. The current analysis does not differentiate such a practice.

¹⁴ For female and male labor, we assume that they perform different agricultural tasks, usually non-substitutable; therefore they can be considered as equal. For example, transplantation, weeding tasks are for women while plowing task is for men.

Other variables inputs

Use of chemical (pesticide, herbicide) is very low, so we decided to ignore it.

Seed is difficult to assess. Its level of use depends heavily on the technology adopted by farmers. With the SRI technologys, farmers use a very low quantity of seeds, up to 15 kg to transplant to one hectare. On the opposite, traditional technologys require three to six times more seeds. Thus, by controlling the cultivated area and the technology used by farmers, we control for seed.

For rice varieties, Goletti et al (1997) showed that there was no significant productivity difference between “new varieties” and “traditional varieties”. Actually, with the exception of specific varieties for high altitude rice produced by FOFIFA in the late 1990's, the agronomic research did not proposed improved new rice variety for the areas of study during the last five years, leading to a misunderstanding on the term “new” and “traditional” varieties by farmers.

Managerial capital

Another important variable in the production function estimation is the level of education at the household. Usually, there are many alternatives to measure this variable but for our study; we will use the household's head number of years of education. This is justified by the role and the place of the household head in agricultural process decision. Its expected positive effect on agricultural production comes from the ability of educated person to a better management and a more efficient information processing.

Animal Traction

We hypothesize that the use of animal traction is a technology choice, and it depends on the availability of draft power on the farm or the existence of an animal

traction market at the village level. Its omission can be misleading because it affects total required labor (Savadogo et al, 1994). However its effect on agricultural productivity is not very clear. First, the effect is hypothesized to be positive for land productivity in the sense that it permits farmers to have land prepared on time. However, possession of animal traction is also associated with the practice of agricultural extensification strategy because it would allow farmers cultivating more land. Nonetheless the aggregated quantity of animal traction collected during the survey is considered to be endogenous to production¹⁵, hence the number of draught oxen present at the farm should be used to control for this variable. However, there is a high degree of correlation between draught oxen and total oxen possessed by farms. As we use this latter to control for the use of manure, we will drop the draught oxen variable from the regression.

Improved Rice Seedling Transplantation

Improved Rice seedling transplantation is used to control for the adoption of SRA technologys. It is measured by the age of transplanted plants. A lower age of the plants at the transplantation would result in higher production, but in turn will require higher need for labor. There is also a high correlation between the age of transplanted plants and the number of tillers per hill and water control. For example the lower the age, the fewer the number of tillers and the better the irrigation control. Thus, the variable age of transplanted plants will control for the adoption of an improved rice seedling technology.

¹⁵ Animal traction was the sum of all tasks performed by animal traction for the plot from plowing, leveling, to transportation. If plowing and leveling, might be assumed as exogenous, transportation is endogenous because the number of days needed to move the paddy-rice from the plot to the farm-storage is a linear function of the quantity produced.

Extension Service

This is a qualitative variable, which shows if farmers have had contact with extension service on the rice production at least once during the last five years. Several technologies besides SRI and SRA were diffused by the extension service. One can adopt the recommendation on seeding date, number of weeding, mulching, use of chemical fertilizer etc. This variable would control for all these technologies, and expected to have positive effect on productivity.

Season

In Madagascar highland, there are two agricultural seasons for rice: the “*vary aloha*” and the “*vakiambiaty*”. The “*vakiambiaty*” rice is sown during the rainy season and harvested in April – May and is the most important in term of cultivated area, while the “*vary aloha*” is sown in July – August and harvested in December – January. We use a dummy variable representing these two seasons. Sometimes, the “*vary aloha*” crop will give higher production because of the relative good land quality that allows farmers to cultivate rice before the rainy season. However, it is penalized by the low temperature during the first stage of plant development, and the negative effect of cyclones during the maturation stage.

Region

We have here two regions: Vakinankaratra and Fianarantsoa plateau, both part of the Highland agro-ecological zone (See appendix 1). Unfortunately, the limited number of zones -- only 2 -- precludes the use of other climatic measurement such as rainfall in the model, because of the perfect collinearity issue.

Land tenure

There are two major land rental market systems that can be observed in Madagascar: leasing and sharecropping. The literature is ambiguous on the effect of land tenure on productivity. The common wisdom is that temporary property rights might have a negative effect on agricultural productivity, as there is less incentive for investments by the temporary or insecure owner. However, empirical results on land titling are mixed. Studies for different countries in Central Africa show neutral effects of legal land rights on agricultural productivity (Place and Hazell, 1993; Platteau, 1996). Other studies have documented that insecure land rights lead to less input use, investments, and therefore, lower productivity (Anim, 1999; Lutz et al, 1994; Reardon et al, 1999; Feder and Feeny, 1991). We expect the argument for land tenure, which is controlled by a categorical variable for land rental to have negative effect on agricultural productivity.

Land Quality

Land quality is very difficult to define and to measure. Most of the studies on agricultural productivity used categorical variables to develop a proxy for land quality. Soil color, soil texture, and soil depth were used by Bhalla and Roy (1988). IFPRI (1997) used irrigation and prices of land. In his study on Indian agriculture, Bhalla (1988) reported that there is a big difference in intra-zonal land quality, so land characteristics cannot be included in the categorical region variables. An individual estimate of land quality is needed for the estimation of the production function.

Land quality can be assessed as a combination of two factors: the inherent soil quality and human-made adjustments. Inherent soil quality is determined by the physical

and chemical characteristics of the soil. By physical, we mean the slope, the location of the plot, and the soil texture and structure. Chemical characteristics regroup the composition of the soil in different nutrients: nitrogen (N), phosphorus (P), potassium (K), iron, minor and trace elements etc. Physical human made adjustments are changes in the land environment such as irrigation, drainage surface, and soil conservation investments, which affect land quality. For example, two plots with the same inherent soil quality are likely to produce different outcomes if the irrigation system is different.

For our study, we will use three categorical variables to control for land quality: the topography location of the plot, the soil texture that is function of the ability of the soil to retain water, and the irrigation system¹⁶. The location of the plot differs from lowland rice field vs. terraced rice field. Texture is between sandy and clay/silty soil. Clay and silty soils are expected to have the ability to retain water longer than sandy soil, resulting in better weeds and water control. Irrigation distinguishes between (i) human-made such as pond, dam, well and (ii) natural sources of irrigation such as rainfall or spring water source. Farmers with controlled irrigation scheme are expected to use more inputs giving the reduction of production risks.

Lastly, many studies introduced the number of plots cultivated by farm as an important variable that would affect farmer's technical efficiency. A high number of plots is hypothesized to have negative influence on the productivity because of a more complex field management.

¹⁶ A drawback of this analysis is that we do not have the soil initial endowment in organic matter and chemical elements. The levels of these components are assumed to be controlled by the use of fertilizer and manure by farmers and by the land quality proxy variables (texture, location).

Natural Shocks

This set of factors that would influence agricultural production is represented by two categorical variables of natural constraints during the agricultural season: inundation and drought problems. They are both expected to have negative relationship with the level of rice production and assumed to be stochastic over the years.

2.3.2. Data patterns

Our study uses data from smallholders in Madagascar highland. This is a mountainous area, with a lot of narrow depressions (bas-fond) where farmers usually grow lowland rice. The average altitude is around 1,200 meters.

For the climatic condition, temperature varies from an average of 26°C in the summer to 13°C in the winter, which restricts rice cultivation during the dry and cold season. Average rainfall is between 1300 and 1600 mm per year, and is concentrated from November to April. This is also a populous area with a demographic density of more than triple the country's average.

