FACTORS INFLUENCING ADOPTION OF RECOMMENDED FARM PRACTICES BY COFFEE FARMERS IN BUTARE, SOUTHERN RWANDA

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Abstract

Factors influencing technology adoption by Rwandan coffee farmers, assessed according to the extent of adoption of soil testing and use of fertilizer, are studied based on a survey of 183 coffee farmers from Rusatira and Muyira districts in Butare Province during 2001. Twenty per cent of farmers surveyed have adopted both practices, however, forty-nine per cent have adopted neither. A chi-square test shows a strong association between the two practices, implying that a farmer who tests soils on his farm is also likely to use fertilizer. Results support expectations that farmers who adopt more recommended technologies and farming practices are more productive and more efficient producers of coffee. A discriminant analysis identified land fragmentation, availability of wealth and liquidity, and education of the principal farm decision-maker as the most important factors influencing the adoption of recommended and appropriate farming practices on coffee farms, followed by gender of farm operator, and farm information acquired by farmers. Transformation of Rwandan coffee farming requires policies that (a) remove obstacles to the development of an efficient land market in order to reduce land fragmentation and to transfer land to more efficient farmers; and (b) improve rural education and liquidity, and reduce gender discrimination in order to improve farmers' abilities and promote adoption of recommended farming practices.

1. INTRODUCTION

In Rwanda, agriculture contributes around 40% of GDP, provides employment for about 90% of the working population and accounts for 85% of foreign exchange earnings (World Bank, 1999). Coffee is the most important crop, accounting for three-quarters of these foreign exchange earnings (MINAGRI & OCIR, 1998). However, Rwandan agriculture, including coffee farming, is beset

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by many problems, including obsolete technology, land fragmentation, inadequate infrastructure and a shortage of skilled manpower (Waller, 1993).

Customary laws governing access to, utilization of and transfer of land in Rwanda are diverse (Place *et al.*, 1994) and have led to land being excessively fractionated through heritage, and settlements generally scattered in rural areas (Takeuchi & Marara, 2000). Although the government has declared some policy change and enacted legislation affecting land rights, land transactions, size of holdings, imposed land taxes, the substance of the law, and the extent to which laws are enforced, an analysis of World Bank data has revealed that these changes have been largely ineffectual (Place *et al.*, 1994). Further, Takeuchi & Marara (2000) contend that co-existence of this written (or "modern") law with the customary laws has resulted in rights to land being so ambiguous that investment tends to be hindered.

Adoption of improved technologies and farming practices has for many years been a major contributing factor to agricultural productivity growth achieved in developing countries (Manning, cited by Rauniyar, 1990). Improved technologies may be packaged in, for example, seeds, pesticides, fertilizers, equipment or resource-management schemes (Welch, 1978). It is important to the on-going effort to transform Rwandan agriculture that farmers adopt appropriate management practices and technologies in order to improve the production efficiency of Rwanda's scarce agricultural land resources. This study, therefore, seeks to determine factors explaining different adoption rates of recommended farming practices and technologies. Factors studied include those related to farmers' managerial abilities (e.g. human capital), and farm physical and financial characteristics. Results have implications for development of a sound agricultural policy in Rwanda.

2. STUDY AREA AND DATA COLLECTION

The study is based on data collected by the senior author from December 2000 to February 2001 using a standardized questionnaire applied to a total of 200 coffee farmers in Rusatira and Muyira districts, Butare province in Southern Rwanda. The sample was selected at random from a population list provided by extension officers in the two areas. The survey collected information on farm operator and farm business characteristics, and in particular on details of coffee production on these farms.

Geographically the two regions are similar. They have similar climates. Temperatures vary little, ranging from 18^0C to 24^0C. Annual rainfall averages between 1 500 mm and 2 000 mm and is well distributed throughout the year.

Both districts have a mountainous landscape, with altitude ranging from 1 400 m to 2 000 m above sea level. They differ in that Muyira is a planned district whereas Rusatira is not, which accounts for farms being on average larger in Muyira (3.30 ha) than Rusatira (1.50 ha).

