ANALYSIS OF SMALL-SCALE FARMERS' EXPOSURE TO ENVIRONMENTAL RISKS: EMPIRICAL EVIDENCE FROM RURAL RWANDA

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ABSTRACT

Agriculture is a backbone of economy in Rwanda. Even if the sector faces environmental challenges, people still depend on it for subsistence and income. Essentially, there is an urgent need of coping and mitigation strategies to shocks. We used the fifth integrated household living conditions survey (EICV 5) cross-sectional data collected from October 2016 to October 2017 by the National Institute of Statistics of Rwanda (NISR). The study used a sample size of 3,081 rural farm households, descriptive statistics were computed to describe the main socioeconomic characteristics of the small-scale farmers in rural Rwanda and the independent samples test was performed to compare means between exposed and non-exposed farmers to environmental risks. Results revealed that some farmers have been exposed to environmental risks and even more affected by impact born from shocks like destructive rains (60.2 per cent), mountain slides (22 per cent) and floods (4.8 per cent). Except for total household consumption expenditures, no significant difference was observed between exposed and non-exposed farmers in terms of crop production, land size, livestock and farm expenditures. Results from econometric analysis identified the age, livestock, farm output, land consolidation, land tenure and farm expenses as the main factors affecting the farmers' exposure to environmental risks. From these finding, farmers should be trained on environmental risks, their effects, as well as the farming practices to cope with them.

Keywords: *small-scale farmers, agricultural risks; environmental risks; binary logit regression; Rwanda*.

RESUME

ANALYSE DE L'EXPOSITION DES PETITS AGRICULTEURS AUX RISQUES ENVIRONNEMENTAUX DANS LES REGIONS RURALES AU RWANDA

L'agriculture est l'épine dorsale de l'économie du Rwanda. Même si le secteur est confronté à des défis environnementaux, les gens en dépendent toujours pour leur subsistance et leurs revenus. Il existe essentiellement un besoin urgent de stratégies d'adaptation et d'atténuation des chocs. Nous avons utilisé les données transversales de la cinquième enquête intégrée sur les conditions de vie des ménages (EICV 5) collectées d'octobre 2016 à octobre 2017 par l'Institut National des Statistiques du Rwanda (NISR). L'étude a utilisé un échantillon de 3.081 ménages agricoles ruraux. Des statistiques descriptives, le test d'échantillons indépendants et l'analyse économétrique sont les méthodes d'analyse. Les résultats ont révélé que certains agriculteurs ont été exposés à des risques environnementaux et encore plus touchés par l'impact de chocs tels que les pluies destructrices (60,2 %), les glissements des terres (22 %) et les inondations (4,8 %). À l'exception des dépenses totales de consommation des ménages, aucune différence significative n'a été observée entre les agriculteurs exposés et non exposés en termes de production agricole, de superficie des terres cultivées, de bétail et de dépenses agricoles. Les résultats de l'analyse économétrique ont identifié l'âge, le bétail, la production agricole, la consolidation des terres, le régime foncier et les dépenses agricoles comme

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les principaux facteurs déterminant l'exposition des agriculteurs aux risques environnementaux. A partir de ces constats, les agriculteurs devraient être formés sur les risques environnementaux, leurs effets, ainsi que les pratiques agricoles pour y faire face.

Mots clés : *petits producteurs agricoles ; risque agricole ; risque environnemental ; régression logistique binaire ; Rwanda.*

INTRODUCTION

Crop production is a primary source of rural development and a cornerstone of farmers' livelihood through the increased yield (Gollin *et al*., 2002) specifically in less developed economies (Jalan and Ravallion, 2002). For most developing countries, the agricultural sector is considered a key sector for their economies and one of the solutions to improving the living conditions of more of the poor people who depend on them (Rutten and Boto, 2014; Imboden, 2014; Miller and Jones, 2010; Yumkella *et al*., 2012). Although many African economies depend on a few raw materials or semi-processed commodities, agricultural products account for a large share of their total export earnings (AfDB, OECD and UNDP, 2017) and contribute to GDP growth. Agriculture-related GDP growth is at least twice as successful in reducing poverty as GDP growth in other sectors, according to a 2008 World Bank study on agriculture for development (World Bank, 2008).

It becomes very hard for farmers to sustain and maintain their big contribution to livelihoods and rural development in general due to the facts that farmers face risks of different categories such as environmental risks and other related issues like weather variability, natural disasters, uncertainties in yields and prices, among others. This leads to high variability of agricultural returns, mainly because of incapacity of farmers to certainly predict both quantities they wish to produce and associated cost (OECD, 2011).

