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Journal of Development and Agricultural Economics

Full Length Research Paper

The on-farm diversity of maize cultivars and landraces in the Lacandon region of Chiapas, Mexico

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The loss of maize landraces is of major global concern. Landraces provide the genetic building blocks for the development of high yielding pest- and drought-tolerant maize varieties, and their loss reduces the capacity to adapt to changing environmental conditions. The extinction of maize landraces is an incidental effect of the planting decisions of farmers. Although maize landraces are important both as a staple food and the source of traditional specialty foods required in particular cultural events and ceremonies, they are frequently displaced by high-yielding cultivars. The study considers the factors influencing on-farm maize diversity in the Lacandon tropical forest in the Mexican state of Chiapas. Using a censored regression model fitted with cross-sectional household farmer data, the factors behind crop choices was investigated, paying particular attention to the relation between crop diversity, wealth, and income transfers. It was found that maize diversity bears a non-monotonic relation to wealth, but is positively associated with both agricultural subsidies and poverty support.

Key words: Crop choice, crop diversity, Lacandon forest, maize diversity, poverty, on-farm conservation, Mexico, censored regression.

INTRODUCTION

One of the most pressing biodiversity conservation problems world-wide is the loss of genetic diversity of landraces and crop wild relatives. High yielding varieties have displaced landraces on farms (Brush, 2000; Perales et al., 2003; Brush and Perales, 2007; Lipper and Cooper, 2009; Perrings, 2018) to the point where many landraces and their wild relatives are now at risk of extinction (Villa et al., 2007; Plucknett and Smith, 2014). In Mexico, for example, the genetic diversity of lima bean (*Phaseolus lunatus*) landraces was found to have declined by 72% (Nei index) between 1979 and 2007 due to allelic displacement (Martínez-Castillo et al., 2012). Similar results have been found for maize (*Zea mays*) (Dyer et al., 2014), which is the focus of this paper.

Why does the loss of maize landraces matter? Maize is the dominant food crop in both Latin America and Sub-Saharan Africa, a major food crop in East Asia, and the leading feed grain world-wide (Sweeney et al., 2013; Fischer et al., 2014; Bellon et al., 2018). Maize production is expected to be compromised by climate change, with yields expected to decline most in tropical and sub-tropical regions (Monterroso et al., 2011; Nelson

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et al., 2010; Fischer et al., 2014). While the development of new varieties through either plant breeding or genetic engineering has some potential for adaptation to changes in climatic conditions, both depend on the existence of genetic material adapted to the new climatic conditions (Brush, 2000; Esquinas-Alcázar, 2005). Since the dominant characteristic of landraces is that are genetically diverse and dynamic, continuously adapting to local conditions, they are the main genetic reservoir for the development of cultivars adapted to changed environmental conditions (Arteaga et al., 2016). The decision to plant landraces offers benefits both to farming households, and to the wider community of plant breeders and genetic engineers. This makes conservation of the genetic diversity of landraces *in situ* a public good. Like many public goods, it is underprovided when left to the market (Smale et al., 2004; Esquinas-Alcázar, 2005; Pascual and Perrings, 2007).

In this paper, we consider the factors influencing the decisions farmers make to plant maize landraces and cultivars in Chiapas, Mexico. Although there is a substantial literature on crop choices in agriculture, there is a sense that the socioeconomic determinants of landrace conservation are still not well-understood (Dyer et al., 2014). Aside from market conditions, two factors have been argued to be important: the management of risk, and culturally determined food preferences. The diversity of landraces, for example, has been argued to have direct value to Mexican rural communities both because it provides insurance against variable environmental conditions, pests, or pathogens, and because it supports a wide range of culturally preferred food types (Perales et al., 2003, 2005; Benz et al., 2007; Brush and Perales, 2007). Both risk management and the production of specialty crops have been shown to be sensitive to farm income and wealth. There is evidence that lowest-income farmers use crop diversity as a production risk-reducing strategy (Bellon, 1996; Leslie, 2008; Harvey et al., 2014), but that as farmers' income and wealth increase, they tend to adopt alternative risk management strategies. In Mexico, Van Dusen and Taylor (2005) found that greater household wealth is generally associated with the lower richness of milpa crops. Bellon and Hellin (2011) found that wealth had a positive effect on the area committed to hybrid maize, which generally implies fewer maize varieties. Typically, wealthier farmers manage production risk by choosing appropriate technology (e.g., through the use of irrigation, herbicides, pesticides, and fertilizers), by maintaining multiple landholdings, or by exploiting both on-farm and off-farm income-earning opportunities (Smale et al., 1998; Meng et al., 1998; Isakson, 2011). Indeed, farmers with larger landholdings have an incentive to exploit economies to scale by farming fewer maize varieties (Bellon and Hellin, 2011; Kruzich and Meng, 2006). At the same time, there is also some evidence that the cultivation of culturally important specialty crops may be increasing in income and wealth. Specifically, wealthier farmers choose to plant different maize varieties, not because of any benefits they might offer for the management of production risks, but because of their culinary, cultural or religious properties (Rana et al., 2000; Jarvis et al., 2000; Smale et al., 2004).

Aside from the effect of farm income and wealth, crop choices may be influenced by government interventions that ostensibly address other issues in agriculture, such as poverty alleviation, price stabilization, or technology transfer. Public policies that change either input prices or farm incomes have been shown to impact crop choice (Bellon, 1996; Di Falco and Perrings, 2005; Pascual and Perrings, 2007; Baumgärtner and Quaas, 2010). Examples include both subsidies on agricultural inputs (e.g., seeds, fertilizers, or pesticides) and direct area payments to farmers. It has been argued that input subsidies promote the adoption of high-yielding maize varieties, while anti-poverty programs may have a positive impact on maize landraces (Bellon and Hellin, 2011).

In Mexico, the poverty alleviation program PROGRESA (Programa de Educación, Salud y Alimentación) provides lump-sum transfers to families designated as poor (SEDESOL, 2018). It is worth noting, though, that anti-poverty support programs include payments to older farmers regardless of their wealth or income. The Mexican agricultural support program, PROAGRO, provides a monetary payment per hectare of cultivated land available to those with property rights to land. The amount decreases as the registered area increases (SAGARPA, 2018; OECD, 2019). Farmers with large landholdings who lack property rights are ineligible. We wish to understand what effect these programs have on farmers' crop choices, and whether the effect on landraces is different from the effect on cultivars.

In what follows, we test the hypotheses (a) that the least and most wealthy farmers, for different reasons, cultivate a greater diversity of landraces than farmers of average wealth; and (b) that agricultural and poverty support policies have different effects on the diversity of landraces and cultivars. We use a censored regression model estimated with cross-sectional household farmer data on farming practices, socioeconomic characteristics, and assets. Our data derive from the Lacandon tropical forest in the Mexican state of Chiapas (Figure 1) which is one of the diversity centers of maize in Mexico (Perales and Golicher, 2014). We take diversity to be measured by an index (Simpson's) of the number of landraces and cultivars planted and the quantity of each produced.

MATERIALS AND METHODS

Nine villages in the municipalities of Marqués de Comillas and Maravilla Tenejapa at the Lacandon tropical forest were selected for this research. Their selection was based on their population size

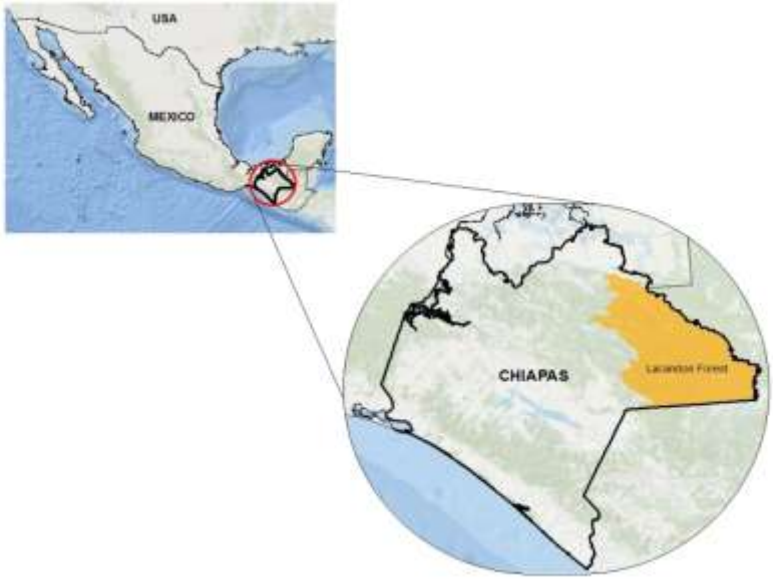

Figure 1. Map of Chiapas, Lancandon forest*. *This map was done with the assistance of Jimena Deschamps and the shapes were obtained from the National Information System on Biodiversity of CONABIO (2019).

(villages with more than 100 inhabitants) and the cooperation provided by their local authorities in the implementation of the surveys. The survey was carried out as a part of the Biological Corridor Project in Chiapas of the Mexican National Commission for the Knowledge and Use of Biodiversity (CONABIO by its Spanish acronym).

The municipalities of Marqués de Comillas and Maravilla Tenejapa are located on the eastern extreme of the State of Chiapas and within the Lacandon tropical forest (Figure 1). The federal and state government have both increased efforts to promote economic and social development in the last decades, especially after the armed rising that occurred in 1994. Cattle ranching and road infrastructure have been promoted as a means to develop the Lacandon region. As a result, cattle ranching has become one of the main economic activities (De Vos, 2002; Bray and Klepeis, 2005; Alemán et al., 2007; Eakin et al., 2014).

Once the villages were selected, a census of all active farmers older than 18 years old (the age of adulthood in Mexico) was provided by the local authorities. Two hundred and forty farmers were then randomly selected from the joint census to complete a household survey, 218 of whom completed the survey. The surveys were carried out between March and June of 2016.

In order to understand how wealth and government subsidies influence farmers´ maize diversity, we also consider farmer households´ market access, environmental constraints, and socio-economic variables that are central to explain the variety choice of households (Meng et al., 1998). Maize varieties in the Lacandon region are mostly landraces and cultivars—creolized (hybrid) varieties that are a mix between a local landrace and a modern variety. Most inhabitants in the study region are formally defined to be in poverty. The variables selected are grouped into four sections: (Section I) social characteristics of the household head; (Section II) biophysical characteristics of land; (Section III) household assets; (Section IV) farm production characteristics; and (Section V) household participation in government programs. These variables are shown in Table 1. These variables were also selected to be consistent with other studies that have examined the factors influencing farmers´ crop choices (Van Dusen and Taylor, 2005; Bellon and Hellin, 2011; Isakson, 2011).

The first section contains the variables: household head age and education. These variables are included because it is presumed that older farmers tend to cultivate more maize diversity because they have traditional preferences and educated farmers cultivate less maize diversity because they are prone to interact with markets (Meng et al., 1998; Smale et al., 2006; Isakson, 2011). The number of household members older than 13-years is also included in Section I. This variable is a proxy for the family labor supply (as well as food demand) and it is hypothesized to be positively correlated with crop diversity as is reported by Smale et al. (2006). Information on ethnicity and gender was obtained for this section, but since more than 92% of household heads are mestizo and men these variables were eliminated.[1]

The second section includes a subjective soil quality index that measures how farmers rank their maize parcels in terms of soil quality and the number of maize parcels cultivated. The latter is a proxy for the environmental heterogeneity of agricultural land, as suggested by Taylor and Bellon (1993). Land heterogeneity is associated with maize diversity because farmers require distinct maize varieties to deal with different agro-ecological conditions (Taylor and Bellon, 1993; Meng et al., 1998). The soil quality index is included to test whether the high opportunity cost of cultivating in high-quality soils discourages farmers from planting insurance or specialty crops, as shown by Taylor and Bellon (1993) and Arslan and Taylor (2009) in other regions of Mexico.

The household assets section, section III, consists of: agricultural landholdings, rangelands, the number of cattle, and the size of the family house owned by the households. We group these variables using their monetary valuation in US dollars of 2017 to measure household wealth. This information was obtained from different interviews in the study region.

Section IV contains farm production variables that influence the cultivation of different maize diversity, such as distance to a regional market, maize production area, number of cash crops, labor intensity, and the use of chemical fertilizers and pesticides.

[1] 7% of the respondents stated that they native Mexican Indians and only 5% were females.

Table 1. Survey results.

Variable	Definition of the variable	Result
Section I: Household head´s characteristics and household members		
Family head´s age	Average age in years	45.5(12.5)
Household head´s years of education	Average education in years	5(3.3)
Household members older than 13-years	Average number of household members	5.3(1.7)
Section II: Biophysical characteristics of land		
Number of maize parcels	Average number of maize parcels	1.4(0.515)
Medium soil quality (where maize is cultivated) (dummy variable)	% farmers that claim that they have medium soil quality	38(.48)
High soil quality (where maize is cultivated) (dummy variable)	% farmers that claim that they have high soil quality	22(0.41)
Section III: Household´s assets		
Household agricultural landholdings	Average agricultural area in hectares	4.2(2.5)
Household livestock holdings	Average cattle heads	13(11)
Household rangelands	Average rangelands area in hectares	15(14)
Size of household´s house	Average house size in square meters	102.4(51)
Value of all assets	Average value in thousands of US Dollars	7.16(4.22)
Section IV: Household´s agricultural practices		
Distance to a major market	Average distance in kilometers	2.8(1.71)
Maize production area	Average area in hectares	1.36(0.46)
Number of cash crops	Average of cash crops	1.27(1.071)
Labor intensity	% of hours	16.72(16.19)
Section V: household participation in government programs		
Household´s participation in agricultural support programs (dummy variable)	% of beneficiaries	60(0.49)
Household´s participation in poverty alleviation programs (dummy variable)	% of beneficiaries	55(0.48)

Total sample size 218 (households). Standard deviation in parentheses.

Since most farmers use pesticides in standard amounts, we dropped this variable. We expected that farmers planting cash crops would be less likely to invest in multiple maize crops. We therefore expected to find a negative correlation between cash crops and maize diversity. In the case of the maize production area, there is evidence that farmers plant a larger number of maize varieties in larger maize production areas (Van Dusen and Taylor, 2005).

In order to test the influence of market development on maize diversity, we included both the distance from the farmers' parcels to the nearest regional markets and the labor intensity of crops. The former variable aims to measure the effects of transaction costs on maize diversity (Van Dusen and Taylor, 2005; Bellon and Hellin, 2011). Different studies have reported a positive correlation between transaction costs and maize diversity in Mexico (Van Dusen and Taylor, 2005; Arslan and Taylor, 2009). This relationship is explained by the fact that farmers cannot cover their demand for maize diversity in the markets or the markets offer poor substitutes for the goods demanded (de Janvry et al., 1991; Bellon 1996). Following Van Dusen and Taylor (2005) we included the labor intensity variable to test the effect of labor markets on maize diversity. In particular, it measures the hired-labor proportion of total labor used to cultivate maize diversity. Because planting different maize varieties is more labor-intensive than planting a single variety, we expected to find a negative relation between labor intensity and diversity (Zimmerer, 1991; Brush et al., 1992; Smale et al., 2004).

In the last section, we include variables that measure the number of households that receive either area payments or poverty alleviation support. Distinguishing between landraces, cultivars, and all crop types together, we estimated a censored regression model (Tobit regression model). On- farm landrace, cultivar, and all maize diversity was measured using a Simpson´s Diversity Index, constructed from information that farmers provided on maize varieties planted and the quantity produced. A censored regression model was utilized to fit the fact that the outcomes of the Simpson´s Diversity Index are left-bounded (Simpson's index has a lower limit of zero if only one variety is planted).

In particular, we employed the farmers' wealth and the square of it to test the influence of wealth over farmers' maize diversity and, as in the Mincer earnings equation; we included the square of the age of the family head to test for monotonicity of the relation between farmers' age and maize diversity. We estimated three models of the diversity of, respectively, landraces, cultivars, and all crop types together, using the STATA software (StataCorp, 2015). Descriptive statistics of the data set are offered in Table 1. Here we note that 93 percent of farmers cultivate cultivars and 63 percent of farmers cultivate landraces. The estimated models were all of the following form (results are presented in Table 2):

$$D_i = \beta_0 + \beta_1 AGE + \beta_2 (AGE)^2 + \beta_3 EDU + \beta_4 HM + \beta_5 MP + \beta_6 MSI + \beta_7 HMI + \beta_8 WLTH + \beta_9 (WLTH)^2 + \mu_i \quad (1)$$

Where: D_i = Diversity of maize category i. (i = Landrace, Cultivar, All crop types together), AGE= Age of household head, $(AGE)^2$= Squared age of household head, EDU= Formal education in years, HM= Members of household, MP= Number of maize parcels, MSI= Medium maize quality index (Medium quality=1, otherwise=0), HMI= High maize quality index (High=1, otherwise=0), WLTH= farm household's wealth, $(WLTH)^2$= squared farm household's wealth, DST= Distance to a major market, PARA= Maize production area, NCP= Number of cash crops, LINT= Labor intensity, AGS= Household´s participation in agricultural support programs, PVS= Household´s participation in poverty alleviation programs (Table 1).

A Durbin-Wu-Hausmann test was used to test the potential endogeneity of the variables used. The test showed the possible endogeneity of the maize production area variable. In order to correct for resulting bias, we ran a regression using an instrumental variable (IV), in which the Durbin method was used to select the instrument. We then re-estimated the models for landraces, cultivars, and all varieties using an instrumental variable. The results are presented in Table 3.

RESULTS

We found that farmers produce maize largely for self-consumption and animal feed. Most planted between one and three varieties: 29% of farmers cultivated only one variety, 50% cultivated two varieties, and 21% cultivated three or more varieties. On average, farmers held 13 head of cattle on 15 ha-approximately one head per hectare. However, the distribution of cattle ownership was highly skewed: 19% of farmers had no livestock, and 20% had fewer than 9 head. The average value of farmers' assets was 7,000 US Dollars. Agricultural and poverty alleviation transfers were received by more than half of farmers, as shown in Table 1.

The regression models in Tables 2 and 3 are very alike in terms of signs and magnitudes (there is no significant difference between the results obtained without the instrument and with the instrument). We found our measure of wealth to bear a negative and statistically significant relationship to maize diversity for all landraces, cultivars, and all crop types together, while wealth squared was positive and statistically significant for land races and all crop types together. Amongst household characteristics, the age of the family head was positively associated with maize diversity for all crop types together, and was significant. However, this effect decreased with age-implying an inverted- U shaped relationship. The turning point in the quadratic equation was at 57 years of age in the third model.

Van Dusen and Taylor (2005) also found a positive but decreasing relationship with a turning point at 60 years of age. Interestingly, in the models for landraces and cultivars separately, the age of the family head was not significant nor was the level of education of the household head or size of the family labor pool. Amongst the biophysical characteristics of farms, soil quality was negatively and significantly associated with the diversity of cultivars, landraces, and all crop types together. Farms characterized by poorer soils tend to see more crops and crop types planted. The number of cash crops and labor intensity were also found to be negatively and significantly associated with across crop types.

Finally, we found that participation in government programs for agriculture and rural poverty alleviation had markedly different implications for the diversity of different crop types. Participation in both programs had a positive and significant effect on crop diversity for all crop types together, but a different association with diversity of landraces and cultivars separately. Participation in PROAGRO, for example, was negatively, but not significantly, associated with landrace diversity, but positively and significantly associated with cultivar diversity. Participation in PROGRESA was positively but not significantly associated with diversity of either landraces or cultivars.

DISCUSSION

The Lancadon region is characterized by conditions frequently associated with the loss of crop genetic diversity. These include increasing market integration, increasing population density, and public policies favoring agricultural intensification. Previous studies of on-farm changes in maize diversity have found diversity to be

Table 2. Censored regression model without instruments.

Maize diversity (Simpson´s diversity index)		Cultivars Regression Coefficients (N=203)	Landraces Regression Coefficients (N=138)	All varieties Regression Coefficients (N=218)
Section I: Family head characteristics	Family head´s age	0.015(0.023)	0.030(0.023)	0.031***(0.008)
	Family head´s age squared	-0.0001(0.0002)	-0.0002(0.0002)	-0.0002***(0.000)
	Family head´s years of education	-0.005(0.013)	-0.015(0.013)	-0.002(0.004)
	Household members older than 13-years	-0.032(0.024)	0.009(0.023)	-0.008(0.008)
Section II: Biophysical characteristics of land	Number of maize parcels	0.136(0.083)	-0.107(0.081)	0.017(0.029)
	Medium soil quality (dummy variable)	-0.257***(0.089)	-0.243***(0.087)	-0.069**(0.028)
	High soil quality (dummy variable)	-0.415***(0.112)	-0.508***(0.109)	-0.315***(0.042)
Section III: Household assets	Wealth index (Value of all assets)	-0.061*(0.0315)	-0.062**(0.030)	-0.029**(0.010)
	Wealth index squared (Value of all assets squared)	0.002(0.001)	0.002*(0.0015)	0.001*(0.000)
Section IV: Household agricultural practices	Distance to a major market (Kilometers)	0.030*(0.018)	-0.002(0.021)	0.004(0.0025)
	Maize production area	0.001(0.090)	0.027(0.087)	0.040(0.029)
	Number of cash crops	0.012(0.035)	-0.056(0.034)	-0.032**(0.012)
	Labor intensity	-0.028***(0.008)	-0.003(0.008)	-0.008***(0.002)
Section V: household participation in government programs	Household´s participation in agricultural support programs (dummy variable)	0.335*(0.198)	-0.018(0.172)	0.064**(0.027)
	Household´s participation in poverty alleviation programs (dummy variable)	0.153(0.110)	0.066(0.165)	0.054*(0.026)
Constant		0.939(0.604)	10.32**(0.587)	-0.297(0.201)

Significance levels are denoted by *, ** and *** at the 10, 5 and 1% levels, respectively.

falling in the Chiapas region (Dyer et al., 2014). To gain an understanding of the factors that lie behind such trends, we distinguished between the diversity of landraces and cultivars (creolized varieties), estimating separate models for each crop type, as well as a model for all varieties together. We hypothesized that on-farm landrace diversity offers two quite different benefits to farmers. One is to reduce on-farm production risks. A combination of varieties with different requirements in terms of soils, nutrients, water availability, and temperature is expected to perform better over a range of environmental conditions than a single variety. The other is to meet culturally specific demand for traditional maize varieties used in the production of locally important dishes, or in locally significant celebrations or events.

While we did not formally model farmers' aversion to environmental or market risk, we did suppose that the utility of maize diversity is sensitive to the range of earned and unearned income sources, and hence to wealth. Implicitly, farmers are risk-averse, and the mix of on- and off-farm activities offers a portfolio of income-earning opportunities, each of which responds to environmental fluctuations in different ways. Low-income farmers choose more maize diversity in order to hedge against production risks. While wealthier farmers have other productive activities to spread risk more efficiently, they have the resources to commit at least some land to the production of specialized crops of cultural significance. The net result is that we expected on-farm diversity to be highest amongst the least and most wealthy farmers. What we found is that the diversity of landraces and all varieties together were congruent with this hypothesis, but that the diversity of cultivars was not. While the diversity of all varieties was first decreasing and then increasing in the wealth of farmers, the up-turn was significant at the ten per cent level only for landraces and all crop types together.

This finding is consistent with the hypothesis that the least and most wealthy farmers tend to cultivate more varieties, and especially more landraces, than farmers of average wealth. The turning point of the quadratic term is 14,600 US Dollars in the third model. From this point on, an increase in farmers’ wealth was associated with an increase in the number of maize varieties cultivated. We note that average wealth in the sample was 7,000 US Dollars, so the positive wealth effect is driven by farmers at the upper end of the wealth distribution.

Table 3. Censored regression results with instruments.

Maize diversity (Simpson´s diversity index)		Cultivars Regression Coefficients (N=203)	Landraces Regression Coefficients (N=138)	All varieties Regression Coefficients (N=218)
Section I: Family head characteristics	Family head´s age	0.026(0.0036)	0.030(0.023)	0.031***(0.008)
	Family head´s age squared	-0.0002(0.0003)	-0.0002(0.0002)	-0.0002***(0.000)
	Family head´s years of education	-0.010(0.021)	-0.015(0.013)	-0.002(0.004)
	Household members older than 13-years	-0.046(0.037)	0.009(0.023)	-0.008(0.008)
Section II: Biophysical characteristics of land	Number of maize parcels	0.199(0.131)	-0.111(0.084)	0.017(0.029)
	Medium soil quality (dummy variable)	-0.335**(0.136)	-0.243***(0.087)	-0.069**(0.028)
	High soil quality (dummy variable)	-0.661(0.187)	-0.513***(0.114)	-0.315***(0.042)
Section III: Household assets	Wealth index (Value of all assets)	-0.097*(0.050)	-0.061*(0.032)	-0.029**(0.010)
	Wealth index squared (Value of all assets squared)	0.003(0.002)	0.002*(0.0015)	0.001*(0.000)
Section IV: Household agricultural practices	Distance to a major market (Kilometers)	0.036(0.031)	-0.002(0.021)	0.004(0.0025)
	Maize production area	0.181(0.256)	0.005(0.164)	0.040(0.029)
	Number of cash crops	0.015(0.054)	-0.056(0.034)	-0.032**(0.012)
	Labor intensity	-0.044***(0.013)	-0.003(0.008)	-0.008***(0.002)
Section V: Household participation in government programs	Household´s participation in agricultural support programs (dummy variable)	0.320*(0.207)	-0.029(0.175)	0.064**(0.027)
	Household´s participation in poverty alleviation programs (dummy variable)	0.155(0.197)	0.058(0.167)	0.054*(0.026)
Constant		0.702(0.993)	10.36**(0.631)	-0.297(0.201)

Significance levels are denoted by *, ** and *** at the 10, 5 and 1% levels, respectively. (A) The Wald chi-square (15) is 22.47 (P value= 0.096) and Wald test of exogeneity is Chi-square of (1) = 0.06 (P value =0.81) with a null hypothesis of no endogeneity. (B) The Wald chi-square (15) is 33.51 (P value= 0.004) and Wald test of exogeneity is Chi-square of (1) = 0.12 (P value =0.72) with a null hypothesis of no endogeneity. (C) The Wald chi-square (17) is 188.45 (P-value= 0.000) and Wald test of exogeneity is Chi-square of (1) = 0.24 (P-value =0.62) with a null hypothesis of no endogeneity.

One result that speaks to the role of diversity in managing production risk is the relation between (perceived) soil quality and crop diversity. For all crop types we found a strongly negative relation between soil quality and crop diversity. Farmers faced with soils of poor quality plant a greater variety of crops than farmers enjoying soils of good quality. Since we would expect some association between soil quality and wealth, this is consistent with the finding that crop diversity is, at least initially, decreasing in wealth.

A second result that also bears on risk is that the diversity of cultivars and all crop types taken together bears a strong negative relation to the labor intensity of crops. Farmers facing a labor supply constraint tend to focus on fewer crop types. We note that labor supply may be constrained both by the total number of working age members of the household, and by the number working off-farm. The diversification of income sources through participation in the wider labor market is also a household risk management strategy, but is likely inconsistent with the diversification of crops. Given the relation between crop diversity and wealth, we were particularly interested in the impact of public policies that affect farm wealth. Since both PROGRESA and PROAGRO make lump-sum transfers to farming households we had expected to find a statistically significant relation between participation in these programs and crop diversity. Bellon and Hellin (2011) found that the poverty alleviation program, PROGRESA, had a positive effect on maize diversity. At the same time, they found that agricultural support programs tended to discourage diversity. That is, they showed that PROAGRO had incentivized the expansion of hybrid maize production which they saw as reducing diversity. This is congruent with our findings, but requires some explanation.

While we found a positive and significant relation between participation in both programs and the diversity of all crop types together, we found no significant relation between participation in either program and the diversity of landraces. We did, however, find a positive and significant relation between participation in PROAGRO and the diversity of cultivars, which are characterized by their high-yield potential as hybrid varieties. That is, PROAGRO is associated to high-yield varieties. We close by considering the scope for using agricultural programs to support landrace diversity a more targeted way. First, public programs have the potential to preserve landrace diversity by increasing the direct incentive to cultivate landraces. Unlike area payments that encourage farmers to increase the area under cultivation, but are blind to the crops being cultivated, agricultural support programs can include targeted compensation payments or contracts for conservation-related to particular crop types (Pascual and Perrings, 2007; Narloch et el., 2011). Payments need to be substantial enough to outweigh the benefits to be had from switching to the production of high yielding varieties for the market.

Second, public programs can strengthen the rights farmers have in landraces. The critical importance of intellectual property rights regimes for the incentive to conserve is well established (Timmermann and Robaey, 2016). Traditional farmers have used selection and breeding to improve locally important traits, and have exchanged seeds to maintain the intra-specific genetic diversity needed to protect crops against environmental fluctuations. The Plant Treaty currently that farmers have rights 'to save, use, exchange and sell farm-saved seed and other propagating material, and to participate in decision-making regarding, and in the fair and equitable sharing of the benefits arising from, the use of plant genetic resources for food and agriculture' (International Treaty on Plant Genetic Resources for Food and Agriculture, 2009). At present, however, farmers' rights are limited by national policies that are primarily focused on the results of modern plant breeding and genetic engineering (Santilli, 2012). An important dimension of the incentive to conserve is the strengthening of farmers rights and seed exchange between farmers (Hodgkin et al., 2007; Jarvis and Hodgkin, 2008; Smale et al., 2004).

Third, although the conservation of maize landraces in Mexico confers benefits to consumers world-wide, the Mexican government has no incentive to take account of conservation benefits beyond Mexico. In the absence of international payments for the conservation of landraces in Mexico, too few resources will be committed to the problem (Perrings, 2018). There is scope for engaging other maize producing countries in efforts to conserve traditional varieties in the Mexican center of origin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Bank credit access trends among farmers in Hurungwe District of Mashonaland West Province in Zimbabwe

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Zimbabwe's economic progress is hinged on the performance of the agricultural sector, which supports the majority of the population. Bank credit empowers farmers to adopt inputs and technologies that are key for enhancing productivity and income. This study sought to establish the bank credit access trends among farmers in the Hurungwe District of Mashonaland West Province in Zimbabwe, comparing the current (2019-2015) and past (2014-2000) periods. A questionnaire was administered on a sample of 354 farmers. SPSS was used for data analysis. Credit access was significantly (p<0.05) influenced by the type of farmers, farmers' education, age, farm size and alternative employment. Credit access was higher (p < 0.05) among Model A2 than Model A1 farmers, farmers with higher educational qualifications, aged between 46-55 years, with more than 35 hectares of farmland, and with alternative occupation. Failure to access bank loans by Model A1 farmers was ascribed to their lack of collateral assets, human capital and weather resilience infrastructure. Government should invest in irrigation infrastructure and create a conducive investment climate to stimulate financial capital inflows. Farmers should invest in physical and human capital to enhance their access to bank credit. Banks should devise collateral substitution models to avoid segregating poor farmers with productivity potential.

Key words: Bank credit, capital formation, credit access, Model A1 farmer, Model A2 farmer.

INTRODUCTION

Several nations like Japan, China and Korea have advanced and entered the ranks of developed nations because of their heavy investment in agriculture (Huang and Ma, 2010). African countries like Burkina Faso, Rwanda, Kenya, Cote d'Ivore, Ghana and Ethiopia that made vast investments in agriculture had great productivity from existing farms; they had 6% productivity increases annually, and had an average annual increase of 4% GDP in (AGRA, 2018). Therefore, no region in the world has developed a diverse, modern economy without initially establishing a successful foundation in agriculture (AGRA, 2017). Agriculture is also important in Zimbabwe, where the majority of the economically active population is self-employed in the sector (Swinkels and Chipunza, 2018). Approximately 36% of the adults in Zimbabwe also entirely rely on money from farming (Finmark Trust, 2014). Despite being central to livelihoods, the Zimbabwean agricultural sector faces various challenges,

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especially the farmers' lack of access to financial capital for their operational and long-term investment needs in human and physical capital.

According to Echanove (2017), Zimbabwe's national budgets have been largely inclined towards consumptive expenditure because of the prevailing economic turmoil, which saw most of the budgeted finance being taken up by administrative costs not operations. The Reserve Bank of Zimbabwe (RBZ, 2006) confirms that government funding from the fiscus has always fallen short of the national agricultural financing requirements, and consequently urges the banking sector to support the government to meet those needs. However, lending by private banks to agriculture is still very low in Zimbabwe. This is evidenced by low agricultural loan books in most commercial banks, which have mostly failed to reach the 20% threshold recommended by the RBZ (2016). The reduction in lending to agriculture is ascribed to the change in land tenure from freehold before independence in 1980, to user rights after the year 2000's Fast Track Land Reform Program (FTLRP) (Richardson, 2005). The RBZ (2019)'s June Quarterly Economic Review showed bank agricultural loan portfolios improving to 20.59%, which improved further to 31.69% in the December Quarterly Economic Review (RBZ, 2019). Despite these improvements, local banks are yet to reach the pre-land reform maximum of 91.3% attained in the year 1999 (RBZ, 2006).