3. ASSESSMENT OF TECHNOLOGY ADOPTION

Technology adoption is simply defined as the act by which a person begins using a new practice to replace an old one. Adoption is taken to be the final outcome of exposure to some practice or innovation, and a variety of sources are used to communicate the message (Brien *et al.*, 1965). Feder & Slade (1984) reported that "improved knowledge regarding a new technology through the accumulation of a stock of information (i.e. with economic return) over time is hypothesized to be one of the main dynamic elements of the technology adoption process". Farm operators with better access to information have higher levels of cumulative information, and will therefore adopt earlier than other farmers, *ceteris paribus* (Feder & Slade, 1984). Welch (1978) contends that education reduces the cost of information and improves allocative efficiency, while demand for education increases with farm size as returns to education are scale proportional (large scale implies broader scope for applying information). Similarly, farmers with better endowments of human capital will acquire higher levels of knowledge and adopt earlier than other farmers. In this study Rwandan coffee farmers' adoption abilities are assessed according to their adoption of soil testing and use of fertilizer.

Soil testing to determine the suitability of regions for the coffee crop, and the adoption of fertilizer, are used to measure adoption of improved farm practices among coffee producers. The adoption of the two farm practices (soil analysis and use of fertilizer) is also used to reflect on the managerial mastery of individual coffee farmers. Coffee is an efficient user of a combination of nitrogen (N), phosphorus (P) and potassium (K), known as NPK 20-10-10, and its timing and placement is critical for the production of high yields of coffee (MINAGRI & OCIR, 1998).

Soil testing on coffee farms was measured as dichotomous, equal to one if farmers have had farm soils tested, otherwise zero. Likewise, use of fertilizer was captured as dichotomous, equal to one if fertilizer is used, and zero otherwise. From a total of 200 coffee farmers surveyed, 183 valid cases were retained, of which 90 (49.2%) neither had soils tested nor used fertilizer, 33 (18.0%) used fertilizer but never had soils tested, 24 (13.1%) adopted soil testing but never used fertilizer, and 36 (19.7%) adopted soil testing and used fertilizer. The other 17 cases remaining were excluded from the final model because of lack of

sufficient information. A chi-squared test revealed a statistically significant association between the two practices (Phi-coefficient = 0.321, Pearson's chi-square = 18.9), implying that farmers' decisions to adopt these practices are not independent of each other: farmers who test soils on their farms are more likely to use fertilizer. Consequently, the two variables may be combined into a single variable as a measure of farmer adoption ability according to whether farmers are *non-adopters*, *partial-adopters* or *full-adopters* of these two practices.

Descriptive statistics, presented in Table 1, indicate that, on average, farmers who have adopted relatively more recommended technologies tend to produce significantly higher yields per hectare and achieve significantly higher net farm income per hectare than farmers who have adopted less and/or have not adopted recommended technologies at all, despite having similar per hectare labour and variable input costs. These trends are consistent with *a priori* expectations that farmers who adopt relatively more recommended technologies tend to be more productive and more efficient coffee farmers. Adopters of recommended technologies also tend to be younger and better educated; operate larger, less fragmented farms; have greater liquidity; perceive greater tenure certainty; and allocate a greater proportion of their arable land to coffee production.

Table 1: Mean farm operator and farm business characteristics by adoption rates, Butare Province, Rwanda, 2001

Variable	Technology Adoption			
	Non-adopters (90)	*Partial-adopters* (57)	*Full-adopters* (36)	F-value
Age of farm operator (years)	50.08	47.58	44.92	3.22**
Education[1]	0.54	1.21	1.78	49.58***
Farm size (ha)	1.88	3.40	3.99	42.87***
% of arable land under coffee	33.48	38.46	38.59	3.94**
Average yield (Kg/ha)	567.06	636.14	728.24	17.02***
Net farm income (RWF/ha)[2]	1858.88	3132.71	3722.71	32.39***
Off-farm income in RWF	1861.11	2696.49	8727.78	11.90***
Monetary value of livestock in RWF	117311.10	89929.82	210166.70	4.72**
% farmers confident of secure tenure	57	67	89	6.28**
Number of plots cultivated	2.94	2.21	1.89	17.44***
Distance between parcels (km)	1.48	0.89	0.59	10.63***
Labour cost (RWF/ha)	1352.78	1265.79	1305.55	1.27
Input costs (RWF/ha)	557.89	510.09	524.58	0.07

*** and ** denote statistical significance at the 1 and 5 per cent levels of confidence, respectively. Figures in parenthesis represent valid cases.