In view of environmental risks that smallholder farmers face, o'Brien *et al*. (2004) and Morton (2007) also have listed some environmental risks which may often lead to undermine household food, nutritional security, income and other indicator of livelihoods, to cite few, pest and disease outbreaks, extreme and uncontrollable weather variability and market shocks are extreme and consequently agricultural production is reduced and food insecurity and nutritional related problems are present accordingly in families. In Rwanda, like in other countries across the world, small-scale farmers occupies a big percentage compared to the rest of population (85 per cent of the world's farms), unpredictable circumstances, less strategies to cope with risks and shocks for these farmers are the main causes of reduction in agricultural productivity which undoubtedly have a significant impact on food and nutritional security, on households income as well as well-being (Hertel and Rosch, 2010; McDowell and Hess, 2012).

Many studies, such as those by Lidsky *et al*. (2017), Cordier *et al*. (2008) and Couty (1989), have been conducted by analyzing agricultural risks in a dispersed manner with a greater focus on their management. Notably, Kevan (1999) and Morton (2007) have conducted research using regional and global simulation models and revealed that the rice, wheat and maize production were negatively affected by an increase in temperature, pest and disease outbreaks, increase the frequency and severity of droughts and floods, which in turn lessen crop production and then cause livestock mortality.

The farmer's role in any economy is robustly recognized, particularly in Rwanda, it respectively contributes at 33 per cent and 70 per cent to gross domestic product (GPD) and country' export revenues. Agricultural as backbone of Rwandan economy employs 80 per cent of the population and most of them are small scale farmers who concentrate their practices on food crops with more than 80 per cent of the total cultivated land, cash crops (7.9 per cent) and new crops introduced for cash and export reasons (fruits, vegetables, flowers and spices) (Murenzi and Hughes, 2006; Ngabitsinze *et al*., 2011; Bizoza, 2014; REMA, 2014). In addition, Rwanda is densely populated country in Sub-Saharan Africa as shown by growth from 2.9 million in 1961 to 11.5 million in 2012 and expect to continue to increase to 25.4 million in 2050 (Havugimana, 2009; NISR, 2012).

Population pressure coupled with their high dependency on agriculture cause land scarcity, environmental degradation, land fragmentation and a shortfall of per capita land (decline from 0.95 ha in 1960, 0.25 ha in 2010, and to 0.10 ha by 2050), 16 to 40 per cent of the arable land is

exposed to soil erosion and the loss of soil nutrient which lead to agricultural disruption and a decline in production (1.4 million tons of fertile soil per annum), thus, this connectivity expose farmers in Rwanda at high risks related to land use, weather variability and to climate change in general (Habiyaremye *et al*., 2011).

Being exposed to environmental risks is inevitable to most farmers but of course under different extent depending on how sensitive they are. The relationship between farming practices and environment they operate in is significant, and in seeking subsistence for households and any other kind of livelihoods would for sure increase farmer's exposure to environmental risks, therefore in similar vein, various researchers argued that farmers and countries might have suitable agricultural policies and means of lowering environmental harms and stresses. For example Lal (1997), Ariaz-Estévez *et al*. (2008), Knowler and Bradshaw (2007), Castellini and Ventrella (2012) reported that the only one way to cope with environmental impacts is to adopt the conservation farming system which is achieved through working hands in hands of government and farmers, adoption of the later system is quite important as is helpful to minimize production cost and other factors for crop production failure, then such system is economically and especially environmentally viable.

Considering the importance of the sector and based on figures and projections, most of population depends on agriculture for food subsistence and other income. However, this sector face many challenges emanating from environmental risk such as weather variability, floodings, droughts, landslides and a decline of farm size. These challenges give room to uncertainties regarding future food and nutrition security in the country, which leads a country to fall into food deficiency and chronic poverty. Therefore, there is a need to put emphasis on adaptation measures that could help small scale farmers in Rwanda to minimize vulnerability to environmental risks and their related several consequences.

A deep evaluation and emphasis of this is possible especially through evaluating effect of environmental risks on productivity, land size, the supply of farm labor, income for farmers and even on farm expenditures (Izuogu and Ekumankama, 2015) having in mind that there an inverse relationship between an environmental risks and a loss of days worked, farm area for cultivation, increase of cost of production and also a reduced formers capacity (Asgary and Levy, 2009).