The government of Zimbabwe formulated various policies over the years seeking to improve the local farmers' access to the indispensable bank credit, for example the 99 Year Lease Agreements (Inter-Ministerial Task-Force (IMT) Technical Committee, 2016) and the Collateral Registry (Government of Zimbabwe (GoZ), 2017; RBZ, 2013). However, concerns over the bankability of the 99 Year Lease Agreements have presented challenges over their acceptability by local banks, whilst the Collateral Registry is yet to be operationalized. Despite these interventions, several studies propagate that credit access constraints still persist in the agricultural sector in Zimbabwe. According to the Ministry of Agriculture (2013), commercial banks withdrew their outreach in rural areas where most farmers reside because of lack of collateral among farmers in the absence of legal title to land. Besides most farmers depend on rain fed agriculture, which exposes them to weather risks, especially droughts (Chakoma and Chummun, 2019; United Nations, 2014). Output price volatility also affects the farmers' performance in terms of revenues and profitability, thereby reducing their loan repayment capacity (Leaver, 2004; Muchapondwa, 2009). Political interferences by the government also repel local banks from financing farmers in the country (Dale, 2009; Masiyandima et al., 2011; United Nations, 2014; Vitoria et al., 2012).

According to Mayowa (2015), agricultural credit includes all loans and advances granted to borrowers for financing and servicing agricultural production activities. Access to credit is key for improving agricultural productivity among poor resource farmers because it enables them to invest in their human and physical capital, thereby creating a pathway for economic development and poverty reduction (Anyiro and Oriaku, 2011). Madafu (2015) avers that credit access occurs when the price and non-price barriers are absent in the use of bank loans or credit by farmers. Therefore, he expounds that improved access to bank credit would mean improving the degree to which bank credit is available to everyone at a fair price. Several studies in Zimbabwe have explored alternative financing options for farmers in light of their failure to fulfil the local banks' stringent collateral requirements (FACASI, 2015; Masiyandima et al., 2011; Vitoria et al., 2012). Besides, policy direction at government level has largely been enthused by the desire to circumvent the collateral hurdle to credit access, and to ensure that agricultural production amongst land reform beneficiaries perseveres despite the absence of collateral assets in resettlement farms. However, a few studies, if any, have attempted to measure the extent to which local farmers have accessed bank credit since the FTLRP, and how credit access varied across different farmer social groups. This is the gap that the study aims to fill, focusing on Model A1 and Model A2 farmers in the Hurungwe District of Mashonaland West Province in Zimbabwe. The study therefore seeks to establish bank credit access trends among farmers in Hurungwe District; and to explore the socio-demographic determinants of credit access among the farmers.

MATERIALS AND METHODS

The study was carried out in Hurungwe District of Mashonaland West province in Zimbabwe (Figure 1), which is a home to 4 273 Model A1 farmers and 1 107 Model A2 farmers (Agritex, 2019). The Model A1 comprises smallholder farmers with landholdings averaging 6 hectares. On the other hand, Model A2 farmers are settled individually on farm sizes ranging from 71-600 hectares, which are operated as commercial entities (Vitoria et al., 2012).

Data collection

A cross-sectional survey was carried out on a sample of 354 farmers. The sample size was determined by the Raosoft sample size calculator. Stratified random sampling was used to come up with 281 Model A1 farmers and 72 Model A2 farmers for the study. The study was underpinned by the positivism research philosophy and adopted quantitative techniques to answer its objectives. A pretested structured questionnaire was used to collect data from farmers.

Data analysis

The Statistical Package for Social Sciences (SPSS) Version 26 was used to analyze the data through frequencies, cross tabulations and Chi Square. Frequencies enabled the researcher to identify the

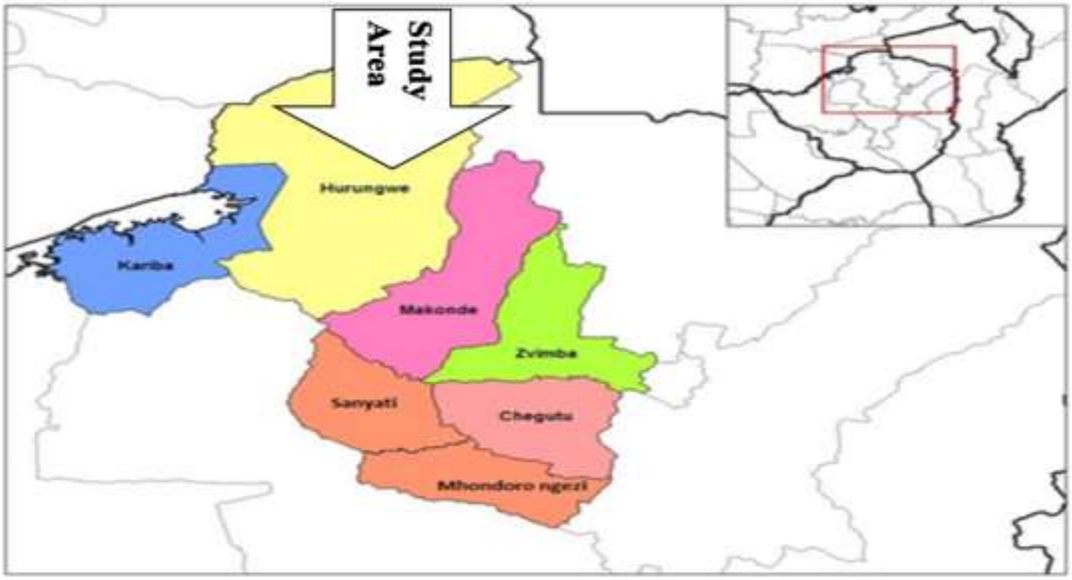

Figure 1. Study area.
Source: Mashonaland West (2019).

number of farmers who accessed/ received term loans from banks in the two periods (2000-2014 and 2015 -2019) and to compare differences in credit access levels. Cross-tabulations also helped to establish the trends of bank credit access by farmers with different demographic characteristics like age, gender and education level. Chi Square enabled the determination of the significance of differences in credit access among farmers in the two periods under study, and to establish relationships between different farmers' characteristics and access to bank credit. Chi Square was suitable for the study because the variable under study (credit access) was measured at the nominal/ordinal level, and was also measured by frequency counts (Mchugh, 2013). Findings from the study were presented using tables and figures.

RESULTS AND DISCUSSION

Figure 2 shows the credit access trends among farmers in Hurungwe District from 2000 to 2019. Since the implementation of the Fast Track Land Reform (FTLRP) in the year 2000 twenty years ago, approximately 98% of Model A1 farmers never accessed any bank credit compared to 45% in the Model A2 sector up to the current period (Figure 2). Within the last 15-20 years, there was also zero credit access among both Model A1 and Model A2 farmers. This supports Richardson (2005)'s assertion that lending to agriculture instantaneously diminished after the FTLRP as farmers could no longer use their land as collateral to secure borrowing. Credit access in both sectors began to grow within the past ten years, but was very marginal as only 0.7 and 1.4% Model A1 and Model A2 farmers accessed bank loans respectively. Whereas credit access grew by 50% in the Model A1 sector in the current period within the last five years, the Model A2 sector experienced a massive 525% growth in credit access. Credit access growth in both farming sectors may be attributed to government driven financing programs like Command Agriculture, which was aggressively implemented through local banks in the country within the past five years. Chisasa and Makina (2012)'s study in South Africa similarly established higher credit access by commercial farmers compared to smallholder farmers who lacked the eligible collateral required by banks, farming skills and technical knowhow.

There was no borrowing for consumptive purposes among Hurungwe District farmers as both Model A1 and Model A2 farmers did not access household expenditure loans (Table 1). Whilst, Model A1 farmers never accessed working capital loans, approximately 6% of Model A2 farmers had access to them. Model A1 farmers also had zero access to asset financing and farm improvement loans, signalling the absence of physical capital formation activities in the sector. The failure by Model A1 farmers to access any bank loans may be ascribed to their lack of collateral assets in the absence of secure property rights as they mostly hold offer letters and permits as proof of land ownership, and also their lack of human capital skills to run vibrant agricultural enterprises compared to their predecessors, the former white commercial farmers (Masiyandima et al., 2011; Richardson, 2005).

In the past period, Model A1 farmers had minimal access to short-term (0-90-days), short-to-medium (91-180-days) and medium-to-long-term (1-3 years) loans, whilst they had zero access to medium-term (181-365 days) and long-term (more than 3 years) loans. Access to short-term, short-to-medium term, medium-term and

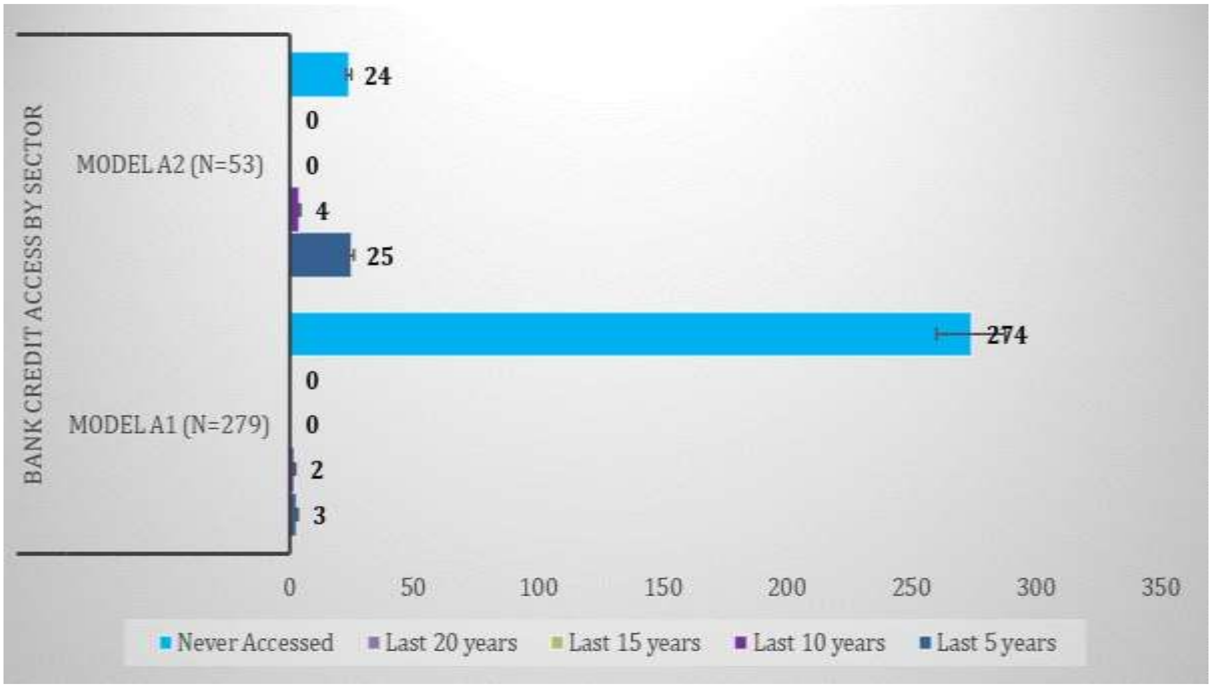

Figure 2. Credit access trends among farmers in Hurungwe District from the year 2000-2019.
Source: Primary Data (2019).

Table 1. Types of loans accessed by farmers in Hurungwe District.

Loan type accessed	Model A1 (n=279)	Model A2 (n=53)
Household expenditure	0	0
Working capital	0	3
Asset finance	0	10
Farm improvement	0	16

Source: Primary Data (2019).

Table 2. Bank loan tenures accessed by farmers in Hurungwe District.

Loan tenure	Model A1(n=279)		Model A2 (n=53)	
	Past access	Current access	Past access	Current access
0-90 Days	1	0	2	0
91-180 Days	1	0	5	2
181-365 Days	0	0	2	0
1-3 Years	3	0	18	16
More than 3 Years	0	0	2	0

Source: Primary Data (2019).

longer-term loans (>3 years) was marginally higher among Model A2 farmers in the same period. However, the Model A2 sector had the highest access to medium-to-long-term tenure loans of 1 to 3 years (Table 2). In the current period, Model A1 farmers had no access to any of the loans, whereas Model A2 farmers only had access to short-to-medium (91-180 days) and medium-to-long-term (1-3 years) loans. As highlighted above, higher access to

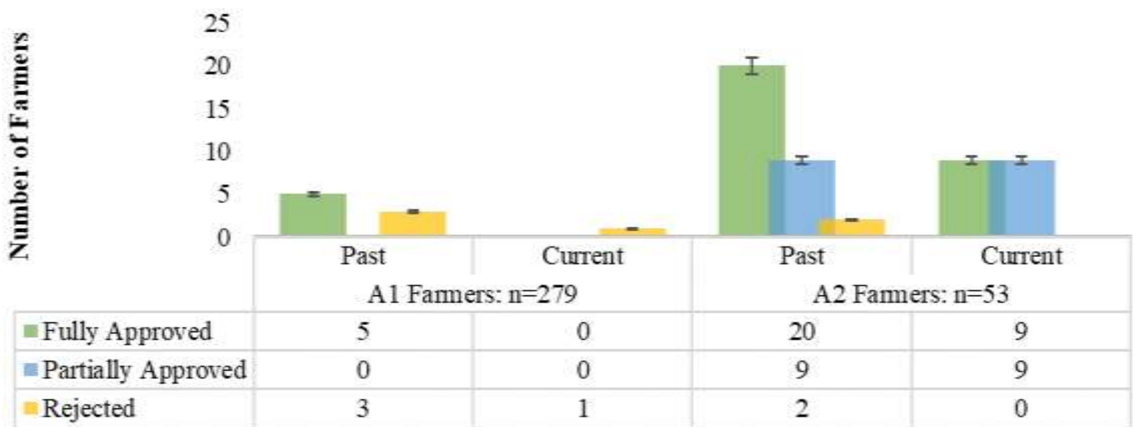

Figure 3. Approval status of loans sought by farmers in Hurungwe District.
Source: Primary Data (2019).

Table 3. Credit access by farmer type in Hurungwe District.

Type of farmer	Credit applications			
	Past	% of farmers	Current	% of farmers
Model A1 (n=279)	5	1.8	0	0
Model A2 (n=53)	29	54.7	17	32.1

Source: Primary Data (2019).

longer tenure loans in the Model A2 sector may signal the presence of physical capital formation activities, which may have contributed to the farmers' enhanced productivity, resilience to weather vagaries like recurring drought spells and capacity to repay loans. All of this may have also contributed to their better access to bank credit than their Model A1 counterparts (Awotide et al., 2015; Bisaliah, 2015; Lemma, 2015; Njoku and Odii, 1991).

In the past period, Model A1 and Model A2 farmers' loan applications were mostly fully approved (Figure 3). The number of Model A2 farmers whose loans were fully approved in the past quadruples that of Model A1 farmers whose loans were also fully approved. Whilst there were no partially approved loan applications in the Model A1 farming sector in the past, 17% of Model A2 farmers had their loan applications partially approved in the same period. However, there was a marginal difference between farmers whose loans were completely rejected in the past in the Model A1 and Model A2 farming sectors, which had 3 and 2 rejections respectively.

The current period had no fully or partially approved loans in the Model A1 farming sector as the only loan application made was rejected (Figure 3). However, rejected loan applications from the Model A1 farming sector decreased by a small margin from 3 rejections in the past to 1 rejection in the current period. Fully approved loans plummeted by 55% in the Model A2 farming sector, whilst partially approved loan applications remained constant in both time frames. The Model A2 farmers' rejected loan applications also marginally decreased from 2 to none in the current period. Based on prior findings of this study, Model A1 farmers may have accounted for most of the rejected loan applications because they have not made any meaningful physical and human capital investments in their farms compared to their Model A2 counterparts, who have higher educational qualifications and are persistently seeking asset financing and farm improvement loans. Therefore, Model A1 farmers have not been able to enhance the agricultural production capacities of their farms through both farm and personal development, hence the higher rejection rate of their loan applications by lenders.

Only 1.8% of Model A1 farmers accessed bank credit in the past period compared to 54.7% in the Model A2 sector (Table 3). In the current period, none of the Model A1 farmers accessed bank credit, whereas 54.7% of Model A2 farmers accessed it. However, access to bank credit in the Model A2 farming sector plummeted by 41.4% in the current period from the past as only 17 Model A2 farmers accessed bank loans compared to 29 farmers who used to access loans in the past. The type of farmer had a significant ($p<0.05$) effect on bank credit access in Hurungwe District in both the past and current periods (Table 4). Credit access was significantly ($p<0.05$) higher among Model A2 farmers compared to Model A1 farmers. Poorer farmers like smallholder Model

Table 4. The influence of farmer type on credit access in Hurungwe District.

Chi-Square Tests: Type of farmer*credit access					
Past period (2000-2014)	**Value**	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson chi-square	135.720[a]	1	0.000		
Continuity correction[b]	130.023	1	0.000		
Likelihood ratio	96.221	1	0.000		
Fisher's exact test				0.000	0.000
Linear-by-linear association	135.311	1	0.000		
No. of valid cases	332				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.43.					
b. Computed only for a 2x2 table					
Chi-square= 135.720 df=1 significance=0.000					

Current period (2015-2019)	**Value**	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson chi-square	94.320[a]	1	0.000		
Continuity correction[b]	87.834	1	0.000		
Likelihood ratio	67.651	1	0.000		
Fisher's exact test				0.000	0.000
Linear-by-linear association	94.036	1	0.000		
No. of valid cases	332				
a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.71.					
b. Computed only for a 2x2 table					
Chi-square=94.320 df=1 significance=.000					

Source: Primary Data (2019).

Table 5. Credit access by farm size in Hurungwe District.

Farm size (ha)	Credit access			
	Past	% of farmers	Current	% of farmers
<5 (n=50)	2	4	0	0
5-15 (n=184)	2	1.1	0	0
16-25 (n=38)	2	5.3	0	0
26-35 (n=13)	5	38.5	3	23.1
>35 (n=47)	23	48.9	14	29.8

Source: Primary Data (2019).

A1 farmers, who lack collateral assets and largely rely on rain-fed agriculture, are perceived as risky to lend to (Nyamutowa and Masunda, 2013; United Nations, 2014). Therefore, they are generally excluded from accessing bank credit. Bigger and highly collateralized farmers, who are mostly found in the Model A2 farming sector, are the most preferred borrowers by local banks (FACASI, 2015; Masiyandima et al., 2011; Vitoria et al., 2012).

Credit access in Hurungwe District was higher among farmers with more than 35 ha of farmland in both the past (48.9%) and current (29.8%) time frames (Table 5). In the current period, there was zero credit access among farmers with 25 ha or less of farming land. However, access to bank credit began to improve among farmers with 26 ha or more in the current period. Credit access also declined by 100% among farmers with less than 5 to 25 hectares, and by 40 and 39% among farmers with 26-35 and more than 35 ha respectively.

Farm size had a significant ($p<0.05$) influence on both current and past credit access in Hurungwe District (Table 6). Credit access was significantly ($p<0.05$) higher among farmers with more than 35 ha of farmland. Total

Table 6. Effect of farm size on credit access in Hurungwe District.

Chi-Square Tests: Farm size*credit access			
Past period (2000-2014)	**Value**	**df**	**Asymptotic significance (2-sided)**
Pearson chi-square	107.738[a]	4	0.000
Likelihood ratio	82.361	4	0.000
Linear-by-linear association	88.092	1	0.000
No. of valid cases	332		
a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is 1.33.			
Chi-square= 107.738 df=4 significance=.000			
Current period (2015-2019)	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson chi-square	82.170[a]	4	0.000
Likelihood ratio	62.864	4	0.000
Linear-by-linear association	67.134	1	0.000
No. of valid cases	332		
a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is 0.67.			
Chi-square=82.170 df=4 significance=.000			

Source: Primary Data (2019).

Table 7. Credit access by education level in Hurungwe District.

Education level	**Credit access**			
	Past	**% of farmers**	**Current**	**% of farmers**
No education (n=26)	0	0	0	0
Primary education (n=24)	0	0	0	0
Secondary education (n=207)	13	6.3	5	2.4
Higher education (n=75)	21	28	12	16

Source: Primary data (2019).

landholdings of farmers in Pakistan also positively influenced their access to agricultural credit because land fulfilled the collateral role (Saqib et al., 2018). Mukasa et al. (2017) also confirmed that farm size significantly reduced the likelihood of farmers being credit quantity constrained in Ethiopia. This is because farmers with large landholdings were perceived as more capable of repaying their loans without defaulting because of their higher income generating potential. Mayowa (2015) equally established that farmers with larger land sizes had better access to bank credit in South Africa because they had higher productivity prospects, which therefore enhanced their ability to repay bank loans.

Uneducated farmers and those who attained primary level education had no access to bank credit in both the past and current periods in Hurungwe District (Table 7). A few (6.3%) farmers with secondary education had access to bank credit, whereas farmers with higher educational qualifications had the highest (28%) access to bank credit in the past period. However, credit access among farmers with secondary education tumbled to 2.4% in the current period. Under the same period, credit access among farmers with higher education also declined by approximately 43% from 21 farmers to only 12 farmers.

Education had a significant ($p<0.05$) effect on the farmers' access to bank credit in Hurungwe District (Table 8). Credit access increased with education level as farmers with higher educational qualifications had significantly ($p<0.05$) higher access to bank credit. Sebatta et al. (2014) in Zambia and Muhongayire et al. (2013) in Rwanda argued that educated farmers' better access to credit was ascribed to their ability to determine the loan amounts required for their agricultural projects through the drafting of business plans or budgets that are usually needed by loan granting institutions. Higher levels of education were also equated to better knowhow, farming skills and familiarity with lenders' bureaucratic procedures, which all enhanced access to bank credit Sebatta et al. (2014). According to Ijioma and Osondu (2015), educated farmers are also considered to have better tendencies of loan management and adoption of new productivity enhancing technologies that improve

Table 8. Influence of education level on credit access in Hurungwe District.

Chi-square tests: Education level* credit access			
Past period (2000-2014)	**Value**	**df**	**Asymptotic significance (2-sided)**
Pearson chi-square	34.970[a]	3	0.000
Likelihood ratio	33.278	3	0.000
Linear-by-linear association	23.793	1	0.000
No. of valid cases	332		
a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 2.46.			
Chi-square= 34.970 df=3 significance=0.000			
Current period (2015-2019)	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson chi-square	24.089[a]	3	0.000
Likelihood ratio	21.098	3	0.000
Linear-by-linear association	14.682	1	0.000
No. of valid cases	332		
Chi-square= 24.089 df=3 significance=0.000			
a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 1.23.			

Source: Primary Data (2019).

Table 9. Credit access by alternative occupation in Hurungwe District.

Farmer's alternative occupation status	**Credit access**			
	Past	**% of farmers**	**Current**	**% of farmers**
Yes (n=32)	18	56.3	7	21.9
No (n=300)	16	5.3	10	3.3

Source: Primary Data (2019).

their repayment potential, which is attractive to lenders.

Farmers with alterative occupations off the farm in Hurungwe District had higher (56.3%) access to bank credit compared to full-time farmers (5.3%) who had no alternative employment in the past period (Table 9). Despite there being a decline in credit access among farmers in Hurungwe District in the current period, access was still higher among farmers with alternative occupations (21.9%) compared to full-time farmers (3.3%).

The farmers' alternative occupation status had a significant ($p<0.05$) effect on their access to bank credit in Hurungwe District (Table 10). Farmers with alternative occupations had significantly ($p<0.05$) higher access to bank credit compared to full-time farmers who were not employed off the farm. Several studies in Zimbabwe confirm that local banks prefer advancing loans to salaried individuals who have less default risk as their salaries are received through the loan granting bank (FACASI, 2015; Makina, 2010). Duflo et al. (2008); Muhongayire et al. (2013) and Vuong Quoc (2012) also established that income from the farmers' alternative employment helped to cushion banks from default risk if they failed to earn meaningful income from their agricultural projects to cover outstanding loan obligations.

In the past period, male farmers had higher (12.8%) access to bank credit compared to female farmers (5.3%) (Table 11). This position persisted in the current period as more males (5.9%) accessed bank credit compared to women (3.5%). However, the decline in credit access was higher (54%) among males than among women (33%) from the past to the current period. Sex had a significant ($p<0.05$) influence on the Hurungwe District farmers' access to bank credit in the past period (Table 12). Male farmers had significantly ($p<0.05$) higher access to bank credit compared to women. This raises questions over the efficacy of gender equity and women empowerment policies like the Gender Commission Act (Government of Zimbabwe (GoZ), 2015) that advocate for women's enhanced access to production resources just like men in the country. Vuong Quoc (2012) similarly established that loan access by farmers was positively related to being a male borrower in Vietnam. Men's better access to credit was ascribed to their high dominance in the agricultural field than women in most developing countries (Samuel et al., 2015). However, Abdul-Jalil (2015) on the contrary revealed that male farmers failed to access credit due to their higher default rates

Table 10. Relationship between alternative occupation and credit access in Hurungwe District.

Chi-square tests: Alternative occupation* credit access					
Past period (2000-2014)	**Value**	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson chi-square	81.552[a]	1	0.000		
Continuity correction[b]	76.107	1	0.000		
Likelihood ratio	50.560	1	0.000		
Fisher's exact test				0.000	0.000
Linear-by-linear association	81.306	1	0.000		
No. of valid cases	332				

Chi-square= 20.462 df=1 significance=0.000.
[a]1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.28.
[b]Computed only for a 2x2 table; The minimum expected count is 1.64.

Current period (2015-2019)	**Value**	**df**	**Asymptotic significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson chi-square	20.462[c]	1	0.000		
Continuity correction[b]	16.823	1	0.000		
Likelihood ratio	12.852	1	0.000		
Fisher's exact test				0.000	0.000
Linear-by-linear association	20.400	1	0.000		
No. of valid cases	332				

Chi-square=81.552 df=1 significance=0.000;
[c]1 cells (25.0%) have expected count less than 5. [d]Computed only for a 2x2 table.

Source: Primary Data (2019).

Table 11. Credit access by farmer sex in Hurungwe District.

Farmer sex	Credit access			
	Past	% of farmers	Current	% of farmers
Male (n=219)	28	12.8	13	5.9
Female (n=113)	6	5.3	4	3.5

Source: Primary Data (2019).

compared to women in Ghana. Thuku (2017)'s study in the Nyeri County of Kenya also established that banks preferred women to men when issuing credit because women honoured their credit obligations better than men. However, in the current period, sex does not have a significant ($p>.05$) effect on the Hurungwe farmers' access to bank credit.

Frequency statistics show that credit access in Hurungwe District was higher among farmers within the 46-55 years age group in both the past (12%) and current (9.4%) periods (Table 13). Credit access also declined in general across all farmer age groups from the past to the current period. The 35-45 years age group recorded the largest reduction (88%) in credit access from the past to the current period. The Chi Square test showed no association ($p>0.05$) between farmers' age and access to bank credit in Hurungwe District only in the past period. However, in the current period, age had a significant ($p<0.05$) effect on bank credit access. Hence, credit access was significantly ($p<0.05$) higher among farmers in the 46-55 years age group in the current period. Credit access increased with age, but decreased as the farmers became older at 55 years or more. Mukasa et al. (2017)'s study in Ethiopia equally established that as potential borrowers' age increased, their risk of becoming credit constrained diminished, but however started to increase with older age. According to the study, older loan applicants' probability of defaulting was perceived as higher than younger ones because of their higher risk of premature death and other recurring age-related health complications that could considerably undermine their ability to generate revenues and repay credit. Hence, their

Table 12. Influence of sex on farmer access to bank credit in Hurungwe District.

Chi-square tests: Farmer sex*credit access					
Past period (2000-2014)	**Value**	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson chi-square	4.532[a]	1	0.033		
Continuity correction[b]	3.755	1	0.053		
Likelihood ratio	5.005	1	0.025		
Fisher's exact test				0.036	0.023
Linear-by-linear association	4.518	1	0.034		
N of Valid Cases	332				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.57.					
b. Computed only for a 2x2 table					
Chi-square= 4.532 df=1 significance=.033					

Current period (2015-2019)	**Value**	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	0.881[a]	1	0.348		
Continuity Correction[b]	0.457	1	0.499		
Likelihood Ratio	0.934	1	0.334		
Fisher's Exact Test				0.437	0.255
Linear-by-Linear Association	0.878	1	0.349		
N of Valid Cases	332				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.79.					
b. Computed only for a 2x2 table					
Chi-square= 0.881 df=1 significance=0.348					

Source: Primary Data (2019).

Table 13. Credit access by farmer age in Hurungwe District.

Farmer age	**Credit access**			
	Past	**% of farmers**	**Current**	**% of farmers**
<35 years (n=47)	5	10.6	1	2.1
35-45 years (n=98)	8	8.2	1	1
46-55 years (n-117)	14	12	11	9.4
>55 years (n=70)	7	10	4	5.7

Source: Primary Data (2019).

lower access to bank credit (Table 14).

Conclusions

The majority of farmers in Hurungwe District from both the Model A1 and Model A2 farming sectors never accessed bank credit since they were allocated farmland under the Fast Track Land Reform Program (FTLRP). Credit access among farmers was zero some 15-20 years ago, marginally improved some 10 years ago, and grew immensely within the last five years. However, access was higher among Model A2 farmers, who mostly accessed asset financing and farm improvement loans with medium-to-long-term tenures of 1-3 years. Smallholder Model A1 farmers accounted for all of the rejected agricultural loan applications in Hurungwe District, whilst Model A2 farmers’ loan applications were either fully or partially approved. Farmers with 35 ha or more of farmland, alternative employment and those with higher educational qualifications had better access to bank credit in both the past and current periods. Male farmers and those in the 46-55 years age range also had better access to bank credit. In the current period, credit access was significantly influenced by the type of farmer, farmers’ education, farm size, alternative occupation and

Table 14. The effect of age on farmers' access to bank credit in Hurungwe District.

Chi-square tests: Age* credit access			
Past period (2000-2014)	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	0.851[a]	3	0.837
Likelihood Ratio	0.865	3	0.834
Linear-by-Linear Association	0.078	1	0.780
N of Valid Cases	332		
[a]1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.81. Pearson Chi-square=0.851 df=3 significance=0.837			

Current period (2015-2019)	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	8.722[a]	3	0.033
Likelihood Ratio	9.711	3	0.021
Linear-by-Linear Association	3.464	1	0.063
N of Valid Cases	332		
a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 2.41.			
Pearson Chi-square=8.722 df=3 significance=0.033			

Source: Primary Data (2019).

age.

RECOMMENDATIONS

The government of Zimbabwe is encouraged to address the infrastructural and human capital development needs of the agricultural sector, especially in the Model A1 farming sector to enhance bank credit access. Special attention must be given to the development of irrigation infrastructure in the Model A1 farms to reduce the farmers' dependency on rain-fed agriculture, which repels financial investors. Banks are also challenged to relax their demands for collateral in smallholder farming, but instead devise a locally adaptive model that prioritizes the farmers' ability to produce and repay and collateral substitution financing models like group financing. Farmers must also invest in personal and farm development initiatives in their own capacity in order to enhance their access to the indispensable bank credit, instead of always waiting for government intervention. Investments in human capital development, especially succession planning must also be prioritized by local farmers to ensure sustainable access to bank credit across all generations. Future studies must attempt to quantify the supply of bank credit to local farmers in actual monetary terms in order to have a clearer picture of the prevailing financing gap in Zimbabwe.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Producers supplying strategic network, value creation and exporting SME growth

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Strategic networks of agricultural suppliers for the creation of value added are an interesting field of research in the developing countries. Indeed, various scientific works were interested with social networks as well as on their members' relationship and on their management. However, social networks as strategic suppliers are able to solve SME's supply credit problems; the need to analyze networks with a view to creating added value for members of these networks remains less examined in literature. To understand the place of the networks in SMEs, a method of content analysis was used to analyze the data collected which included five focus groups of 8 people and twelve interviews. Most participants are producers / suppliers of cassava and shea nuts. The results show that supplier networks allow members to increase their revenues and also improve their skill level.

Key words: Supplier networks, added-value, income, welfare.

INTRODUCTION

Export increases income and the development of regional trade (Binti, 2011, 2010; Swinnen and Maertens, 2007). In 2011, African regional exportation rate was 3.3% while Asian regional trade rate was 31.1% (WTO, 2013). According to World Bank (2001, 2008), the simple increase for 1% of export market share may explain an expansion of one-fifteenth of sub-saharan African mean incomes, which generated yearly incomes in foreign currency of around 70 billion dollars. Therefore, researches on how to increase sub-Saharan African countries share at world trade were getting priority for this part of the world.

In 2008, Benin's exports represented 19.78% of GNP (World Bank, 2009). Despite Benin's presence on the international market, it is clear that its participation in international trade is very insignificant for several reasons. Indeed, Sotindjo (2014) shows that Benin's exports to the rest of the world are very rigid and mono-produced (Before 1894, the slave trade, between 1894-1975 Oil and palm kernel - Exports of cotton fibers and

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seeds, and finally from 1975-1990, some oil and soap factories).