[1] Scale ranging from zero to three to symbolize no formal schooling, grade 6 and below, grade 7 to grade 12, and tertiary education, respectively.

[2] RWF denotes Rwandan Franc. (During January 2001, 1ZAR = 52.5RWF.)

4. ANALYSIS OF TECHNOLOGY ADOPTION

The technology adoption behaviour of farmers may be conceptualised as a function of farm and farmer attributes, the technology itself and the farming objective (Mafuru *et al.*, 1999), as well as existing institutions and infrastructure. Accordingly, a linear discriminant analysis (LDA) was conducted to identify factors associated with adoption of soil testing and use of fertilizer by coffee farmers in Southern Rwanda. LDA is a statistical technique that distinguishes between groups using characteristics on which the groups are expected to differ (Manly, 1994). A LDA model was specified to discriminate between *full-adopters*, *partial-adopters* and *non-adopters* of soil testing and use of fertilizer. Table 2 lists the explanatory variables specified in the LDA together with an explanation of why each is included in the model.

Table 2: Variables that discriminate between adoption of soil testing and use of fertilizer by coffee farmers in Rwanda

Farm size	Returns to information, technology and management are scale dependent (Welch, 1978), consequently, relatively smaller farm businesses have less incentive to adopt new technologies.
Age	Younger farmers tend to be more willing to adopt new technologies due to longer planning horizons (Celis *et al.*, 1991).
Gender	Social customs in Rwanda tend to discriminate against women (MINAGRI/PNUD, 1996), reducing their access to information and new technologies.
Education	Formal education and training in agriculture improves farmers' abilities to acquire accurate information, evaluate new production processes, and use new agricultural inputs and practices efficiently (Ashby, 1981; Mbowa, 1996).
Information	Usefulness of farm information is likely to promote adoption of appropriate agricultural practices. For example, training workshops expose farmers to new technology and information sources outside their farms (Adesina & Baidu-Forson, 1995); and contact with extension staff is expected to promote adoption of recommended farm practices (Abdulkadir, 1992).
Off-farm income	Increased off-farm income earnings could alleviate on-farm liquidity constraints, since labour has close substitutes (Lyne & Nieuwoudt, 1991).
Value of livestock	Farmers who have more wealth in the form of livestock may be better able to finance the cost of technology adoption (Essa & Nieuwoudt, 2001).
Tenure certainty	Farmers are more likely to improve parcels over which they have a long-term interest (Place & Hazell, 1993), hence increasing the probability of a farm adopting modern production methods.
Land fragmentation	Land fragmentation, as a result of continuous land distributions and growing population, creates a sense of insecurity among farmers, hence preventing them from making additional investments to increase production (Gebeyehu, 1995).

The following LDA model was postulated to identify factors associated with the adoption of appropriate farm practices:

$$Z_i = a_1 FMS + a_2 AGE + a_3 GDR + a_4 EDU + a_5 TRG + a_6 WSP + a_7 VST + a_8 INFO + a_9 OFI + a_{10} LVT + a_{11} TNR + a_{12} PLT + a_{13} DST + a_{14} ACO \quad (1)$$