**Table 1 – Descriptive Statistics on rice production variables by farm size tercile,
563 fields, Madagascar highlands, 2000.**

		Overall samples		Tercile		
Variables	Units	Sample means	Standard Deviation	Small	Med.	Large
Dependent variable						
Production quantity	Kg of rice	1,009	997	352	820	2,012
Area and yield						
Total cultivated rice area	Ares per household	44.82	47.64	8.60	30.33	95.55
Yield	Kg / are (w)	22.52	15.16	45.99	25.28	19.40
Choice variables						
Family labor	Man-days / are (w)	0.99	1.38	3.39	1.20	.70
Hired labor	Man-days / are (w)	1.04	1.12	2.66	1.27	.80
Child labor	Child-days / are (w)	0.14	0.32	.34	.13	.12
Number of oxen	Number	2.53	2.99	1.15	2.21	3.77
Fertilizer use	Dummy (1 = use)	0.10	0.30	.12	.10	.09
Fertilizer application	Kg of fertilizer/are (w)	0.08	0.34	.12	.09	.07
Improved RST	Dummy (1 = yes)	0.06	0.24	.07	.06	.06
Conditioner variables						
Education level	Number of years	4.91	2.89	4.54	5.39	4.70
Number of plots	Number of plots	3.00	1.38	2.16	2.89	3.66
Extension service contact	Dummy (1 = yes)	0.17	0.37	.12	.21	.15
Land tenure	Dummy (1 = renting)	0.11	0.31	.06	.16	.10
Season vary aloha	Dummy (1 = yes)	0.15	0.36	.19	.16	.11
Region Vakinankaratra	Dummy (1 = yes)	0.56	0.50	.72	.54	.11
Land quality and natural shocks variables						
Irrigation	Dummy (1 = yes)	0.40	0.49	.49	.32	.42
Lowland location	Dummy (1 = yes)	0.39	0.49	.42	.37	.38
Texture clay	Dummy (1 = yes)	0.73	0.44	.60	.78	.78
Flood problem	Dummy (1 = yes)	0.44	0.50	.37	.44	.48
Drought problem	Dummy (1 = yes)	0.68	0.47	.63	.65	.72
Other interesting variables						
Household size	Number	6.7	2.9	6.02	6.43	7.42
Family labor for weeding	Day/are	4.4	7.6	.68	.27	.18
Hired labor for weeding	Day/are	3.6	6.4	.42	.23	.15
Family labor for transplantation	Day/are	2.1	2.7	.37	.13	.08
Hired labor for transplantation	Day/are	3.7	4.7	.48	.21	.16
Water management	Day/are	1.2	2.5	.21	.06	.05

(w) Average weighted by plot area

Source: Agricultural Production Survey, Madagascar Highland June 2000

The data come from a farm survey conducted by the Cornell ILO/FOFIFA project in Madagascar in July - August 2000. It includes rice production during the dry season 1999 (*vary aloha*) and the wet season 1999-2000 (*vakiambiaty*). The sample is constituted by 237 rice growers, which correspond to 563 rice plots after data cleaning process. The map in appendix (1) shows the area of study.

The questionnaire has data on the characteristics of each plot cultivated by farmers: plot area, texture, irrigation system, and topography location. It also has information about the cultivated area, the quantity of labor used (family, hired, male, female, children), the number of days of animal traction used (family, hired), the quantity of chemical fertilizer, the level of production, the type of seedling transplantation methods adopted, and the natural conditions during the production process including flood and drought.

Table 1 shows the descriptive statistics of the variables used in our study. In general, there is relative high variability in the sample. For example, the total rice cultivated area, and all the labor use, have coefficients of variation higher than 100 percent. Chemical fertilizer use and improved rice seedling transplantation (RST) adoption exhibit also a very high variation more than 400 percent.

For our sample, the average yield, weighted by plot area, is around 22.5 kg per are, with a standard deviation of 15.2 kg. This average yield is higher than those reported by Bernier and Dorosh (1993), Roubaud (1997), and IFPRI (1997). These previous studies reported average yield between 13.0 and 20.1 kg per are for aquatic rice. We have

however to notice that these studies used different yield computation method compared to the current analysis¹⁷, thus we cannot compare the yield or the change over time.

Use of labor is quite high with averages of 0.99 and 1.04 man-day per are respectively for family and hired labor. First, there is the fact that rice technology requires a lot of manual works from the nursery field, the planning, the transplantation, the weeding, through the harvesting. As some of these tasks should be done at a limited period, intensive need of hired labor is quite normal. Also there is the existence of a kind of fixed tasks such as water management, guarding against crop-thief, where labor quantities do not depend on the size of the plots. These “fixed” labor increase the per-are labor used¹⁸ inversely proportional to plot area.

One can observe the usual low percentage of chemical fertilizer adopters, with only 10% of the sample. When we observe the rate of application, for all plots (those which received and not received chemical fertilizer), we have a figure of 8 kg per hectare, while for plots that received fertilizer; farmers apply 81 kg per hectare¹⁹. This corresponds approximately to one fourth of the extension service recommendation²⁰. In most of the cases, farmers apply chemical fertilizer on cash crop under a contracting system such as tobacco, sugarcane, cotton, and barley rather than on rice (IFPRI, 1997). The key reason for this difference in input use is that the contracting firms supply fertilizers to farmers. Also, farmers have access to more information especially price

¹⁷ The current analysis use average yield computed directly from plot data weighted by the plot area while the other two studies seem to use average yield computed at the farm level, which is already an average from the plot level. Bernier and Dorosh (1993) includes low land productivity slash and burn technologies from the Middle East zone (excluded from our sample). Also, we did not use any weight to get representative samples.

¹⁸ We will come back to this issue later on the analysis of the labor use by farm size.

¹⁹ Previous studies in Madagascar (Bernier and al, 1993; IFPRI, 1997) presented similar results.

²⁰ For rice in the Highland, the extension service from the Ministry of agriculture recommends 300 kg of NPK 11-22-16 plus 66 kg of Urea per hectare (Bernier and Dorosh, 1993).

information that allows them to make more optimal decisions on input use and input allocation. Similarly, improved RST adopters are also very few with only 6 percent of total sample. We have classified farmers as adopters of improved RST if they transplant young plants less than 25 days.

Although the two regions of study are part of the highland region, which is the most densely infrastructured region in Madagascar, it is surprising that only 17 percent of farmers have had a contact with the extension service.

The percentage of plots with physical human-made irrigation with 40 percent of all plots is higher than the national average of 24 percent (FAO, 2000). This contributes significantly to drop the inundation to affect only 44 percent of the total plots²¹ (Table 1).

Most of the rice lands are clay or silty textured. This is a common morphological characteristic of the narrow lowland in the Highland region. These plots are frequently flooded, thus subject to sedimentation from the watershed.

Table 1 also shows descriptive statistics by farm size. Farms were classified into tercile according to the total rice cultivated area²². We found that for our sample, the average rice area cultivated by household is 8.60; 30.33; and 95.55 ares for respectively tercile 1, 2 and 3, which represent small, medium and large smallholder farms. Each tercile contains around 79 households²³.

Like the findings from many studies in developing countries, average land productivity indicates that small farms have higher land productivity than large farms (Byiringiro, 1995; Barrett, 1994; Feder, 1985; Deolalikar et al, 1981). From tercile 1 to

²¹ In the coastal area where modern irrigation is almost inexistent, inundation risk may reach 90 percent of cultivated land during the cyclone season.

²² We use total rice cultivated area as a proxy for farm size. This constitutes a good proxy for farm size. The correlation coefficient between these two variables is greater than 0.70 (SMTIS, 1989).