This uncomfortable situation explains the importance of the scientific thesis on export. In fact, in the absence of large exporting companies, some small and medium-sized enterprises are involved in the country's export activities. However, the current concern concerns the access of smallholders to the market. In addition, market access for smallholders is an instrument to reduce poverty (Maertens and Swinnen, 2009), stimulate economic growth (Dolan and Humphrey, 2000; Kirsten and Sartorius, 2002; Govereh and Jayne 2003) and strengthen their means of sustainable livelihoods (Omiti et al., 2009; van Braun 1995; Swinnen and Maertens, 2007). But the access of smallholders to the markets of small and medium-sized enterprises (SMEs / SMIs) in the perspective of a dynamic supply chain in order to create added value remains a concern in the literature on relations with social networks suppliers (Humphries and Mena, 2012). The arable land resources available in Benin are estimated at 8,300,000 ha of source. Located in an intertropical zone, the precipitation recorded in the various regions varies between 750 and 1200 mm. This rainfall is very favorable for all agricultural crops including cassava and shea.

Despite Benin's agricultural potential, it is very paradoxical that there is no integrated production chain for added value which may be supplied by small producers as their market is accessed.

The central research question, in this context, is how networks of agricultural suppliers can create more value to better meet their living needs. The ultimate goals of this works were thus to improve the understanding of functioning of the small farmers' difficulties to supply SME firms and to suggest possible ways of strengthening their efforts to supply by their networks SME firms and livelihood. To better answer this question, we used literature on supplier social networks and theories of value creation. The present work is presented in three parts. The first part synthesizes the literature to extract the theoretical analysis framework. The second one describes the methodological approach used and the last part presents the results with their discussion.

LITERATURE REVIEW

Social networks and information sharing

Humphries and Mena (2012) explain how actions are constrained or facilitated because their social networks allow it. For them, social capital is the sum of resources, current or virtual, which increases for the individual or the group, the virtue of the possession of a sustainable network of more or less institutional relations formed of links and mutual recognition. In fact, a social network consists of a set of actors and relations ("ties" or "edges") between the actors.

The network's nodes can be individuals or groups, organizations or companies (Aydin, 2018). Relationships can enter the levels of analysis (relationship of individuals to individuals) or can be through levels of analysis (relationships of individuals to groups) (Mekonnen et al., 2018; Humphries and Mena, 2012). Social networks have several links expressed by information flows and materials flux. Literature on the social networks of suppliers has shown that knowledge is an important productive resource (Koliba et al., 2016; Humphries and Mena, 2012). The challenge of exchanging information in social networks for the purpose value has become a concern in the literature. Koliba et al. (2016) show in their work that the exchange of information between network members improves the production of value. Similarly, Mekonnen et al. (2018), in their work on agricultural innovation in Ethiopia, conclude that the sharing of information and knowledge among network members influences agricultural innovation.

Wang and Hu (2017) recently conducted a study on the mediating role of information exchange in social networks between collaborative innovation activities and the innovative performance of enterprises in China. Yan et al. (2017) share the same perspective when they demonstrated that the internal resources of supplier networks are a source of competitive advantage for the client companies of these suppliers. However, studies of social networks from a dynamic supply chain perspective as a source of supply for SMEs need scientific insight, especially for the purpose of value creating and reducing poverty.

Social network and competence strengthening

Many livelihood markets appear to be characterized by cultures that place high value in social relations (norms, continuation, affective, and normative commitments) and kinship networks (Viswanathan et al., 2010; Wang and Hu, 2017). These markets, most of which are in developing or emerging countries, are micro-enterprises that manage their relationships and commitments with consumers and use their families as they struggle for survival. According to the theory of industrial marketing and purchasing, social networks engage in a long-term process that emphasizes the mutually beneficial relationships to network members in the provision of industrial goods (Humphries and Mena, 2012). Small producers, not really in a context of the industrial market with large quantities sales, thrive with difficulties to produce and sell individually products on the industrial market (Adekambi et al., 2015; Garnett and Godfray, 2012). Thus, social networks can constitute a secure supply chain of raw materials for exporting SMEs to solve two problems, namely strategic supply group to African SMEs' markets and earning of incomes to face life needs and to reduce poverty in Africa. Adekambi et al. (2015) enlightened producers' information use and sharing. Contribution of social networks of agricultural producers in a value creation perspective remains a field to explore especially when its effect can reduce poverty.

Social networks a mechanism for creating added value

Network is beneficial to agricultural producers. It constitutes information and knowledge exchange context especially international market knowledge (Aydin, 2018). In addition, the notion of customers' added value arises in the marketing literature, particularly market orientation. Indeed, market orientation (OM) is defined as the set of organizational activities that are related to the generation and dissemination of information and good reaction to market demands (Kohli and Jaworski, 1990). Market orientation has a positive influence on firms' performance (Kirca et al., 2005; Narver and Slater, 1990). The small sales, in an informal context, of activities and the search for the well-being of small producers force them to develop an opportunistic behavior where they sell their products to better requesters (NEPAD, 2013). It is therefore necessary to recognize the need to coordinate networks to make them a source of supply. Trust, commitment and dynamism of networks can shed light on the relationship between small producers and SMEs. Since some decades, smallholders in Africa practice early sale to solve daily problems. Indeed, when small-producer is in financial difficulty, he sells his products even if he will later suffer from this behavior in lean times. In this way, small producers organized within supplier networks may profit from SME's markets not only by selling their products (earning revenues) but also to have financial credit they need to better cope with survival charges.

SMEs, because of their inability to access credit, need strategic networks of suppliers to increase their skills and advantages in competitive and changing markets (Xu and Lin, 2010). With strategic networks of suppliers, SME can select the most suitable suppliers. While the selection of strategic supplier networks is recognized for their importance in meeting market requirements in developed countries, there is a need for more refined knowledge about the influence of supplier networks on SME exporters' success and agricultural suppliers' livelihood.

MATERIALS AND METHODS

According to Cropley (2019), qualitative research is a non-experimental design in a real-life setting, involving collection of verbal reports describing respondents' construction of the situation in question, and content-based analysis of these reports. Data collection took place from November to December 2016 and covered all departments of southern and central Benin for cassava, and central and north for shea. Cassava and shea are concerned as products. This choice is justified because these products are joined in added value chains which are sustainable added value chains in Benin. Indeed, our exploratory research revealed that these products are used in two ways of added value industries such as distillery and oil factory. They are raw materials established in secure strategic supply-chain for SME firms. This methodology treated three points, first intervention zones and interviewees; second interview guides; and finally data analysis and interpretation tools.

The data collection area and the study sample

Analysis of potential sources of supply includes the organization's mechanism of the supply chain that ensures the sustainability of the raw materials used in the manufacture of distillery (alcohol) in Benin, both qualitatively and quantitatively. Three areas emerged from the literature as the most potential for the availability of raw materials used in the production of alcohol. They are the departments of Zou-Collines, Oueme Plateau, Mono-Couffo. But only cassava producers in Hills department are retained because they use cassava as incomes products. People who composed our interview database are the producers of raw materials, especially those who produce cassava used by two alcohol factories in Collines (Hills) department. Afterword women's groups in Borgou, Alibori, Atacora, Donga and Collines department, who collect and transform shea nuts into shea butter and sell to the FLUDOR SA, are concerned. Five focus groups of 8 people were organized to obtain the opinions, comments or their motivations to produce these raw materials. Similarly 12 interviews were conducted (Figures 1 and 2).

The interview guides

For the focus group discussions, the interviews with cassava producers focused on the structure of the raw materials market, commercial practices, customer relations, producer organizations, storage decisions, traceability importance, information sharing, acquisition of skills in networks and value creation. As for the alcohol factories, the maintenance concerned the quantity and quality of the alcohol, the existence of the markets of flow, the quantities produced, the problems related to the industrial production of the alcohol, and then the durability of this production.

Data analysis and results interpretation

Cropley (2019) explains that qualitative analysis aims to reveal data meaning. Data were recorded and transcribed. This transcript is 127 pages long. The content analysis was the method of understanding the corpus of the speeches of our focus group and interviews conducted. Similarly, summary tables of speeches were used. Interpretation of the results relates to the importance of networks in the exchange of information, the acquisition of skills, and the network members' increasing of incomes. The prospect of securing the supply chain for raw materials by exporting SMEs and SMIs was examined in order to ensure the sustainability of revenues and partnership relations with them.

RESULTS

Market accessibility

Results suggest that producers are looking for markets

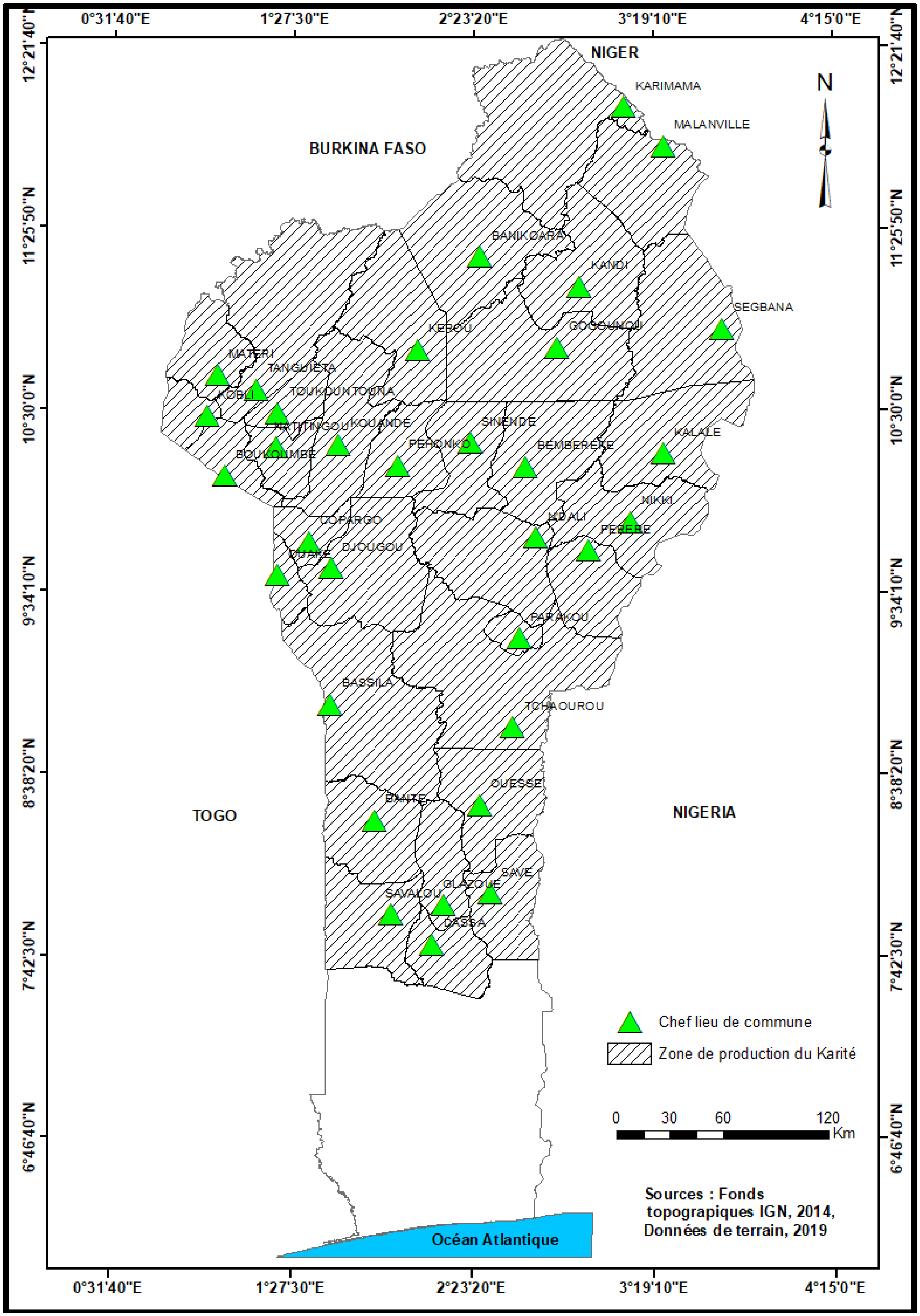

Figure 1. Map of shea production areas in Benin.

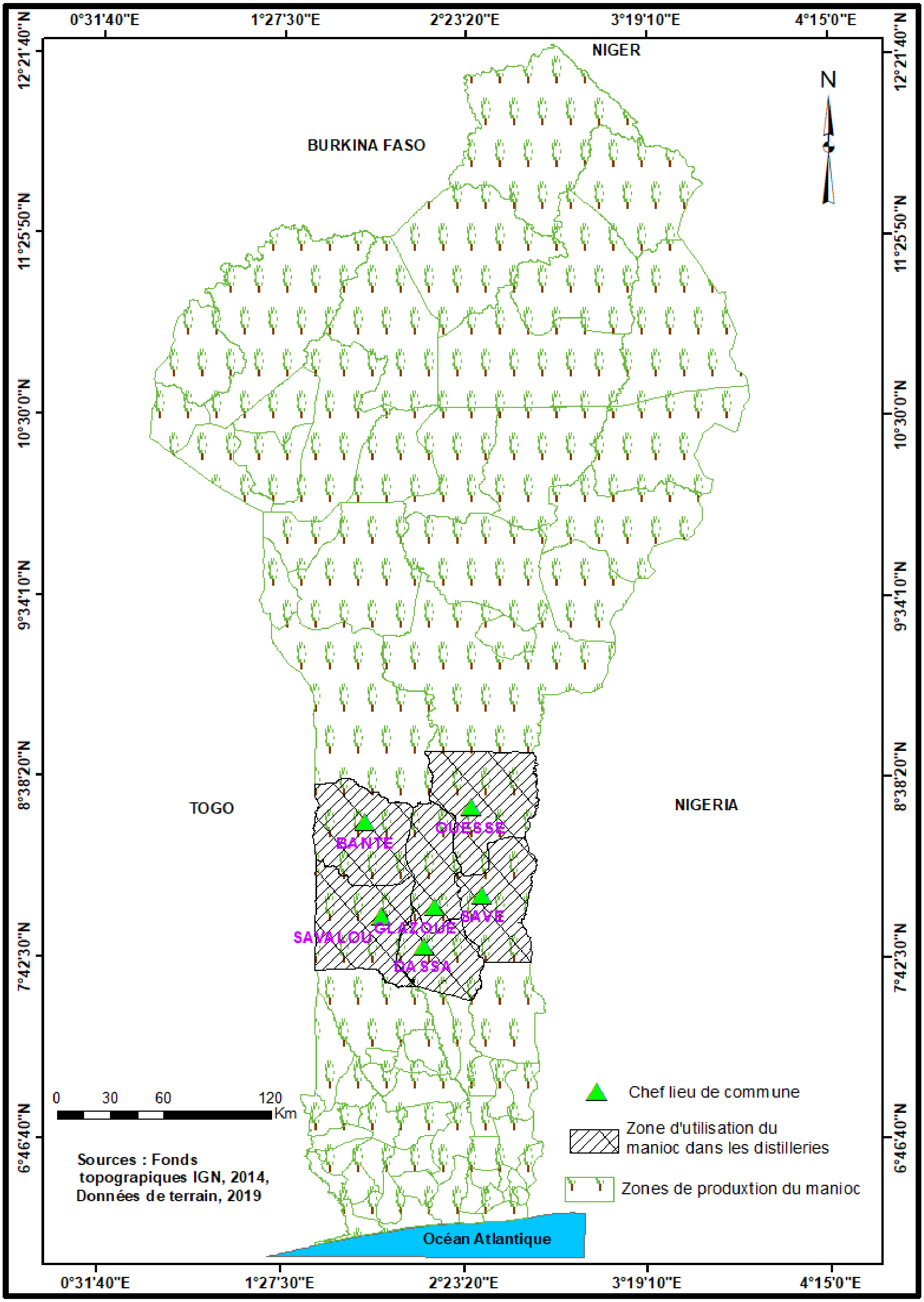

Figure 2. Map of cassava production and industrial use areas in Benin.

for their raw products because they do not have technologies for processing and/ or lack facilities for storing their crops. In fact, in the absence of adequate transport infrastructure, small producers face great difficulties in accessing markets (Mkenda and van Campenhout 2011; Ismael et al., 2015; Garnett and Godfray, 2012). Cassava growers have some possibilities for processing cassava into finished products, marketed in national and regional markets, namely gari, tapioca, lafu etc. Cassava ships selling is a new opportunity for them because its transformation requires less effort compared to other finished products. Similarly, it is paid in cash, which limits the risk of unpaid payments that small producers in Africa often face when they sell their other finished products especially gari which is delivered to intermediaries on credit to be paid when they have sold the product. This is what a group member in Bantè suggests: "*We are looking for markets where we will have the opportunity to sell our products faster in order to obtain such a large amount of income*". Income idea is also decisive through the comments of a member of the group settle at Ouessè in the village Laminou "*We are used to transform cassava into gari, but any calculation done, the sale of cassava chips in alcohol factories in either Savé and Savalou gives us more income than the other transformations".*

Information sharing in network

Cassava is an unorganized agricultural speculation. The distilleries industry market is an opportunity to review how to support producers to better respond to market requirements, especially since the sale is done in cash. Thus the networks of providers exchange experiences on types of varieties that have high productivity. All of them recognize that the variety "ODOHOUNGBO", not only, does it have a very high productivity compared to other varieties, but also does not turn into a stalk (deteriorate) because it has lasted in the field before being uprooted. Information exchange is very useful in producer networks. They demonstrate this through the fact that they have popularized a more interesting variety of cassava. At Tchogodo in the district of Savalou, a member of a group affirms: "*The variety of cassava Odohoungbo, remains by far the one we all appreciate, because it gives us time to make the others harvests; it is also of short cycle, a year to eighteen months maximum for a good performance. We had the information by other members of the network who received training which we did not take part''*. The same remarks are observed at Bantè on the sharing of information between networks. A producer of a network in Bantè says: "*Through our networks of friends of producers, not only do we exchange information about varieties, but we also benefit from mutual support from members of our networks. Once programmed the day of the sale, to save the time to the carriers, we form teams to accompany the loading of the trucks. Group sales are more considered in the factories".*

Skills and competencies importance

As for the production of cassava chips, the processing techniques of this product are learned between members of supplier networks. Compliance with international standards that increase the quality of the product is the goal pursued by the networks. The chips should be sliced obliquely to be easily dried; they should be clean, free from leaf and shrub debris and without sand grains. To respect these conditions, it is necessary to have equipment to cut the cassava, and the carpets to dry the chips. Unfortunately, small producers do not have the resources to individually respect these standards, so they use networks to gain the skills from the experience of network members. They exchange skills on the process leading to the product value added. Speaking of exchange of skills, a producer from a group of Ouessè confesses "*I do not know that, to make cassava chips, still requires competences. My first sale served as a lesson. I delivered it at 85F per kilogram while the normal price was 105F. These Chinese refused to pay me at the market price. It was after this mishap that my cousin showed me the horizontal cutting technique of cassava chips. This skill has been of great use to me. Indeed, my second sale was twenty tons, the gain obtained for this skill is around 20F times 20 000kg or 400 000F. It is very important". The same misadventure was also made by a producer of Bantè. He says 'Today we have understood that staying alone in one's corner is very earnest. I learned a lot from the members of my network, they share their expertise to help us increase the quality of the products. In addition, we also share the costs of transport which was also crazy to sell the products''.*

Networks have bargaining power

Once the production has been completed, the issue of product transporting from farms to the SME markets is a major concern for network members. Producers come together to divide transport costs by pooling crops to sell on the markets. They agree not only to distribute the expenses but also to distribute the resources obtained from sales according to the productions of the various members of the network. Finally, industries recognize the importance of chips as the only raw material needed to run their industries. The managers of these companies recognize the quality of purchased cassava chips that has a yield of up to 95%. The continuity of supplying of the raw material made it possible to produce alcohol for a period of 10 months out of twelve on the one hand and 4 and a half months on the other hand for the two existing

Table 1. Synthesis of the four themes derived from the interview and focus group data analysis.

Themes	Statements
Market access need	(i) "We are looking for markets where we will have the opportunity to sell our products faster in order to obtain such a large amount of income". (ii) "We are used to transform cassava into gari, but any calculation done, the sale of chips in alcohol factories in either Save and Savalou gives us more income than the other transformations".
Information exchange is very useful for network producers	(i) "The variety of cassava Odohoungbo, remains by far the one we all appreciate, because it gives us time to make the other harvests, it is also of short cycle, a year to eighteen months maximum for a good performance, we had the information by other members of the network who received training which we did not take part». (ii) "Through our networks of friends of producers, not only do we exchange information about varieties, but we also benefit from mutual support from members of our networks. Once programmed the day of the sale, to save the time of the carriers, we form teams to accompany the loading of the trucks. Group sales are more considered in the factories".
Market skills and competencies influencing profit	(i) "I don't know that to make cassava chips, you still need skills. My first sale was a lesson. I delivered it at 85F per kilo when the normal price was 105F. These Chinese refused to pay me at the market price. It was after this mishap that my cousin showed me the technique of horizontal cutting of cassava chips. This skill was of great use. Indeed, my second sale was twenty tonnes, the gain obtained for this skill is about 20F times 20,000kg or 400,000F. This is very important. "Today, we have understood that it is very serious to be alone in one's corner. I learned a lot from members of my network, they share their expertise to help us increase the quality of products. In addition, we also share the shipping costs which were also crazy to sell the products "
Network bargaining power	(i) "When I used to sell my product alone, they pay it back with many difficulties and they told me regularly that the quantity is too low, but since we start selling in network group, we are considered with respect. It is very easy to sell and we do not waste time". (ii) "When we sell in network group, they do not complain about the product quality. But, in the same condition, single seller can pay less than a kilogram; the buyers may explain it by the bad quality of the product. Network sellers are appreciated and buyers take care with them".

Source: Interview data collected and analysed, from Novembre-December 2016.

distilleries. All their productions are sold on both national and regional markets (notably Togo and Ghana). However, the absence of an organization of the sector is exploited by those responsible for these industries who abuse the suppliers, especially those who are not in networks and who have small quantities to sell. For this category, they are entitled to arbitrarily set sales prices or reject the product for low quality. In this last condition, the producer loses all his production (whose tonnage can be from one ton to three tons) because he did not seek the adequate information to better present his product according to the requirements of the market. All these efforts are worthless.

Then, importance of network is shown. Networks constitute the bargaining power of producers. It is what one member, of Ouesse cassava ships producers, explains: *"When I used to sell alone my product, they pay it back with many difficulties and they told me regularly that the quantity is too low, but since we start selling in network group, we are respected by them. It is very easy to sell and we do not waste time". Other member based à Bantè expressed this reality "When we sell in network group, they do not complain about the product quality. But, in the same condition, single seller can be pay less than a kilogram; the buyers may explain it by the bad quality of the product. Network sellers are appreciated and buyers take care with them".*

This raises network bargaining power and it influences group sale. SME firms are the institutional context for producers to learn about international market. As they have contract with export market, the respect of international market standard is an obligation for them to entertain commercial relation. The study limits are relative to the number of agricultural sectors such as cassava producers and shea nut collectors and transformation we have integrated in this study. All the results are synthetized in the Table 1.

DISCUSSION

Our results reveal that small producers' market access remains a worrying issue. The need to sell their products in creditworthy markets is a puzzle to the producers. These results are consistent with those obtained by Ismail et al. (2015) and Garnett and Godfray (2012) who argued that small producers are in need of markets access. WFP (2015)'s work supports these results and the author argued that when market access is not matched with appropriate pre and post-harvest handing, storage and transportation facilities, there may be food loss and quality issue that may affect the nutrition quality food. Adekambi et al. (2019) command smallholders' market learning as one of the keys factors to satisfy their market integration requirements. For these authors, market learning enables smallholders to select the customers, and as such marketing channels that are most suitable for their situation and seize the opportunities provided by these customers.

Social networks constitute the sources of informal information exchange. Our result stated that network members exchange information related to crops varieties, market days and transportation fees. This finding is consistent with Viswanathan et al. (2010) and Koliba et al. (2016) whose studies support information exchange between network members. Moreover, sharing skills and experiences between network members improves quality practices in product processing. Our finding is also consistent with those of earlier studies of Mekonnen et al. (2018) and Humphries and Mena (2012) that stated that skills and competences are exchanged in network teams. Skills, competences and experiences exchanges in our work provide revenues for network members. Then, the more the network members have competences, the more the team will benefit from his market integration.

The finding revealed that networks have bargaining power. The producers highlighted the importance of network in supporting the integration process of small producers with markets. They justifies this power through facilities, such as transportation cost reduction, they obtain when selling in network teams. To limit waiting lines, SMIs appreciate group sales because they save time.

This result is supported by the results of some earlier works (Yan et al., 2017; Humphries and Mena, 2012) who stated that networks have bargaining power in business negotiations. Our results pointed out that the team power is more remarkable than the network negotiation power. Future research can be directed towards strategic partnerships that can lead to the development of industrial fabrics where small producers will be supplying SMI. Similarly, longitudinal studies must be conducted to better shed light on supplier networks with SMI relationships in developing business relations between producers' networks and SMI.

Conclusion

The extant literature has largely analyzed market access for small producers as a way of reducing poverty (Mearstens and Verhofstadt, 2013; Romalis, 2007). However, small producers are organized into strategic networks of suppliers of SME exporters to increase the presence of African countries in foreign markets. The present work aims to better understand market access for small producers through markets of exporting SMEs.

The results showed that supplier networks have the capacity to engage in a process of value creation to improve their standard of living. For cassava growers, the formation of supplier networks is forged or imposed by the industrial client units to make small producers group their productions and enhance the buying price which increases from 25 to 45 francs CFA per kg. This constraint of being members of networks before attempting to sell to SMEs allows producers to exchange experiences about the required standards by industries in order to increase the added-value to products on one hand and to secure the supply of the raw material on the other hand. As for shea producers, supplier networks are formed for training purposes to improve skills in the collection of nuts and to deliver nuts of superior quality, leading to increase in the per kilogram price. The motivations of the suppliers are the improvement of skills, the increase of the revenues and the creation of the added value.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Social and economic values chain assessment of key non-timber forest products around Mbam and Djerem National Park's ecoregion of Cameroon: Case of *Xylopia aethiopica, Beilschmiedia anacardioides* and *Beilschmiedia jacques-felixii*

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The periphery of Mbam and Djerem National Park in Cameroon harbors valuable forest resources including key non-timber forest products (NTFPs) that contribute to sustain livelihood of many people in terms of consumption and income generation. However, poor studies have been carried out to assess the socio-economic importance of the value chain of key NTFPs, threats on resources and implication for trade development. We used the value chain analysis approach to map and assess the socio-economic importance of the value chain of three key NTFPs such as *Xylopia aethiopica, Beilschmiedia anacardioides* and *Beilschmiedia jacques-felixii,* from forest to market place. The results of the study showed that interesting parts of the plants are the fruits that are harvested and processed for sale or local consumption. Annual profit margins for 17 producers of *B. anacardioides* and *B. jacques-felixii*are was estimated at 1,196,188 FCFA (2023.45 USD) representing 68%, and for 52 producers of *X. aethiopica* was estimated at 31,280,000 FCFA (52912.57 USD) accounting for 85%. This constitutes an important contribution to the total income of producers of these NTFPs across the region. Profit margins of wholesalers are more important than that of producers and can be classified as follows: 11 wholesaler's of *B. anacardioides* and *B. jacques-felixii*, 1,908,937 FCFA (3229.12 USD) representing 75% (t-test, df= 26; p= 0.0004); and 20 wholesalers of *X. aethiopica,* 51,888,000 FCFA (87772.61 USD) representing 94% (t-test, df= 70; p=0.0009). The exploitation of *X. aethiopica* is practiced by felling the trees and the species recorded a high vulnerable index (VI = 2.61). This practice jeopardizes the natural regeneration of the species in the undergrowth and alters the structure and floristic composition of the plant communities. In the north-eastern part of the park, local people manage the existing species through enrichment plantings.

Key words: Values, plant species, products, park, Cameroon.

INTRODUCTION

Millions of rural and urban dwellers across the world make use of a wide diversity of forest products, including timber and non-timber forest products, to fulfill their livelihood requirements. Such forest products are gathered for household consumption, to generate cash income, and as a fall back in times of emergency or a means to income diversification. All these roles are significant, and often, non-timber forest products (NTFPs) perform multiple functions simultaneously (Shackleton et al., 2011). NTFP trade development required mapping of actors engaged along the trade, from forest to market places, and exports. This approach is termed by some actors as value chain analysis assessment, and aims at examining the full range of activities that are required to bring a product in a particular enterprise from its conception to its end markets.

As NTFPs become increasingly important commercially, local efforts to take advantage of the opportunities they present can be complicated by value chain development context and environment. In remote forest areas, as in mountain regions, markets in general are underdeveloped, and even in more developed regions monopoly buyers and sellers are well established and discourage the emergence of small-scale enterprises (Scherr et al., 2003). NTFPs produced in remote areas are sold through a long marketing channel which is inefficient and does not provide a fair share of the profits to collectors of the products. Karki and Bhattarai (2006) reported that producers and collectors of NTFPs in general receive between 15 and 20% of the final value of the products in the market chain. In the case studies from sub-Saharan Africa, most of the NTFPs contribute less than 50% to household incomes and in nine cases, less than 25%. In only three cases, NTFPs, especially in Cameroon, contribute more than 70% to household incomes, namely *Prunus africana, Gnetum* spp. and *Irvingia* sp. (Awono et al., 2002a; Sunderland and Ndoye, 2004; Endamana et al., 2016; Muhammad et al., 2017).

Timko et al. (2010) noted that in Africa, over two-thirds of the continent's 600 million people are estimated to rely on forest products, either in the form of subsistence uses or as cash income derived from a wide range of timber and non-timber forest products (NTFPs). There is a significant long regional trade in NTFPs amongst other Central Africa countries in some products such as *Gnetum africanum, Gnetum buchholzianum, Irvingia gabonensis, Irvingia wombolu, Baillonella toxisperma*, *Cola acuminate* and *Cola nitida.* However, for many NTFPs, the social and economic values and quantities harvested and traded are not assessed in a precise manner (Wasseige et al., 2009) and threats affecting the value chain are poorly known, especially for trade development.

It is widely acknowledged that forests and NTFPs play a key role in the daily life of millions of people living in rural areas in Cameroon (Cosyns et al. , 2011; Awono et al., 2016).

The Cameroonian 1994 Forestry Law identifies and sets out controls for special forest products, many of which are NTFPs. However, it does not define NTFPs nor is there an explicit logic in the selection of products or prioritization of NTFPs to enable sustainable management or monitoring. Ingram and Schure (2010) identified 45 NTFPs as priority or key meaning that they were attributed the highest values based on the level of consumption, extent and volume of trade, multiple uses of species and use of multiple parts of a species and the level of vulnerability. Data concerning actors involved in such NTFPs value chain, harvested, consumed, processed and traded amounts as well as gross and net mean revenues generated are poorly known around Mbam and Djerem National Park's ecoregion in Cameroon, especially for trade development and management. Apart from Arabic gum that is well-known, the northern part of Cameroon is not well represented on terms of NTFPs production (Awono et al., 2016).*Xylopia aethiopica, Beilschmiedia anacardioides* and *Beilschmiedia jacques-felixii* which are key NTFPs widely distributed in the ecoregion of Mbam and Djerem National Park situated in the northern part of Cameroon are little known in terms of volumes, values and sustainable management. They are mostly collected by local communities at the periphery of the protected area. Souare et al. (2012) have shown that the mean number of stems cut for harvesting these products was 15.5±5.5 stems/ha in the disturbed sites. Since the key NTFPs are more available inside the Park and the buffer zone and given the fact that there isno any exploitation permit, conflicts between communities and forestry agents are very tough. The study was conducted specifically to:

i) examine the local uses of *X. aethiopica, B. anacardioides* and *B. jacques-felixii* around the Mbam and Djerem National Park's ecoregion;
ii) assess the economic values of the three key NTFPSalong the value chain from forest to market places;
iii) assess the vulnerability status of such key NTFPs species around the Mbam and Djerem National Park's ecoregion.