Where, Z_i is the discriminant score for each category of *non-adopters* and *partial-adopters* and *full-adopters*; and $a_1,..., a_n$ are the weighting (standardized discriminant function) coefficients; FMS is farm size, measured in hectares; AGE is the farm operators age in years; GDR is a dummy variable equal to one if the farm operator is male, otherwise zero; EDU is the education of the farm operator measured on a scale from zero to three where no schooling = 0, grade 6 and below = 1, grade 7 to grade 12 = 2, and tertiary education = 3; TRG is a dummy variable equal to one if the farm operator has undergone training in agriculture, otherwise zero; WSP is the number of agricultural workshops attended by the farm operator during the preceding two years; VST is an index ranging from zero to four positively related to the number of field extension officer visits received by the farm operator in the last two seasons; INFO is an index ranging from zero to four representing the farm operators assessment of the usefulness of farm information sources, where zero is not useful and four is very useful; OFI is the monthly cash income earned (e.g. pensions and wage remittances from self and wage employed members) in Rwandan Francs; LVT is a continuous variable indicating the monetary value of all livestock in Rwandan Francs, both cattle and small-stock owned by the farm operator; TNR is a dummy variable scoring one if the farm operator feels assured of his long term tenure, zero otherwise; land fragmentation is analysed in terms of geographic dispersion of plots (i.e. number of arable plots (PLT) and distance travelled by farm operators from the farm house (DST)); and ACO represents the percentage of arable land under coffee.

Statistically significant co-linearity was identified within this set of explanatory variables. Because co-linearity may lead to biased parameter estimates (Norušis, 1990), Principal Components Analysis (PCA) was used to condense the variables into fewer orthogonal variables, each measuring different dimensions in the data (Manly, 1994). Variables with factor loadings greater than 0.5 were used to interpret the PCs, and eigenvalues greater than one are reported in Table 3.

Table 3: Loadings and eigenvalues of the elicited principal components

Variable	PC_1	PC_2	PC_3	PC_4
Farm information	0.893			
Training workshops	0.804			
Farm visits by field extension officers	0.784			
Agricultural training	0.705			
Number of plots		0.709		
Distance between parcels		0.666		
Age of farm operator		0.649		
Farm size		-0.578		
Monetary value of livestock			0.790	
Off-farm income			0.736	
Education of farm operator			0.583	
Tenure certainty				0.750
Gender of farm operator				0.643
% of arable land under coffee				0.610
Eigenvalue	3.49	1.92	1.56	1.20
Percentage variability	24.9	13.7	11.2	8.6

The first principal component, PC_1, captures information accessible to farmers from extension support and can, therefore, be interpreted as an *index positively related to usefulness of information*. PC_2 is an *index of farm operator's age*, reflecting that older farmers tend to operate relatively smaller and more fragmented farms. PC_3, has high loadings for the monetary value of livestock, off-farm income, and education of the farm operator, which are all related to liquidity. Accordingly it is interpreted as an *index positively related to ability to finance agricultural inputs.* The monthly cash income earned is a variable, which shows the availability of a reliable income source, and the ownership of livestock signifies wealth status and a source of finance. PC_4 has high loadings for tenure certainty, gender of the farm operator and proportion of arable land under coffee. It is interpreted as an *index of access to agricultural resources*, reflecting that men tend to have better access to agricultural resources and perceive greater tenure certainty than women.

These four orthogonal PCs were substituted for the original (x) variables in the LDA model, thus averting the co-linearity problem (Jolliffe, 1986). Initially the discriminant model was based on the three groups namely *non-adopters*, *partial-adopters* and *full-adopters*. The separation between the three groups was poor; therefore the two extreme groups of *non-adopters* and *full-adopters* were used to get better results. The variable classifying both groups was captured as dichotomous, equal to one for *full-adopters*, and zero for *non-adopters*. The

discriminant function was therefore estimated based on 126 respondents from the two extreme groups. Results of the LDA model are presented in Table 4.