²³ Use of per capita cultivated area shows similar results (see Appendix 4)

tercile 3, we respectively have significant different average yields of 45.99; 25.28; 19.40 kg per are.

To eliminate the doubt that the inverse relationship between riceland holding and rice productivity may be caused by some artifacts in regrouping data by tercile, we will use the method suggested by Deolalikar (1981). It consists in running a single regression function of the form:

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

where Y_i is the yield in kg; X_i is the size of the farm in are, and ε_i is the i.i.d. error term.

There is inverse relationship if the parameter β exhibits a negative sign.

For our sample, the result of this regression presents a negative and significant coefficient of -49.0 for X , with a t-value -10.0 and an R squared of 0.16 . This corroborates the hypothesis that there is indeed an inverse relationship between farm size and rice productivity. We found also that the pairwise correlation coefficient between plot area and land productivity is -0.41 , statistically significant at 1 percent level.

There are significant differences on the quantity of input uses by tercile of farm size. For example, family labor per are decreases from 3.4 for small farms to $.7$ for large farms. Hired labor, and use of organic and chemical fertilizers follow similar patterns. Inversely, the number of oxen is more important for large farms than for small and medium farms. Logically, a decrease in family and hired labor should correspond to an increase in the use of animal traction because of the possible substitution effect between these two categories of inputs. We can observe this tendency in Table 1.

These high quantities per-are of family and hired labor confirm the hypothesis that small farms would allocate more labor to the available land than large farms, and this

partially explains their higher land productivity. The per-acre average quantity of labor allocated to weeding and transplanting (Table 1) illustrate this situation. For example, either for weeding or transplanting, family labor use per-acre for large farms represents only one fourth of the same variable for small farms. As these two tasks (weeding and transplanting) are key-factors for rice production, it is not surprising if small farms have higher land productivity than large farms.

Small farms are also facing lower opportunity costs of labor than large farms. It is then in their logic to allocate large quantity of labor on the available land.

As there are some fixed tasks to be performed independently of the size of the plots, farmers are sometimes obliged to spend the same amount of time whatever the plot size is. This is the case of water management, which occupies .21 man-day per acre for small farms against only .05 man-day per acre for large farms, a ratio of 4 to 1. The overall result is an increase of the relative per acre use of labor for small farm. Time spent in guarding against harvest theft falls also under this category. Theft problem is crucial for certain villages and can make big differences in labor productivity (IFPRI, 1997).

For the conditioner variables, the existence of extension contact presents no significant differences between the tercile of farm size, while monotonic changes are noticed for seasonal and regional variables.

Irrigation quality does not vary significantly across tercile of farms size. In general, one can say that large farms are facing higher production risks than small and medium farms. For example, in 1999-2000, table 1 shows that inundation and drought occurrences were statistically higher as tercile goes from 1 to 3 (small to large farms). Lands of large farms seem to be located in worse area than those of small farms. Thus

they are more subject to bad natural conditions such as inundation or drought. On the other hand, large farm have more plots, and if all plots have the same, independent probabilities of being flooded, then large farms will have higher probability of inundation.

Following the same pattern, small farms have higher chance to grow rice during the dry season, indicating a relative good irrigation scheme.

3. Regression Results and Interpretation

3.1. Effect of Land Quality and Natural Shocks on Agricultural Production

The results from estimating equation (8) are shown in Table 2. Overall, the model fits the data extremely well. It is evident that land quality and natural shocks do influence rice production in Madagascar. Some coefficient parameters of the variables controlling for land quality and natural shocks or their interaction terms with other variables were found to be statistically different from zero.

- a. Jointly tested at 1 percent level, the F-test on variables controlling for land quality and natural shocks from the full specification model leads to reject the null hypothesis of “*all δ 's and γ 's are equal to zero*”²⁴ with a $F(30, 470) = 3.36$.
- b. Tested separately, at the 1 percent level, we also reject the null hypothesis (See. Paragraph 3.3) that all land quality variables do not have any influence on productivity and conclude that at least one of the land quality coefficients is different from zero with a $F(18, 470) = 2.85$.
- c. The same test applied to natural shocks variables presents a $F(12, 470) = 3.39$, which supports also the null hypothesis rejection.

²⁴ Respectively δ and γ represent the parameters of land quality and natural shocks variables and their interaction terms— See equation 7.

Table 2 – Madagascar Highland Rice Production Function**With and Without Land Quality and Natural Shocks****Plot level analysis, 563 fields, Madagascar Highland 2000**

	Full Specification WITH land quality and natural shocks		Short Specification WITHOUT land quality and natural shocks	
Dependent variable = Rice production in kg	Coeff. Sig.	Std. Err.	Coeff. Sig.	Std. Err.
Plot area in are (AREA)	0.991 *	0.596	1.459 **	0.593
Family labor in day (LABF)	2.440 ***	0.683	1.431 **	0.656
Hired labor in day (LABH)	1.167 ***	0.407	0.352	0.415
Child labor in day (LABC)	-0.134	0.693	0.853	0.696
Number of oxen owned by farmer (OXEN)	3.306 ***	0.931	-0.193	0.880
Chemical fertilizer use - YES = 1 (FERT)	4.442 **	2.223	0.851	2.332
Improved RST - YES = 1 (IRST)	3.988	3.074	1.539	3.160
Region Vakinankaratra - YES = 1 (DVAK)	1.414	1.375	-0.660	1.373
Extension service contact - YES = 1 (VULG)	1.851	1.281	0.985	1.406
Land tenure - Renting land = 1 (RENT)	5.621 ***	1.676	2.332	1.675
Head education level in year (EDUC)	-0.266	0.238	-0.185	0.242
Season vary aloha - YES = 1 (DSEA)	-0.909	1.360	0.157	1.488
Number of plots per farm (PLOT)	-0.662	0.477	-0.319	0.501
Human made irrigation - YES = 1 (IRRI)	2.632 **	1.106		
Topography location - low = 1 (TOPO)	2.371 **	1.017		
Soil texture - Clay/silty = 1 (TEXT)	4.237 ***	1.178		
Inundation in 1999- YES = 1 (FLOO)	0.719	1.099		
Drought in 1999 - YES = 1 (DROU)	1.360	1.104		
<i>Interaction Terms</i>				
AREA*AREA	-0.193 ***	0.054	-0.150 **	0.062
LABF*LABF	-0.193 ***	0.051	-0.150 ***	0.052
LABH*LABH	0.036	0.031	0.018	0.035
LABC*LABC	0.210 **	0.098	0.157	0.116
OXEN*OXEN	0.228	0.209	0.489 **	0.212
AREA*LABF	0.347 ***	0.081	0.250 ***	0.089
AREA*LABH	0.168 ***	0.065	0.163 **	0.077
AREA*LABC	-0.091	0.089	0.017	0.103
AREA*OXEN	0.062	0.132	0.024	0.141
AREA*FERT	0.833 *	0.434	0.857 *	0.488
AREA*IRST	-0.956 *	0.551	-1.294 **	0.607
AREA*DVAK	1.883 ***	0.280	1.655 ***	0.298
AREA*VULG	-0.553 *	0.295	-0.261	0.334
AREA*TENU	0.164	0.284	0.108	0.320
AREA*PLOT	0.008	0.092	0.136	0.100