MATERIALS AND METHODS

Study site

The study was carried out at the catchment of Mbam and Djerem National Park in Cameroon. The park covers an area of 416 512 ha which is one of the highest protected area in Cameroon after the Dja Biosphere Reserve which covers 526,000 ha. It lies between 5°30' to 6°13' N and 12°23' to 13°10' E at the northern limits of the

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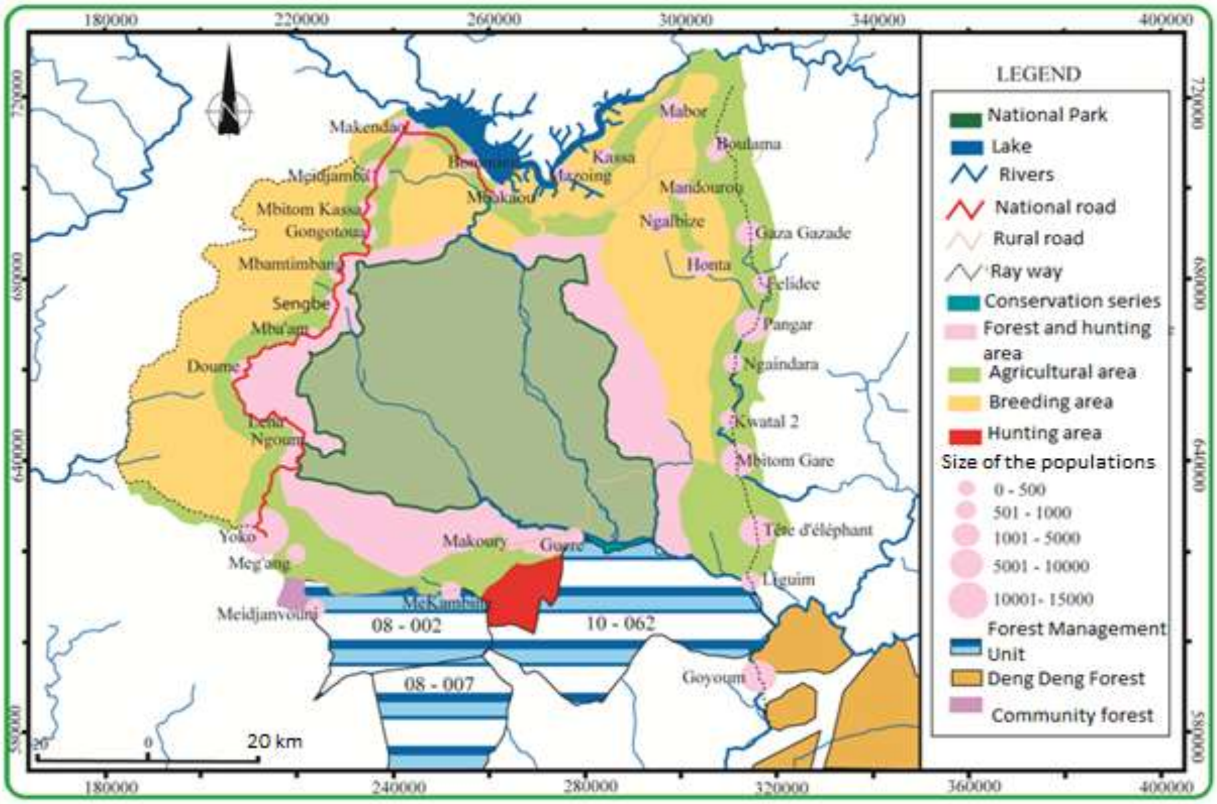

Figure 1. Map of location of the study site (adapted from the management plan of the park).

Congo Basin rainforest, in the Sudano-Guinean zone. Statistics indicated by Souare (2015) showed that about 28 694 inhabitants for 74 villages live at the immediate periphery of the Park. The land reserved for agriculture, livestock, hunting and the collection of forest timber products and non-timber forest products covers an area of 1,148,170.887 ha (Figure 1).The geological substratum consists of a series of gneiss and undifferentiated granites. The study site is characterized by two seasons: the wet season that extends from April to November and the dry season occurs from December to March (Souare, 2015). The mean annual precipitation is 1765.52 ± 214.17 mm, with a mean monthly temperature ranging from 22.2 to 27.7°C. The wettest months are from June to October (Figure 2). The hydrography of the area consists of many rivers: rivers flowing on rocky beds, small waterfalls and the great River Djerem. The main vegetation type consists of semi-deciduous forest, gallery forest and savannas (Letouzey, 1985). Most of the people who live at the periphery of the park rely solely on agriculture, livestock and forest resources to meet their basic needs. Non-timber forest products exploitation has been extensive in some areas, mainly in the northern and eastern part of the park. Since key NTFPs are more available inside the Park and the buffer zone, local communities sometimes make incursions in these zones. This situation is causing conflicts between the local communities and the ecoguards.

Data collection and analysis

Local uses and assessment of key NTFPs production

Local uses and production assessment were conducted in 11 villages at the periphery of the park. They were selected on the basis of the size of the population, the number of actors involved in the sector (producers, traders, buyers) and the importance of the market (availability of products in the market). Beside a total of 69 collectors of key NTFPs, with 17 producers of *B. anacardioides* and *B. jacques-felixii* along with 52 producers of *X. aethiopica*, participatory rural appraisal developed by David-Case (1990) was performed in order to appreciate their local uses. Among the 69 producers, there was no woman since harvesting is mostly done by felling the trees and then needs a lot of physical effort. For each harvester, a sheet or book of accounts was given and filled accordingly, and local uses of plant organs were acknowledged. The monitoring and collection of the information available on the sheets occurred every two to three weeks throughout the production period. The information collected related to the type of container, quantities harvested, consumed and sold, the costs (handling fees, storage, transport, communal taxes, custom taxes, forest agents) and profit margins. Quantities were measured with a balance. Other information concerned the places of harvest, the distance from the village and the abundance of resource species in the harvesting sites.

Market study and economic values of key NTFPs at the periphery of Mbam and Djerem National Park

A market study was carried out among the actors involved in the market chains of the key NTFPs at the periphery of the Mbam and Djerem National Park. The actors were 31 traders including semi-wholesalers, wholesalers and retailers. Only one female wholesaler was found among the 31 and concerned *B. anacardioides* and *B. jacques-felixii*. All the retailers found in the markets were women. The study considered the accessibility of markets and role they play

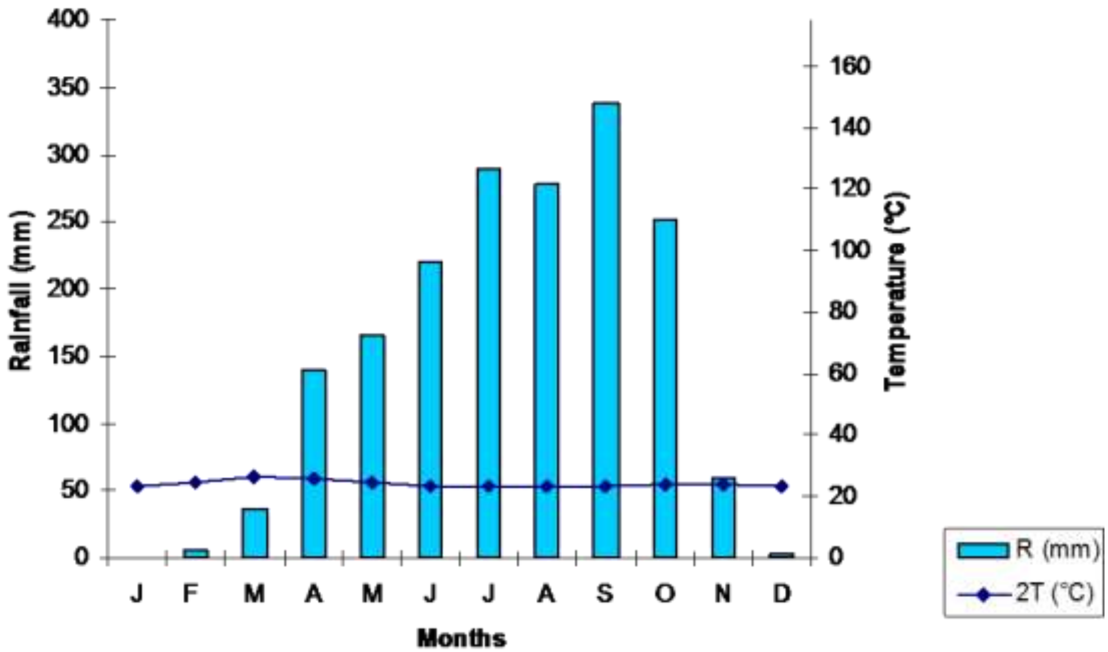

Figure 2. Ombrothermal diagram of the area (Hydroelectric Dam of Mbakaou, Adamawa Region).

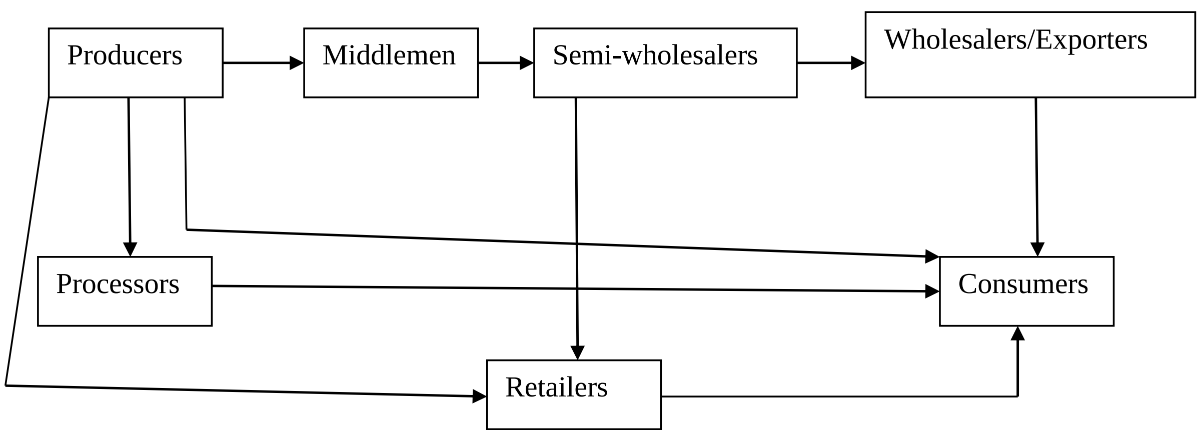

Figure 3. Key NTFPs market value chain at the periphery of Mbam and Djerem National Park.
Source: Adapted from Awono et al. (2016).

in the concentration and distribution of key NTFPs, their links with other markets and neighboring countries.Ten (10) local markets were chosen and completed by thirteen (13) railway stations.An accounting sheet was given to each actor to be filled after an activity, mainly semi-wholesalers and wholesalers. The information concerned the quantities of key NTFPs purchased and sold, the dates and places of purchase and sale, processing and packaging, costs, trade margins and the number of traders involved.

According to Awono et al. (2016), in the context of free economy in Cameroon, economic value of a good is the maximum amount a buyer is willing to pay or has paid for it. The economic value considered in this paper is the financial value of the quantities of key NTFPs sold. Also, the rate of key NTFPs destined for self-consumption is estimated. The market value chain considered in this paper was already developed by Awono et al. (2016) (Figure 3). Only middlemen do not own capital but act on behalf of semi-wholesalers and wholesalers.

The profit margins of the collectors were calculated according to the general pattern (Fuashi et al. 2011):

$$PM = SP – TC$$

where PM = Profit margins of collectors; SP = Sale price; TC = Total costs.

The following formula was used to calculate the profit margins of the traders:

$$PMW = SP – (PP + TCC)$$

where PMW = profit margins of the Wholesalers; SP = sale price; PP = purchase price; TCC = total costs of the commercialization.

Table 1. Important parameters for vulnerable index (VI).

Parameter	Vulnerability to an uncontrolled exploitation		
	Weak (scale = 1)	**Moderate (scale = 2)**	**High (scale = 3)**
Frequency of use (FU)	FU ≤ 20%	20% ≤ FU ≤ 60%	FU ≥ 60%
Number of uses (NU)	NU < 2	2 < NU < 4	NU > 5
Organ of plant used (OPU)	Leave, latex	Fruit, branch	Wood, seed, bark, root, flower
Method of collection (MC)	Picking	-	Picking, logging
Stage of development (SD)	Old or senescent	Adult	Young
Relative frequency (Fr)	Fr ≥ 2/3 Fm	1/3 Fm ≤ Fr ≤ 2/3	Fr ≤ 1/3 Fm

Fm = maximal relative frequency.
Source: Adapted from Betti (2001).

The t-test was used to establish the average differences between producers and wholesalers.

Assessment of vulnerability status of the three key NTFPs

The vulnerability status was assessed through 69 actors' perceptions involved in the production of the three key NTFPs. The following questions were asked: collected organs, domains of the use, mode of collection, stage of development of the organ, the interviewee's point of view on the state of abundance of the species, the possible causes of the scarcity of plant resources and proposals for strategies for the conservation of useful species. The three-level vulnerability scale, from 1 to 3, proposed by Betti (2001), was used to calculate species vulnerability: 1 for species with weak vulnerability; 2 for species with moderate vulnerability; and 3 for a high vulnerable species (Table 1). The vulnerability index of the species (VIi) was calculated from the following formula (Betti, 2001):

VIi = N/6 with N = N1 + N2 + N3 + N4 + N5+ N6; N1 = frequency of use; N2 = Number of uses; N3 = organ of plant used; N4 = method of collection; N5 = stage of development; N6 = relative frequency.
VIi<2, the species is weakly vulnerable; 2 ≤ VIi <2.5, the species is moderately vulnerable;
VIi ≥ 2.5, the species is highly vulnerable.

RESULTS

Local uses of resource species

The resource species are sought either for their reproductive organs notably fruits and seeds,or for their vegetative organs constituted ofstems and leaves. As such, they are grouped intotwo categories namely reproductive organs and plant structures (Table 2).

*X. aethiopica*is mainly used by forest dwellers for its fruits as seasoning. They are added to some drinks such as milk, coffee and porridge, and are considered as real tonic both for man and woman. These fruits are also used in traditional pharmacopoeia to treat toothache, rheumatism, herpes and asthma. In cross-border areas, namely Chad, Libya, Sudan and Nigeria where the product is exported, it is used in the manufacture of perfume according to some foreign traders thatwe encountered. Furthermore, the stem of *X. aethiopica* is used as pole for the construction of roof. The wood is hard, resistant to rot and animal parasites, especially termites. The leaves are consumed raw or cooked as vegetable by the local people.

B. anacardioides and *B. jacques-felixii* are used for their fruits and seeds as seasoning and thickening of sauce. The seeds transformed into powder serve in preparation of maize fritters. The sauce prepared with the powder is recommended to pregnant women in order to facilitate childbirth.

Economic value and contribution to the households

Fruits of *X. aethiopica, B. anacardioides* and *B. jacques-felixii* are collected from forest galleries and mosaic forest-savanna by local people at the periphery of Mbam and Djerem National Park. Collectors are mainly constituted of men since the exploitation by felling systematically the trees need a lot of physical effort. Theysell their products to middlemen, semi-wholesalers or wholesalers. The commercialization channel of these products goes beyond the sphere of the park. The fruits of *X. aethiopica* are sold to foreigners who come from Chad, Sudan, Nigeria and Libya and constitute the wholesalers. The fruits of *B. anacardioides* and *B. jacques-felixii* are sold to semi-wholesalers living in the villages and wholesalers coming from other regions of the country. These wholesalers resell the products expensive to retailers during shortage period.To avoid post-harvest losses, fruits of *X. aethiopica* are dried with fire and then spread to the sun before being packaged. Also, fruits of *B. anacardioides* and *B. jacques-felixii* are boiled, dried and packaged in bags before being sold in regional and/or national markets (Figure 4).

The estimated quantity of *X. aethiopica* collected was 172.96 tons for six months of exploitation and both for*B. anacardioides* and *B. jacques-felixii* 2.513 tons for five months of exploitation (Table 3). The sale values obtained from *X. aethiopica* appear to be the most important, reaching 36,800,000 FCFA for 52 collectors and 55,200,000 FCFA for 20 wholesalers. Production

Table 2. Various uses of NTFPs according to actors engaged in the value chain.

Species	Categories of product	Collected organs	Local uses
Xylopia aethiopica A. Rich., *Beilschmiedia anacardioides*Rob. & Wilcz., *Beilschmiedia jacques-felixii*Rob. & Wilcz.	Reproductive organs	Fruits	Traditional pharmacopoeia[a], tonic[a], perfume[a] Food[abc]
*Beilschmiedia anacardioides*Rob. & Wilcz., *Beilschmiedia jacques-felixii*Rob. & Wilcz.		Seeds	Food[bc], facilitation of childbirth[bc]
Xylopia aethiopica A. Rich.	Plant structures	Stem, leaves	Construction (stem), food (leaves)

a: *Xylopia aethiopica*; b: *Beilschmiedia anacardioides*; c: *Beilschmiedia jacques-felixii.*

Figure 4. Fruits and seeds of key NTFPs at the periphery of Mbam and Djerem National Park, a) Bags of *Xylopia aethiopica* fruits stored before exportation, b) Bags of *X. aethiopica* fruits in a lorry for exportation, c) Seeds of *Beilschmiedia jacques-felixii* in Ngaoundal Market, d) Fruits of *B. anacardioides* in Ngaoundal Market.

costs represented 15% for *X. aethiopica* and 32% for *B.anacardioides* and *B. jacques-felixii*while marketing costs varied from 6 to 25% for *X. aethiopica,B. anacardioides* and*B. jacques-felixii* respectively. The high costs for producers are due to the fact that they pay handling fees, storage fees, transport, communal taxes, forest agents and even traditional rulers. Costs for wholesalers of *X. aethiopica* include mainly custom taxes (flat rate) and transport accounting for 6%.Investigations showed that about 92% of *X. aethiopica* is marketed and 80% of *B. anacardioides* and *B. jacques-felixii* is marketed. The other percentages (8 and 20% respectively) are destined to producers' households, family members and friends. Monthly incomes for producers are above the guaranteed minimum wage in Cameroon (36,270 FCFA). Profit margins of key NTFPs varied from 68 to 85% for the 69 collectors and from 75 to 94% for 31 wholesalers.

The main markets of *B. anacardioides* and *B. jacques-felixii* are Ngaoundal (0.89 t), Tibati (0.42 t) and Pangar (0.31 t) which represent 32.96, 15.55 and 11.48% respectively (Figure 5). Wholesalers obtain more profits

Table 3. Volumes and sale values of key NTFPs at the periphery of Mbam and Djerem National Park.

Key NTFPs	Number of producers	Volume (t)	Average unit sale price of producers (FCFA)	Production costs* (PC)	Average unit sale price of wholesalers	Marketing costs* (MC)	Sale value of producers	Sale value of wholesalers	Profit margins of producers (PMP)	Profit margins of wholesalers (PMW)
Beilschmiedia anacardioides	17	1.023	700***	229 152 (32%)	1 250***	319 688(25%)	716 100	1 278 750 (11)****	486 948(68%)	959 062(75%)
Beilschmiedia jacques-felixii		1.49	700***	333 760 (32%)	850***	316 625 (25%)	1 043 000	1 266 500 (11)****	709 240(68%)	949 875(75%)
Xylopia aethiopica	52	172.96	10 000**	5 520 000 (15%)	15 000	3 312 000(6%)	36 800 000	55 200 000 (20)****	31 280 000 (85%)	51 888 000 (94%)

*Handling fees, storage, transport, custom taxes, communal taxes, forest agents, traditional rulers; **Corresponding value of a 47.1±1.9 kg bag; ***Corresponding value of 1 kg; ****Number of identified wholesalers.

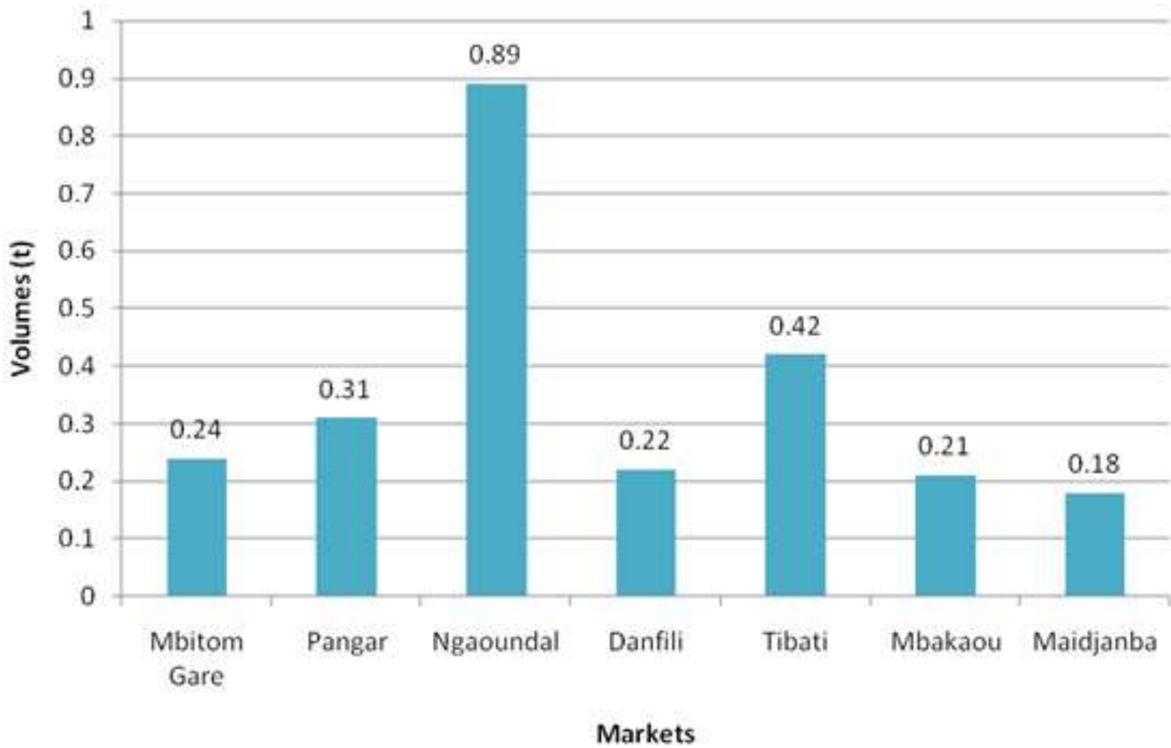

Figure 5. Different markets and volumes of *Beilschmiedia anacardioides* and *B. jacques-felixii* fruits.

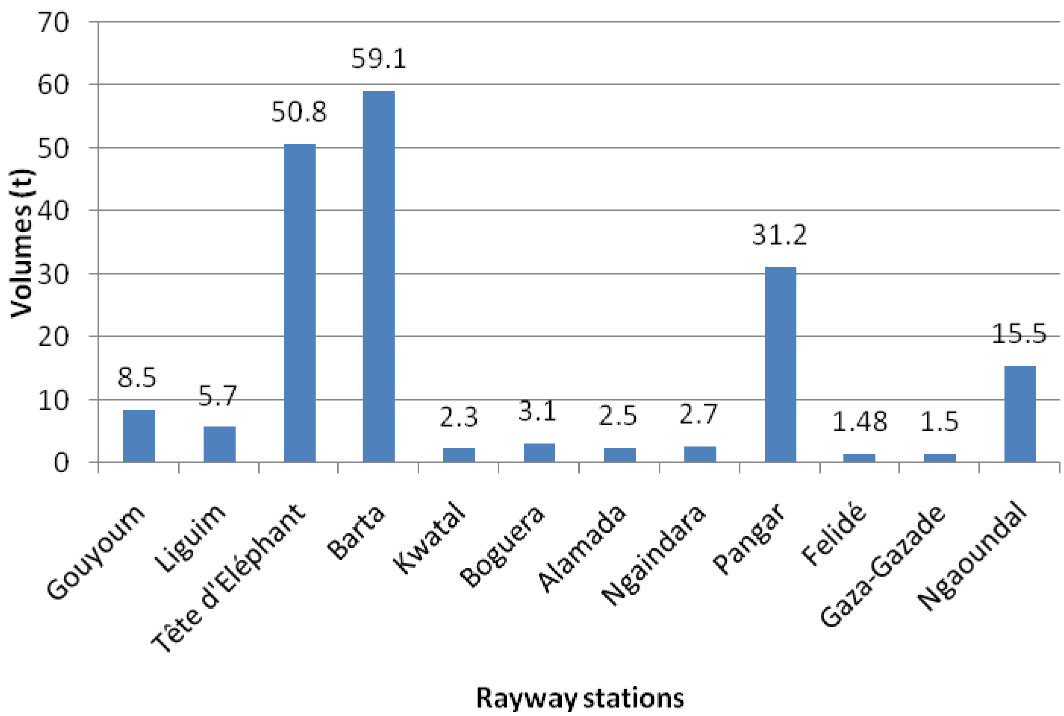

Figure 6. Different railway stations and volumes of *Xylopia aethiopica* fruits.

Table 4. Vulnerable status of the three key NTFPs.

Species	Vulnerable index of the species (VIi)
Beilschmiedia anacardioides	1.87
Beilschmiedia Jacques-felixii	1.84
Xylopia aethiopia	2.61

than the collectors (t-test, df = 26; p= 0.0004). Investigations showed that the retailers are exclusively constituted of women.

Fruits of *X. aethiopica* are gathered in railway stations before being bought by wholesalers who come from Chad, Sudan, Libya and Nigeria.The main railway stations are Mbitom gare (59.1 t), Tête d'Eléphant (50.8 t) and Pangar (31.2 t) accounting for 31.94, 27.45 and 16.86%, respectively (Figure 6). Wholesalers have more profits than the collectors (t-test, df = 70; p = 0.0009).

Vulnerability status of the three key NTFPs species

The three key NTFPs perform various vulnerable index: *B.jacques-felixii*(VI = 1.84); *B.anacardioides* (VI = 1.87) and *X. aethiopica* (VI = 2.61) (Table 4). *B. anacardioides* and *B. jacques-felixii* are weakly vulnerable (VI < 2) whereas *X. aethiopica* is highly vulnerable (VI > 2.5). This high vulnerability could be mostly attributed to the exploitation by felling systematically the resource species and its high demand.

DISCUSSION

Importance of forest resources and related NTFPs around the Mbam and Djerem National Park's ecoregion

The Mbam and Djerem National Park's ecoregion hosts valuable forest resources such as *Borassus aethiopum, Calamus deerratus, Canarium schweinfurthii, Ekebergia senegalensis, Laccospermum secundiflorum, Nauclea diderrichii, Nauclea vanderguchtii, Oxytenanthera abyssinica, Parkia bicolor, Pleurotus ostreatus, Ricinodendron heudelotii, Termitomyces aurantiacus,B. anacardioides, B. Jacques-felixii* and *X. aethiopica*. The last three resource species constituted the key three NTFPs of the ecoregion (Souare, 2015). Two categories of product were identified: reproductive organs (fruits, seeds) and plant structures (stem, leaves) (Table 2). All the key species are predominantly used for food and also intervene in the healthcare of local populations who, in majority, resort to the therapeutic heritage. Two reasons explain the situation: a low level of purchasing power of consumers, and the expensive costs of pharmaceutical products. Forests significantly contribute to the nutrition and healthcare of local populations. Adekunle and Bakare (2009) argued that in Nigeria, majority of rural households and large proportion of urban households depend on forest products to meet parts of their nutritive needs.In humid zone of Cameroon, Ingram and Schure (2010) indicated that 67% of key plant products (*G. africanum*, *G. buchholzianum*, *P. africana*, *R.heudelotii, Irvingia* sp.) are used for food and oils, followed by medicinal products (60%). This trend was also shown by Falconer (1992) at the periphery of TanoOffin Reserve in Ghana.

Actors' gross and net mean income generation from the three key NTFPs species along the value chain

X. aethiopica, B. anacardioides and *B. jacques-felixii*are of economic importance as they are traded regionally and nationally (*B. anacardioides* and *B. jacques-felixii*) and internationally (*X. aethiopica*). They contribute between 68 and 85%to the households of the producers (Table 3). The income obtained enables the local people to meet their basic needs and those of their families such as purchase of medicinal products, kerosene, soap, clothes, construction of houses, and payment of dowry and school fees. This result supports the general observation for some case studies from Africaunderlined by Sunderland and Ndoye (2004) that the contribution to household income is particularly important at times of economic needs such as payment of school fees or provides seasonal income when agricultural labor needs are low, particularly in the rainy season.

X. aethiopica is the major plant resource species in the region and accounted for 85% of income of local people engaged in the trade of plant NTFPs. In comparison to seventeen case studies in Sub-Saharan Africa (Sunderland and Ndoye, 2004), this rate falls above the range of 60 to 78% where are found the highly valued plant NTFPs. These resource species are *Cassiprounea flanaganii* (78%) in South Africa, *P. africana* (70%) in the region of Mount Cameroon, *G. africanum*and *G. buchholzianum*(62.5%) in the entire forest region in Cameroon. Angelsen and Babigumira (2010) found that the average regional rate in Central Africa varies between 25 and 40%. Therefore, *X. aethiopica, B. anacardioides* and *B. jacques-felixii* make significant contributions to livelihoods and economies, such that if their abundance or supply is jeopardized, it can have measurable repercussions on the well-being of local communities and households. The study reveals also that incomes from plant non-timber forest products vary considerably depending on markets and productsas Angelsen and Babigumira (2010) have stated as regards the contribution of NTFPs in Central Africa.

Social and economic value chain of the three key NTFPs around the Mbam and Djerem National Park's ecoregion

The opportunity to earn significant incomes through non-timber forest products trade depends on economic factors of the product and the ecoregion. These factors concern the quality of the product, the quality of the transformation, the reliability of the production and the existence of competitive products. *B.anacardioides, B. jacques-felixii* and *X. aethiopica* are transformed before their commercialization. *X. aethiopica* fruits are harvested fresh and then dried with fire and in the sun. Dried fruits are packaged in sacks and stored before sale. The seeds of *B. ancardioides* and *B. jacques-felixii* are treated with warm water and dried in the sun. They can be transformed into powder and packaged in plastics before sale.

These practices permit reduction of the post-harvest losses and to increase the shelf life of the products for at least one year. However, collectors are not sufficiently informed of market requirements in terms of quality and quantity of the products. Also, sales of products within the same community are not organized, and the potential of local transformation of the products that can make them more attractive and competitive is weak. Therefore, the more transformation of the products, the higher the contribution of NTFPs to cash income. The survey revealed that the adding value at the level of wholesalers is more important than that of the collectors ($p < 0.001$). Authors in some case studies from Africa (Awono et al., 2009) and in the area of South-East Asia (Wollenberg and Ingles, 1998) demonstrated that when products are accessible and significantly processed locally, costs are low and profit margins are high for harvesters.

Actors' perceptions on the threats on key NTFPs species and implication for value chain sustainability around the study area

Generally, it has been established that the overall ecological effects, impacts and responses of forest utilization are underpinned by floristic composition, the magnitude or intensity, and the modes and seasons of the harvesting (Arnold and Ruiz Pérez, 2001). The study reveals that the three key resource species of non-timber forest products are exploited for their fruits and seeds. The most common practice for harvesting these organs consists of felling systematically the trees (*X. aethiopica*). This harmful practice has direct impact on the vital rates, namely the survival of the harvested individuals. Ticktin (2004) demonstrated that even low levels of harvest may result in a significant decline in long-term population growth rates. That is not the case with some tree species that can tolerate very high levels of fruit, seed or flower harvest with little or no decrease in long-term population growth rates (Ticktin,2004). For example, it was reported that the estimated sustainable harvest rate for Marula fruits (*Sclerocarya birrea* subsp. *caffra*) in South Africa is 92% (Emanuel et al., 2005).

The extractivism is undertaken at the periphery of the protected area as regards *B. anacardioides* and *B. jacques-felixii*. They are weakly vulnerable (VI < 2), and local people manage the existing individuals in their farms. About *X. aethiopica* with a high vulnerable index (VI = 2.61),harvesting is happening almost near the park, and even in the buffer zone where the resource species are more available.This situation is causing open conflicts between the communities and the forest agents, namely the ecoguards. However, at the north-eastern part of the park, local people have begun to manage the species through enrichment plantings. This can lead in long-term to the goals of conservation of the protected area and the sustainable management of the resource species.