In this context, this work aims to formulate a model to help farmers to sustain in production and development under constraints of environmental risks and once this is achieved, will lead in general the whole country to improved well-being and good standards of living to farmers in particular, mainly, this study will also help proposing the adaptive strategies and mitigation to environmental damages within the context of Rwanda.

The broad objective of this study is to analyze the small-scale farmers' exposure to environmental risks in rural Rwanda. It specifically intends to (1) identify the majour environmental problems and highlight the main sources of environmental information that are available to rural small-scale farmers, (2) assess the variability of selected agricultural factors and household characteristics between small-scale farmers exposed and those non-exposed to environmental risks, and (3) to ascertain the factors that explain the likelihood of a small-scale farmer's household to be exposed to environmental risks.

MATERIALS AND METHODS

The study used the fifth integrated household living conditions survey (EICV 5) cross-sectional data collected from October 2016 to October 2017 by the National Institute of Statistics of Rwanda (NISR). The study has used a sample size of 3,081 rural households. Data collection used an open-ended structured questionnaire and the analysis selected only variables highlighting the main features pertaining to the objective of the study.

Descriptive statistics were computed to describe the main socioeconomic characteristics of the small-scale farmers in rural Rwanda. They were also computed to indicate the situation about environmental problems and sources of environmental information among small-scale farmers. Besides, the Student test was used to analyze the variability of crop production, cultivated land area, the number of all types of animals held by a household, farm expenses, annual household consumption expenditures, through comparing their mean scores between

farmers exposed (reference group) and those non-exposed (comparison group) to environmental risks.

The comparison of mean scores for two independent samples, n_1 and n_2, known as t-test originated from Student (1908). It is a proficient and powerful analytical tool to compare the mean score of group1, μ_1, and the mean score of the group2, μ_2. Following van Elst (2019), this is described by the equation (1).

$$T_{n1,n2} = \frac{\bar{X}_{n1} - \bar{X}_{n2}}{\mathrm{SE}(\bar{X}_{n1} - \bar{X}_{n2})} \sim t(\mathrm{df}) \qquad (1),$$

where T stands for the Student statistic; n_1 and are n_2 the sample 1 and sample 2, respectively; X_{n1} and X_{n2} the estimated means of the sample 1 and sample 2, respectively; SE the standard error

$$(\mathrm{SE}(\bar{X}_{n1} - \bar{X}_{n2}) = \sqrt{\frac{S_{n1}^2}{n_1} + \frac{S_{n2}^2}{n_2}}$$ (, where S_{n1}^2

is the estimated sample variance for the sample 1; S_{n2}^2 is the estimated sample variance of sample 2); t the Student distribution; df the degree of freedom; $n_1 \geq 50$ and $n_2 \geq 50$. This entails that the size of both reference and comparison groups should be bigger than or equal to 50 observations.

With the aim of identifying the factors affecting the small-scale farmers' exposure to environmental risks, the binomial logistic regression model with a dichotomous dependent variable Y_i with two values, 1 (when a farm household is exposed to environmental risks) or 0 (otherwise) was specified, and data were analyzed using the maximum likelihood method (see Agresti, 2018; Breen *et al*., 2018). The set *X* of *p* explanatory variables is made by continuous (or quantitative) and categorical/ dichotomous (or qualitative) variables. The probability that a household *i* has is exposed to environmental risks is given by the equation (2).

$$\pi_i(X) = \frac{e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip}}}{1 + e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip}}} \quad (2).$$

Then $\frac{\pi_i}{1-\pi_i}$ are the odds in favor of the household being exposed to environmental risks.

Hence, by applying the natural logarithm on both sides of equation (2), the logit model is written as per the equation (3).

$$\ln\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip} \qquad (3).$$

Equation (3) is estimated by the maximum likelihood estimation method and the basic assumptions of normality, linearity, and homogeneity of variance for the independent variables are not a requirement.

RESULTS AND DISCUSSION

PRESENTATION OF THE RESULTS

The results in a table 1 represent the main characteristics of the respondents. Out of 3,081 respondents, 2,211 of them were male, representing the majority (71.8 per cent). For the respondents' level of education, the results show that 1,502 surveyed smallholder farmers (equals to 48.8 per cent) did not complete primary education while 639 (20.7 per cent) have completed the primary education. The results also show that 2.2 per cent managed to complete secondary education, whereas 18.8 per cent have reported that they have been involved in other levels of education (not specified). Land use consolidation was has been adopted 71.7 per cent while 85.4 per cent have reported to adopt erosion control measures. Concerning the land tenure, 1,919 out of 3,081 (62.3 per cent) of surveyed farmers own a land lease title. In terms of phone ownership and access to credit, results indicate that only 37.1 per cent of the respondents have a phone and 74.1 per cent have access to credit.

