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Strategies for Improving Adoption of Soil-Fertility Technologies in Rwanda

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Technology holds great potential for raising agricultural productivity and reducing poverty. This is particularly true in Rwanda where agriculture is the most important sector of the economy. However, the agriculture sector is beset by many problems of which obsolete technology is paramount. Using soil testing and fertilizer application practices by farmers as a measure of adoption of agricultural technologies, this brief assesses the factors influencing technology adoption and the implications for transforming the sector for coffee farmers in the Southern Province of Rwanda. Results show there is a strong association between the two practices, as a farmer who tests the soils on his or her farm is also highly likely to use fertilizer. Younger, wealthier, better-educated farmers with relatively less fragmented farms, better access to agricultural training, and information sources are relatively more likely to adopt technologies. This means that targeting younger, wealthier, and better-educated farmers will be an important short-term strategy for raising agricultural performance in Rwanda. But improving agricultural education and access to services among the resource-poor farmers will be critical for ensuring long-term economywide benefits of the government's transformation agenda.

BACKGROUND

Agriculture contributes a significant proportion of Rwanda's Gross Domestic Product (34 percent in 2010) and is the main source of employment and income for over 80 percent of the population (NISR 2010a). It also plays an important role in foreign revenue, with over 70 percent of the country's receipts from export crops (NISR 2010b). Coffee and tea are the two main export crops and the most widely cultivated cash crops. Farming is primarily undertaken by smallholder farmers, who may grow some cash crops, but generally practice agriculture for subsistence. They tend to use traditional methods and obsolete technology therefore obtaining low yields.

Evidence demonstrates the need for increasing agricultural productivity to foster overall economic growth, reduce poverty, and enhance food security (World Bank 2007). Technological change, leading to marked productivity increases, has clearly occurred in other parts of the developing world. This was particularly evident during the Green Revolution with increasing fertilizer-efficient use (Freebairn 1995). Average cereal yields in the developing world increased by 2.7 percent per annum between 1966 and 1982 (IFAD 2001). Results were most impressive in South Asia with 240 percent growth (Kerr and Kolavalli 1999).

Low productivity in Rwanda is also reflected in the low average fertilizer application rate of 8 kilograms per hectare (kg/ha) (MINAGRI 2011), compared to Africa's and Asia's average of 10 and 148 kg/ha, respectively (IFDC 2007).

Rwanda´s commitment to the New Partnership for Africa's Development (NEPAD) Comprehensive Africa Agricultural Development Programme (CAADP) has fundamentally reformed the country´s policy environment leading to an agricultural transformation agenda, which includes the goal of increasing the average fertilizer application rate to 25 kg/ha.

POLICY FRAMEWORK

In its strategic vision, Vision 2020, Rwanda set ambitious

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goals for its development. For example, the government seeks to raise per capita GDP from $250 in 2000 to $900 by 2020, which implies that the overall economy needs to expand by over 600 percent when population growth is taken into account (MINECOFIN 2000). This makes the coffee industry a priority focus area, given its historic position as the country's leading export revenue earner and an important employment opportunity for nearly 500,000 coffee grower families (MINAGRI 2008). The Vision 2020, together with the Poverty Reduction Strategy Paper (PRSP), and the subsequent Economic Development and Poverty Reduction Strategy (EDPRS), emphasized a sustainable production environment. In 2002, the government of Rwanda issued a national coffee strategy that included developing soil testing capabilities and enabling application of tailored fertilizer blends.

PROBLEM STATEMENT AND OBJECTIVES

Rwandan soils were considered generally fertile. Soil was maintained primarily by using locally-available organic fertilizers in combination with other practices such as crop rotations and intercropping. But agricultural productivity started declining in the late 1980s, and it became evident that these fertilization methods could not support the nutrient needs of continuous and intensive cropping activities. Use of chemical fertilizers became inevitable, particularly in areas of the southern province where the soils are derived from basic rock, granite, and schist and are vulnerable to changes in land use (CPR 1993). This differs from soils in the northern province, which are derived from volcanic material and reputed to be very fertile. However, past trends of fertilizer consumption in the country suggest that the areas that need fertilizers the most are those where fertilizers are used the least (Kelly et al. 2001). In the first part of the 2000 season for example, the southern province accounted for only three percent of the total 1,947 tons of fertilizer used (Kelly et al. 2001). Because coffee is an important cash crop in these areas, declining soil fertility and low use of fertilizers has severe economic and social implications. The aim of this brief is to analyze fertilizer adoption patterns of farmers in different areas and to assess the factors influencing the adoption.