	Full Specification WITH land quality and natural shocks		Short Specification WITHOUT land quality and natural shocks	
Dependent variable = Rice production in kg	Coeff. Sig.	Std. Err.	Coeff. Sig.	Std. Err.
AREA*EDUC	-0.094 **	0.042	-0.064	0.045
AREA*DSEA	-1.300 ***	0.280	-1.463 ***	0.325
LABF*LABH	-0.193 ***	0.060	-0.106	0.067
LABF*LABC	-0.157	0.100	-0.268 **	0.106
LABF*OXEN	-0.010	0.137	0.189	0.133
LABF*FERT	-0.739 **	0.361	-0.469	0.400
LABF*IRST	0.475	0.528	0.914 *	0.514
LABF*DVAK	-1.110 ***	0.342	-0.878 ***	0.334
LABF*VULG	0.097	0.259	0.239	0.255
LABF*TENU	-0.553	0.375	0.097	0.378
LABF*PLOT	0.013	0.109	-0.054	0.114
LABF*EDUC	0.130 **	0.054	0.074	0.054
LABF*DSEA	0.678 ***	0.261	0.425	0.297
LABH*LABC	0.076	0.062	-0.045	0.074
LABH*OXEN	-0.114	0.102	-0.119	0.113
LABH*FERT	-0.534	0.328	-0.200	0.390
LABH*IRST	0.061	0.296	0.128	0.315
LABH*DVAK	-0.053	0.201	0.341	0.217
LABH*VULG	0.129	0.198	0.038	0.229
LABH*TENU	-0.639 **	0.251	-0.530 **	0.252
LABH*PLOT	0.109	0.074	-0.030	0.082
LABH*EDUC	0.047	0.032	0.059	0.036
LABH*DSEA	0.719 ***	0.237	0.826 ***	0.269
LABC*OXEN	-0.053	0.164	-0.143	0.171
LABC*FERT	-0.390	0.441	-0.019	0.501
LABC*IRST	-0.712	0.714	-0.605	0.809
LABC*DVAK	-0.196	0.316	0.024	0.341
LABC*VULG	-0.296	0.347	-0.112	0.412
LABC*TENU	-0.191	0.413	-0.021	0.428
LABC*PLOT	0.250 **	0.120	0.138	0.120
LABC*EDUC	-0.026	0.060	-0.049	0.058
LABC*DSEA	0.686	0.464	0.298	0.507
OXEN*FERT	-1.182 *	0.623	-0.447	0.668
OXEN*IRST	-1.070	0.660	-0.047	0.713
OXEN*DVAK	-0.780 **	0.364	-0.393	0.387
OXEN*VULG	0.336	0.489	0.281	0.493
OXEN*TENU	-0.625	0.550	-0.432	0.556
OXEN*PLOT	-0.153	0.130	-0.132	0.132
OXEN*EDUC	-0.009	0.066	0.026	0.065
OXEN*DSEA	-0.394	0.502	0.390	0.548
CONSTANT TERM	-4.496 **	2.246	2.852	2.025
<i>Land characteristics and Natural shocks</i>				
AREA*IRRI	-0.281	0.209		

	Full Specification WITH land quality and natural shocks		Short Specification WITHOUT land quality and natural shocks	
Dependent variable = Rice production in kg	Coeff. Sig.	Std. Err.	Coeff. Sig.	Std. Err.
AREA*TOPO	0.752 ***	0.208		
AREA*TEXT	0.532 **	0.228		
AREA*FLOO	-0.308	0.240		
AREA*DROU	0.605 **	0.279		
LABF*IRRI	-0.038	0.244		
LABF*TOPO	-0.564 **	0.233		
LABF*TEXT	-0.620 **	0.265		
LABF*FLOO	0.143	0.247		
LABF*DROU	-0.312	0.240		
LABH*IRRI	-0.116	0.152		
LABH*TOPO	-0.441 ***	0.168		
LABH*TEXT	-0.389 **	0.191		
LABH*FLOO	-0.058	0.187		
LABH*DROU	-0.452 **	0.197		
LABC*IRRI	-0.503 **	0.234		
LABC*TOPO	-0.162	0.288		
LABC*TEXT	-0.505 *	0.276		
LABC*FLOO	-0.122	0.314		
LABC*DROU	0.836 ***	0.318		
OXEN*IRRI	0.200	0.291		
OXEN*TOPO	-0.310	0.321		
OXEN*TEXT	-1.020 ***	0.379		
OXEN*FLOO	-0.626	0.409		
OXEN*DROU	-1.316 ***	0.386		
R squared	.91		.88	
Adjusted R squared	.89		.86	
Overall F test	F(98, 464)= 47.5		F(68, 494)= 51.5	
Residual Sum of Squares	3510		5376	

*, **, *** Respectively significant at 10, 5, and 1% level

The F test between the two models specification (full and short) showed a $F(30, 563) = 141$ which implies that at 10 percent level, we reject the null hypothesis and conclude that the two models do not have the same explanatory power.

The very high R squared is an artifact resulting from the econometric method used. With a linear functional form, the R squared is .62 for the full specification.

Source: Agricultural Production Survey, Madagascar Highland June 2000

Moreover, the Wald²⁵ tests performed on each variable confirm the hypothesis that land quality and natural shocks affect significantly rice production in Madagascar (Appendix 4). It shows that topography location, irrigation, and drought are significant at the 1 percent level. Soil texture is significant at the 10 percent level while inundation risk is significant at the 5 percent level.

3.2. Changes in Land, Labor, and Fertilizer Marginal Return Due to the Omission of Land Quality and Natural Shocks in the Model Specification

Table 3 presents the changes in MPP between a full specification model with land quality and natural shocks variables and a short specification model without these two sets of variables. Marginal productivity is obtained from equation (9), itself obtained from the first derivative of the production function presented in equation (8). The overall results show that the omission of land quality and natural shocks variables in the model specification affects significantly the estimation of the marginal productivity of some factors of production.

Although there are no significant changes on land and hired labor between the two models, one can observe a small variation on the return to family labor, with a 9% change. The short specification tends to overestimate the return to this factor. For both models, hired labor shows a higher return than family labor. For example, the full specification model shows a hired labor MPP of 4.7 kg per man-day and a family MPP of 2.7 kg per man-day, therefore indicating a net advantage of using hired labor.

²⁵ See Appendix 4 for detail of Wald test.

**Table 3 – Marginal Input Productivity With and Without Land Quality
and Natural Shocks, Estimation at the Sample Means
Plot level analysis, 563 fields, Madagascar Highland 2000**

		Full Specification		Short Specification		Relative change ^a	Sig.
		MPP	Output Elasticity	MPP	Output Elasticity		
<i>MPP and Elasticity of some choice variables</i>							
Land	Kg rice per are	13.5	.60	13.5	.60	0%	
Family labor	Kg rice per man-day	2.7	.12	2.9	.13	9%	*
Hired labor	Kg rice per man-day	4.7	.22	4.8	.22	2%	
Child labor	Kg rice per child-day	-4.3	-.03	-1.2	-.01	-71%	***
Number of plots	Kg rice per number	-6.5	-5%	-7.8	-5%	19%	
Number of oxen	Kg rice per ox	6.7	.04	12.3	.07	84%	***
<i>Switching effect of some categorical variables</i>							
	Unit of quantity	Quantity change	Percent change	Quantity change	Percent change	Relative change ^a	Sig.
Education of head	Kg rice per year	1.7	2%	3.4	4%	102%	**
Chemical Fertilizer	Kg rice if using fertilizer	396	10%	414	10%	4%	
Extension service	Kg rice if access	207	8%	360	14%	74%	***
Rice seedling	Kg rice if IRST	391	6%	109	2%	-72%	*
Season	Kg rice if season 2	-111	-4%	26	1%	-124%	***
Region	Kg rice if Vakinankaratra.	231	30%	241	31%	4%	
Land tenure	Kg rice if rented	291	8%	241	6%	-17%	
<i>Switching effect of Land quality and Natural shocks variables</i>							
	Unit of quantity	Quantity change	Percent change				
Irrigation	Kg rice if irrigated	87	8%				
Topography location	Kg rice if lowland	97	9%				
Texture	Kg rice if clay	41	7%				
Inundation	Kg rice if no flood	-100	-10%				
Drought	Kg rice if no drought	-10	-2%				

a = Change relative to the full specification model, computation from equation (2a)

*, **, *** are respectively significant at 10, 5, and 1% level, See Appendix 5 for the Bootstrap method and the t-test results.