Table 4: Estimated discriminant functions for *non-adopters* and *full-adopters* of improved farm practices, 2001

Explanatory variable	Standardized coefficient	t-value	Component score group means		
			Non-adopters	*Full-adopters*	F value
PC_2	-0.790	-6.293**	1.033	-1.467	25.791**
PC_3	0.647	5.136**	-0.768	1.770	24.147**
PC_4	0.566	4.278**	-0.820	0.764	10.656**
PC_1	0.424	3.148*	-0.396	0.602	4.348*
Number of valid cases			90	36	
F value		71.3**			
Wilk's Lambda		0.55			
Canonical correlation		0.66			
Classifications: *non-adopters*		93.3%			
full-adopters		75.0%			
Total		88.1%			

** and * denote statistical significance at the 1 and 5 per cent levels of confidence, respectively.

The LDA model correctly identifies 93.3% of *non-adopters* and 75.0% of *full-adopters* cases, respectively. A Wilk's lambda value of 0.55, and 88.1% overall correct classification of adoption indicates an effective classification ability of the estimated discriminant function.

Results indicate that wealthier, younger, better educated, male farmers, with relatively less fragmented farms, greater tenure certainty, and good access to agricultural training and information sources are relatively more likely to adopt appropriate and improved farming practices on coffee farms. All of these relationships are consistent with *a priori* expectations and agree with findings of previous research (e.g. Strauss *et al.*, 1991; Celis *et al.*, 1991; Essa & Nieuwoudt, 2001; Abdulkadir, 1992).

PC_2 and PC_3 (age of the farm operator and wealth/liquidity, respectively) are statistically the two most important dimensions discriminating between *non-adopters* and *full-adopters* of the two recommended farming practices, followed by PC_4 (access to agricultural resources) and PC_1 (access to agricultural information). This finding does not necessarily imply a diminished role for provision of agricultural information in promoting adoption of recommended farming practices. Rather, it may reflect that concurrent policies are required to ensure that farm operators can efficiently use this information to assess

agricultural practices, have training to effectively implement these practices, have access to sufficient resources (large farms) to provide incentives to adopt new technologies, and have the ability (e.g. wealth and liquidity) to adopt these practices. This points towards the need for a strong collaborative link between the *Rwandan Industrial Crops Authority* (OCIR), which serves the entire coffee industry of improved coffee varieties, control of pests and diseases, effective extension services and cultivation practices, with field extension staff who are mainly in close contact with farmers to facilitate the dissemination of relevant information on better farming methods.

The negative relationship identified between age and adoption indicates that younger farmers may be more innovative and quick learners of new techniques, long planning horizons and less risk averse. Furthermore, the fragmentation and diminution of land as a result of continuous land distributions and growing population create a sense of insecurity among farmers (Gebeyehu, 1995). This insecurity deters farmers from adopting new technologies. The negative impact of fragmentation may reflect recent Rwandan policy to reallocate relatively larger farms to more efficient farmers through a villagization policy, which aims at reducing the present dispersed distribution of land (MINAGRI, 1997).

5. CONCLUSIONS AND POLICY IMPLICATIONS

The research has studied factors influencing the adoption of recommended and improved farming practices on coffee farms in Southern Rwanda with the objective of making policy recommendations towards the development of sound agricultural policy in Rwanda. Results indicate a strong relationship between technology adoption and farm performance. Farmers who have adopted relatively more recommended technologies also tend to enjoy greater tenure certainty. It is concluded that agricultural policy in Rwanda should seek to (a) increase farmers' abilities to adopt new technologies, and (b) seek to allocate more land to more efficient farmers. A negative relationship was identified between land fragmentation and technology adoption, suggesting that policies that promote consolidation of land are important to achieving improved agricultural performance in Rwanda.

The second important conclusion of this research is that provision of information alone is not sufficient to promote adoption of recommended farming practices by Rwandan coffee farmers. It is important that policies are in place that improve rural education to improve farmers' abilities to effectively use information provided; policies should be in place to reduce farmers financial constraints to adopting new technologies and to provide

farmers with sufficient access to agricultural resources to spread fixed costs associated with adoption of new technologies and practices.

The need for consolidating land and allocating land to efficient farmers can possibly be achieved through institutions and policies that simply removing obstacles to a rental market to enable farmers to acquire more land. Finally, gender of the farm operator is an important determinant of the likelihood of adoption, which supports the expectation that female heads of household have poor access to new technologies compared to their male counterparts. Policies in Rwanda should seek to address issues of rural gender discrimination.

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