Conclusion

Non-timber forest products have been widely recognized in Sub-Saharan Africa as a source of significant livelihood value, especially for rural people, since they generate cash incomes, supplementary food and other products required daily. The Mbam and Djerem National Park's ecoregion in Cameroon harbor valuable forest resources, including key non-timber forest products, namely *X. aethiopica*, *B. anacardioides* and *B. jacques-felixii*.Market study methods were used to assess the socioeconomic importance of the three plant resource species. Interesting parts of the plants are the fruits that are harvested and processed for sale or local consumption. Annual profit margins for 17 producers of *B. anacardioides* and *B. jacques-felixii* are estimated at 2023.45 USD (1,196,188 FCFA) representing 68%, and for 52 producers of *X. aethiopica* are estimated at 52912.57 USD (31,280,000 FCFA) accounting for 85%. This constitutes an important contribution to the total income of producers of these NTFPs across the region. Wholesalers dominate the chains in terms of profit margins and inappropriate standards lead to the exploitation of collectors and inequity in the chain: 11 wholesalers of *B. anacardioides* and *B. jacques-felixii*, 3229.12 USD (1 908 937 FCFA) representing 75% (T-test, df= 26; p= 0.0004); 20 wholesalers of *X. aethiopica,* 87772.61 USD(51 888 000 FCFA) representing 94% (T-test, df= 70; p= 0.0009). The three key NTFPs species record the following vulnerable index: *B. jacques-felixii* (VI = 1.84); *B. anacardioides* (VI = 1.87) and *X. aethiopica* (VI = 2.61). Local people are aware of the dangers faced by the high valued species. Their awareness is revealed by the interventionist management through enrichment plantings undertaken in some parts of the periphery of the protected area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Characterization and analysis of farming system of Cheliya and Ilu Gelan districts of West Shewa Zone, Ethiopia

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The study characterizes and analyzes the existing farming system and identifies the production and marketing constraints of Cheliya and Ilu Gelan districts with cross-sectional data of 105 sample households. The farming system of the study areas is characterized as mixed farming systems with 59.1 and 27.44% contribution of crop and livestock, respectively for livelihood activities. From the survey results, disease (96.19%), shortage of grazing land (73.33%), feed shortage (48.57%), shortage of veterinary medicine (20.95%), shortage of water (18.10%) and lack of improved breeds (14.29%) were identified as major important constraints in livestock production. High transaction cost (71.43%), lack of capital (35.24%), lack of market information (23.81%), price and demand fluctuation (21.90%), lack of market linkage (14.29%) and unorganized marketing system (12.38%) were reported as major constraints in livestock marketing. Pests, high cost of inputs, shortage of land, weed infestation, shortage of inputs, low yield, poor quality of seed and poor soil fertility were identified as important crop production constraints. High transaction cost, low price output, lack of market information and lack of market linkage were summarized as major crop marketing constraints. Besides, soil erosion, soil fertility decline, water logging, soil acidity and termite were reported as important constraints in natural resources. Improving livestock productivity through improved breed, forage, control disease and control illegal livestock trade needs attention. Additionally, improving crop productivity through Integrated Pest Management (IPM), improved varieties, minimizing transaction cost, focusing on high value crop, expanding soil and water conservation, strengthening market information and linkage needs urgent concentration for interventions.

Key words: Crop, farming system, livestock, natural resource.

INTRODUCTION

Agriculture is the most important sector in Ethiopia and contributes significantly to the livelihoods of the study areas with fastest growing economic (Paul et al., 2016). Agriculture of the country areas has been characterized by low productivity due to land degradation, low technological inputs, low soil fertility, weak institution

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linkage, lack of appropriate and effective agricultural policies and strategies (Aklilu, 2015; Abush et al., 2011). Smallholder farmers in the study areas are not focused on market oriented productions rather than substance production in dynamics of farming system. These challenges call for characterization and analysis of farming system of the study areas to enhance production and productivity of crop, livestock and natural resources.

A farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well defined practices in response to the physical, biological and socio-economic environment and in accordance with the household goals preferences and resources (Garnett et al., 2013). The Ethiopian agriculture is dominated by about 11.7 million smallholders responsible for about 95% of the national agricultural production while large farms contribute only 5% of the total production (CSA, 2017). This shows that the overall economy of the country and the food security of the majority of the population depend on small-scale agriculture.

Farming systems comprise complex production units involving a diversity of mixed crops and livestock in order to meet the multiple objectives of the household (Dennis et al., 2012) which is similar to the study areas. The combination of these activities depends on environmental conditions, resource endowment and the management skills of the farmer. Understanding the interdependence of the elements of the farming system and maintaining the balance in the complex set of farmer's objectives are relevant to outlining promising development strategies for such systems (FAO, 2016). The classification of developing countries may be varied as available natural resource base, climate, landscape, farm size, tenure and organization, dominant pattern of farm activities and household livelihood. This determines the intensity of production, diversification of crops and other activities.

Therefore, a classification of the farming systems into homogeneous groups is proposed which allows the analysis of the existing farm organization and the interrelationships among the system's elements and evaluation effects of optimal allocation of farm resources and technological innovations in the areas.

Specific objectives

(1) To characterize and analyze the existing farming system of major agro-ecology of the study areas;
(2) To identify the production constraints and opportunities of the farming system for interventions.

RESEARCH METHODOLOGY

Sampling techniques

A multi-stage technique was employed to select sample households from the population. In the first stage, West Shewa Zone was stratified into two agro-ecologies which are high land and mid land that are more homogenous than the total population. In the second stage, from each stratum one district was selected purposively based on agro-ecology, crop potential, livestock and natural resources. Accordingly, Cheliya district was selected from highland and Ilu Gelan district was selected from midland agro-ecology. In the third stage, two kebeles were selected purposively from each district based on agro-ecology, crop potential, livestock, natural resources and accessibility. Finally, 105 sample households were selected randomly using probability proportional to size.

Data type and data collection analysis

The study was based on both primary and secondary data. Primary data were collected from the sample households using a semi-structural schedule by trained enumerators. In order to capture better information of the study areas, qualitative data collection such as focus group discussion was conducted using checklist schedule. Each group consisted of at least 20 considering gender and wealth status based on formal survey. Secondary data were also collected from published and unpublished materials from the respective West Shewa zone and districts for a comprehensive report and rational conclusion.

Data analysis methods

Descriptive statistics such as mean, standard deviation, frequency and percentage were used to analyze quantitative data gathered from sampled households. The constraints were analyzed using pair wise ranking to prioritize the constraints.

RESULTS AND DISCUSSION

Sample household characteristics

About 4.8% of the sample households were female headed with zero percentage observed in Ilu Gelan District. Regarding technology adoption 28.69% of sample households were model farmers and 71.40% were followers. According to key informants interview model the farmers adopted new technologies early than followers. Only 12.40% of sample households were rich in wealth status (Table 1). The average household size across the surveyed households was 7.39 whereas the average number of adults was 5.91 using conversion factors which consider age and sex of the member.

Land holding and acquisition methods

Land is the most important asset of sample household in Ethiopia and the availability of land permits the production of more crops (Bekele et al., 2017). The study indicated land tenure and how land under the farmers control was utilized. The survey result revealed that, the average of 2.04 ha per farmer was owned by sample households and 1.56 ha per farmer was cultivated. The average grazing land, forest land and residential land is summarized in Table 2. About 0.42, 0.18 and 0.07 ha per

Table 1. Sample households' characteristics.

Variable		Cheliya (49)		Ilu Gelan (56)		Total (105)	
		Frequency	%	Frequency	%	Frequency	%
Sex of household head	Male	44	89.80	56	100	100	95.2
	Female	5	10.20			5	4.8
Wealthy status of household	Rich	9	18.40	4	7.10	13	12.40
	Medium	31	63.30	37	66.10	68	64.80
	Poor	9	18.40	15	26.80	24	22.90
Farmers' category	Model	13	26.50	17	30.40	30	28.60
	Follower	36	73.50	39	69.60	75	71.40

Source: Survey Results (2017).

Table 2. Land ownership (hectare) and acquisition methods of sample households.

Land category	Cheliya (49)			Ilu Gelan (56)			Total (105)		
	%	Mean	Std. Dev.	%	Mean	Std. Dev.	%	Mean	Std. Dev.
Own land	100	1.66	1.62	100	2.37	1.68	100	2.04	1.68
Cultivated land	95.92	1.50	1.50	96.43	2.16	1.57	96.19	1.86	1.56
Grazing land	48.98	0.53	0.48	87.50	0.49	0.39	69.52	0.50	0.42
Forest land	22.45	0.17	0.06	35.71	0.23	0.22	29.52	0.21	0.18
Degraded land	4.08	0.25	0	0	0	0	1.90	0.25	0
Residential land	71.43	0.18	0.08	94.64	0.07	0.07	83.81	0.18	0.07
Rented in/out	20.41	0.57	0.28	14.29	1.22	1.49	17.14	0.86	0.99
Shared in/out	65.31	0.96	0.60	58.93	1.01	0.52	61.90	0.98	0.55

Source: Survey Results (2017).

farmer were allocated for grazing land, forest and residential land, respectively. In the survey sites, fallow land was not a common practice due to shortage of land. There was minimum activity on land renting and more than half apply crop sharing system during the survey period (Table 2).

Ownership of farm equipment, communication technology and others

Ownership of production assets is a proxy for households' socio-economic status. These help in increasing farm productivity and assessing the means to disseminate technology information to famers. Households own ox-plough, hoe and other (Spade, axe, etc.) farm equipment which are the most important in farming activities. The result indicated that on average 100, 93.90 and 71.40% per farmer ox-plough, sickle and hoe were owned for agricultural activities, respectively.

Information technology was more informed and can be used as contact farmers through mobile, radio and TV. About 49.50% sample households own radio while about 64.80 and 5.70% own mobile phone and TV which are used as technology information disseminated to farmers in the study areas (Table 3).

Livelihood activities of sample households

The farming systems in the west Shewa zone were characterized as mixed farming systems. In the mixed farming systems both livestock and crop production take place within the same locality.

The major sources of livelihood activities of farmers in study districts were crop production, livestock rearing and off/non-farming. As indicated in Table 4, about 100 and 98.10% of sample households' livelihood depend on crop production and livestock rearing which contributed 59.10 and 27.44% of total annual income, respectively. Besides, off/non-farming activities like crop and livestock trading, daily labors, petty trade, and wood craft were additional income and food sources of households. The result indicates that about 53.33% of sample households participated in off/non-farming activities which contributed 13.46% to annual income generation.

Table 3. Ownership of farm equipment and information communication technology.

Asset	Cheliya (49)		Ilu Gelan (56)		Total (105)	
	%	Mean	%	Mean	%	Mean
Ox-plough	100	1.24 (0.48)	100	1.48 (0.79)	100	1.37 (0.67)
Sickle	93.90	3.17 (1.45)	98.20	3.33 (1.48)	96.20	3.26 (1.46)
Hoe/Jembe	71.40	2.26 (1.62)	83.90	2.70 (1.72)	78.10	2.51 (1.68)
Others	38.80	2.03 (1.19)	44.60	2 (1.22)	52.40	2.02 (1.19)
Radio	46.90	1.09 (0.29)	51.80	1.07 (0.26)	49.50	1.08 (0.27)
Mobile	61.20	1.23 (0.68)	67.90	1.39 (0.94)	64.80	1.32 (0.84)
Television	6.10	1	5.40	1	5.70	1

*[2] = only two farmers have hydro/line electricity and numbers in parentheses are standard deviations.
Source: Survey Results (2017).

Table 4. Livelihood activities of sample households.

Activity	Cheliya (49)		Ilu Gelan (56)		Total (105)	
	Percent	Contribution (%)	Percent	Contribution (%)	Percent	Contribution (%)
Crops	100	57.65	100	60.35	100	59.1
Livestock rearing	100	28.1	96.40	26.87	98.10	27.44
Off/non-farming	59.18	14.25	48.21	12.78	53.33	13.46

Source: Survey Results (2017).

Livestock ownership

Table 5 presents livestock ownership in terms of herd size and composition. Result shows that a high percentage of the population in the survey areas own cows and oxen types of livestock at 92.40% with 2.11 herd sizes and 88.60% with 2.54 herd sizes, respectively. The result indicated that in the study areas cow and ox keeping were the most important. Sheep and goats were important as income source by the farming population. About 46.70 and 14.30% of sample households own sheep and goats, respectively. Mules, donkey and horses were used for transportation services. About 25.70, 20 and 9.50% of sample households owned horses, donkey and mule for means of transportation service and income generation source.

Analysis of the herd size shows that cattle lead in the number kept with average herd sizes of 2.11 and 2.54 TLU for cows and oxen, respectively. This is consistent with other results by Svein (2002) which indicates the relative importance of cattle ownership in Ethiopia which acts as symbol of prosperity. Although chicken was kept by 70.50% of sample households which is more than shoats and equines with only 6.70% households keeping improved poultry.

The average milk per day was 1.48 and 1.30 L at Cheliya and Ilu Gelan districts, respectively. Majority of sample households reported milk productivity decreased from time to time over last five years due to feed shortage and disease.

Livestock ownership is generally regarded as key to rural livelihoods which are sources of power and fertilizer for crop production, supply human food, transportation, income generation sources and wealth communication (Behnke and Fitaweke, 2011; Amede et al., 2011). Moreover, the role of oxen availability played in the timely adequate cropland preparation could contribute to increase food-feed crop production.

Livestock production and marketing constraints

Livestock producers were asked to give their perspectives on most important constraints affecting their livestock farm operations and their responses are summarized in Table 6. The three most frequently reported production constraints were disease like trypanosomiasis, black leg, anthrax, pastevrellosis and mastitis (96.19%), shortage of grazing land (73.33%) and feed shortage (48.57%). Lack of capital was reported as an important constraint by 25.71% of the households during the survey period. Similarly, shortage of veterinary medicine, shortage of water and lack of improved breed were reported as important production constraints by 20.95, 18.10 and 14.29% of the households keeping cattle, respectively.

Disease (pasteyrellosis, lichen, leg and foot and mouth and dermatophytosis) and shortage of grazing land were the most important production constraints of shoats and equines. There are about 52.38 and 49.52% of disease

Table 5. Household livestock ownership, proportion of owners and herd sizes (TLU).

Livestock type	Cheliya (49)		Ilu Gelan (56)		Total (105)	
	% h. holds	Mean (TLU)	% h. holds	Mean (TLU)	% h. holds	Mean (TLU)
Cows	93.9	1.80 (1.29)	91.10	2.39 (1.72)	92.40	2.11 (1.55)
Oxen	89.8	2.33 (1.08)	87.50	2.73 (1.38)	88.60	2.54 (1.26)
Heifers	55.1	1.36 (1.02)	64.30	1.72 (1.41)	60	1.57 (1.27)
Bulls	63.3	0.95 (0.70)	48.20	1.27 (1.14)	55.20	1.09 (0.93)
Calves	75.5	0.38 (0.24)	73.20	0.45 (0.38)	74.30	0.42 (0.32)
Goats	14.3	0.26 (0.19)	14.30	0.23 (0.14)	14.30	0.24 (0.16)
Sheep	67.3	0.47 (0.41)	28.60	0.35 (0.31)	46.70	0.43 (0.38)
Donkeys	24.5	0.91 (0.42)	16.10	0.82 (0.28)	20	0.87 (0.35)
Horses	46.9	2.02 (1.18)	7.10	1.60 (0.8)	25.70	1.97 (1.14)
Mules	-	-	17.9	0.70	9.50	0.70
Poultry	77.3*4.1	0.08 (0.07)	64.30*8.9	0.08 (0.06)	70.50*6.7	0.08 (0.06)
Total TLU	100	6.97 (4.82)	100	7.16 (4.41)	100	7.07 (4.58)

*Percentage of crossbred poultries and numbers in parentheses are standard deviations.
Source: Survey Results (2017).

Table 6. Major livestock production and market constraints of sample households.

Production constraints (n=105)	Percentage of households reported as constraints and their rank							
	Cattle	Rank	Shoats	Rank	Equines	Rank	Poultry	Rank
Shortage of grazing land	73.33	2	49.52	3	30.48	2	-	-
Disease	96.19	1	52.38	1	31.43	1	66.67	1
Shortage of veterinary medicine	20.95	-	4.76	-	3.81	-	-	-
Lack of capital	25.71	-	3.81	-	-	-	-	-
Lack of improved breed	14.29	-	2.86	-	-	-	-	-
Feed shortage	48.57	4	5.71	-	-	-	16.19	5
Water shortage	18.1	-	6.67	-	-	-	-	-
Market price/demand fluctuation	21.90	-	14.29	-	6.67	-	16.19	5
Lack of capital	35.24	5	16.19	-	-	-	10.48	-
Lack of information	23.81	-	33.33	4	9.52	4	18.10	4
Lack of market linkage	14.29	-	28.57	5	8.57	5	19.05	3
Unorganized marketing system	12.38	-	8.57	-	7.62	-	10.48	-
High transaction cost	71.43	3	52.38	1	14.29	3	23.81	2

Source: Survey Results (2017).

and shortage of grazing land by keeping shoats. Regarding keeping equines about 31.43 and 30.48% of sample households reported disease and shortage of grazing land as important production constraints, respectively. Disease and feed shortage were very important production constraints by 66.67 and 16.19% of sample households keeping poultry, respectively.

The main marketing problems of livestock were market price/demand fluctuation, lack of capital, lack of market information, lack of market linkage, unorganized marketing system and high transaction cost summarized in Table 6. High transaction cost (71.43%) and lack of capital (35.24%) were reported as main marketing constraints by sample households keeping cattle. Lack of market information and market price/demand fluctuation were reported as important constraints in the marketing of cattle. The result indicates that about 23.81 and 21.90% of sample households reported to lack of market information and market price/demand fluctuation, respectively. In the study areas lack of market linkage (14.29%) and unorganized marketing system (12.38) of sample households were reported as constraints in cattle marketing.

As presented in Table 6, high transaction cost (52.38%), lack of market information (33.33%) and lack of market linkage (28.57%) were the main constraints

Table 7. Livestock feed sources and feeding system of sample households

Common feed source	Cheliya n=(49)		Ilu Gelan (n=56)		Total (n=105)	
	N	%	N	%	N	%
Own grazing land and crop residue	42	85.71	51	91.10	93	88.57
Communal land and crop residue	7	14.29	2	3.60	9	8.57
Supplementary feed (Fegullo, etc.)	9	18.40	6	10.70	15	14.29
Most common crop residue used						
Teff straw	49	100	53	94.64	102	97.14
Stover of maize and sorghum	5	10.20	32	57.14	37	35.24
Wheat and barley straw	17	34.69	-	-	17	16.19
Faba bean and field pea straw	3	6.12	12	21.43	15	14.29

Source: Survey Results (2017).

Table 8. Beekeeping farm practices of sample households.

Variable	Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
	N	Mean	N	Mean	N	Mean
Beehives (traditional)	9	2.67 (1.58)	20	5.35 (3.53)	29	4.52 (4.16)
Honey harvest (kg)	8	15.13 (5.69)	20	47.55 (48.63)	28	38.29 (33.53)
Unit price of honey (kg^{-1})	8	53.13(10.67)	20	41.10 (8.45)	28	44.54 (10.51)
Constraints	**N**	**% hhs**	**N**	**% hhs**	**N**	**% hhs**
Aunts and wild animal	5	10.20	15	26.79	20	19.05
Chemical (herbicide)	5	10.20	14	25	30	28.57
Shortage of bee	6	12.24	2	3.57	8	7.62
Shortage of bee forage (forest)	6	12.24	16	28.57	22	20.95
Price fluctuation	2	4.08	12	21.43	14	13.33

Numbers in parentheses are standard deviations.
Source: Survey Results (2017).

reported by sample households keeping shoats. Besides, lack of capital, market price/demand fluctuation and unorganized marketing system were reported as important constraints of shoats marketing.

High transaction cost was the major constraint in equines and poultry marketing. About 14.29 and 23.81% of sample households reported transaction cost as important constraints in equines and poultry marketing, respectively. Lack of market information, lack of market linkage, unorganized marketing system and market price/demand fluctuation were reported in both equines and poultry marketing as constraints. Lack of capital was constraint in poultry marketing. Generally, in livestock marketing, high transaction cost is the most important constraint in cattle, shoats, equines and poultry production.

Livestock feeding system

Types of livestock feeding systems were summarized in Table 7. Livestock producers practiced three grazing systems and their combinations. Straw (teff, barley, wheat, bean, pea) and stover of maize and sorghum were extensively used and animals were grazed on crop stubble due to palatable by livestock and no other feed option for their livestock. About 97.14 and 35.24% of sample households used teff straw and stover of maize and sorghum, respectively.

There are no apparent private or public sector efforts in improving the use of crop residues and improved forages by sample households during the survey period. Supplementary feeds like fagullo and salt were used by few farmers during the survey period.

Beekeeping practices

Beekeeping practice is a common practice of rural livelihoods as income generation source and home consumption. Table 8 presents beekeeping practice and major constraint in terms of number and production

Table 9. Major crop pattern and productivity of sample households.

#Plot and crop type	Cheliya (n=49)			Ilu Gelan (n=56)			Total (n=105)		
	% hhs	Mean	Productivity	% hhs	Mean	Productivity	% hhs	Mean	Productivity
Maize	36.73	0.45 (0.37)	30.13 (9.24)	98.21	1.01 (0.64)	32.80 (9.74)	69.52	0.88 (0.63)	32.14 (9.63)
Teff	89.80	0.66 (0.48)	11.36 (3.24)	94.64	1.04 (0.88)	10.40 (3.45)	92.38	0.86 (0.75)	10.83 (3.37)
Sorghum	26.53	0.31 (0.17)	14.46 (7.17)	21.43	0.39 (0.18)	14.50 (5.54)	23.81	0.35 (0.18)	14.48 (6.31)
Wheat	71.43	0.54 (0.32)	18.81 (7.18)	14.29	0.42 (0.36)	22 (9.55)	40.95	0.52 (0.32)	19.41 (7.65)
Barley	55.10	0.57 (0.25)	16.37 (4.81)	3.57	0.63 (0.53)	13.50 (16.26)	27.62	0.56 (0.26)	16.17 (5.61)
Faba bean	42.86	0.30 (0.12)	13.71 (5.52)	7.14	0.28 (0.16)	14(5.16)	23.81	0.29 (0.12)	13.76 (5.36)
Field pea	12.24	0.29 (0.10)	9.69 (3.67)	-	-	-	5.71	0.29 (0.10)	9.67 (3.67)
Potato	34.69	0.33 (0.27)	111 (44.95)	8.93	0.18 (0.07)	78.40 (22.20)	20.95	0.30 (0.25)	103.59 (42.77)
Nug	-	-	-	12.50	0.57 (0.19)	4.57 (0.98)	6.67	0.57 (0.19)	4.57 (0.98)
Soybean	-	-	-	7.14	0.17 (0.07)	15.33 (1.15)	3.81	0.17 (0.07)	15.33 (1.15)

Numbers in parentheses are standard deviations.
Source: Survey Results (2017).

honey. Result shows that a few percentage of the sample households in the survey areas own traditional types of beehives (27.62%) with 4.52 numbers per farmer beehives. The four most frequently reported constraints were herbicide (28.57%), shortage of bee forage (20.95%), ants and wild animals (19.05%) and price fluctuation of honey (13.33%). Shortage of bee (7.62%) was also important constraint by bee production marketing system during the survey period.

Crop pattern and productivity

Cropping patterns adopted by farmers in the study areas depend on agro-ecology factors like climate, soil types, crop types and markets. The major crops produced in selected districts were maize, teff, sorghum and wheat among cereal crops; faba bean, field pea, soybean and nug among pulse and oil crops and potato from horticultural crop (Table 9). The result shows that 99.05% of the sample households owned farm plots with 3.18 plots per farmer. This implies that land sub-division issues may be disadvantaging for economic of labor and other inputs usage (Fekadu and Bezabih, 2009; Wondimu, 2010). Teff and maize were the most important crops in the study areas which were produced by 92.38 and 69.52% of sample households on 0.86 and 0.88 ha of land, respectively.

Analysis of crop yields was done separately at the district level and overall expressed in quintal per hectare as summarized in Table 9. The yield of sample households during the survey period was below national and regional average (CSA, 2017). This implies that all concerned bodies may work on how to increase the productivity through improved varieties, appropriate inputs recommended of these crops.

In the study areas soil fertility management practice was reported though in medium usage (Table 9). About 75.24% of sample households reported their soil status to be good depending on their perception. Some of the soil fertility enhancing practices identified includes conservation tillage, crop residue retention, maize-legume intercropping and cereal-legume rotation, especially in Ilu Gelan district. Soil fertility management has been shown to improve yields more than using of chemical fertilizers (Tchale and Sauer, 2007). Therefore, it implies that improved soil fertility increases crop yield than using of appropriate improved inputs.

Crop land preparation and planting system

The farming systems of smallholders in West Shewa zone were predominantly annual crop productions by using similar cropping calendar of rainfall. Table 10 shows that for these annual crop productions, land ploughing frequency, inputs used rate, planting methods and planting period were presented. Land ploughing frequency of plots for major crops average ranges of 4.26 times

Table 10. Crop land preparation and planting system of sample households.

Crop type	% hhs holding	Ploughing frequency	Seed rate (kg/ha)	% hhs used Urea	Urea rate (kg/ha)	% hhs used NPS	NPS rate (kg/ha)	Method of planting (%)		Time planting
								Row	Broadcasting	
Maize	69.52	3.60	25.14	67.62	159.15	67.62	96.48	69.50	-	May
Teff	92.38	3.93	30.04	32.38	41.91	90.40	54.21	-	92.38	June-July
Sorghum	23.81	2.20	21.16	4.76	50	7.62	40	-	23.81	April-May
Wheat	40.95	4.26	95.58	38.10	59.38	40.95	65.58	-	40.95	June-July
Barley	27.62	4.04	122.69	27.62	72.12	27.62	59.62	-	27.62	June-July
F/bean	23.81	2.08	94.79	2.86	50	8.57	66.67	3.80	19	June
Field pea	5.71	2	82.22	0	0	0	0	-	5.71	June
Potato	20.95	2.63	833.11	20.95	90.79	20.95	86.84	20.95	-	March-April
Nug	6.67	2	10.71	0	0	0	0	-	6.67	June
Soybean	3.81	2.33	50	3.81	4*	3.81	-	3.81	-	June

4*=four sachets inoculants were recommended per hectare.
Source: Survey Results (2017).

for wheat to 2 times for nug and field pea. The result shows that ploughing frequency varied among the crops and land soil fertility status.

The sample households used inputs like seed and fertilizer (both NPS and Urea) for all crops was below recommendation rate except maize and soya bean, but the seed rate of teff was above recommendation rate. Therefore, below recommendation inputs used can express low productivity. However, the seed and fertilizer rate as well as application methods were recommended before a decade. All sample households for all crops use traditional land ploughing and planting using man and oxen power through source of labor.

The majority of producers in both districts plant their crops by row and broadcasting from March to end July. All sample households used row planting method for maize, potato and soya bean and partially for faba bean. Crops like teff, wheat, barley, sorghum, field pea and nug were planted by broadcasting method (Table 10). In addition to low inputs, using unsuitable planting methods may decrease crop productivity. The result shows that teff, wheat, barley, faba bean, field pea, nug and soya bean planting times were in June and July. Potato, sorghum and maize planting calendar range from March to end May. In general, there is a knowledge gap using inputs appropriate rate and time of application.

Major weed and weeding systems

All crops across the study areas were affected by two or more types of weeds throughout the cropping season. The dominant weeds by different crops frequently observed in crop fields were guizotia scabra spps (*hadaa/tufoo*), bromuss (*Keelloo*) and snowdenia polystarcya (*Mujjaa*). Besides, Oxallis (teff), avena fatua (wheat and barley), commelina benghalesis (maize), raphatum (field pea) and cuscuta compestris (nug) were reported as important weeds in the study districts during the survey period.

Weed management options exercised by sample households was typically hand weeding and herbicide like 2-4-D. Hand weeding was conducted throughout the crop stage ranging from 1 to 3 times depending on crop types and weed infestation. After 2-4-D herbicide application at least one-time hand weeding was common in the study areas.

Cropping system

Cropping system of the study areas is summarized in Table 11. The term cropping system is crop sequences and the management techniques used in a particular field over a period of year.

The result shows that mono cropping, crop rotations and double cropping systems were common cropping systems practiced in the study areas. Mono cropping system is the most dominant cropping system in the study areas mainly focused on cereal mono-cropping. Result shows that about 48.57% of sample households

Table 11. Cropping system and improved crop technologies used by sample households

Cropping system		Percent used technology (%)			Current used technology
		Cheliya (n=49)	Ilu Gelan (n=56)	Total (n=105)	
Mono-cropping		34.69	60.71	48.57	-
Crop rotation		65.31	39.29	50.48	-
Double cropping		40.82	3.57	20.95	-
Crops	**Varieties**				
Maize	Improved varieties	36.70	96.40	68.60	68.60
Teff	Improved varieties	6.10	5.40	5.70	5.70
Wheat	Improved varieties	22.40	5.40	13.30	13.30
Potato	Improved varieties	24.50		11.40	11.40
Soybean	Improved varieties	-	7.14	3.81	3.81

Source: Survey Results (2017).

applied mono-cropping system especially maize and wheat mono cropping in Ilu Gelan and Cheliya districts, respectively.

Crop rotation practiced in West Shewa zone was cereal with pulse and oil crops and/or cereal with cereal for different root depth crops (eg teff-maize-pulse or wheat/barley-maize/sorghum-teff-pulse and oil crops). Besides, double-cropping (sequential cropping) was another common practice applied in the study areas like potato-field pea/barley one after other within a year. According to the survey result about 50.48 and 20.95% of sample households practiced crop rotation and double cropping for soil fertility improvement, crop diversity and double yield advantage. Generally, crop rotation and double cropping were practiced depending on land availability, economic and dietary importance of crop and farmers' knowledge of cropping system.

The present survey results revealed that majority of farmers have limited access to improved seed except maize. Out of 69.52% about 68.60% of sample households used maize improved varieties. There is a gap of using improved varieties due to high price of seed, lack of seed, poor seed quality, untimely available except maize and soya bean. This implies that the lack of quality, timely improved varieties with appropriate management may decrease the crop productivity.

In addition to crop rotation and double cropping practices for soil, fertility improvement manure and compost practices were applied in the study areas. The result indicates that majority of sample households use manure organic fertilizer. This implies that manure organic fertilizer was the most known by sample households.

Major crops production and marketing constraints

An in-depth quantitative analysis was undertaken to understand the constraints that inhibit crop production by the farmers. These crop production constraints include pests (disease and insect), high cost of inputs, lack of capital, untimely inputs supply, shortage of land, weed infestation, shortage of inputs, low yield, poor seed quality and poor soil fertility presented in Table 15.

Results presented in Table 12 show that high cost of inputs (60.95%), pests (57.14%), weed infestation (31.43%) and low yield (23.81%) were reported as important constraints in maize production. Majority of the sample households (72.38%) identified low yield as a constraint in teff production. This implies that the issue of low yield is not only widespread in the surveyed zone but is also the most important to the farmers, compared to other constraints. Other constraints such as high cost of inputs (53.33%), weed infestation (47.62%), shortage of inputs (improved seed, fertilizer and chemicals) (45.71%), and shortage of land (39.05%) were reported as important constraints in teff production.

Wheat, faba bean and barley crops were affected by various constraints like pests, shortage of land, low yield, shortage of inputs and poor soil fertility reported as main constraints. The most important constraints in potato, nug and field pea were pests and low yield as presented in Table 12. Generally, pests and low yield reported in all crops as main constraint by majority of sampled households.

According to the survey result presented in Table 12, low price of output, lack of capital, lack of market information, lack of market linkage and high transaction cost were reported as important marketing constraints of major crops in the study districts. Lack of market information and high transaction costs were reported as main marketing constraints in major crops produced by the sample households. In general, the market access and market related issues of grain were similar in both the study districts. So most of the subsistence farmers were net buyers of crop produced and selling the produce

Table 12. Major crops production and marketing constraints of sample households.

Major crops constraints (n=105)	Percentage of households reported as constraints									
	Maize	Teff	Soybean	Wheat	Potato	Field pea	Faba bean	Sorghum	Barley	Nug
Disease and insect	57.14	40.95	-	29.52	17.14	0.95	20	19.05	23.81	5.71
High cost of inputs	60.95	53.33	-	10.48	3.81	-	-	-	0.95	-
Lack of capital	13.33	13.33	-	16.19	3.81	2.86	1.90	5.71	5.71	3.81
Untimely input supply	2.86	0.95	-	14.29	-	-	-	-	1.90	-
Shortage of land	22.86	39.05	0.95	27.62	8.57	-	8.57	3.81	20.00	4.76
Weed infestation	31.43	47.62	5.71	14.29	2.86	-	0.95	4.76	0.95	-
Shortage of inputs	14.29	45.71	0.95	10.48	0.95	4.76	18.10	15.24	20.95	-
Low yield	23.81	72.38	1.90	30.48	10.48	2.86	20	20.00	22.86	7.62
Poor seed quality	4.76	-	-	-	-	-	-	-	-	-
Poor soil fertility	8.57	18.10	-	8.57	-	-	0.95	-	0.95	-
Low price of output	49.52	7.62	0.95	8.57	9.52	-	1.90	4.76	2.86	0.95
Lack of capital	18.10	17.14	-	27.62	7.62	6.67	4.76	14.29	15.24	12.38
Lack of information	23.81	33.33	2.86	18.10	17.14	11.43	27.62	18.10	23.81	8.57
Lack of market linkage	12.38	8.57	3.81	10.48	1.90	7.62	8.57	10.48	12.38	4.76
High transaction cost	42.86	61.90	-	37.14	19.05	14.29	21.90	33.33	23.81	

Source: Survey Results (2017).

Table 13. Forestry and rainfall pattern for last five years of sample households.