Source: Agricultural Production Survey, Madagascar Highland June 2000

Several explanations for this exist. First there is the effect of “supervision” by family labor that would result in better performance of hired labor (Frisvold, 1994). A

second hypothesis is the nature of tasks attributed to hired labor, such as transplantation and weeding. These are among the key constraints to get higher rice productivity as any delay in transplantation and weeding will result in lower production. Third, there is the issue of heterogeneity in family labor, i.e. quality of family labor is on average lower even if we take out child labor. It should be noted that family labor might have low returns but its presence is required in order to get higher returns from hired labor.

Child labor MPP from the short specification is estimated to be 71 percent less for the short specification compared to the value from the full specification model. This indicates that child labor is also correlated with some land quality and natural shocks variables. The coefficients are both negative for the two model specifications. Nonetheless, low production might not be the effect of child labor *per se*, but is related to the task attributed to children. For example, it is expected that child labor is used to keep birds away, but children's presence might not reduce the loss to zero. The low production would then be the effect of the damage done by birds but not child labor on itself. In some cases, there might also be a negative direct effect of child labor, i.e. for example, if they perform poorly some difficult tasks such as transplantation or harvesting. Moreover, children can have a negative MPP if they require supervision from adults that reduce the work the adult can do.

Other variables that have substantial positive effects are ownership of oxen, the level of education of the head of household, and access to extension services. Ignoring land quality and exogenous shocks would inflate the effect of these factors on agricultural production. For example, in the case of access to extension services, instead of having a production increase of 201 kg from the full specification, one would expect to get 360 kg

from the short specification, i.e. a 74 percent difference. The expected bias as a result of agricultural policy interventions is clear. A policy focused on extension services will have a smaller impact on production when land quality and natural shocks are taken into account.²⁶

The seasonal effect and improved rice seedling transplantation are also affected negatively by the omission of land quality and natural shocks as the short specification shows a reduction of the magnitude of the switching effect from the adoption of IRST and the practice of "vary aloha".

In table 3, we also have additional information on the effect of land quality and natural shocks variables on other determinants of rice production. The long specification shows a marginal return of 8 percent for irrigation. This value is very close to the findings from IFPRI (1997), which reported an irrigation effect between 4 and 7 percent on land productivity. Lowland plots are expected to produce 9 percent more than rice fields in terraces. Clay or silty soil texture contributes to an increased total production of 9 percent. With respect to natural shocks, inundation is expected to reduce rice production by 10 percent. This is clearly an average value as in certain cases, flood can completely destroy the crop²⁷.

Lastly, the land rental dummy shows a significant and positive effect on agricultural productivity. It indicates that instead of reducing productivity, short-term land markets improve it. In theory, land rental arrangement might have two opposite effects on productivity: creating more insecurity to the cultivator or leading to

²⁶ The Ministry of agriculture reports an average increase of 4.68 kg of rice per kg of fertilizer used from 0 to 366 kg per *hectare*. Our fertilizer marginal physical product at an average rate of application of 81 kg per *hectare* is here 3.24 kg with the full specification.

²⁷ Some plots in the sample did not report production because of flooding.

reallocation of the land to more efficient tenants. The results of the regression indicate that the latter effect is more important as land under rental agreement slightly increase productivity. This supports the hypothesis that in our area of study, land was rented out to a group of farmers who could cultivate it more efficiently (see also Dorosh et al, 1998). However, we also can see in the descriptive statistics that access to rental lands seems to be difficult for poorer households, as they use only 5.5% of the rental land.

3.3. Effect of Farm Size on the MVP of Land, Labor, and other factors

Marginal Land Productivity

The patterns of marginal land productivity presented in Table 4 support the existence of the inverse relationship between land productivity and farm size for rice production in Madagascar highland. The Marginal Value Product (MVP) is computed from MPP and an exogenous average price of one kilo of paddy-rice, collected at the village level. From our sample, this average output price is 274 ariary²⁸. The ratio is that of MVP divided by the factor price²⁹.

Table 4 also shows that for any tercile, land MVPs lay above the market price of land. We have estimated the market price of land from the cost of renting one “are” of land during one agricultural season. As such, we obtained from our sample a value of around 2,600 ariary. The fact that these land MVP is greater than the factor price seem to indicate that land markets do not function perfectly and that poor people are often constraint to rent out land because of liquidity constraints.

²⁸ In 1999, the average exchange rate for \$ 1 US is 1,300 ariary.

²⁹ A ratio less than 1 indicates an over-use of the factor while inversely, a ratio greater than 1 is a sign of an under-use of the factor of production.

One can also notice the relative low elasticity output estimates of land. In table 4 we see an average output elasticity varying from .49 to .54, which is comparable to the .50 reported by Minten et al (2000) but definitely lower than the land output elasticity found by Sherlund et al (2001) on rice in Ivory Coast. Does this result imply that agricultural policy should focus on land redistribution in order to increase land productivity? The answer is not straightforward as if the behavior of farmers is a consequence of their landholding, an increase in the cultivated area for small farms would result in a reduction of their technical efficiency. On the other hand, reducing the land area for a large farm would not automatically result in an increase of their technical efficiency. Other factors might inhibit this improvement such as the reduction of the return to labor as land productivity increases.

Marginal Labor Productivity

For labor MVP, both family and hired labors present a significant difference inter-tercile (Table 4). We see the same pattern observed for the whole sample. Independently of farm size, family labor MVPs are lower than the hired labor MVP.

Table 4 – Inputs MVP and Switching Value of Binary Variables
by Farm Size Tercile, 563 fields, Madagascar Highland 2000

Full specification model	Tercile of farm size				
	Average	Factor prices	Small	Medium	Large
Land MVP (ariary per are)	3698	2,600 (a)	6138	3725	2873
<i>From small to (Col)</i>				-39%	-53%
<i>From medium to (Col)</i>					-23%
Ratio MVP to Factor prices			2.4	1.4	1.1
Elasticity of land			.49	.54	.54
Family Labor MVP (ariary per day)	741	760 (b)	184	861	1088
<i>From small to (Col)</i>				369%	492%
<i>From medium to (Col)</i>					26%
Ratio MVP to Factor prices			.2	1.1	1.4
Elasticity of family labor			.05	.15	.14
Hired labor MVP (ariary per day)	1286	760 (b)	845	1217	1650
<i>From small to (Col)</i>				44%	95%
<i>From medium to (Col)</i>					36%
Ratio MVP to Factor prices			1.1	1.6	2.2
Elasticity of hired labor			.18	.22	.25
Child labor MVP (ariary per day)	-1185	-	-1803	-1573	-494
<i>From small to</i>				-13%	-73%
<i>From medium to</i>					-69%
Elasticity of child labor			-.05	-.03	-.01
Number of oxen MVP (ariary per ox)	1824	-	2230	1629	1858
<i>From small to</i>				-27%	-17%
<i>From medium to</i>					14%
Elasticity of oxen			.05	.04	.04
Percent Change on MVP from Switching Value of Binary Variables					
Chemical fertilizer use	10%		13%	11%	7%
Extension access	8%		24%	11%	1%
Irrigation	8%		22%	11%	1%
Topography	9%		4%	9%	10%
Texture	7%		15%	9%	3%
Land tenure	8%		25%	10%	-1%
Inundation	-10%		-1%	-10%	-14%
Second season	-4%		17%	-3%	-17%
SRA	6%		43%	10%	-11%
Drought	-2%		-4%	-4%	0%
Education (d)	2%		9%	2%	-1%
Number of plots (d)	-5%		-8%	-6%	-1%

(a) This is the average price in ariary for renting one are of land for one season.