[2] The test showed a strong and significant association between the two practices (Phi-coefficient = 0.321, Pearson chi-square = 18.9). Both were statistically significant at the one percent level.

METHODOLOGY AND DATA SOURCES

Measurement of technology adoption

Because of the belief that farmers' use of fertilizer is contingent on the fertility of the soils on their farms, we utilize both soil testing and use of fertilizer to capture adoption. Soil testing is measured as dichotomous, equal to one if farmers have had their farm soils tested and zero otherwise. Likewise, use of fertilizer is measured as dichotomous, equal to one if fertilizer is used and zero otherwise. The notion of the interdependency between two practices is confirmed by a large and statistically significant chi-square test statistic associated with the correlation between the two variables[2].

Conceptual framework of adoption

The literature shows that there are several factors that influence technology adoption. These include factors measured at the individual or household level such as gender, age, education, economic status, endowments, and access to services. They also include farm level factors of soil characteristics, land use, and tenure security. Technology adoption is further influenced by community and higher-level factors, such as availability of services and policies. The literature also shows that these factors affect adoption in different ways and that the sign of the effect is indeterminate a priori. Regarding gender for example, a MINAGRI/UNDP (1996) report has shown that social customs in Rwanda tend to discriminate against women, reducing their access to information and new technologies. As such one would expect adoption of fertilizers to be lower among women. Because of the gender bias many programs tend to address this issue upfront and so it is likely that gender may not be a significant factor in the end. Age too can have both positive and negative effects (see e.g. Adesina et al. 2000 and Hassan 1998). On one hand younger farmers are more likely than their older counterparts to adopt new technologies. This is because older farmers tend to be more efficient in their practices and require much greater returns to change their practices compared to younger and inexperienced farmers who are just starting out and have lower marginal productivities. However, older farmers will have a first-hand experience and better sense of the declining soil fertility and yields and so they may be more likely to adopt fertilizers (Celis et al. 1991). The economic status of a farmer has an important influence on adoption behaviour (Feder et al. 1985). It is more likely that wealthier farmers are able to finance the cost of a new technology. Adesina et al. (2000) have shown that non-farm income has positively influences adoption of technologies and Essa and Nieuwoudt (2001) reported that farmers who have more wealth in the form of livestock may be better able to finance the cost of technology adoption.

In the coffee industry, farmers may have access to several sources of farm information, including: (i) economic advisors from MINAGRI, (ii) experiment research stations, (iii) field extension officers, (iv) farmer participation in field day-demonstrations and practical training workshops in coffee growing, (v) interaction with other farmers, and (vi) the use of farm magazines. Farmers with better access to information have higher levels of cumulative information, and will therefore adopt earlier than other farmers (Feder and Slade, 1984). Similarly, farmers with greater endowments of human, physical, financial, and social capital are more capable of adopting new technologies (Nkonya et al. 1997). But greater endowments also offer greater exit options out of agriculture. And so endowments may also have positive or negative effects on adoption. This is true for many of the factors found to affect adoption, meaning that the direction of their effect is context specific. And so we try to capture in our analysis the key variables considered in the literature. These are presented following the discussion of the data sources.

Quantitative methods

We use a linear discriminant analysis (LDA) to assess the magnitude and significance of the different factors that are hypothesized to influence the adoption of technologies. The objective is to find a linear function of the explanatory variables that distinguishes between the two groups of adopters and non-adopters. Because many of the explanatory variables considered tend to be correlated with one another, a principal component analysis (PCA) was first used to condense the explanatory variables into fewer orthogonal variables, each measuring a different dimension in the data (Manly 1994). Using Kaiser's criterion (Norušis 1990), only principal components with eigenvalues greater than one are retained for further analysis. This criterion is more accurate when the number of variables used in the PCA is relatively small (Stevens 1986).

Data sources and variables

The analysis is based on primary data from 183 household surveys that were conducted in 2001 in the Rusatira and Muyira sectors of the Huye district in the southern province of Rwanda where the soil fertility problem is most severe. Coffee is the main cash crop produced in the two areas, which makes them economically important, as coffee is one of the country's foremost exports (MINAGRI 2008).