Forest type	Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
	Frequency	%	Frequency	%	Frequency	%
Natural	5	10.20	-	-	5	4.80
Plantation	14	28.60	22	39.30	36	34.30
Both	12	24.20	22	39.30	34	32.4
Purpose						
Income generation	28	57.14	44	89.80	72	68.57
Soil erosion control	19	38.78	10	20.41	28	26.67
Climate balance	7	14.29	9	18.37	16	15.24
Soil improvement	17	34.69	10	20.41	26	24.76
Rainfall pattern in the last five years						
Early on set and off set	15	30.61	1	1.80	16	15.20
Late on set and early off set	34	69.40	55	98.20	89	84.80

Source: Survey Results (2017).

was necessary for fulfillment of short term needs like quantities, prices and market infrastructure (Denning et al., 2009).

Forestry and agro-forestry

According to the survey reported, the forestry and agro-forestry of the study areas were both natural and plantation and both of them. The result shows that about 34.30 and 32.40% of sample households were grown plantation and both natural and plantation for income generation, soil erosion control, soil improvement and climate balance purpose, respectively.

Over the last five years the status of plantation increased (41.90%) and the same (33.30%) sample households reported, respectively (Table 13). This implies that different natural rehabilitation practices of the last five years may increase the plantation. Though, it needs deep analysis of plantation change over time in the study areas. Eucalyptus tree was the dominant one in both districts due to different purposes, especial in terms

Table 14. Soil and water conservation type and major constraints of sample households.

Practices		Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
		Frequency	%	Frequency	%	Frequency	%
Type of SWC	Terraces	4	8.20	6	10.70	10	9.50
	Check dam	31	63.30	33	58.90	64	61
Plantation grown on SWC	Elephant grass	1	2.04	3	5.36	4	3.81
	Getra	3	4.08	1	1.79	4	3.81
	Gravilia			10	17.90	10	9.52
Major constraints of SWC	Soil erosion	42	85.71	44	78.57	86	81.90
	Water logging	17	34.69	29	51.79	46	43.81
	Soil fertility decline	22	44.90	43	76.79	65	61.90
	Soil acidity	32	65.31	3	5.36	35	33.33
	Termite	7	14.29	6	10.71	13	12.38

Source: Survey Results (2017).

of income generation following gravilia. Majority of the sample households grow plantation around their home (garden), along the farming land and marginal land for plantation. Though, the result indicates that strategic plan for plantation needs attention.

Agriculture in the study areas was dominant in rain fed and it is highly dependent on rainfall on set and offset. According to the survey result, about 84.80% sample households were reported as late on set and early offset rainfall. Only about 15.20% of sample households reported early on set and off set rainfall (Table 13). These results imply that there is rainfall shortage and fluctuation in the study areas.

Soil and water conservation (SWC)

Natural resource is a common property of social arrangement regulating the preservation, maintenance and consumption of common pool resources like forest, soil and water. Soil and water conservation received attention from government to sustainable uses of natural resource.

According to the survey result, about 61 and 9.50% of sample households practiced on their land check dam and terraces soil and water conservation, respectively for soil erosion decrease and improved soil fertility. Few farmers grow gravilia, getra and elephant grass on their soil and practice water conservation (Table 14).

The major constraints of natural resources identified by sample households were soil erosion, soil acidity, water logging, soil fertility decline and termite. Result shows that about 81.90 and 61.81% of sample households reported soil erosion and soil fertility decline as main important constraints, respectively. About 43.81 and 33.33% of sample households reported water logging and soil acidity as important constraints, respectively. Only 12.38% of sample households reported termite as constraint in the study areas.

Agricultural extension services

Technology adoption is highly dependent on information access (Berhanu et al., 2006). The type of information to disseminate to farmers and the sources of that information are critical in speeding up the rate of adoption of new technology. Asserting the importance of information sources (Lohr and Salomonsson, 2000) noted that information sources rather than subsidies are more effective in encouraging fast adoption.

Majority of extension service sources were DAs, research center, NGOs and BoANR. The result shows that 97.14 and 29.52% of sample households obtained information/advice services from DAs and BoANR, respectively. Only about 2.86% of sample households gained extension service from research centers. The extension services are focused on crop production (97.14%), livestock rearing (64.76%) and natural resource (58.10%) managements through training and/advice services (Table 15). The result indicated that all farmers may obtain services on crop production, livestock rearing and natural resource or one of them.

The government extension was still the major source of information training and advising farmers. More information on varieties with full package was received from the DAs through FTC and field visit model farmers. About 51.43% of sample households visited demonstration of FTC and model farmers. Regarding adopted technologies visited, about 47.60% adopted who they visited demonstration (Table 15). This implies that field day is better than training and advising services in terms

Table 15. Agricultural Information sources of sample households.

Extension service sources		Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
		Frequency	%	Frequency	%	Frequency	%
Sources of extension services	Development agents	48	97.96	54	96.43	102	97.14
	Research centers	1	2.04	2	3.57	3	2.86
	NOGs	2	4.08			2	1.90
	BoANR	8	16.33	23	41.07	31	29.52
Extension services specified	Crop production	48	97.96	54	96.43	102	97.14
	Livestock rearing	28	57.14	40	71.43	68	64.76
	Natural resource	25	51.02	36	64.29	61	58.10
Visited demonstration		32	65.31	22	39.29	54	51.43
Practice visited technology		31	63.30	19	33.90	50	47.60

Source: Survey Results (2017).

Table 16. Credit utilization and constraints of sample households.

Credit		Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
		Frequency	%	Frequency	%	Frequency	%
Credit obtained		19	38.78	27	48.21	46	43.81
Source	Microfinance	19	38.78	27	48.21	46	43.81
Purpose to receive credit	Input purchase	19	38.78	27	48.21	46	43.81
	Fattening	16	32.65	22	39.29	38	36.19
	Petty trade	12	24.49	11	19.64	23	21.90
Major credit constraints	High interest rate	5	10.20	5	8.93	10	9.52
	Collateral	19	38.78	26	46.43	45	42.86

Source: Survey Results (2017).

of technology adoption.

Credit utilization

In this study, we analyzed the various credit needs of farmers by district. It is the most important in technology adoption in terms of input purchase. Results presented in Table 16, about 43.81% of sample households utilized credit for purchasing inputs (fertilizer, seed and chemical). Fatting and petty trade were important activities attached to credit. Results show that about 36.19 and 21.90% of sample households were used for fatting and petty trade activities, respectively (Table 16). The result indicates that there is a big gap for credit access among the rural farmers with viable options for cheaper credit, a subject for further investigation.

Disaggregation between the districts shows that a higher percentage needed credit to buy input following fatting activity. The source of this credit was microfinance like Oromia saving and credit, Eshet and Wasasa share companies. The majority of sample households reported collateral (42.86%) and high interest rate (9.52%) as important constraints (Table 16).

Market and mode of transportation

Market access is critical in economic transformation of rural livelihoods. Improving market linkages along the value chain of major crops increases the opportunities and choices of rural farmers and reduces fluctuations between household consumption and income. Efficient integrated value chains, access to markets and other infrastructure help reduce transaction costs thus raising incomes of the rural poor (Denning et al., 2009).

Table 17. Market and mode transportation of sample households

Variable	Cheliya (n=49)		Ilu Gelan (n=56)		Total (n=105)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Market accessible	1.47	0.58	1.05	0.23	1.25	0.48
Distance to market (minutes)	118.95	34.67	89.02	47.68	113.43	37.12
Main mode of transport	**N**	**%**	**N**	**%**	**N**	**%**
Donkey	44	89.80	53	94.64	97	92.38
Horse	23	46.94	32	57.14	55	52.38
Cart	3	6.12	7	12.50	10	9.52

Source: Survey Results (2017).

Table 18. Market information of the sample households.

Information access	Yes	41	83.67	45	80.36	86	81.90
	No	8	16.33	11	19.64	19	18.10
Source of information	DA	13	26.53	12	21.43	25	23.81
	Traders	37	75.51	29	51.79	66	62.86
	Neighbor	36	73.47	31	55.36	67	63.81
	Cooperatives	6	12.24	11	19.64	17	16.19

Source: Survey Results (2017).

Results from analysis of the market situation were summarized in Table 18. Famer on average access market place 1.25 with average walks of 113.48 min. The main mode of transport is also analyzed in Table 17. Result shows that donkeys and horses were the major transport mode in the study areas. About 92.38 and 52.38% of sample households used donkey and horse for transportation service, respectively. Besides, 9.52% of sample households used cart for transportation service.

Marketing information

Information flow reduces market imperfections with choices for the type of market of farmers to sell their product. Regarding market information access, about 81.90% of sample households access market information before selling their product.

The main sources of this market information were extension office (DAs), traders, neighbor farmers and cooperatives. The result shows that about 63.81 and 62.86% of sample households obtained information from neighbor farmers and traders, respectively. About 23.81 and 16.19% sample households gained information from DAs and cooperatives, respectively (Table 18). Among these sources, neighbor farmers, traders and cooperatives were more preferable by sample households with information reality. There are significant opportunities for sustainable agriculture-led growth in this system, through market access and input supply chains (Kindu et al., 2014).

CONCLUSION AND RECOMMENDATIONS

Livestock production is the important assets in the study areas for different purposes including sources of food (milk, meat and byproduct of milk), draught power, transportation service, source of income generation (sale live and byproduct) and manure production for soil fertility improvement. Livestock management practices in the study areas are based on traditional knowledge and local breeds. The feed resources commonly used in the study areas were primarily natural pasture (communal and own grazing), crop residues and purchased supplementary feed. Improved forage crop was not common practice in the study areas by sample households during the survey period. Few farmers practiced traditional beekeeping with herbicides, shortage of bee forage, ants and wild, price fluctuation and shortage of bee constraints.

The major problems of livestock production were disease and parasite, shortage of grazing land, shortage of feed, lack of improved breeds, shortage of veterinary medicine, shortage of water and lack of capital. The main livestock marketing constraints were high transaction cost, market price/demand fluctuation, lack of market information, unorganized marketing system and lack of market linkage. The main livestock diseases were fugal (poultry disease), trypanosomiasis, pastevrellosis, mastitis, anthrax, black leg, mouth and foot, lichen and lamp skin. Majority of the farmers used vaccination and drug for controlling disease with poor quality and knowledge. To improve livestock production and productivity access improved breed, improved forage, control disease infection and improving marketing linkage are crucial.

In all crop types produced in the districts, average productivity per hectare is below national average productivity due to different constraints. The major constraints in crop production were pests (diseases and insects), high cost of inputs, shortage of land, weed infestation, shortage of inputs, low yield, poor quality of seed, lack of capital and poor soil fertility. High transaction cost, low price output, market price/demand fluctuation, lack of market information, lack of capital and lack of market linkage were reported as major crop marketing constraints. To enhance production and productivity of crops supply improved inputs capacitates farmers' awareness on integrated pest managements (IPM) to control pests and strengthen marketing linkage.

A large number of tree species were observed in natural forest found scattered on farmlands, garden areas as live fences and marginal land as a source of income generation, control soil erosion and soil fertility improvement. The major constraints of natural resources which account for productivity were soil erosion, termite attack, soil acidity, soil fertility decline, water logging and lack of sustainable land management caused by over cultivation, overgrazing and deforestation. However, expanding natural resource conservation and more awareness about the use of physical and biological soil conservation are more critical for soil improvement and increased productivity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Explaining output growth and total factor productivity changes using production frontier: The case of Ethiopian smallholder's farming

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This paper provides a parametric decomposition of output growth and total factor productivity changes, extending production approach to the case of non-neutral stochastic frontier. The results were based on unbalanced panel data from Ethiopian smallholder farmers observed over the period 1999–2015. The study decomposes output growth into input growth and total factor productivity changes while both were further decomposed into components. Output growth was decomposed into individual inputs contribution, whilst total factor productivity change decomposed into technical change, scale effect and technical efficiency changes. The empirical findings indicate output growth was mainly driven by total factor productivity changes (71%) while 22% attributed to input growth. Technical change found to be the main source of total factor productivity while scale effect also contributed significantly. Technical efficiency change was found to be the main source for the reduction of total factor productivity and so in output growth. The result indicates both changes due to inputs use and farm-characteristics were found the most important, in explaining technical efficiency changes, cancelling the negative impact due to autonomous changes and environmental factors. The finding implies there are total factor productivity changes and the output growth in cereal farming is mainly driven by technical change, suggesting policies aim at enhancing technology adoption and investment in modernizing agriculture are significantly effective. Thus policies directed toward enhancing agricultural technologies that improve technical change, enable farmers to benefit from scale of operations and their best practice form essential part of the overall agricultural policies.

Key words: Output growth, total factor productivity, decomposition, stochastic frontier, farming, Ethiopia.

INTRODUCTION

As accumulating factor of production and productivity growth, appears among the major determinants of economic growth; enhancement in production efficiency and total factor productivity (TFP) are probably the key

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elements that can ensure a continuous economic growth with a relatively low cost. Particularly in agrarian society, production performance study is an important indicator for the analysis of the overall economic growth, provides society with an opportunity to increase people's welfare and global competitiveness. Production performance analysis is an important field of research with possible implication in the discussions on food security and poverty alleviation, especially in the developing world. Besides a high rate of factor productivity growth in the agricultural sector is a necessary presupposition for a self-sufficient economy, at least in insuring own food security. Moreover, the raising of unemployment in a country in combination with the increase of population requires, necessarily, a growth in agricultural production and its productivity. It is, therefore, worthwhile to ask: What determinants should policymaking focus on to enhance productive efficiency and TFP growth. Analyzing farm production performance, identifying the sources of TFP growth and inefficiencies is an important step forward to assess the developmental role of agriculture in developing agrarian economies, like Ethiopia.

Agricultural sector plays an important role in overall economic growth in Ethiopia (World Bank, 2017), and it has significant spillover effects on the other sectors of the nation as well. Agriculture accounts for 38.5% of the country's gross domestic product (GDP), up to 81% of total export earnings and provides livelihood to more than 83% of the population (African Development Bank [AfDB], 2018). Despite frequent droughts and traditional farming practices in the country, Ethiopia has huge agricultural potential due to its ample arable land, an abundant workforce and diverse Agro-Ecological Zones (Beyan et al., 2013). The country's agriculture is known by low productivity, caused by an adverse combination of demographic, institutional constraints including environmental factors. In the country's crop production, mainly by the smallholder farmers, who provide the major share of the agricultural output; commonly employ backward production technology and limited modern inputs. Ethiopia's grain crop production is mainly dominated by cereal farming which is the most vital crop in the country; as the major food crop; comprise about two-third of the agricultural share of GDP and one-third of the national GDP. Ethiopia's agricultural sector is characterized by inefficiencies and heterogeneous increase in TFP growth in which cereals have shown a steady low productivity growth rate in recent decades; is one of the main challenges facing the country (AfDB, 2018). These underline the importance of assessing farm performance; with a potential policy implication is an important issue for such an agrarian country with a food deficit gap and limited capacity for adopting new technologies, is not a matter of choice but is instead a must.

Several studies have been done on farm performance in Ethiopian agriculture; however, few of these studies have linked productive efficiency to TFP growth decomposition. More importantly most studies have paid relatively little attention to connect efficiency analysis to output/TFP growth and its determinants while explaining TFP growth analysis in Ethiopian agriculture including the cereal subsector (Yohannes, 2016; Gebreegziabher et al., 2013). Moreover, most studies on crop productivity and efficiency in the country are outdated and have ignored unobserved heterogeneity and weather factor effects in productivity and efficiency analysis. Beside, results from previous performance studies have shown that methodological approaches (estimation techniques) and other study-specific characteristics (functional form, sample size, dimensionality, and geographical region) could affect the empirical estimates of productivity growth and efficiency analysis. In assessment of the farm performance, approach to use, which is the mainstay methodology of analysis, it is not distinguished to focus on the analysis of TFP or on the analysis of technical efficiency, but could be both. For instance, the conventional index number approach to the analysis of TFP cannot distinguish between a shift of production function (technical progress) and a movement along a production function (technical efficiency). In contrast the econometric approach is a flexible technique not only for identifying the sources of output growth and TFP changes but also for considering the technical efficiency of farms by explicitly specifying the underlying production structure. Therefore, it requires assessing level of productive efficiency and TFP growth as well as knowing root cause of their differentials in Ethiopian cereal farming. Along these lines, this paper provides a parametric decomposition of output growth and TFP change, extending the production approach to the case of non-neutral stochastic frontier that incorporates technical inefficiency. The empirical results were based on unbalanced panel data of Ethiopian smallholder cereal farmers observed during the 1999-2015 cropping period.

The paper used a Stochastic Frontier Analysis (SFA) applying recently developed- a four-component error panel data stochastic production frontier (SPF) model due to Kumbhakar et al. (2014), distinguished between farm-heterogeneity, persistent and transient inefficiencies and random error components. The model has an advantage over the traditional approaches by separating time-invariant heterogeneity from inefficiency. Accordingly, after estimating technical efficiency components, we decomposed output growth and TFP changes following Kumbhakar (2000) and other related growth decomposition approaches. In particular we utilized Karagiannis and Tzouvelekas (2005) who extended the earlier methods and adapted to the parametric approach for the decomposition of output growth and TFP changes to the case of non-neutral SPF. Consequently, output growth is decomposed into input growth (size effect) and TFP growth, and each was further decomposed into several components. The output growth is decomposed into individual inputs contribution while TFP growth was decomposed into the technical change (TC), scale effect (SE) and technical efficiency changes (TECs). Within the proposed formulation, however, the TEC effect itself is attributed not only to autonomous changes (passage of time) but also attributed to change due to inputs use, change due to farm specific-characteristics and change due to environmental factors. Thus, the TECs in turn are decomposed into four components: (a) change in passage of time, (b) change in inputs use, (c) change in the farm-specific characteristics and (d) change in environmental factors.

The study contributes to the existing literature and provides valuable information on the country's farming performance. Apart from analytical reasons, having farm-heterogeneity disentangled estimates and information about persistent and transient components of inefficiency is important; as each component provides different information with different policy options. Furthermore, appropriately quantifying the sources of output growth and TFP changes is also important for analyzing a sector's long-term prospects and policy-related issues. The greater the portion of output growth attributed to TFP is, the better the long-term prospects for farm production are, as the size effect (input growth) is considered a costly source of growth; whereas TFP is costless, at least from farmers' point of view. In addition, the relative importance of each TFP component is by itself informative as the factors (and seemingly the policies) affecting the various sources of TFP growth are not necessarily the same. For example, as stated in Karagiannis and Tzouvelekas (2005); R&D has a considerable impact on the TC effect but it rarely affects TECs. In contrast, for instance, agricultural extension service may have an effect both through its impact on the rate of diffusion and by improving farmers' managerial and organizational ability. Hence, if the driving forces of growth are to be taken into account in shaping development policies, then decomposition analysis could provide some useful insights. To the best of our knowledge, this is the first paper that examines output growth as well as decomposes TFP growth into TC, SE, and TEC with further decomposition of TECs in turn into four components, for Ethiopian cereal farming.

MATERIALS AND METHODS

Brief overview of stochastic production frontier model with four-error components

The method used in this paper is basically drawn from Kumbhakar et al. (2014) and Karagiannis and Tzouvelekas (2001, 2005). The recently introduced penal data SPF models (Kumbhakar et al., 2014) are extended to include four-component error terms in which technical efficiency and technological progress vary over time and across production units. Consider that, there are sample data on N-farmers operating in time period t that utilize various inputs to produce a non-negative farm output through a technology described by a well-behaved production frontier. The specification of panel data versions of the 1990s SPF model can be generally written as:

$$Y_{it} = f\left(X_{it}, t; \beta\right) * \exp(\varphi_{it}) = f\left(X_{it}, t; \beta\right) * \exp(\varepsilon_{it} - \tau_{it}) \quad (1)$$

where, $i = 1, \ldots, N$ denotes observations – is an index for i^{th} farmer and $t = 1, \ldots, T$ denotes time period t. Y_{it} is output produced by farmer i at time period t while X_{it} is a (1 × k) vector of input variables of the i^{th} farmer at time period t. f (x_{it}, t; β), the SPF, where t is a time index that serves as a proxy for TC and β is a (k×1) vector of unknown parameters to be estimated. The term: φ_{it}, is a "stochastic composed error term; where, the $\tau_{it} \geq 0$ is technical inefficiency term of individual i; and ε_{it} is a symmetric random error that accounts for statistical noise term. However, a number of SPF models in panel data have been developed successively giving rise to alternative measures of technical inefficiency. Kumbhakar and Heshmati (1995) interpreted $\tau_{it} \geq 0$ as time-varying technical inefficiency and added an extra component $\eta_i \geq 0$ to represent persistent inefficiency. The persistent component is consistent with the models used in the 1980s (Schmidt and Sickles, 1984), whereas the time-varying component is consistent with the models developed in the 1990s (Battese and Coelli, 1992). On the other hand, recently a philosophical question about the way of interpreting η_i has been raised -- should one view it as persistent inefficiency as in Kumbhakar and Heshmati (1995) or as firm-heterogeneity that captures the effects of (unobserved) time-invariant covariates that have nothing to do with inefficiencies as in Greene (2005a, 2005b). More recently Kumbhakar et al. (2014) and others introduced the first panel data SPF model including the arguments (heterogeneity and persistent inefficiency) by splitting the error term into four-components persistent inefficiency, transient inefficiency, random farm-heterogeneity and the random noise; thus decomposed the error term in equation (1) as: $\tau_{it} = \eta_i + u_{it}$ *and* $\varepsilon_{it} = \mu_i + \upsilon_{it}$ to obtain a model:

$$Y_{it} = f\left(X_{it}, t; \beta\right) * \exp(\varphi_{it}) = f\left(X_{it}, t; \beta\right) * \exp(\mu_i + \nu_{it} - \eta_i - u_{it}) \quad (2)$$

The model in (2) can be written as: $y_{it} = \alpha_0 + x_{it}'\beta + \mu_i + \nu_{it} - \eta_i - u_{it}$ after taking logarithms of both sides; where, y_{it} is logarithm of the output variable, x_{it} is logarithms of the input variables. The parameter α_0 is a common intercept; $\boldsymbol{\mu_i}$ is a farm-specific effect that captures time-invariant farms' heterogeneity (e.g. soil quality), which has to be disentangled from persistent individual effects (e.g. skill of the farmer). The term $\boldsymbol{\nu_{it}}$ is the random noise term, while the non-negative terms $\boldsymbol{\eta_i}$ and $\boldsymbol{u_{it}}$ capture persistent inefficiency and transient inefficiency effects, respectively.

The SPF model in (2) due to Kumbhakar et al. (2014) refers to as the Generalized True Random Effects (GTRE) model because it is a generalization of the true random effect model. A model can be estimated assuming that either the inefficiency component (u_{it}) is a fixed parameter that directly influences the dependent variable (the fixed-effects model) or assuming that the inefficiency component (u_{it}) is a random variable that has a correlation with the independent variables (the random-effects model).

Theoretical framework: Decomposing output growth and TFP changes

To decompose output growth and TFP changes, following

Kumbhakar (2000), based on the specification of Kumbhakar et al. (2014) and the methods of Alexander et al. (2015) and Karagiannis and Tzouvelekas (2005), we adopted the parametric approach to the case of non-neutral SPF. Consider a panel data production function of single production output, with the deterministic production frontier part of (2). Since farmers are not necessarily technically efficient, $Y_{it} \leq f(X_{it}; t)$. Hence, based on Farrell's, 1957 the output-oriented measure of technical efficiency of a producer at a certain point in time can be expressed as the ratio of actual output to the maximum potential output; given as $TE_{it}(X_{it}; t) = Y_{it} / f(X_{it}; t)$, where $0 < TE_{it}(X_{it}; t) \leq 1$. Now in order to compute the output growth, we rewrite the above productive efficiency expression as in Equation 3:

$$Y_{it} = f(X_{it}, t; \beta)\, TE_{it}(X_{it}, t) \tag{3}$$

By omitting the "*it*" subscripts for simplicity, taking logarithm of both sides of Equation 3 and totally differentiating with respect to time, we obtain:

$$\frac{d\ln TE}{dt} = \frac{d\ln Y}{dt} - \sum_{i=1}^{k} \frac{\partial \ln f(X,t;\beta)}{\partial X_i} \frac{dX_j}{dt} - \frac{\partial \ln f(X,t;\beta)}{\partial t}$$

which can be rewritten as

$$\frac{d\ln Y}{dt} = \frac{\partial \ln f(X,t;\beta)}{\partial t} + \sum_{j=1}^{k} \left\{ \frac{\partial \ln f(X,t;\beta)}{\partial X_j} \frac{1}{X_j} \frac{dX_j}{dt} + \frac{d\ln TE}{dt} \right\}$$

Now let y = ln*Y* and similarly x = ln*X* and denoting the growth rate of a variable *Z, by* $\dot{z}$ - that is, $\dot{z} = \partial \ln Z / \partial t$; equivalently we have:

$$\begin{aligned}\dot{y} &= \frac{\partial \ln f(x;t)}{\partial t} + \sum_{j=1}^{J} \frac{\partial \ln f(x;t)}{\partial \ln x_j} \dot{x}_j + \frac{\partial TE(x;t)}{\partial t} \\ &= \dot{T}(x;t) + \sum_{j=1}^{J} \frac{\partial \ln f(x;t)}{\partial \ln x_j} \dot{x}_j + \dot{TE}(x;t) = TC + \sum_{j=1}^{J} \varepsilon_j(x;t)\dot{x}_j + TEC\end{aligned}$$

where, $\dot{T}(x;t) = \partial \ln f(x;t) / \partial t$ is the technical change (TC), $\dot{TE}(x;t) = \partial TE(x;t) / \partial t = \partial u / \partial t$ is the technical efficiency change (TEC), and $\varepsilon_j(x;t) = \partial \ln f(x;t) / \partial \ln x_j$ is the output elasticity of the j^{th} input. Now we include a vector of farm-specific characteristics and vector of environmental factors in the above formulation to extend our model to correspond the Huang and Liu (1994) model. For this let $z = (z_1, ..., z_m)$ & $w = (w_1, ..., w_k)$ are the inefficiency effects vectors; includes a vector of farm-specific characteristics and vector of environmental factors, respectively. Hence following Karagiannis and Tzouvelekas (2005), (3) above can be rewritten as:

$$Y = f(X, t; \beta)\, TE(X, z, w; t) \tag{4}$$

So by making necessary rearrangement and substitutions; and taking logarithm of both sides of (4) and differentiating with respect to time, we obtain an extended form of decomposed output growth which has a form of:

$$\begin{aligned}\dot{y} &= \dot{T}(x;t) + \sum_{j=1}^{J} \frac{\partial \ln f(x;t)}{\partial \ln x_j} \dot{x}_j + \dot{TE}(x,z,w;t) + \sum_{j=1}^{J} \frac{\partial TE(x,z,w;t)}{\partial \ln x_j} \dot{x}_j + \sum_{m=1}^{M} \frac{\partial TE(x,z,w;t)}{\partial \ln z_m} \dot{z}_m + \sum_{k=1}^{K} \frac{\partial TE(x,z,w;t)}{\partial \ln w_k} \dot{w}_k \\ &= TC + \sum_{j=1}^{J} \varepsilon_j(x;t)\dot{x}_j + TEC + \sum_{j=1}^{J} \frac{\partial TE(x,z,w;t)}{\partial \ln x_j} \dot{x}_j + \sum_{m=1}^{M} \frac{\partial TE(x,z,w;t)}{\partial \ln z_m} \dot{z}_m + \sum_{k=1}^{K} \frac{\partial TE(x,z,w;t)}{\partial \ln w_k} \dot{w}_k\end{aligned} \tag{5}$$

Now following Kumbhakar (2000) to decompose TFP into components, we defined TFP growth as output growth unexplained by input growth; that is,

$$\dot{TFP} = \dot{y} - \sum_{j=1}^{J} S_j \dot{x}_j \tag{6}$$

This is a conventional Divisia index of productivity change defined as the difference between the rate of change in the output and the rate of change in the input quantity index. Substituting this index into Equation 5, that is replacing $\dot{y}$ in Equation 6 with Equation 4, the TFP growth in Equation 5 can be rewritten as:

$$\begin{aligned}\dot{TFP} &= \frac{\partial \ln f(x;t)}{\partial t} + \sum_{j=1}^{J} \left\{ \varepsilon_j(x;t) - \lambda_j \right\} \dot{x}_j + \frac{\partial TE(x,z,w;t)}{\partial t} \\ &+ \sum_{j=1}^{J} \frac{\partial TE(x,z,w;t)}{\partial \ln x_j} \dot{x}_j + \sum_{m=1}^{M} \frac{\partial TE(x,z,w;t)}{\partial \ln z_m} \dot{z}_m + \sum_{k=1}^{K} \frac{\partial TE(x,z,w;t)}{\partial \ln w_k} \dot{w}_k\end{aligned} \tag{7}$$

Further by letting $RTS = \sum_{j=1}^{J} \varepsilon_j(x;t)$ denotes the returns to scale (RTS) so that $\lambda_j = \varepsilon_j / RTS$; (7) may be rewritten as:

$$\begin{aligned}\dot{TFP} &= \frac{\partial \ln f(x;t)}{\partial t} + (RTS - 1) \sum_{j=1}^{J} \left\{ \frac{\varepsilon_j(x;t)}{RTS} \right\} \dot{x}_j + \frac{\partial TE(x,z,w;t)}{\partial t} \\ &+ \sum_{j=1}^{J} \frac{\partial TE(x,z,w;t)}{\partial \ln x_j} \dot{x}_j + \sum_{m=1}^{M} \frac{\partial TE(x,z,w;t)}{\partial \ln z_m} \dot{z}_m + \sum_{k=1}^{K} \frac{\partial TE(x,z,w;t)}{\partial \ln w_k} \dot{w}_k\end{aligned} \tag{8}$$

Equation 8 is the TFP change, in which TFP changes may be attributed to three sources: the TC effect; scale effect and TEC effect (the sum of the last four terms). Thus, in decomposing the TFP changes as in Equation 8: (i) The first term on the right-hand side (RHS) measures the TC effect that relates to the technological progress, including not only advances in physical technologies, but also innovation in the overall knowledge base that leads to better decision making and planning. The technological progress is positive (negative) under progressive (regressive) TC, respectively or vanishes when there is no TC. (ii) The second term on the RHS measures the SE that refers to the proportionate increase in output due to proportionate increase in all inputs in the production process. Note that the sign of SE depends on both the magnitude of the inputs elasticity and the changes of the aggregate input over time. It is positive (negative) under increasing (decreasing) RTS as long as input use increases and vice versa. This term vanishes when either the technology is characterized by constant RTS. (iii) The remaining terms (last four terms) on the RHS constitute the TEC measure, which contributes positively (negatively) to TFP growth as long as efficiency changes are associated with movements towards (away from) the production frontier. Thus, what really matters is not the degree of technical efficiency per time, but its changes overtime. That is, even at low levels of technical efficiency, output gains may be achieved by improving resource use. These TECs may be due to four factors: changes due to passage of time, due to input use, due to the farm-specific characteristics, and due to environmental factors; the third, fourth and last terms in the RHS of Equation 8 respectively.

These four terms are closely related to the form of the production frontier. If it is specified as non-neutral SPF, which is the most general formulation, all of these terms are relevant and should be taken into account. If instead a neutral SPF is assumed, the fourth term vanishes and then there are two alternatives. If technical efficiency is specified as a technical inefficiency effect model (Battese and Coelli, 1992), both the third and the fifth term should be considered, but if technical efficiency is modeled as a pure time-varying process, following the specifications of Kumbhakar (1990) only the third term should be taken into account. To extend the above non-neutral parametric approach decomposition of TFP changes, to similar decomposition of the output growth, we include the input growth to Equation 8. Thus the output growth decomposition format will be given by:

$$\dot{y} = \frac{\partial \ln f(x;t)}{\partial t} + (RTS-1)\sum_{j=1}^{J}\left\{\frac{\varepsilon_j(x;t)}{RTS}\right\}\dot{x}_j + \frac{\partial TE(x,z,w;t)}{\partial t} + \sum_{j=1}^{J}\frac{\partial TE(x,z,w;t)}{\partial \ln x_j}\dot{x}_j + \sum_{m=1}^{M}\frac{\partial TE(x,z,w;t)}{\partial \ln z_m}\dot{z}_m + \sum_{k=1}^{K}\frac{\partial TE(x,z,w;t)}{\partial \ln w_k}\dot{w}_k + \sum_{j=1}^{J}\frac{\varepsilon_j(x;t)}{RTS}\dot{x}_j \tag{9}$$

Where; the last term in Equation 9 refers to the size effect that captures the contribution of aggregate input growth (factor accumulation) to output growth. Output increases (decreases) are associated with increases (decreases) in the aggregate input, ceteris paribus. Also, the more essential an input is in the production process, the higher its contribution is on the size effect. Thus, within Equation 9, however, TECs are attributed not only to change components presented in Equation 8 but also to changes in input use. A very different relationship has been used in previous studies to decompose output growth, simply by focusing on rate change of output under constant RTS; namely:

$$\dot{y} = \dot{TE}(z,w,x,t) + \dot{T}(x;t) + \sum_{j=1}^{J}\varepsilon_j(x;t)\,\dot{x}_j = TC + \sum_{j=1}^{J}\varepsilon_j\dot{x}_j + TEC \tag{10}$$

This approach is a step back from the TFP changes, but it might be easier to explain and is, perhaps, more intuitive; due to its restrictive version of Equation 9 in the sense that it implicitly assumes (i) a neutral SPF, (ii) a pure time-varying specification for the technical inefficiency model, and (iii) a constant RTS technology. Thus, Equation 9 and 10 would yield very different results concerning the sources of output growth. Specifically, the relative contribution of TFP to output growth is overestimated (underestimated) when Equation 10 is employed and decreasing (increasing) RTS prevail; whereas the opposite is true for the size effect. Based on Equation 9, RTS and the rate of TC can be calculated as:

$$RTS_{it} = E_{jit} = \sum_{j=1}^{J}\varepsilon_{jit} = \sum_{j=1}^{J}\left(\beta_j + \sum_{k=1}^{J}\beta_{jk}X_{kit} + \beta_{jt}T\right)$$

where ε_{jit} are input elasticities

$$TC_{it} = \dot{T}_{it}(x;t) = \frac{\partial \ln y_{it}}{\partial \ln T} = \beta_t + \beta_{tt}T + \sum_{j=1}^{J}\beta_{jt}\ln X_{jit} \tag{11}$$

Note that, the TC in Equation 11 consists of two parts; the pure/neutral TC: ($\beta_t + \beta_{tt}T$) and the non-neutral TC: ($\Sigma\, \beta_{jt} \ln X_{jit}$) parts. Pure TC refers to neutral shift of the production function due to time alone, non-neutral TC means input-biased TC.