(b) This is the average agricultural wage rate at the village level

(col) = medium or large

(d) These are the change in MVP from one unit of change in the dependent variable

Source: Agricultural Production Survey, Madagascar Highland June 2000

The ratio for family labor for small farms is less than one, indicating an over-use of this factor. This corresponds to a MVP of 184 ariary per day, which at first, appears to be irrational. In theory, within a competitive labor market environment, the optimal solution for profit maximizing farmers is to equate labor MVP from rice to the agricultural wage rate, i.e. assuming that renting out labor constitutes the next best alternative. If labor markets are imperfect - which might to be the case in rural Madagascar highland - farmers might implicitly be forced to use family labor on the available land as long as the marginal return is not negative.

A failure in the output rice marketing system will also alter the optimal solution previously mentioned. If there are high uncertainties for rice supply during the lean period, risk-averse farmers would maximize rice production in order to minimize the risk of rice shortage. Real prices of rice would be higher because of transaction and transportation costs, resulting in higher MVP that farmers would use as benchmark for their input allocation decision. Over-using family labor on rice production would then be rationally justified.

Historical changes in the labor market may explain the adoption of the controversial SRI technology. In the late 1980's, Madagascar just came out of the centrally planned economic system. Thus labor mobility was limited. Moreover, the rice market was not entirely liberalized; rice distribution remained under the control of the government and did often not reach rural and remote area. Given these two constraints, many small farmers were over-using family labor for rice production, resulting in an increase in the numbers of SRI adopters. As the country is now moving towards a more liberalized economic system with an improvement in rice distribution, farmers who can

find better opportunities by selling their labor would reduce labor use on their own rice production, thus leading to a SRI disadoption. This situation would affect small farms more than medium or large farms because using hired labor is not a rational option for them, giving that their ratio of hired labor MVP over wage rate is already less than unity.

A second important finding concerning labor MVP is that hired labor presents a beneficial marginal return for medium (MVP = 1217 ariary per day) and large farms (MVP = 1650 ariary per day), but not for small farms. Approximately, the ratio of MVP over wage rates are 1.6 and 2.2 respectively for medium and large farms. Hence, they should be better off by using more hired labor for rice production. However, they might be constrained by the non-existence of a well functioning credit market. As hired labor requires cash in a period where resources are scarce (IFPRI, 1997; SECALINE, 1997), the existence of a well-functioning credit market constitutes a necessary condition for farmers. We estimate that an interest rate of 21 percent³⁰ applied on the current wage rate will raise agricultural wage rate to 920 ariary later in the year. This results in reducing the relative ratio of marginal return over wage rate for medium and large farms to respectively 1.2 and 1.8. The break-even for medium farms will be an interest rate of 60 percent during the agricultural season. Large farm would continue to obtain positive net return (marginal return – factor price) so long the interest rate stays below 117 percent. At this level of interest rate, farmers would no longer have an incentive to use additional hired labor.

³⁰ Currently, bank and micro-finance organization practice an interest rate varying from 2.5 to 3 percent per month. This corresponds approximately to a 21 percent interest during the rice season.

Also, labor may be simply unavailable when needed. In many agricultural settings, the MVP becomes very high in peak labor demand period such as for weeding and transplanting. In that case, they clearly exceed prevailing wages.

Other factors MVP

Chemical fertilizer is shown to have a higher marginal return for small farms than for large farms. This is consistent with the findings from Bernier and Dorosh (1993). This might indicate that small farms have better agronomic practices such as timely fertilizer application, more homogenous and timely weeding, which reduces the competition between weeds and rice. These conditions improve the effect of chemical fertilizer on rice production. This result also supports the idea that small farms have lower vulnerability from natural risks, which allows fertilizer to have higher MVP. For example, Table 1 shows that small and medium farms have lower inundation risk than large farms. Consequently, they would have a higher expected marginal return for fertilizer. Fertilizer has less effect on flooded plots because of the bigger problem with leaching.

Other factors show a difference in return between small and large farms. Such results are useful for poverty reduction strategies. For example, access to extension services and to education offer higher absolute and relative returns for small compared to large farms.

The differential effects of natural conditions and land quality on different farm size indicate that large farms face higher risks than smaller farms. For example, inundation decrease rice production by 1 percent for small farms while the losses may

reach 14 percent for large farms. As this variable should be stochastic, the sole explanation seem to come from the difference in the plot location. Plots located in the lowlands are flooded longer than plots in higher areas.

Lastly, RST would give a higher return to small than large farms. It is expected to increase rice production by 43 percent for small farms. This might be the result of timely and homogeneous agricultural practices combined with better land quality.

3.4. Incremental Land and Labor MVP of Productivity Intervention

In this section, we will analyze the change in land and labor MVP when farmers choose to move from a given level of technology to another. Improved Rice Seedling Transplantation (RST) is a good example of an alternative technology for increasing land productivity, using local production factors. It also constitutes a feasible alternative to the labor-intensive SRI technology.

The percentage of improved RST adopters in Table 5 indicates clearly that farmers adopt different technologies on different plots. It seems that farmers take soil characteristics into consideration and act accordingly. For example, there are fewer farmers who adopt IRST on flooded soil, which will have a high risk of submerging young plants.

Table 5 – Incremental Land and Labor MVP from**Adoption of Improved Rice Seedling Transplantation Technology (RST)****563 fields, Madagascar Highland 2000**

State of land quality and natural shocks	Percent of adopters	Improved RST	Ratio MVP over factor price	Traditional RST	Ratio MVP over factor price	<i>Incremental change from without to with RST</i>
<i>Land</i>						
Rainfed	6%	4639	1.8	3786	1.5	23%
Irrigated	7%	4593	1.8	3438	1.3	34%
Low	8%	3938	1.5	3336	1.3	18%
Terrace	4%	6799	2.6	4148	1.6	64%
Sandy	5%	3627	1.4	3455	1.3	5%
Clay	9%	5212	2.0	3715	1.4	40%
Non-flooded	9%	4753	1.8	3930	1.5	21%
Flooded	3%	4143	1.6	3337	1.3	24%
<i>Family labor</i>						
Rainfed	6%	762	1.0	702	.9	9%
Irrigated	7%	570	.8	811	1.1	-30%
Low	8%	1050	1.4	969	1.3	8%
Terrace	4%	419	-.6	391	.5	-207%
Sandy	5%	1321	1.7	981	1.3	35%
Clay	9%	224	.3	643	.8	-65%
Non-flooded	9%	763	1.0	714	.9	7%
Flooded	3%	509	.7	776	1.0	-34%
<i>Hired labor</i>						
Rainfed	6%	1374	1.8	1296	1.7	6%
Irrigated	7%	1150	1.5	1275	1.7	-10%
Low	8%	1583	2.1	1407	1.9	12%
Terrace	4%	561	.7	1075	1.4	-48%
Sandy	5%	2008	2.6	1526	2.0	32%
Clay	9%	888	1.2	1208	1.6	-26%
Non-flooded	9%	1366	1.8	1489	2.0	-8%
Flooded	3%	798	1.1	1065	1.4	-25%

Source: Agricultural Production Survey, Madagascar Highland June 2000

Table 5 presents the results of the change in land and labor MVP due to farmer's choice to adopt or not the improved rice seedling transplantation technology. All land

MVPs show a significant increase ranging from 5 to 64 percent. Obviously, if the increase of land MVP is the main objective, the conclusion is that all farmers should adopt improved rice seedling transplantation. The overall result indicates that this technology seems to overcome bad land quality and high risk from natural shocks. To achieve national self-sufficiency of its staple food, this technology might be a feasible alternative. It is therefore not surprising that in the mid-1990's, the Government propagated this technology as a national strategy to increase rice production.