Geographically the Rusatira and Muyira sectors are similar with an average annual temperature of 18°C and rainfall of 1,500–2,000 mm that is well distributed throughout the year. Both sectors have a mountainous landscape, with altitude ranging from 1,400 to 2,000 meters above sea level. Similar crops are grown in the two sectors. The main differences between the two are that Muyira is a planned sector whereas Rusatira is not, and the average farm size is larger in Muyira (3.3 ha) than in Rusatira (1.5 ha).

Table 1. Use of soil testing and adoption of fertilizer (percent of total)

Had soils tested?	Used chemical fertilizer?	
	Yes	No
Yes	19.7	13.1
No	18.0	49.2

Source: Authors' calculation based on MINAGRI-OCIR (1998)

Technology adoption

Based on the definition and measurements of the variables on soil testing and fertilizer use, there are four mutually exclusive groups that can be identified: those that adopted soil testing and used fertilizer (which make up 10.7 percent of the total of 183 households or farmers); those that used fertilizer but never had soils tested (18.0 percent); those that adopted soil testing but never used fertilizer (13.1 percent); and those that neither had soils tested nor used fertilizer (49.2 percent) (see Table 1). In the analysis, we tried to use these four categories but it quickly became complicated. Therefore we tried different re-classifications to capture full-adoption (i.e. adoption of both soil testing and fertilizer), partial-adoption (i.e. adoption of either soil testing or fertilizer), and non-adoption (i.e. no adoption of either soil testing or fertilizer). Still the results of the discrim-

Table 2. Explanatory variables and descriptive statistics

Variable name	Measurement	Mean	
		Adopters	Non-adopters
Farm size	Area of farm in ha	3.99	1.88
Age	Number of years	44.92	50.08
Gender	Male=1, female=0	79.0	71.0
Education	No schooling=0, primary=1, secondary=2, tertiary=3	0.54	1.78
Agricultural training	Undertook any training in agriculture=1, no training=0	0.92	0.60
Workshops	Average number of agricultural workshops attended in 1999 and 2000	3.52	1.72
Extension visits	Average number of field extension officer visits received in 2000	2.2	1.0
Farm information	Index of usefulness of farm information sources: not useful=0, less useful=1, useful=2, very useful=3	1.1	0.7
Off-farm income	Average monthly off-farm cash income in Rwandan Francs	8,728	1,861
Value of livestock	Value of all livestock owned in Rwandan Francs	210,167	117,311
Tenure certainty	If feels assured of long term tenure security=1, otherwise=0	0.57	0.89
Number of plots	Number of arable farm plots	1.89	2.94
Distance to plots	Average travel distance between home and plots	0.59	1.48
Land under coffee	Percentage of farm size under coffee	38.59	33.48

Source: Authors' calculation based on MINAGRI-OCIR (1998).
Notes: Number of adopters and non-adopters are 36 and 90, respectively.

inant analysis were poor. The best results were found when we used the two extreme cases of full-adoption and non-adoption. Therefore, we present the detail analysis and results for this case, but discuss the others where it is instructive to do so.

Explanatory variables

The explanatory variables used in the analysis and their measurements and descriptive statistics are shown in Table 2. On average, adopters of technologies tend to be younger and better educated; operate larger and less fragmented farms; have greater liquidity; perceive greater tenure certainty; and allocate a greater proportion of their arable land to coffee production than farmers who have not adopted technologies. Farmers who have adopted technologies are also exposed to more agriculture training, information, and extension visits.

Table 3. Results of the principal components analysis (PCA)

Explanatory variable	PC1	PC2	PC3	PC4
Farm information	0.89			
Workshops	0.80			
Extension visits	0.78			
Agricultural training	0.70			
Number of plots		0.71		
Distance to plots		0.67		
Age		0.65		
Farm size		0.58		
Value of livestock			0.79	
Off-farm income			0.74	
Education			0.58	
Tenure certainty				0.75
Gender				0.64
Land under coffee				0.61
Eigenvalue	3.49	1.92	1.56	1.20
Percentage variability	24.9	13.7	11.2	8.6

Source: Authors' illustration based on the PCA model results.