Table 1: Main characteristics of the respondents.

Caractéristiques principales des petits producteurs agricoles faisant objet de notre échantillon.

Characteristics	Attributes	Frequency	Percentage
Sex	Male	2,211	71.76
	Female	870	28.24
Education	No education	246	7.98
	Pre-primary	1	0.04
	Primary not completed	1502	48.75
	Primary completed	639	20.74
	Post-primary	46	1.49
	Secondary	68	2.21
	Other	579	18.79
Land use consolidation	Yes	2,210	71.73
	No	871	28.27
Erosion control	Yes	2,631	85.39
	No	450	14.61
Owning a land title	Yes	1,919	62.28
	No	1,162	37.72
Phone ownership	Yes	1,142	37.07
	No	1,939	62.93
Access to credit	Yes	2,282	74.07
	No	799	25.93

The results in the table 2 report the environmental problems and the sources of environmental information among the small-scale farmers in rural Rwanda. The results indicate that 17.6 per cent were exposed to environmental harms, while around 82.4 per cent are not exposed to environmental risks. The major environmental problems are destructive rains and mountain slides as reported by 60.2 per cent and 22 per cent of investigated smallholder farmers, respectively. Floods and other environmental problems (not specified by the respondents) were respectively reported by 4.8 per cent and 13.1 per cent. It was also reported that 82.8 per cent of the surveyed farmers have reported to receive some environmental information about environmental problems. Meetings and trainings, and radio and television were reported as the main channels of information related to environmental issues at the rates of 79.3 per cent and 20.4 per cent, respectively. Furthermore, 92.2 per cent of investigated farmers have reported to access the environmental information via internet. The details on the situation about environmental problems and sources of environmental information are presented in table 2.

Table 2: Situation about environmental problems and sources of environmental information.

Situation des problèmes environnementaux et sources des informations sur l'environnement.

Characteristics	Attributes	Frequency	Percentage
Exposure to environmental risks	Yes	542	17.59
	No	2,539	82.41
Majour environmental problems	Destructive rains	326	60.15
	Mountain slides	119	21.96
	Floods	26	4.80
	Other	71	13.10
Received any environmental information	Yes	2,550	82.77
	No	531	17.23
Main sources of information on environmental issues	Meetings and trainings	2,022	79.29
	Radio and television	521	20.43
	School	4	0.16
	Other types of media	2	0.08
	Other sources	1	0.04
Access to environmental information via internet	Yes	240	7.79
	No	2,841	92.21

We have tested for the variability of crop production, land size, livestock (TLU), farm expenditures and consumption between the group of non-exposed farmers and that of farmers exposed to environmental risks. In this vein, mean differences and p-values have been computed with a purpose of investigating whether the mean scores between the groups are statistically different, or whether their differences are statistically different from zero. The results in table 3 reveal that there is no significant difference of mean scores of crop production (mean difference: 29.3, p-value: 0.17), cultivated land size (mean difference: -4.2, p-value: 0.59), livestock (mean difference: 0.02, p-value: 0.39), and farm expenses (mean difference: -1,938, p-value: 0.27) between the group of farmers non-exposed and that of farmers exposed to environmental risks. Quite the opposite, the mean difference of farmers' consumption are between the two groups is statistically different from zero (mean difference: -60,992, p-value: 0.00).

Table 3: Variability of crop production, land size, farm expenditures, and household's consumption expenditures between exposed and non-exposed farmers to environmental risks.

Variabilité de la production agricole, la surface cultivée, les dépenses agricoles et les dépenses totales de consommations des ménages entre les petits producteurs exposés et ceux non exposés aux risques environnementaux.

Variable	Mean score for non-exposed farmers	Mean score for exposed farmers	Difference	p-value
Crop production	266.25	236.97	29.28	0.17
Land size	41.22	45.43	-4.21	0.59
Livestock (TLU)[a]	0.43	0.41	0.02	0.39
Farm expenditures	18.814	20.752	-1,938	0.27
Consumption	846.490	907.482	-60.992	0.00

[a] TLU stands for tropical livestock units.