However, adoption of this RST technology seems to affect other production factors. Family labor MVP is affected negatively. We are also facing a significant decrease in the MVPs for certain situations such as on terraced, irrigated, clay textured, and flooded land. These cases are also associated with low marginal productivity of family labor, showing often a ratio MVP over factor price of labor less than unity. For plots in terraces, the MVP is even negative, which might be interpreted as follow: the values of the increase in the production do not offset the costs of the increase in the number of family labor. More generally, the results show that the return to family labor from an RST adoption is not beneficial for farmers who have irrigated land. However, these farmers are the target population for this technology as it requires better water management control. The RST technology requires not as much a large quantity of irrigation water but more so a very high quality of the irrigation system, as it should allow the plot be watered or drained at any period.

The results for hired labor follow a similar pattern as for family labor. However, the magnitude of changes is smaller. The sole exception is that IRST increases significantly the family and hired labor MVP on sandy soil. This might be the effect of

the combination of the special water management system for IRST and the relative ease of working on sandy soil. On top of IRST, certain farmers apply the SRI technology, which is based on the assumption that rice is not an aquatic plant, thus there is no need to maintain a film of water above the rice field. The SRI technology requires that the best management is to treat rice like other plants, and alternate dry and humid soil without flooding the root. In this case where permanent water is not needed, sandy soil that requires less labor force because of its texture will give higher output and might value labor more.

In general, the positive but low marginal return and the decrease in the marginal return to labor might explain the relative disappointing level of adoption of improved rice seedling transplantation. However, this is not the only reason. The constraint of available cash during the beginning of the agricultural season is also important. Improved RST requires the need of large amount of labor during a peak period, often situated in the lean season. Thus labor and credit market imperfections would play an important role in the relative disappointing level of adoption of IRST.

Nonetheless, the results show that using hired labor is a good choice in many cases as the marginal returns are staying above the factor price. Table 5 indicates that with the exception of terraced and flooded soil, one can have a ratio MVP over factor price of hired labor greater than 1.

Conclusions

This thesis analyzes the effect of land quality and natural shocks on rice productivity in Madagascar. It is shown that these variables do have non-neutral impacts on rice productivity and that they are correlated with some of farmer's choice variables. It is shown that the omission of land quality and natural shocks in analytical models leads to a bias in the marginal physical product of land, labor, and other factor of production, which would result in misleading agricultural policy-makers about the productivity of these factors.

As findings in other developing countries studies where many agricultural tasks are still manually performed have shown, small farms allocate more labor per unit of land. This allows them to reach higher land productivity. However, this is usually associated with lower labor productivity, especially for family labor. The consequence might be less interest to adopt labor-saving new technologies, unless imperfections in the local labor market and in rice markets are solved, as these might put them in an insecure food situation.

Medium and large smallholders show a high return from hired labor. This makes them a potential target for labor-intensive technology, under the condition that there is a well-functioning and financially accessible credit market. In general, results from the comparison between tercile of farm size appear to be important in targeting different households who might be interested or not in a given technology. If farmers were considered as customers for various technologies, then a market segmentation approach would be a better strategy for extension service delivery.

More generally, all farms are experiencing a low family labor marginal value product. Increasing labor productivity could involve two types of related policies. First is the improvement policy, which consists in improving MVP by reducing labor input. This would lead to a higher labor MVP, but might also lead to lower land MVP because of the reduction of the input use. One can imagine a movement along the production curve, toward the origin. For a profit maximizing manager viewpoint, the optimal point, where the average product maximizes the return to labor, would be the one where labor MVP is equal to the implicit wage rate.

This might be solved practically by identifying and promoting small tools that allow farmers to reduce the amount of labor needed per land unit, without harming the quality of the labor while maintaining the level of land productivity. A good illustration for this is the use of mechanical tools for weeding given that this task occupies almost 21 percent of total labor needed by farmers. In practice, farmers are aware of this situation of low productivity of family labor, thus they already modified the SRI technology to optimize their labor input use. Various other practices by farmers illustrate this behavior. For example, they use older plants instead of a 8-day old plants in order to reduce labor for the transplantation. One also notes a reduction of the number of weeding from 5 to 3; or a more flexible water management, all of this in order to reduce the quantity of labor needed.

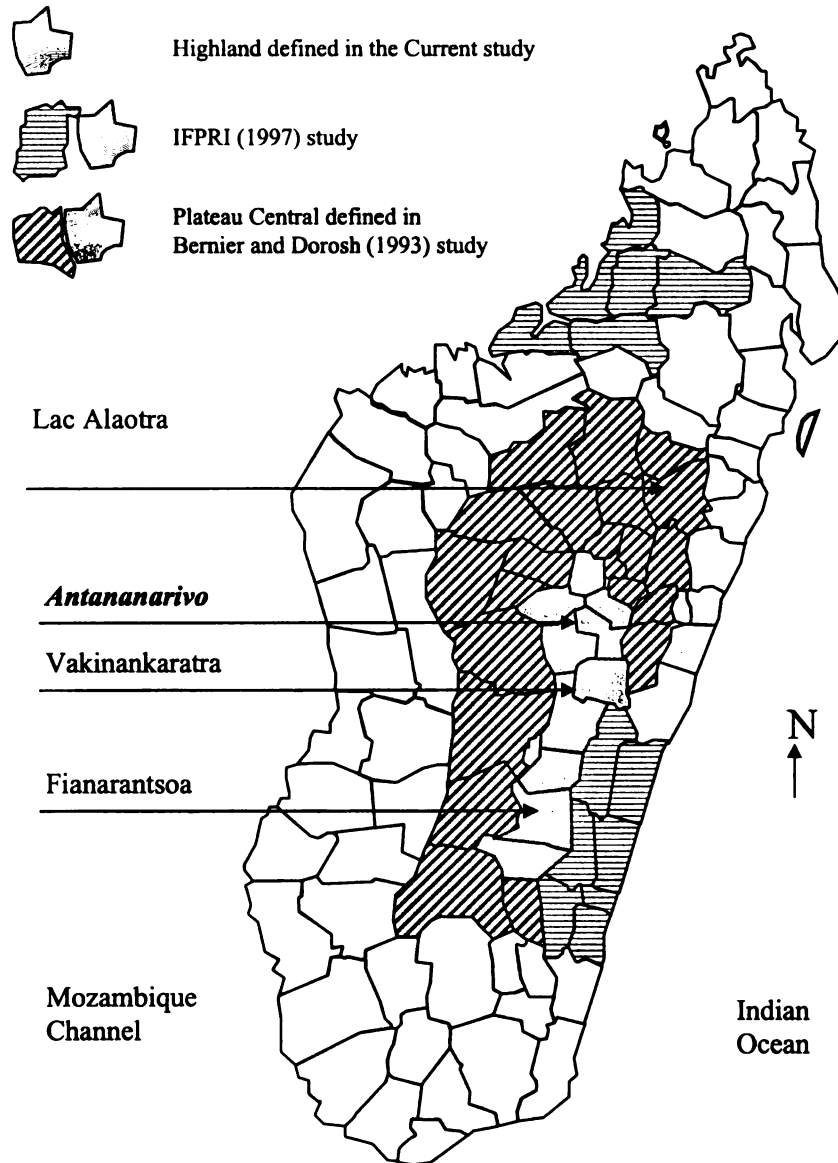
A second policy option is the transformation approach. This consists of a more structural change, led by agricultural research. The objective here is to improve the responsiveness of rice from the use of different inputs, in order to have higher productivity and result in an increase in labor MPP. One can imagine here a non-parallel

upward shift of the production curve, corresponding to higher output from the same level or even reduced inputs. This approach involves substantial changes and relies more on the efficiency of the agricultural research system. Of course, a combination of these two approaches would solve more efficiently the low labor productivity issues.