Table 4. Standardized discriminant function coefficients

Explanatory variable	Coefficient	t-value
PC2	-0.79	-6.29**
PC3	0.65	5.14**
PC4	0.57	4.28**
PC1	0.42	3.15*
F-statistic	71.30**	
Wilk's Lambda	0.55	
Canonical correlation	0.66	
Prediction (percentage)	84.90	

Source: Authors' illustration based on the LDA model results.
Notes: ** and * mean statistically significant at the 1% and 5% levels of confidence, respectively.

Table 5. Classification for adopters and non-adopters of technologies

Explanatory variable	Component score		F-statistic
	Adopters	Non-adopters	
PC2	-1.47	1.03	25.79**
PC3	1.77	-0.77	24.15**
PC4	0.76	-0.82	10.66**
PC1	0.60	-0.40	4.35*
Prediction (%)	88.90	83.30	

Source: Authors' illustration based on the LDA model results.
Notes: ** and * mean statistically significant at the 1% and 5% levels of confidence, respectively.

ESTIMATION RESULTS AND DISCUSSION

The PCA generated four linearly uncorrelated variables or principal components (PC) that accounted for the variability in the data associated with both the adopters and non-adopters of technologies as shown in Table 3. Utility of farm information, number of workshops attended, number of extension visits received, and having obtained agricultural training (together as PC1 in Table 3) accounted for the bulk of the variability in the data (about 25 percent). This was followed by fragmentation (number of and distance to plots), age, and farm size (PC2). Contingent on being orthogonal to the other variables, tenure certainty, gender, and land under coffee (PC4) accounted for the least variability in the data (about 9 percent). These four PCs are used in the subsequent analysis (LDA), whose results are presented in Table 4.

The results in Table 4 show that PC2 (number of and distance to plots, age, and farm size) and PC3 (wealth and education) are statistically the two most important dimensions discriminating between adoption and non-adoption of the two soil fertility technologies. However, while PC2 has a negative effect, i.e. more fragmented plots and older farmers are less likely to adopt the technologies, PC3 has a positive effect, i.e. wealthier and educated farmers are more likely to adopt the technologies. The results show that gender, tenure security, and access to agricultural information through workshops, extension, and training are not as critical in determining adoption. This is not surprising and is consistent with other findings, which suggest that farmers are already well informed about the importance of these technologies in maintaining soil fertility and increasing their yields, but it is the ability to access and purchase the technologies that poses a problem. A Wilk's lambda value of 0.55 and 84.9 percent overall correct classification of adoption and non-adoption indicates an effective classification ability of the estimated discriminant function.

The results of the discriminant function separately for the two groups, judged from the magnitude of the canonical correlation associated with that function, are shown in Table 5. The LDA model correctly identifies 88.9 percent of the adopters and 83.3 percent of the non-adopters.

CONCLUSIONS AND POLICY IMPLICATIONS

Factors influencing the adoption of soil-fertility technologies (measured by soil testing and use of chemical fertilizers) in key areas of the southern province, where soil-fertility problems are prevalent and potentially impact the performance of the coffee sector, were studied. The results of the analysis, using household survey data, principal components, and linear discriminant analysis, show that farm fragmentation, age, wealth, and education are the most important factors influencing adoption of the two soil-fertility technologies.

Greater land fragmentation was associated with greater likelihood of non-adoption, suggesting that policies that promote consolidation of land are important to achieving improved agricultural performance in Rwanda. Younger, wealthier, and more educated farmers were associated with greater likelihood of adoption. This points towards the potential of short-term gains in increasing agricultural production and productivity by targeting these farmers. For example, because younger farmers tend to be inexperienced and resource-strapped, improving their access to extension and training coupled with financial assistance to acquire the necessary technologies will be critical. Because the wealthier farmers are already in a position to acquire the technologies, giving them access to more land will be important. They, and the more educated farmers, can be engaged to assist and train the younger farmers who have less experience farming.

Gender, tenure security, and access to agricultural information through workshops, extension, and training were not as critical in determining adoption, suggesting that most farmers seem to be already well-informed about the importance of these technologies, but it is the ability to purchase the technologies that poses a problem. This reinforces the earlier finding of the strong positive effect of wealth on adoption and points towards the need for a strong collaborative link between the provision of agricultural extension services and provision of financial and credit facilities to farmers.

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