Results from binary maximum likelihood (ML) estimations (Table 4) show that the age of the household head, the land use consolidation, the land tenure security, farm production and farm expenses have significant and positive effect on small-scale farmers' exposure to environmental risks, while the number of domestic animals held by the household is the primary factor to smooth significantly the farmers' exposure to such risks. On the other hand, the sex of the household head, the family size, the phone ownership by the household head, the access to credit by the household and the size of the cultivated land affect positively the farmers' exposure but with no significant effect, whereas the education level of the household head has negative effect on farm household's exposure to environmental risks.

Table 4: Binary ML estimates of small-scale farmers' exposure to environmental risks.

Identification par la méhode du maximum de vraisemblance des facteurs déterminants de l'exposition des petits exploitants agricoles aux risques environnementaux.

Environmental risks	Coeff.	St.Err.	t-value	p-value	[95% Conf.	Interval]	Sig
Age	1.014	0.005	2.62	0.009	1.003	1.024	***
Sex (1=Female)	1.225	0.172	1.45	0.147	0.931	1.612	
Education	0.981	0.016	-1.21	0.226	0.951	1.012	
Family size	1.007	0.033	0.22	0.827	0.944	1.074	
Phone ownership (1=yes)	1.028	0.121	0.23	0.817	0.815	1.296	
Credit access (1=yes)	1.246	0.170	1.61	0.107	0.954	1.628	
Land size	1.000	0.000	0.71	0.476	1.000	1.001	
Livestock (TLU)[a]	0.814	0.092	-1.83	0.067	0.653	1.014	*
Farm output	1.000	0.000	-2.36	0.018	0.999	1.000	**
Consolidation (1=yes)	1.223	0.148	1.67	0.096	0.965	1.549	*
Land tenure (1=yes)	1.272	0.154	1.99	0.047	1.003	1.612	**
Farm expenses	1.000	0.000	2.18	0.029	1.000	1.000	**
Constant	0.084	0.031	-6.64	0.000	0.040	0.174	***
Mean dependent var		0.184		SD dependent var		0.388	
Pseudo r-squared		0.022		Number of obs		2256	
Chi-square		46.653		Prob > chi2		0.000	

Note: *** *p<0.01, ** p<0.05, * p<0.1*. Coefficients are reported as odds ratios. [a] TLU stands for tropical livestock units.

DISCUSSION OF THE FINDINGS

Along with the results of this study on characteristics of the respondents, small scale farmers are less educated. In view of this, 56.8 per cent of small-scale farmers did not complete even primary. Therefore, there is a crucial need of investments in educating farmers, so as to prepare potential farmers able to raise productivity, and who have knowledge required to enable to adopt new technologies and then boost agricultural and rural development. In this way, various researchers (see Appleton and Balihuta, 1996; Weir, 1999; Gasperini, 2000; Asadullah and Rahman, 2009) confirmed the positive effect of education on agricultural productivity. The results also show that 85.4 per cent of farmers have adopted measures to prevent soil erosion, which is very important, in terms of Bakker *et al*. (2005), to maintain soil nutrients and keep crop productivity and farmers' well-being stable. It is worth noting that 74.1 per cent of surveyed farmers have access to credit, which implies that they have not capital constraints. As a result, they can use quality inputs, expand their farming, deal with changes and financial based shocks, and increase the farm production (Feder *et al*., 1989; Petrick, 2004) and farm income. Results revealed that 62.9 per cent of small-scale farmers did not have mobile phone. This is very crucial since they may not be having information concerning weather, environmental risks and other forecasting information on time (Aker and Mbiti, 2010) so that they may work and plan accordingly. This low access of small-scale farmers to mobile phone could be explained by the facts that buying mobile phones is very expensive for rural farmers in developing countries like in Rwanda (Frempong *et al*., 2007).

It was also reported that small-scale farmers were challenged by destructive rains (60.2 per cent), landslides (29.6 per cent), floods (4.8 per cent), and miscellaneous environmental risks not specified (13.1 per cent). This leads to low agricultural yield and farmers' income due to the loss of soil productivity (Pimentel, 1993). In presence of these kinds of risks, farmers are expected to be affected in terms of becoming homeless, loosing health, livelihoods disruption, damage to properties as well as infrastructures (Okuyama and Sahin, 2009; Dewan, 2015; Desai *et al*., 2015; Parvin *et al*., 2016). The significant difference of consumption between non-exposed and exposed small-scale farmers to environmental risks could entail that the farmers in the second group have different strategies to smooth their incomes and consumption.