Lastly, credit policy should not be targeted only in the supply of chemical inputs or seeds, usually seen in contracting financial scheme. We demonstrated that the use of hired labor, which means a need for cash, constitutes a good investment for medium and large farms. The use of improved rice seedling transplantation technology appears to be promising in many ways. It allows an increase of land MVP under any state of land quality and natural shocks. However, the effect on labor productivity, both family and hired, seems to be negative, resulting in a moderate level of adoption of this technology. This is however a good alternative for farmers having low opportunity costs of labor and facing high rice supply insecurity.

A potential extension of this thesis might be the analysis of the variance effects of different factors of production. This research would contribute to the reason why farmers do not adopt a given technology. Also, to better assess initial land quality, it is suggested to have some variables that control for the initial endowment of the plot. It is indeed interesting to know what decision rule farmers apply in allocating fertilizer on their plots. Do they apply fertilizer on good quality plot or is the reasoning vice-versa? The results will change the estimated effect of fertilizer application on the production level because of the effect of previous fertilizer application.

Appendix 1 – Madagascar - Mapping of Surveys Sites



Appendix 2 – Mackinnon White Davidson (MWD) Test For Non-Nested Models

The MWD test consists in identifying the “best among the tested” functional form for the data. It is used for non-nested models that have different dependent variables measurement units. The test involves the following steps (Gujarati, 1995):

1. Estimate model 1 and compute the estimated value **mhat1**
2. Estimate model 2 and compute the estimated value **mhat2**
3. Convert mhat1 in model 2 dependent variable units, let say we have **mhat1b**
4. Take the difference between **mhat1b – mhat2**, let say **mhat**
5. Estimate model 2 with adding **mhat** in the RHS
6. Using asymptotic t-test, test mhat
 - a. If **mhat** estimates = 0 → Reject model 1
 - b. If **mhat** estimates not equal to zero → cannot reject model 1
7. Repeat in the opposite way to test for model 2

1 – MWD Test between Square root generalized Leontief (GL) and Translog

	Coefficient	t-value	p-value	
GL/Translog	0.64	3.54	0.000	GL is a valid functional form Significant at 1% level
Translog/GL	0.63	3.10	0.003	Translog is a less valid functional form Even significant at 1% level

2 – MWD Test between Square root generalized Leontief (GL) and Quadratic

	Coefficient	Stand. Err.	p-value	
GL/Quadratic	1.33	11.88	0.000	GL is a valid functional form Significant at 1% level
Quadratic/GL	0.31	3.25	0.001	Quadratic is a less valid functional form Even significant at 1% level

Appendix 3 – Correlation between choice, conditioners and land quality – natural shocks variables

	Location				
	Irrigation	topography	Soil texture	Inundation	Drought
<i>Choice variables</i>					
Plot area in ares	.040	.029	.067	.068*	.085*
Family labor in days	-.097*	.061	-.030	.056	-.007
Hired labor in days	.006	.024	.082*	.013	.046
Child labor in days	.014	.141*	.001	-.018	.021
Chemical fertilizer in kg	.030	.020	.046	-.062	-.090
Number of oxen	.023	.030	.037	-.181*	.098*
Rice seedling transplantation in days	.006	-.072*	-.072*	-.113*	-.099*
<i>Conditioner variables</i>					
Extension contact = 1	.032	.023	.052	-.031	.155*
Region Vakinankaratra = 1	.047	-.074*	.087*	-.117*	.158*
Season Vary aloha = 1	.030	-.006	.071*	-.037	-.068
Education of household head	.034	-.086*	.013	-.123*	.116*
Number of plots	.040	-.029	.013	.450*	.063

* Significant at least at 10 percent level

Source: Agricultural Production Survey, Madagascar Highland June 2000

Appendix 4 - Wald Test results

The F statistic for testing a set of linear restrictions is no longer distributed as F because neither the numerator nor the denominator has the necessary chi-square distribution. However, the Wald statistic $JF[J, n - k]$ does have a chi-square distribution asymptotically and can be used instead (Greene, 1993). 'Wald test' tests linear hypothesis about the estimated parameters. The significance means that the regressors jointly explain a significant amount of variation in the production level.

Variables		t-value	p-value	Significance level
Plot area	F(18, 470)	35.07	.000	***
Family labor	F(18, 470)	8.02	.000	***
Hired labor	F(18, 470)	11.58	.000	***
Child labor	F(18, 470)	1.94	.012	**
Fertilizer	F(18, 470)	3.88	.000	***
Draught oxen use	F(6, 470)	1.04	.396	
Dummy Vakinankaratra	F(6, 470)	20.52	.000	***
Acces to extension service	F(6, 470)	1.20	.306	
Dummy season	F(6, 470)	5.10	.000	***
Head education	F(6, 470)	2.38	.028	**
Land tenure	F(6, 470)	1.51	.170	
Rice seedling transplantation	F(6, 470)	11.85	.000	***
Irrigation	F(6, 470)	3.25	.004	***
Topography location	F(6, 470)	3.93	.000	***
Soil texture	F(6, 470)	1.93	.074	*
Inundation	F(6, 470)	2.53	.020	**
Drought	F(6, 470)	3.69	.001	***

*, **, *** are respectively significant at 10, 5, and 1% level

Appendix 5 - Bootstrap Method and t-test between two means

Difference significance is based on a t-test between the two means of MPP from the full and the short specification. Because we computed the MPP from the sample mean on each regression result, there is no variation on the values of MPP, thus the variances would be estimated by bootstrapping the distribution of MPP.

This method consists in drawing randomly lots of replicates (50 in our cases) of the original data -- with replacement -- and then computing the MPP for each of those random samples. We can take the variances of MPP from the hundreds resulting MPPs and use t-test to look at the significant difference between the two means.

This is easily done with STATA using the following syntax:

bs "regress y x1 x2 x3" "MPP = $\partial y / \partial x_i$ ", reps(50)

Results of t-test between the MPP from full and short specification

	Full specification		Short specification		t-value	p-value
	Mean	Std. Err.	Mean	Std. Err.		
Plot area	13.49	.89	13.45	.80	.236	.814
Family labor	2.70	.81	2.95	.64	-1.712	.090
Hired labor	4.69	.47	4.76	.70	-.587	.558
Child labor	-4.32	6.13	-1.24	5.50	-2.644	.009
Number of oxen	6.66	3.68	12.25	3.40	-7.889	.000
Land tenure	291	250	241	292	.918	.360
Extension access	207	163	360	138	-5.050	.000
Season "aloha"	-111	227	26	198	-3.221	.002
Region Vakinankaratra	231	37	241	39	-1.246	.216
Improved RST	391	851	109	723	1.76	.077
Chemical fertilizer use	396	327	414	453	-.224	.823
Education of head	1.39	3.59	2.79	2.85	-2.159	.033
Number of plots	-5.43	7.33	-6.46	5.83	.777	.489

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