Lastly, following Wang and Schmidt (2002) the components of the TECs - Change due to passage of time (TEC_T), changes due to farm-characteristics (TEC_Z), changes due to environmental factors (TEC_W) and changes due to inputs (TEC_X) are computed respectively as:

$$TEC_{T,it} = \delta_t + \delta_{tt}T;\quad TEC_{Z,it} = \sum_{m=1}^{M}\delta_m\dot{z}_m;\quad TEC_{W,it} = \sum_{k=1}^{K}\delta_k\dot{w}_k \ \ and\ \ TEC_{X,it} = \sum_{j=1}^{J}\delta_j\dot{x}_j \tag{12}$$

The above relationships, Equations 9 to 12 are used to implement the decomposition of TFP changes and output growth.

The empirical model and estimation approach

For the estimation purpose, given the SPF in model (1), we approximate the underlying technology $f(x_{it};\beta)$ using a translog (TL) functional form; a technology that commonly has been preferred as a more flexible form that allows for interaction of inputs. Thus; we estimate a SPF panel data model using specification:

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{J}\beta_j \ln X_{jit} + \beta_t T_t + \frac{1}{2}\left(\sum_{j=1}^{J}\sum_{h=1}^{H}\beta_{jh}\ln X_{jit}\ln X_{hit} + \beta_{tt}T_t^2\right) + \sum_{j=1}^{J}\beta_{jt}\ln X_{jit}T_t + \varphi_{it} \quad (13)$$

where: $\ln Y_{it}$ is the logarithm of output of farmer *i,* in time period *t.* $\ln X_{it}$ is a vector of logarithm of inputs. T is a time trend and βs are unknown parameters to be estimated. φ_{it} , is a stochastic composite error term; that can be decomposed as: $\varphi_{it} = \varepsilon_{it} - \tau_{it} = (\mu_i + \nu_{it}) - (\eta_i + u_{it})$.

To specify the determinants of transient inefficiencies we make the variance parameters of $\boldsymbol{u_{it}}$ function of the determinants. In modeling $\boldsymbol{u_{it}}$, it is assumed that the mean of the pre-truncated distribution depends on both input use and farm-specific characteristics assuming a homoscedastic distribution for the variance parameter. For this, following Karagiannis and Tzouvelekas (2005), we implemented inefficiency effect model that corresponds to a non-neutral SPF model (Huang and Liu, 1994). Thus the inefficiency term $\boldsymbol{u_{it}}$ as explained in Equation 1 is given as:

$$u_{it} = \delta_0 + \sum_{m=1}^{M}\delta_m Z_{mit} + \sum_{k=1}^{K}\delta_k E_{kit} + \delta_t T + \sum_{j=1}^{J}\delta_j X_{jit} + w_{it} \quad (14)$$

Where: u_{it} refer to farmer's transient inefficiency indices as estimated by SPF model; Z, E and X represent vectors of independent variables assumed to influence transient inefficiency. The variable Z_{it} denotes a vector of (farmer as well as farm-specific characteristics); E_{it} is a vector of environmental factors; X_{it} denotes the vector of production inputs. The terms δ's are the inefficiency parameters to be estimated, and w_{it} is the corresponding statistical noise.

After substituting Equation 13 and (14) into Equation 1) the resulting model is estimated using fixed-effect model which allows addressing the influences of omitted variables and provides consistent estimators (Baltagi, 2008). For estimation purpose we used multi-stage maximum likelihood estimation (MLE) method (Kumbhakar et al., 2015) to obtain estimate of efficiency components and compute marginal effects of the determinants of each type of inefficiency. Hence, in the one-stage approach, all parameters – frontier production in Equation 13 and inefficiency effects in Equation 14 are estimated simultaneously. It uses three steps to estimate the model, initially by rewriting the model in Equation 2 $y_{it} = \alpha_0 + x'_{it}\beta + \mu_i + \nu_{it} - \eta_i - u_{it}$ as follows:

$$y = \alpha_0^* + f(x_{it};\beta) + \alpha_i + \varepsilon_{it}^*$$

where

$\alpha_0^* = \alpha_0 - E(\eta_i) - E(u_{it})$; *and* $\alpha_i = \mu_i - \eta_i + E(\eta_i)$; *and* $\varepsilon_{it}^* = \nu_{it} - u_{it} + E(u_{it})$

while α_i and ε^*_{it} have zero mean and constant variance. Here, the newly rewritten model can be estimated in three steps as follows: The first step includes a standard random effect panel regression to estimate β and predict the values of α_i and ε^*_{it}. In the second step, the time-varying technical efficiency is estimated using the predicted value of ε^*_{it} from previous step by assuming $\upsilon_{it} \sim N(0,\sigma_\upsilon^{\,2})$ and $u_{it} \sim N^+(0,\sigma_u^{\,2})$. This procedure predicts the residual (transient) technical inefficiency index following Jondrow et al. (1982) or residual technical efficiency (RTE) index and marginal effects (MEs) using Battese and Coelli (1988): $RTE_{it} = \exp(-u_{it}|\varepsilon_{it}^*)$.

In Step 3, following a similar procedure as in Step 2, η_i is used to obtain the persistent technical efficiency (PTE) estimates and the corresponding inefficiency effects parameters simultaneously. For this, the best linear predictor of $\alpha_i = \mu_i - \eta_i + E(\eta_i)$ is estimated by assuming $\mu_i \sim N(0,\sigma_\mu^2)$ *and* $\eta_i \sim N^+(0,\sigma_\eta^{\,2})$ and applying standard half-normal SFM in a cross-sectional setting. The persistent technical inefficiency (η_i) is obtained through Jondrow's estimator and PTE index and MEs can be estimated using the BC formula: $PTE = \exp(-\hat{\eta}_i)$. Finally the overall technical efficiency (OTE) is then obtained from the product of persistent and residual efficiencies, that is, $OTE_{it} = PTE_i \times RTE_{it}$.

DATA AND THE STUDY VARIABLES

The data and description of variables of the study

This study employed panel data from the Ethiopian Rural Household Survey (ERHS) data of 4-rounds in years 1999, 2004, 2009 and 2015 collected from local Farmers Associations (FAs). The ERHS data were collected from randomly selected farm households in rural Ethiopia. It includes farm production and economic data collected from local FAs that were selected to represent the country's diverse farming systems. Moreover, important weather data; monthly average observations of rainfall and maximum and minimum temperature were obtained from Ethiopian Meteorology Authority from years 1994–2015 collected in stations close to the study villages.

Study variables

The output variable contains the value of cereal outputs, which combines aggregate cereal crops output measured in Ethiopian Birr (ETB) used as dependent variable for the frontier function. The input variables include conventional agricultural inputs: farm labor employed measured in Man-Day Units (MDUs); cereal sown farmland in hectares; amount of fertilizers used in kilograms; agricultural machinery implements in ETB; livestock ownership in Tropical Livestock Units (TLUs) as a proxy for wealth and livestock asset endowments; agro-chemicals in ETB including pesticides, herbicides and insecticides; and oxen as animal draft power in number of the oxen owned as these are used during land preparation and harvesting periods; as the country's farming is mainly traditional. All monetarily measured variables were transformed to fixed ETB prices. In addition, we also included sets of inefficiency explaining

Table 1. Summary statistics of continuous variables.

Frontier variables	Mean	SD	Min.	Max.	Inefficiency variables	Mean	SD	Min.	Max.
Output	1.952	2.682	34.0	51.100	Aver. Rainfall (AMP)	82.1	26.9	47.5	145.9
Fertilizers	116.1	138.9	0.1	1.400	Aver. Temp. (AMT)	18.5	3.5	13.2	23.9
Agrochemicals	133.9	447.2	0.01	8.560	Rainfall Variation	0.02	0.01	0.01	0.03
Labor	342.6	714.2	3.0	8.333.9	Temp. Variation	6.1	3.03	1.9	14.
Machinery	336.7	1.776	0.5	36.540	Household's size	5.8	2.7	1.0	18.0
Livestock	6.5	5.9	0.01	58.8	Number of plots	3.6	2.5	1.0	16.0
Oxen	1.8	1.3	0.01	9.0	Head's age	51.2	15.4	18.0	103.0
Farm-area	1.7	1.2	0.02	11.0					

Source: Author's calculations.

Table 2. Summary statistics for inefficiency effect dummy (1 = yes) variables.

Variable	Percentage	Variable	Percentage	Variable	Percentage
Credit-access	52.25	Tertiary-schooling	1.03	Remittance	18.51
Head's-gender (female)	23.42	Soil-conservation	39.87	Irrigation	19.42
Primary-schooling	40.17	Water-harvesting	26.58	Off/non-farm	31.25
Secondary-schooling.	7.90	Agricultural-extension	38.29	If any ox	80.64

Source: Author's calculations.

variables. Based on the existing literature source of technical inefficiency includes farmer-specific characteristics (e.g., education, age, gender, and farming experience); household physical endowments (e.g., farm-size and family-size); and access to agricultural extension and credit use, adoption technologies and environmental (weather/ecological) factors. Besides the time trend variable is also included both in the production as well as the inefficiency functions. The time trend variable in the production function represents the rate of TC; while the time trend in the inefficiency function represents changes in technical inefficiency over time.

The weather dataset contains Annual Mean Precipitation (AMP) measured in millimeters (mm) and Annual Maximum Temperature (AMT) in degree Celsius (°C) and their variability (measured by their coefficients of variation). AMT is based on two indicators: Monthly Mean Temperature (MMT) and the Diurnal Temperature Range (DTR). MMT is calculated as the median between the observed monthly maximum and minimum temperatures, whereas DTR is the difference between the monthly temperatures. Finally, AMT is calculated by adding half of DTR to MMT (Harris et al., 2014) and is used as a measure of extreme temperature because it captures temperatures at a time when evaporation is higher. In addition to the mean of the weather variables, following Barnwal and Kotani (2013), we used coefficient of variation, which is a measure of monthly deviation within a year to capture variability. Annual climatic data for the weather variables in the study were calculated as the 12-month average (Harris et al., 2014). The summary statistics of the data is provided in Tables 1 and 2. Table 1 shows that the sampled farmers produced an average of 19.52quintals of cereal with the largest producer producing 511quintals of cereals.

As evident from the table, there was relatively little use of cultivated farmland which is typical of smallholders, cereal farming and considerable variations in the amount of inorganic fertilizers, agro-chemicals, and machinery implements and farm-labor use patterns. For such production the farmers cultivated cereal on average of 1.8 ha. The farmers used an average of 342 MDUs of labor, ranging from 3 to 8,334 MDUs; which may reflect the fact that cereal production is labor intensive in Ethiopia. Fertilizer application was minimal with an average of 116.1kg; while their average expense for agrochemicals and machinery use was 133.9 and 336.27 ETB respectively. The livestock ownership was on average 6.5 TLUs while oxen ownership was around 1.8meaning almost two oxen per farmer, ranging from no ox to 9 oxen.

To describe some of farm-specific characteristics, as can be observed from tables, male-headed households constituted 76% of the total sample. Average farmers age was 51 years ranging from 18–103 years while household-size ranged up to 18members, with a mean of six members. Looking at the weather variables in the study area, we find that average annual rainfall was

82.1 mm ranging from 47.5-145.6 mm while the average temperature was 18.48°C ranging from 13.16-23.96°C. In sum the climate/weather data show a significant declining trend in average rainfall and warming trends in the temperature variable annually during the study period.

Extension participation was represented by extension visits per week/month in which the farmers reported contact with extension agents. Accordingly, about 38% of the farmers reported contacting with extension agents, seeking agricultural advisory services. Almost half of the sampled farmers had access to credit while 19% of them obtained remittances from different sources. Female-headed households constitute about 24% of the total sample. About 40% of the sample farmers adopted soil conserving technologies while 26.6% of them were involved in water harvesting activities and 19% of them used irrigation for cropping. Moreover, 19% of them used irrigation for farming. The educational level of the household head also varied over the years with mean schooling of five years. About 43.44% of them had attended formal schooling ranging from primary level to tertiary level; out of which 40% had completed primary level; 7.9% secondary; and only 1% had completed tertiary schooling.

ESTIMATION RESULTS AND DISCUSSION

The SPF parameter estimates

The estimated parameters of the SPF obtained from simultaneously estimating the TL-functional form and inefficiency models are presented in Tables 3 and 4 respectively. Prior to estimation, we performed Hausman test (Wooldridge, 2002) to see if the unobserved-effects were best treated as fixed or random-effects. The result revealed that the fixed-effect provides a consistent estimation as compared to random-effect. Accordingly, we report fixed-effect estimation, with robust standard-error to diminish the heteroscedasticity problem.

As shown in Table 3, although the parameters from TL function do not have any direct economic interpretation, it is interesting to note that most of the estimated parameters are significantly different from zero at the 5% or lower significance level. This indicates the fit of the model is very good. Moreover, the estimated parameters could be used in conjunction with the estimated technical inefficiency to estimate additional measures of interest, such as TC, RTS, and TFP growth. Further, the estimated parameters satisfied all production economic theory regularity conditions which require the estimated first-order parameters to be non-negative and less than one, whereas the bordered Hessian matrix of the first and second-order partial derivatives was negative semi-definite and so they are valid at the point of approximation.

The goodness of fit measured either by the *R*-squared or log likelihood function, is satisfactory in the models indicating that the proposed model is a good representation of the data-generation process. Moreover, the parameter γ associated with variances in SPF, is highly significant, revealing that a great percentage of the disturbance term is due to the presence of technical inefficiency. The results indicate that inefficiency effects did make a significant contribution to the level and variations in cereal production in the study area. Hence, differences in technical efficiency among farms are relevant for explaining output variability in cereal growing farmers. Concerning the other estimated parameters, the majority of coefficients in the SPF are significant at conventional levels. Indeed, some of the interaction and squared terms turned out to be insignificant, due to the nature TL estimation. However, it is widely recognized that in TL, there is high level of multicollinearity due to the interaction and squared term, which causes certain estimated coefficient to be insignificant. Estimates of the trend and its squared term were significantly positive at 1% level showing that cereal farmers experienced a technical progress with an increasing rate over time.

Technical inefficiency effects

Empirical finding concerning the sources of efficiency differentials is presented in Table 4. The MLE's results on inefficiency effects show that transient inefficiency was positively and significantly affected by the age, secondary schooling and extreme temperature variations. The age of the farmer, as a proxy of experience and learning-by-doing, is one of the factors enhancing efficiency, while the negative sign of the squared term supports the notion of decreasing returns to experience. Schooling helps farmers to use information efficiently since a better educated farmer acquires more information and is able to produce more from a given input vector. However, inefficiency was negatively and significantly related to the gender, household-size and number of plots. It was negatively and significantly related to remittances, annual average rainfall and average extreme temperature levels. Hence, an increase in these factors, ceteris paribus, led to an increase in efficiency during the period. Similar results were found by Madau (2011) and Bamlaku et al. (2009).

Interpreting the magnitude of the marginal effects of the MLE results, we find that the marginal effect of head's gender on the technical inefficiency was negative, the mean being about 0.06. Thus inefficiency was reduced by 6% for a 10-point increase in the household head's gender. Similarly, an increase in the share of household size and number of plots by one percent reduced inefficiency by 0.011 and 0.019% respectively. On the other hand, a 1 year increase in the age of the household head and secondary educational level, on average, increased inefficiency by 0.015 and 0.095% respectively.

Table 3. Parameters from the TL production frontier.

Parameter	Estimate	Rob. SE	Parameter	Estimate	Rob. SE	Parameter	Estimate	Rob. SE
β_0	5.002***	0.419	β_{FM}	-0.002	0.004	β_{WA}	0.002	0.018
β_F	0.024	0.050	β_{FW}	-0.010**	0.004	β_{OA}	0.010	0.035
β_P	0.020	0.030	β_{FO}	0.016**	0.009	β_{tF}	-0.013	0.010
β_L	0.369***	0.119	β_{FA}	0.020*	0.013	β_{tP}	-0.003	0.006
β_M	0.280***	0.065	β_{PL}	0.001	0.005	β_{tL}	-0.130***	0.021
β_W	0.057	0.070	β_{PM}	-0.006*	0.003	β_{tM}	-0.016	0.015
β_O	0.109	0.122	β_{PW}	0.008**	0.004	β_{tW}	0.002	0.013
β_A	0.456**	0.180	β_{PO}	-0.020***	0.006	β_{tO}	0.020	0.022
β_{FF}	-0.002	0.010	β_{PA}	0.001	0.009	β_{tA}	0.092***	0.032
β_{PP}	0.005	0.007	β_{LM}	0.032***	0.008	β_t	0.498***	0.164
β_{LL}	-0.027	0.023	β_{LW}	0.014	0.011	β_{tt}	0.418***	0.053
β_{MM}	0.059***	0.013	β_{LO}	-0.020	0.020	R^2	Within	0.761
β_{WW}	0.025**	0.010	β_{LA}	-0.045	0.029		Overall	0.704
β_{OO}	0.084**	0.046	β_{MW}	0.002	0.006		σ_u	0.613
β_{AA}	-0.066	0.069	β_{MO}	-0.004	0.011		σ_v	0.744
β_{FP}	0.001	0.002	β_{MA}	-0.009	0.016		γ	0.406
β_{FL}	0.006	0.008	β_{WO}	-0.012	0.013			

*P <0.05, **P <0.01 and ***P <0.001. Subscripts on β coefficients refer to inputs: F = Fertilizers; P = Agrochemicals; L = Labor; M = Machinery; W = Livestock; O = Number of oxen; A = Farm-area.

Table 4. Technical inefficiency effects result.

Variable	Coef.	SE	MEs	Variable	Coef.	SE	MEs
Farm-specific factors							
Head's-gender	-0.314*	0.18	-0.061	Secondary-schooling	0.485*	0.282	0.095
Head's-age	0.075**	0.031	0.015	Tertiary-schooling	0.396	0.7	0.077
Age sq.	-0.061**	0.029	-0.012	Credit-access	0.056	0.149	0.011
Household-size	-0.052*	0.033	-0.010	If any ox	-0.234	0.181	-0.046
Primary-schooling	-0.006	0.162	-0.001	Remitances	-0.387*	0.222	-0.075
Adoption technologies							
Number of plots	-0.097*	0.054	-0.019	Irrigation	-0.213	0.219	-0.042
Soil-conservation	-0.205	0.166	-0.04	Off/non-farm	0.113	0.165	0.022
Water-harvesting	-0.273	0.189	-0.053	Ext. services	-0.237	0.159	-0.046
Weather factors							
PRECIP	-0.076**	0.03	-0.015	Rainfall variation	-59.151	67.514	-11.54
AMT	-1.806**	0.843	-0.352	Temp. variation	0.323***	0.113	0.063
Constant	-1.29***	0.068		Log LH	-1512.15		

*: p<0.05; **: p<0.01; ***: p<0.001.

Technical efficiency scores

Estimates of technical efficiency scores in the form of percentage distributions are reported in Table 5. The persistent technical efficiency component is found to be about 80%, on average with a less dispersion. On the other hand, the transient technical efficiency component is found to be quite low, scoring mean of 71%. This variability between persistent and transient efficiency scores which is in line with the findings of Kumbhakar et al. (2014) and Filippini and Greene (2016) clearly demonstrates the existence of significant farm-heterogeneity in the sample and should be considered in efficiency modeling and specifications. As the combination

Table 5. Distribution of technical efficiency scores.

Parameter	Mean	Std. Dev.	Min	Max
Transient Technical Efficiency	0.71	0.12	0.05	0.93
Persistent Technical Efficiency	0.80	0.05	0.56	0.92
Overall Technical Efficiency	0.57	0.10	0.03	0.80

Source: Author's computation.

of the two efficiency components, estimate of the overall technical efficiency shows a mean score of 57% during the period, whilst most farms in the sample (65 to 81%) have achieved technical efficiency scores greater than 75%.

The overall implication of these results for overall or each year is that the cereal farmers were technically less efficient. Since technical efficiencies scores were calculated as an output-oriented measure, results indicate that there was room for improvement, and output could have increased substantially if inefficiency was eliminated. Meaning that, the farmers could be able to increase their output by about 43% using their resources more effectively. Expressing in other way, a 43% increase in total output could have been achieved during this period by decreasing proportionally the quantity of inputs used without altering the total volume of production.

Output and TFP growth decomposition results

The decomposed components of output growth and TFP changes of the cereal farmers over the period of 1999–2015 are presented in Table 6, where the first two columns are based on Equation 9 and the last two on Equation 10. In each case, the average annual rate change during the period under consideration is reported first, followed by the relative contribution of each effect to the observed output growth and TFP changes. TFP is then decomposed into its three main components, namely, TC component which is dominated by the time trend effect, the TECs and the SE components. The first two components further decomposed into several sub-components such as contributions from different technology shifters. In particular, the TC effect has decomposed into sub-components such as neutral and biased components. The TECs has decomposed into sub-components such as contributions from autonomous change; change due to inputs; change due to farmer/farm-specific characteristics and change due to environmental factors.

From Table 6 it is clear that Equations 9 and 10 yield different results regarding the sources of output growth. This is to be expected, as the hypothesis of constant RTS has been rejected and the computation of the SE and the TEC effects has been performed differently. As evidence of increasing RTS has been found, the relative contribution of TFP to output growth is underestimated when Equation 10 is employed, whereas the opposite is true for the SE, as long as the TECs and the SEs are measured in the same way. In this case, part of output growth would be falsely attributed to TFP changes whereas it is in fact associated with increases in input use. However, this is not reflected in the results when different measures of both the TECs and the SEs have been used. Besides these differences, it should be noticed that the portion of unexplained residual is greater when the decomposition of output growth is based on Equation 10.

Given the rejected hypotheses of constant RTS and neutral production frontier, we precede the decomposition analysis of output growth and interpretations based on Equation 9. As can be seen from Table 6 during the period, average annual output growth was 1.29. A greater share of the observed output growth (71.13%) was due to the TFP growth and a smaller share (22.3%) to SE. Specifically, 0.29% of the observed output growth is attributed to the aggregate input growth mainly associated with farm-size and labor growth while the rest percentage of the output growth was attributed to the TFP changes. TC was found to be the most important source of TFP changes and thus to the output growth having a positive estimate. In particular, an average annual rate of TC is estimated at an average growth rate of 1.16 that accounts for 89.76% of the observed output growth. This rate of TC is indicating the cereal farming was technically progressed. Regarding the sources of TC, it can be seen from Table 6 that 1.82% was due to the neutral component and only 0.66% reduction was due to the biased component. The result is in accordance with previous empirical findings reported that TC is the main source of TFP growth (Karagiannis and Tzouvelekas, 2005; Alexander et al., 2015).

The empirical result also exhibits the SE has affected positively the TFP growth that compromises with the exhibited increasing RTS and aggregate increase in input usage results reported over time. However, the relative contribution of SE was small compared to that of TC. During the period 1999–2015, SE has contributed to the annual TFP growth by an average rate of 2.57%.This indicates that, the SE component and thus its effect is a significant figure that would have been ignored if constant RTS were falsely assumed. In such a case, TFP growth

Table 6. Decomposition of output growth and TFP changes.

Decomposition	Based on Equation 9		Based on Equation 10	
	Mean	Percentage	Mean	Percentage
Output growth	1.29	100	1.29	100
Size effect	0.29	22.30	0.25	19.36
Fertilizers	0.01	0.57	0.01	0.60
Agrochemicals	0.01	0.78	0.02	1.90
Labor	0.04	2.82	0.05	3.64
Machinery	0.01	0.78	0.004	0.28
Livestock	0.05	4.08	0.03	2.55
Oxen	0.05	3.52	0.04	3.49
Farm-area	0.13	9.75	0.09	6.89
Total Factor Productivity *(*TFP) Changes	1.003	71.13	1.12	86.67
Technical Changes *(TCs)*	1.16	89.76	1.16	89.76
Neutral	1.82	140.94	1.82	140.94
Biased	-0.66	-51.18	-0.66	-51.18
Scale Effect *(SE)*	0.028	2.57	-	-
Technical Efficiency Changes *(TECs)*	-0.18	-15.12	-0.04	-3.09
Change due to passage of time	-0.04	-3.09		
Change due to inputs	0.001	0.81		
Change due to environmental factors	-0.15	-11.40		
Changes due to farm-characteristics	0.002	0.17		
Unexplained Residuals	0.073	5.650	0.078	6.029

Source: Author's computation.

would have been overestimated. Specifically, the estimated average annual rate of TFP growth would have been 86.67% instead of 71.13%. Consequently, the results demonstrate that, there would have been significant differences in TFP growth by not accounting simultaneously for the SE. Furthermore, not accounting for the SE can lead not only to errors but also to misconceptions concerning the potential sources of TFP and output growth, as noticed in similar studies (Karagiannis and Tzouvelekas, 2005).

On the other hand, the TECs have affected negatively both TFP changes and hence the output growth. Its effect is unconstructive, as the pattern of changes in technical efficiency indicated movements contrary to the production frontier over time. Hence, the empirical result exhibits the TEC was the main source for the reduction of TFP and output growth. In particular, it evinces an average reduction of 0.18 in TFP growth and hence a decline in 15.12% of the observed growth was attributed to changes in TEC or changes in its components during the period 1999-2015. This result (the negative effect of TECs), is in line with the results from technical efficiency scores, as evidenced in Table 6 that technical efficiency estimates has dropped between 1999 and 2015 years. Moreover, to get more insights into the sources of TECs that contributed in reduction of TFP, we turn our attention to the components of TECs from Equation 9 to draw some analysis.

Specifically, the empirical result indicates that changes due to environmental factors were the most significant determinants as a main cause for deteriorating TECs; meanwhile only a small portion of this decline was due to pure autonomous changes. On the other hand, it is found that the changes due to the inputs factors and due to farm-characteristics were essential in minimizing the worst effect of TECs on the TFP growth, by positively contributing to the TECs. Meanwhile it is important to notice that the effect of the inputs factor on TEC over time has similar result as that of the size effect on the output growth. That is, a change due to the inputs factor improves the performance (increased TECs) similar to the positive effect of aggregate input use on the output growth. In general from the components of TECs; change due to inputs and changes due to farm-characteristics were the most important, both cancelling the negative impact of the environmental factors. Hence the empirical findings reveal that TFP changes and thus the output growth was largely due to adoption of improved technologies and scale effect rather than improvement in technical efficiency of the smallholders. It demonstrates that TFP has been increasing, driven primarily, by positive TC, changes due to SE and changes due to inputs.

CONCLUSION AND POLICY IMPLICATIONS

This paper provides a parametric decomposition of output growth and TFP changes extends production approach to the case of non-neutral stochastic frontier. The analysis is based on five-point unbalanced panel dataset from Ethiopian smallholder cereal farmers observed for the period of 1999–2015. The paper used recently developed SPF panel data model that decomposes technical efficiency into components and extends the model to include the output growth and TFP growth decompositions. Output growth was decomposed into two of its sources – factor accumulation and TFP changes, and each was further decomposed into components. Input growth itself was decomposed into individual inputs contribution while TFP growth was intern decomposed into rate of TC, SE and TEC components. Further TEC was also decomposed into components such as – autonomous changes, changes in inputs use, changes in the farm-specific characteristics and changes in weather/environmental factors.

Efficiency estimation results show that the potential for improving the production efficiency of cereal farmers is immense, as some farmers are operating at as low as 45% level of efficiency. Input elasticities were significantly positive and hence show an increase in the use of each input has contributed to enhance cereal production. Results from growth decomposition models evinced that a greater share of the observed output growth was due to the TFP changes compared to that of input growth. Specifically, aggregate input use increased at annual mean rate of 29 (22.3%) while the rest percentage was attributed to that of TFP changes. The findings further indicate TFP changes have been increased mainly driven by TCs, while SE contributed significantly over the period. This indicates that, there would have been significant differences in TFP growth by not accounting simultaneously for the SE.

On the other hand, TECs was found to affect negatively the rate of TFP changes and hence on the output growth, though its effect was very little. Consequently, TEC was found to be the main source for the reduction of TFP changes and output growth. In particular, during the period 1999-2015 significant reductions in both TFP changes were attributed to the depressing changes in TEC streamed from changes in its components. In this regard the empirical results indicate that changes due to passage of time and due to environmental factors were found to affect negatively the rate of TFP while changes due to inputs and due to farm-characteristics were positive. Hence the effects of change due to inputs use and change due to farm-characteristics on TEC, is in line with that of size effect we found on the output growth over the period. In sum from the components of TECs, change due to inputs and changes due to farm-characteristics were the most important, both cancelling the negative impact of the environmental factors. It should be noticed that change due to inputs was far more important in explaining changes in technical efficiency contributing 0.81%, in contrast to their explanatory role for the size effect.

In sum, the analysis undertaken in this paper demonstrated that the output growth was largely due to change arising from two components – the TFP change and the input growth over time. On the other hand, the TFP growth showed that TC and SE are the two most important determinants of TFP growth over the period. This demonstrates TFP has been increasing, driven primarily by change due to TC, and due to changes in SE, and also due to changes inputs and changes due to farm-characteristics. In connection to these, though the average level of technical efficiency of the cereal farmers is as high as 57%, yet the result suggests that technical efficiency does not play significant role on TFP changes and output growth as the technical efficiency did not improve overtime which might be attributable to TEC effect. This implies that TFP growth and thus the output growth was largely due to adoption of improved technologies and SE rather than improvement in technical efficiency of the smallholders.

An important implication of these results is that the rate of TFP changes hence the output growth in cereal crops is mainly driven by technological progress, suggesting that policies aiming at enhancing the adoption of technological innovations and at increasing investments in agricultural extension services are significantly effective. Specifically, the increase of TFP in Ethiopian cereal production requires policies aiming at improving technological change, taking into account the farmer's know-how, could be intensified to improve cereal farm productivity growth significantly. For instance public investment in agricultural extension service and technological innovations, such as escalating adoptions strategies, could be intensified to improve cereal farm productivity growth and output growth. Therefore, government policies directed toward enhancing investment for agricultural extension service that improves technological progress and enables farmers to benefit from optimal input operations and farms best practice should form an essential part of the recommendations drawn from the study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Cocoa farmers' choice of alternative livelihood in mining communities in Upper Denkyira West District, Ghana

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Mining and cocoa production are important livelihoods for people in Ghana, particularly in rural communities like Upper Denkyira West District. However, mining activities can have negative impacts on cocoa production and access to basic necessities for the sustenance of the people. This study sought to investigate cocoa farmers' perception of the impact of mining on socio- economic activities in Upper Denkyira West District and the determinants of their choice of alternative livelihoods. A structured questionnaire was used to collect primary data from 211 respondents who were selected via a multi-stage sampling method for the study. The study found that cocoa farming households agree that mining has negative impacts on socio-economic activities in the district. It was also revealed that about two-thirds of the cocoa farming households were engaged in farm-based and nonfarm-based alternative livelihoods, in addition to cocoa farming. Results from the empirical multinomial logistic regression model showed that sex, years of formal education, farm income, technical skills, extension services, and perception that mining have reduced farm sizes, and farm outputs significantly influence cocoa farming households' choice of alternative livelihood. The study recommends the need for policies aimed at promoting skills acquisition and facilitating access to markets for products of alternative livelihoods.

Key words: Mining, cocoa, alternative livelihoods, multinomial logistic regression, Upper Denkyira West District, Ghana.