From econometric estimations, it was reported that the farmer's age is positively associated with the exposure to environmental risks. In terms of Füssel *et al*. (2006), older farmers (compared to the young) don't adopt easily new farming technologies and prefer to maintain traditional modes of farming. Land use consolidation increases the probability of a farmer to be exposed to environmental risks. Such as situation is explained by Derlich (2002) and Hartvigsen (2014) who stated that, through land use consolidation, farmers decide to change position of arable land and make pressure on land with the purpose to produce more, which could expose land to diverse risks, including environmental risks. As for livestock, this fights considerably the farmers' exposure to environmental risks. Livestock can also be a valuable asset on the farm, assisting agricultural activities and providing organic manure and soil nutrients, both of which are low-cost and long-term fertilizers (Kato *et al*., 2011). Because of Rwanda's physical situation characterized by mountains, terracing, and climate change sensitivity (Lal, 2004), organic manure's ability to retain water minimizes the risk of soil erosion (Calzadilla *et al*., 2013). According to Liu *et al*. (2013), organic manure is critical for the sustainability of agro-ecosystems in places with widespread terracing because it improves water retention capacity by increasing soil water storage in-between growing seasons. They also stressed that livestock ownership is also linked to increased agricultural output.

Results also indicate that even land owners did not adopt measures to mitigate the negative effect of some environmental risks. This could be due to the fact that farmers to not have enough knowledge required (Asadullah and Rahman, 2009). This also contrasts Owusu's (2008) finding that indigenous farmers are more motivated to put effort on adaptation measures to help them mitigating the negative effect of

some environmental risks, especially in protecting land against erosion (Kuhlman, 2010; Zeleòáková *et al*., 2014). In the same way, increasing farm production in order to improve human well-being could also lead to environmental degradation via the loss of soil nutrients, deforestation, air pollution thanks to the use of chemical fertilizers and pesticides (among other practices with negative impacts on the environment), which may make small-scale farmers unable to resist to climate change and other uncertainty (Millennium Ecosystem Assessment, 2005). The increase in farm expenses could be viewed as the enabling factor to access different farm inputs including chemicals. The use of chemicals results in extending productivity and land use consolidation (or the overuse of land), which in turn exposes farmers to the risks of climate variability in short term, and to climate change in medium and long term (de Janvry, 2010). The overuse of the soil by farmers will fundamentally end up with a decline in production together with a loss of environmental quality (Kintomo *et al*., 2008).

CONCLUSION AND RECOMMENDATIONS

This study attempted to assess the small scale farmer's exposure to environmental risks in rural Rwanda. The study aimed specifically at (1) identifying the major environmental problems that affect farming activities of small-scale farmers, (2) highlighting the main sources of environmental information that are available to rural small-scale farmers, and (3) assessing the variability of selected agricultural factors and household characteristics between small-scale farmers exposed and those non-exposed to environmental risks. The results pointed out that the majority of the persons involved in small-scale farming are less educated: around 57 per cent of the surveyed farmers did not complete even the primary education. It was merely reported that 71.7 per cent of the surveyed farmers have consolidated their arable land to raise their productivity. Majority of the farmers (85.4 per cent) revealed that they were aware of the harms of soil erosion on agricultural productivity, which encourage them to adopt erosion control measures. Whatsoever, some farmers reported to be exposed to environmental risks and have been affected in one way or another. The findings show that 60.2 per cent, 21.9 per cent and 4.8 per cent of farmers were challenged by destructive rains, mountain slides and floods respectively, which result in the loss of soil productivity and lower agricultural yield and thus farmers' income.

The results also indicate that land use consolidation and land tenure are favorable to small-scale farmers' exposure to environmental risks. Moreover, small-scale farmers' access to credit (74.1 per cent) leads them to improve their farming practices. Farmers have reported, however, that they are facing two main communication constraints: low percentage of farmers possessing phones coupled with a big number of farmers who do not access to internet (92.2 per cent). In intend of getting of environmental information, they have used other communication channels, namely meetings and trainings (79.3 per cent), as well as radio and television (20.4 per cent). The results from the test for the variability point to significant difference of consumption between exposed and non-exposed farmers to environmental risks. The results from econometric estimations revealed that the age of the household head, the land use consolidation, the land tenure security, farm production and farm expenses were the most influential factors that should be considered while coping with small-scale farmers' exposure to environmental risks and their effects in rural Rwanda.

Based on the research findings in this paper, the government intervention through (1) training farmers so as to raise awareness on environmental problems, (2) training them to scale up the mindset changes, and (3) setting up mechanisms that enable them to adopt innovative technologies and sustainable farming practices necessary to counter environmental risks and reduce vulnerability to other shocks related to environment would be recommended.

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