INTRODUCTION

In Africa, Ghana comes second after South Africa in terms of gold production and the country is also a significant exporter of other minerals such as bauxite, manganese and diamond (Holmes, 2018). There has been an increasing influx of foreign mining firms into Ghana since the Structural Adjustment Programme of the World Bank was introduced into the country in the mid-1980s. This has increased the mining of minerals in the country, which has contributed positively to the economy (Owusu-Ansah and Smardon, 2015). The sector has

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been a major contributor in terms of GDP, with an average contribution of 6.63% from 2010 to 2017, and government revenues including taxes (Ghana Statistical Service (GSS), 2018). Moreover, mining firms have also contributed to the provision of roads, jobs, clinics and other social amenities in mining areas. Small-scale and artisanal mining also offer opportunities for individuals and groups with inadequate resources to engage in mining as a livelihood source. Mining without license, known as ‘galamsey’, is also an important livelihood source for people without the required equipment (Boateng et al., 2014).

Despite the benefits of mining to the economy, it has negative impacts on the environment, health, agriculture and the society in general. Mining has resulted directly in the removal of vegetation cover, pollution of water bodies, depletion of soils and degradation of lands in mining communities. Some major waterbodies in the country such as the River Offin which passes through Upper Denkyira West District and serve as source of water for irrigating farms and other uses, have been polluted by mining activities (Adjei et al., 2012). Moreover, the six hospitals in Upper Denkyira West District assert that malaria is the most reported health problem in the district. The hospitals recorded about 18,300 cases of malaria in 2009 and 24,700 cases in 2010 alone (Upper Denkyira West District Assembly, 2012). According to Hilson (2001), the open pits left uncovered by the activities of illegal miners serve as breeding grounds for mosquitoes. Boateng et al. (2014) asserted that between 1 and 20 ha range of cocoa lands have been taken over by galamsey activities in several cocoa producing areas in Ghana such as Upper Denkyira West District. About 24,000 acres of forest lands have been taken over by miners in Diaso, the capital city of Upper Denkyira West District alone (Dokosi, 2019). Removal of vegetation cover by mining activities affect the carbon cycle and soil fertility in the district, thereby negatively affecting the productivity of tree crops such as cocoa (David and Mark, 2005).

Mining and agriculture require natural resources for their operations. The two sectors face competition over the use of resources such as land, water and human capital. About 75.29% of rural households are into agriculture (Ministry of Food and Agriculture (MoFA), 2016). This means that agriculture is the main economic activity of rural areas in Ghana. However, the output of agricultural produce such as maize, cowpea, sorghum and cocoa has reduced over the years (MoFA, 2016). For instance, output of cocoa in the country reduced from 1,024,554 metric tonnes in 2010/11 season to 953,566 metric tonnes in the 2014/15 season (MoFA, 2016). According to Bangmarigu and Qineti (2018), Ghana was the leading producer of cocoa in the world for decades until Ivory Coast overtook Ghana in 2013. Mining has been noted to be a major contributor to the reduction of cocoa yields from an estimated 207.25 to 98.03 kg/ha in Ghana (Osei-Bagyina, 2012). According to Essabra-Mensah (2013), illegal miners have encroached between 1 and 2 million hectares of cocoa lands in Ghana. Moreover, contribution of cocoa to GDP has shown a declining trend over the years. According to GSS (2018), cocoa contribution to GDP has reduced from 3.6% in 2011 to 1.8% in 2017. The decline in the output and contribution of cocoa to the economy has been attributed in part to the rampant mining activities in the country.

Mining firms as part of their corporate social responsibilities introduce projects, termed as alternative livelihoods, which are intended to recompense and assist people who have been negatively impacted by their mining operations. These projects are sustainable when they can cope with, and maintain their capabilities and assets, to create opportunities for future generations, and in the short and long run, profit the locality and the world (Krantz, 2001). Unfortunately, expectations of sustainable livelihood activities have not been fully realized in the District and this has led to an active involvement of residents in small-scale mining, especially ‘galamsey’ (Addah, 2014). Engaging in mining, particularly galamsey, as a source of livelihood is as a result of poverty (Adjei et al., 2012).

As established by several studies that mining, even though contributes positively towards the development of the economy, has several adverse impacts on cocoa production and agriculture, which is the main economic activity of households in Upper Denkyira West District. Hence, cocoa farming households in the district have to engage in alternative livelihoods to augment their basic source of income. This study therefore sought to investigate factors that influence cocoa farmers’ choice of alternative livelihoods. Specifically, the study assessed cocoa farming households’ perception on the impact of mining on socioeconomic activities in the study area; identified alternative livelihoods of cocoa farming households in the study area; analyzed factors influencing cocoa farmers’ choice of alternative livelihoods; and examined constraints faced by cocoa farming households in their alternative livelihoods in the study area. The study hypothesized that cocoa farmers’ choice of alternative livelihood is influenced by their socioeconomic characteristics such as sex, formal education, access to credit, farm ownership and their perception of the impact of mining on agriculture.

METHODOLOGY

Description of the study area

Upper Denkyira West District has the lowest population in the Central Region of Ghana with a population of 60,054 (GSS, 2013) (Figure 1). This constitutes about 2.7% of the population of the Region. Furthermore, the district is a rural community (GSS, 2013). The district covers only about 3% of the land area of the region with a size of about 579.21 km^2. Upper Denkyira West District lies within

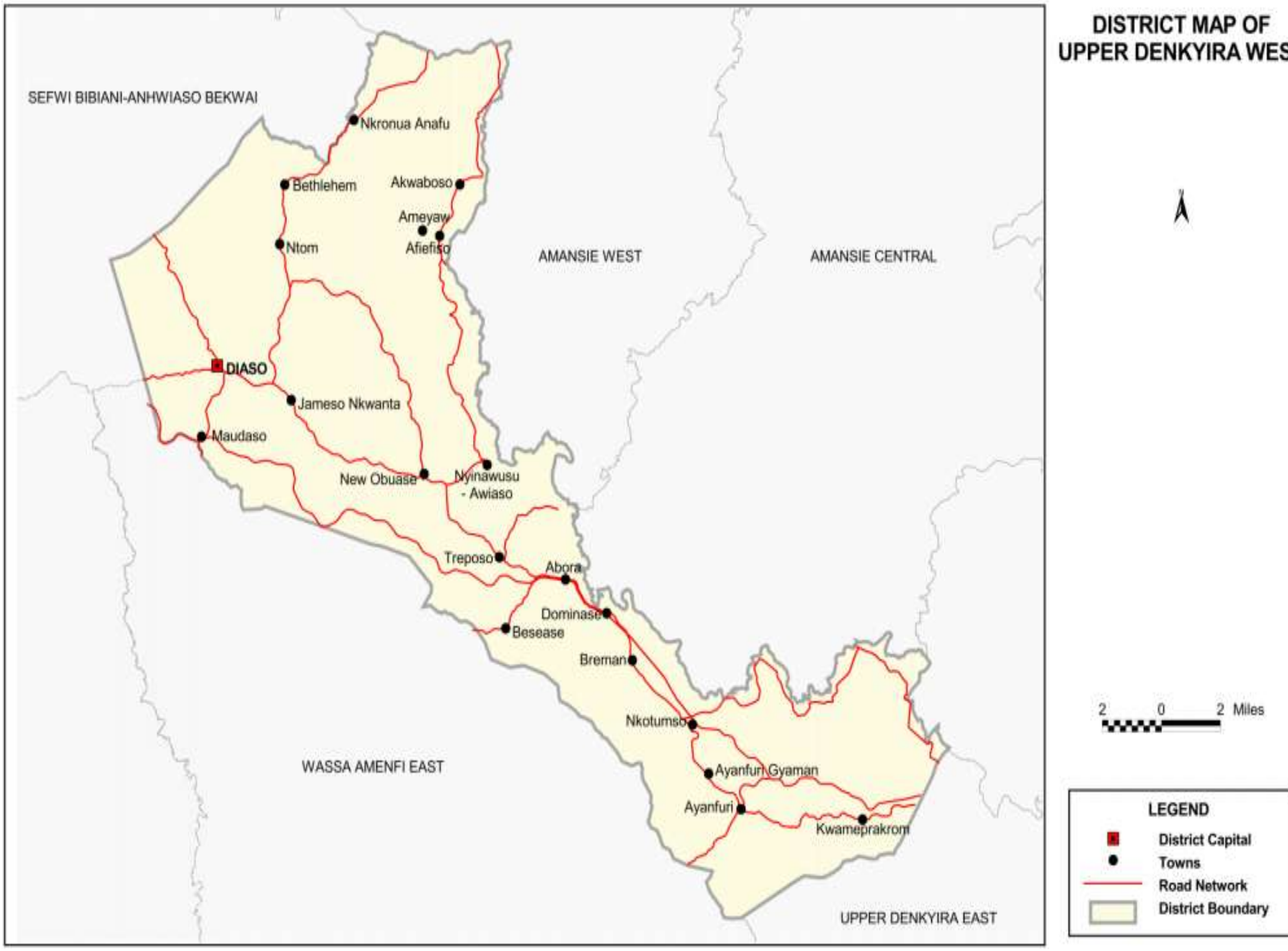

Figure 1. Upper Denkyira West District map.
Source: GSS (2013).

latitudes 5° 30' N and 6° 02' N of the equator and longitudes 1° W and 2° W of the Greenwich Meridian. Furthermore, the district falls within the semi equatorial zone with a mean temperature of 30°C per annum during hot periods and 26°C per annum during the cool periods. Also, the district has two rainy seasons in a year, with a mean rainfall of ranging between 1,200 and 2,000 mm (GSS, 2013).

Its capital is Diaso. The district is rich in minerals resulting in increasing mining activities, both legal and illegal in the area. Cocoa trees occupy about 50% of the total arable lands in the District. Also, about 71% of the workforce in the district is engaged in some form of agricultural activity such as crop farming and livestock rearing. In addition, about 7.9% of the populace are engaged in mining activities either by being employed formally or engaging in galamsey (GSS, 2013).

Population, sample size and sampling technique

The population for this study was 8,372 cocoa farming households (GSS, 2013). A household is defined to be a cocoa farming household, if at least one member in the household engages in cocoa farming. Multi-stage sampling technique was used to select 211 respondents for the study. First, five communities in the district where mining and farming occur simultaneously were chosen purposively. Second, the sample size from each community was determined proportionally based on the total cocoa farming households in the selected communities. Finally, a systematic random sampling technique was applied to select the cocoa farming households from each community. The systematic random sampling was done by selecting every tenth cocoa farming household in a community, starting with the first randomly interviewed cocoa farming household. The number of respondents interviewed from the five communities chosen for this study is shown in Table 1.

The sample size for this study was computed based on the following formula as provided by Yamane (1967):

$$n = \frac{N}{1+N(e^2)} = \frac{8372}{1+8372(0.06^2)} = 269$$

Where n = sample size, N = population size and e = level of

Table 1. Sampled respondents from each community.

Community	Cocoa farming households	Sample size (target)
Diaso	762	58 (73)
Jameso Nkwanta	710	52 (68)
Ayanfuri	647	41 (62)
Agona Portuguese	355	31 (34)
Maudaso	334	29 (32)
Total	2808	211 (269)

precision.

Therefore, the targeted sample size for the study was 269. However, a response rate of 78% representing 211 respondents was achieved during the data collection. According to Fincham (2008), the goal of every researcher is to have a response rate of at least 60% to minimize nonresponse bias. In addition, Perneger et al. (2005) concluded that even though nonresponse bias exists in surveys, it has less influence on the conclusion or outcome of the survey.

Data collection

Primary data and secondary information were used for this study. Secondary information were obtained from various sources including journals, articles, Ghana Statistical Services and Ministry of Food and Agriculture, relevant books and online sources. The secondary information provided information about the study area, relevant literature, and background to this study. Primary data focused on respondents' demographic characteristics, their perceptions on the impact of mining on socioeconomic activities and their alternative livelihoods. A structured questionnaire was used to collect primary data from the respondents.

Data analysis conceptual framework

According to the random utility theory, every individual is a rational decision maker, with the aim of choosing an option which offers the maximum utility from a choice set given some constraints (Loureiro and Umberger, 2007). Maximizing utility from a particular alternative livelihood motivates a household to choose a particular alternative livelihood. The individual assigns to each option among the available options a perceived value and chooses the option with the maximum benefit. The value given to each option is subject to the characteristics of the said alternative and of the individual. Therefore, it is assumed that, the cocoa farmers as rational beings, will choose from the set of alternative livelihood options, one which offers maximum utility, considering the attributes of themselves and that of the option. The utility for an individual *i* to choose option *j* in the available set of options *s, Uijs, is Uijs* = *Vijs* + *eijs*; where *Uijs* is the perceived utility the decision maker *i* assigns to each option *j*, *Vijs* is the vector of attributes related to option *j* and to the individual *i,* while *eijs* is the unobserved components of the function including the measurement errors, which are assumed to be independent of *Vijs*.

Empirical model

For this study, the outcome variable was the choice of alternative livelihood for cocoa farmers in the study area. The options were four categories, namely having no alternative livelihood (solely cocoa farming), having only farm-based alternative livelihood, having only nonfarm-based alternative livelihood and having both farm and nonfarm-based alternative livelihoods. Thus, a cocoa farming household has the option of a main alternative livelihood at a time. With the nature of a nominal variable with more than two categories, the multinomial logistic regression was appropriate to determine the factors that influence a cocoa farming household to select a particular alternative livelihood option as against others. The explanatory variables hypothesized to have effect on the dependent variable are presented in Table 2. Specifically, the econometric model for this study was specified as:

$$Yij = \beta0 + \beta_1 Age + \beta_2 Sex + \beta_3 Mar\_Stat + \beta_4 Edu\_yrs + \beta_5 HH\_Size + \beta_6 Dep\_Ratio + \beta_7 Tec\_Skills + \beta_8 Ext\_Serv + \beta_9 F\_Size + \beta_{10} F\_Own + \beta_{11} F\_Income + \beta_{12} Credit + \beta_{13} Percp\_Foutputs + \beta_{14} Percp\_Fsize + \mu i;$$

where Yij = Alternative livelihood options, β0 = Constant, β1-β14 = coefficient of explanatory variables, and μi = error term.

Cocoa farmers' perception on the impact of mining on socioeconomic activities in the district was assessed using a five-point Likert scale (strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5)) to estimate a perception index. Participants responded to specific perception statements which covered four socioeconomic or welfare indicators including agriculture, health, security and education. The mean score (MS) for each perception statement was calculated by this approach:

$$\frac{[(fsd \times 1)+(fd \times 2)+(fn \times 3)+(fa \times 4)+(fsa \times 5)}{x}$$

where fsd = frequency of strongly disagree; fd = frequency of disagree; fn = frequency of neutral; fa = frequency of agree; fsa = frequency of strongly agree, and x = total number of responses to the perception statement.

The overall perception index (PI) for the various perception indices was calculated using the following formula:

$$\frac{MS_{AGRI}+MS_{HEALTH}+MS_{SEC}+MS_{EDU}}{n}$$

where MS = mean score for perception on each socioeconomic indicator's statements (including agriculture, health, security and education); n = number of mean scores; AGRI = perception on agriculture; HEALTH = perception on health; SEC= perception on

Table 2. Definition of variables for the regression model.

Variable	Measurement	Expected Sign
Age (Age)	Age in years	-
Sex (Sex)	1 if male, 0 if otherwise	+
Marital Status (Mar_Stat)	1 if married, 0 if otherwise	+
Education (Edu_yrs)	Years of formal education	+
Household size (HH_Size)	Number of persons in the household	+
Dependency Ratio (Dep_Ratio)	Dependent household members divided by independent household members	+
Technical Skills (Tec_Skills)	1 if Yes, 0 if otherwise	+
Access to Extension Services (Ext_Serv)	1 if Yes, 0 if otherwise	-
Farm Size (F_Size)	Acres	-
Farm ownership (F_Own)	1 if Owner, 0 if otherwise	-
Farm income (F_Income)	Annual cocoa income in GH₵	-
Access to credit (Credit)	1 if Yes, 0 if otherwise	-
Perception that mining has reduced farm outputs (Percp_Foutputs)	1 = strongly disagree to 5 = strongly agree	+
Perception that mining has reduced farm sizes	1 = strongly disagree to 5 = strongly agree	+

security, and EDU = perception on education.

Descriptive statistics such as percentages, frequencies, pie chart, radar chart and means were used to summarize responses on the alternative livelihoods of cocoa farming households in the district.

Based on a five-point Likert scale (very low = 1: very high = 5), mean scores were computed and used to rank the constraints that affect the alternative livelihoods of cocoa farming households in the district. The constraint with the highest mean score was ranked as the most important in affecting the alternative livelihoods in the district. The mean score for each constraint was computed using this formula:

$$\frac{[(fvl \times 1)+(fl \times 2)+(fm \times 3)+(fh \times 4)+(fvh \times 5)]}{x}$$

where fvl = frequency of very low; fl = frequency of low; fm = frequency of moderate; fh = frequency of high; fvh= frequency of very high; and x = total number of responses to the constraint.

The Chi-square test of independence was conducted to ascertain if there exist a relationship between the alternative livelihoods and socioeconomic characteristics of cocoa farmers in the district.

Data collected from the respondents were subjected to statistical analysis with the use of Stata 14 and Microsoft Office Excel. Stata 14 was used to run the descriptive statistics and the multinomial logistic regression while Microsoft Office Excel was used to compute the perception index and create the charts.

RESULTS AND DISCUSSION

Socioeconomic characteristics of the cocoa farming households

Table 3 presents the results of the socioeconomic characteristics of the respondents. The average age of the household heads was 54 years indicating that cocoa farmers in the district are in the working category, but an aging population. The mean age of cocoa farmers in the district is slightly higher than the national average which is 50 years (Lowe, 2017). Majority of the interviewed households (81%) were male-headed households, and about 70% of the household heads had no technical skills. The technical skills identified included carpentry, masonry, driving, mechanic, barbering, electrician, hairdressing, tailoring, plumbing, painting, footwear making and blacksmithing. About 66% of the respondents had formal education, implying a high literacy among the cocoa farmers in the district. This agrees with the finding by Amoah (2013) that about 62% of the cocoa farmers in Upper Denkyira West District are literate. The average years of formal education of the respondents was seven years with majority being basic education.

About 67% of the respondents were married and majority (88.63%) owned their farmlands. Among the tenants, some rented the lands while others practiced share cropping. The average farm size of the respondents was 9.5 acres with a minimum of 0.5 acres and a maximum of 40 acres. This result corroborates the findings by International Cocoa Initiative (ICI, 2017) about

Table 3. Socioeconomic characteristics of cocoa farming households (n=211).

Categorical variable	Frequency	Percentage		
Sex				
Male	170	80.57		
Female	41	19.43		
Educational level				
No formal education	72	34.12		
Primary	72	34.12		
Middle school	47	22.27		
Secondary	13	6.16		
Tertiary	7	3.32		
Marital status				
Married	141	66.82		
Not Married	70	33.18		
Technical skills				
No	147	69.67		
Yes	64	30.33		
Farm ownership				
Landlord	187	88.63		
Tenant	24	11.37		
Extension service				
No	107	50.71		
Yes	104	49.29		
Electricity access				
No	6	2.84		
Yes	205	97.16		
Credit access				
No	113	53.55		
Yes	98	46.45		
Alternative livelihood				
No	85	40.28		
Yes	126	59.72		
Continuous variable	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Education in years	7	5.45	0	20
Age (years)	54	13.02	27	82
Household size	7	3.19	1	18
Number of dependents	3.56	1.84	0	8
Dependency ratio	1.52	1.21	0	6
Farm Size (acres)	9.52	7.59	0.5	40
Farm income (GH₵)	4911.21	4243.58	900	19950

Source: Field Survey (2019).

cocoa farming in West Africa. International Cocoa Initiative (2017) found that the average size of cocoa farms is 8.6 and 9.88 acres in West Africa and Ghana, other crops such as vegetables, cocoyam, plantain and cassava were grown mainly for subsistence with a few respondents indicating that they only sell the surplus. The average annual income from the sale of cocoa by the farmers was GH₵4,911.21 (USD917.14) with the minimum income being GH₵900 (USD168.07) and the maximum being GH₵19,950 (USD3725.56).

The average household size was seven persons, with the minimum being one person and the maximum being 18 persons. This concurs with the finding by ICI (2017) that the average household size of cocoa farmers in West Africa is eight. The household size comprised mostly of the household head with his or her nuclear family and/or other relatives. The average number of dependents in a cocoa farming household was found to be 3.56. The dependents in a cocoa farming household included children, aged and disabled household members, who do not engage in any economic activity. The average dependency ratio for the households was 1.52, with the highest being six and the lowest being zero. Moreover, more than half (53.55%) of the cocoa farming households did not have access to credit, whether formal or informal in the previous production season. That notwithstanding, only two cocoa farming households borrowed in the previous year; the amounts borrowed were GH₵600 and GH₵1,500 for their petty businesses, respectively. About 50.71% of the farming households did not have access to extension services. Majority (59.72%) of the cocoa farming households were engaged in alternative livelihoods in addition to their cocoa farming.

Cocoa farmers' perception on the impact of mining on socioeconomic activities

Perception index was used to assess cocoa farming households' perception of the impact of mining on socioeconomic activities in the study area. The socioeconomic activities included agriculture, health, security and education. Figures in parenthesis in Table 4 represent the scores of the level of agreement multiplied by the frequency of cocoa farmers who selected that level of agreement. The overall perception index was 3.91 (Table 4), implying that the cocoa farmers perceive mining to have negative impact on socioeconomic activities in the district. The mean score of 4.26 for the impact of mining on agriculture indicates that the respondents agreed that mining has negatively impacted agriculture in the district (Table 4). Specifically, the respondents agreed that mining has reduced the size of lands available for farming; this opinion is supported by the finding by Boateng et al. (2014) that agricultural lands have been taken over by miners in mining communities in Ghana. Furthermore, the respondents had a strong agreement (4.77) to the statement that mining has polluted water bodies needed for irrigation and domestic uses. This perception also corroborates the finding by Kitula (2005) that pollution of water bodies with mercury and dust is the most critical impact of mining in mining communities. The respondents also agreed to the statement that mining has reduced the supply of labour for farming activities. Moreover, they agreed that farm outputs have also reduced due to mining; this agrees with the finding by Adjei et al. (2012) that mining has reduced agricultural outputs in Ghana. Some respondents disclosed that they used to grow significant quantities of rice some years ago in marshy areas until mining started in the district and destroyed these marshy areas conducive for rice production.

Also, the perception index for health was estimated at 3.86, indicating an agreeing perception of the negative impact of mining on health. With a mean score of 4.89, the respondents had a strong agreement to the statement that mining has increased malaria cases; they attributed this to the pits left unfilled by the miners, which become breeding grounds for mosquitoes. This perception agrees with the assertion by Hilson (2001) that mining activities leave stagnated water which serves as a breeding ground for mosquitoes. However, in terms of the statement that mining has increased respiratory diseases in the district, the respondents had a neutral point of view, explaining their unawareness of any particular respiratory disease which is predominant among people in the district. However, the respondents had an agreeing perception towards the statements that mining has increased dust in the air as well as death cases in the district. Nonetheless, findings by Aswathanarayana (2003) indicate that the procedures involved in mining, especially processing of minerals result in respiratory diseases such as tuberculosis and silicosis. The respondents explained that the dust in the air is made worse during the harmattan season. They also had an agreeing perception to the statement that mining has polluted waterbodies making them unsafe for drinking. They linked this to the muddy nature of waterbodies and thus suspect their contamination with some chemicals from the mining activities. They further expressed their concerns that there are frequent water shortages because the rivers in the district have been polluted. The aforementioned opinions of the cocoa farming households about the negative impacts of mining on health agree with findings by Kitula (2005) and Hilson (2009) who reported that pits and underground excavations by miners are associated with risks and accidents.

Moreover, Table 4 shows that the perception index of the impact of mining on security (such as incidence of robberies) in the district was 3.58, indicating that the respondents agree that mining has negatively impacted security in the district. This result is in line with Kitula (2005), who reported that mining has increased robberies in mining areas due to the influx of migrants into mining areas in search of jobs. However, some respondents who disagreed to that statement explained that the increased robberies are as a result of the ban on galamsey in the

Table 4. Cocoa farmers' perception on the impact of mining on socioeconomic activities.

Perception statements	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean score
Mining has reduced farmland sizes	6 (6)	17 (34)	15 (45)	105 (420)	68 (340)	4.00
Mining has caused decline in soil fertility	1 (1)	3 (6)	17 (51)	93 (372)	97 (485)	4.33
Mining has polluted waterbodies needed for irrigation	0 (0)	5 (10)	3 (9)	27 (108)	176 (880)	4.77
Mining has reduced labour supply for farming	2 (2)	16 (32)	10 (30)	114 (456)	69 (345)	4.10
Mining has decreased farm output	1 (1)	8 (16)	17 (51)	133 (532)	52 (260)	4.08
Perception Index on agriculture						**4.26**
Mining has increased malaria cases	1 (1)	0 (0)	0 (0)	20 (80)	190 (950)	4.89
Mining has caused increase in respiratory diseases	49 (49)	31 (62)	64 (192)	51 (204)	16 (80)	2.79
Mining has polluted waterbodies making them unsafe for drinking	17 (17)	35 (70)	2 (6)	23 (92)	134 (670)	4.05
Mining has increased dust in the air	3 (3)	29 (58)	58 (174)	84 (336)	37 (185)	3.58
Mining has resulted in deaths of people	7 (7)	5 (10)	47 (141)	75 (300)	77 (385)	4.00
Perception Index on health						**3.86**
Mining has increased robbery cases	3 (3)	11 (22)	14 (42)	40 (160)	143 (715)	4.46
Mining has increased rape cases	47 (47)	43 (86)	70 (210)	42 (168)	9 (45)	2.83
Mining has resulted in strives between residents and mining companies	10 (10)	33 (66)	60 (180)	58 (232)	50 (250)	3.50
Mining has increased drug abuse	2 (2)	23 (46)	68 (204)	90 (360)	28 (140)	3.56
Mining has increased prostitution	13 (13)	39 (78)	36 (108)	69 (276)	54 (270)	3.53
Perception Index on security						**3.58**
Mining has increased school dropout	6 (6)	35 (70)	18 (54)	39 (156)	113 (565)	4.03
Mining has increased truancy in school	6 (6)	14 (28)	11 (33)	72 (288)	108 (540)	4.24
Mining has increased child labour	34 (34)	35 (70)	19 (57)	54 (216)	69 (345)	3.42
Mining has reduced academic performance	7 (7)	15 (30)	22 (66)	70 (280)	97 (485)	4.11
Perception Index on education						3.95
Overall Perception Index						3.91

Source: Field Survey (2019).

country. The respondents also agreed that mining has resulted in strives between residents and mining companies. This finding concurs with that of Boateng et al. (2014) who found that mining is a major source of conflict between mining firms and residents of mining communities. The respondents agreed that mining has increased drug abuse and also that mining has increased prostitution in the district. This opinion is supported by the finding by Dogbe (1995) that mining has increased drug abuse and prostitution in mining areas.

Lastly, the respondents had an agreeing perception that mining has negatively impacted education in the district. Table 4 shows that the

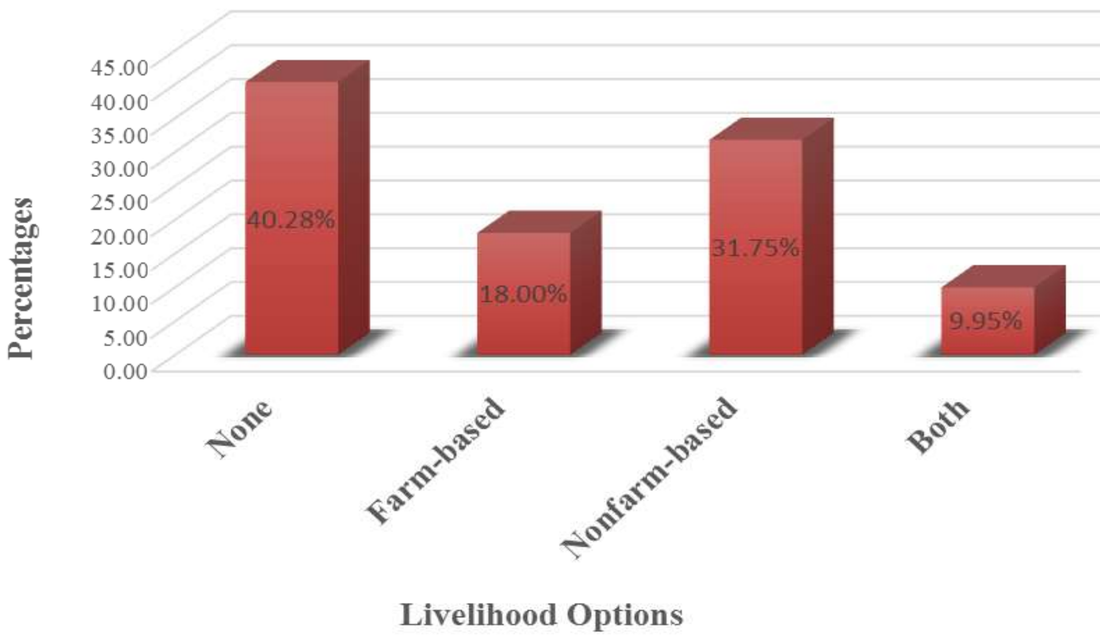

Figure 2. Alternative livelihood options.
Source: Field Survey (2019).

respondents agreed that mining have increased school dropouts and also truancy in schools. This, they attributed to the fact that the students find no reason for being in school if the aim of education is to make money in the future. The respondents indicated that the students believe a job after school is not guaranteed, but galamsey offers them the income needed for survival. Furthermore, the respondents agreed that mining has reduced academic performance of students in the district. According to Boateng (2017), students indulge in galamsey activities during school hours, which have resulted in the drop in the academic performance of students in mining communities. The respondents, however, had a neutral view on the statement that mining has increased child labour in the district.

Alternative livelihoods of cocoa farmers in Upper Denkyira West District

About 60% of the cocoa farming households interviewed were engaged in alternative livelihoods in addition to their cocoa farming (Figure 2). The results show that 18% of the total respondents engaged in only farm-based activities in addition to cocoa farming as their alternative livelihoods, 32.54% engaged in nonfarm-based activities in addition to cocoa production, and the remaining 9.95% engaged in both farm-based and nonfarm-based alternative livelihoods in addition to cocoa production. These findings agree with a study by Yizengaw et al. (2015) who reported that majority of rural farming households choose a nonfarm-based alternative livelihood as against a farm-based alternative to diversify risks. Since cocoa is the main income source of the cocoa farming households in the study area, income from the sale of food crops such as cassava and vegetables was considered as an alternative livelihood. The farm-based alternative livelihoods identified from the study were sale of food crops as well as rearing of livestock (Figure 3). The nonfarm activities included artisans, traders, among others (Figure 4).

Major alternative livelihoods

Figures 3 and 4 show the distributions of the farm-based and nonfarm-based alternative livelihoods of the cocoa farmers in the district, respectively. Livestock rearing was the major (69%) alternative livelihood among the farm-based alternative livelihoods (Figure 3), indicating that livestock rearing is a popular alternative livelihood among the cocoa farmers in the district. This result is inconsistent with a study by Njuguna (2015) who found that crop farming such as potato, beans and maize farming, was the major alternative livelihood among rural households in the Solio Settlement in Kenya. The major livestock reared by the respondents included chicken, sheep and goat. Most of the livestock farmers further revealed that they allow their livestock to free- range. This indicates the practice of agro-pastoral farming as recommended for perennial crop production like cocoa. Figure 4 shows that carpentry was the major alternative livelihood among the non farm-based alternative

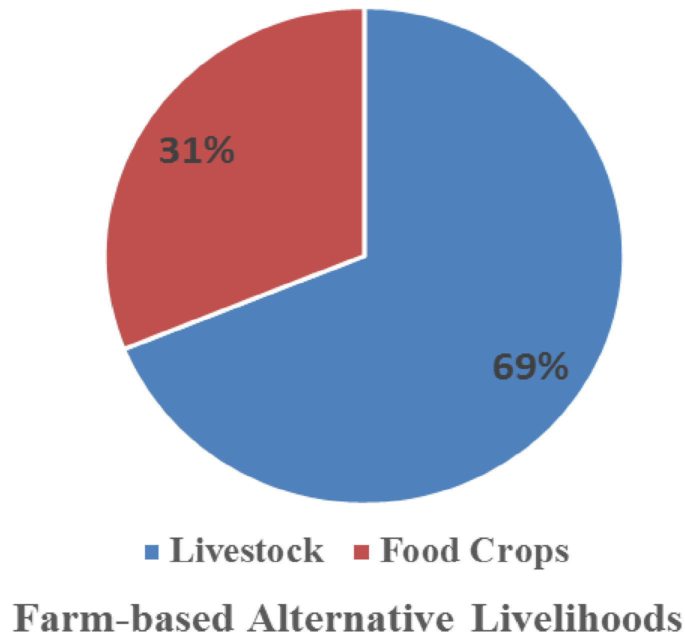

Figure 3. Farm-based alternative livelihoods.
Source: Field Survey (2019).

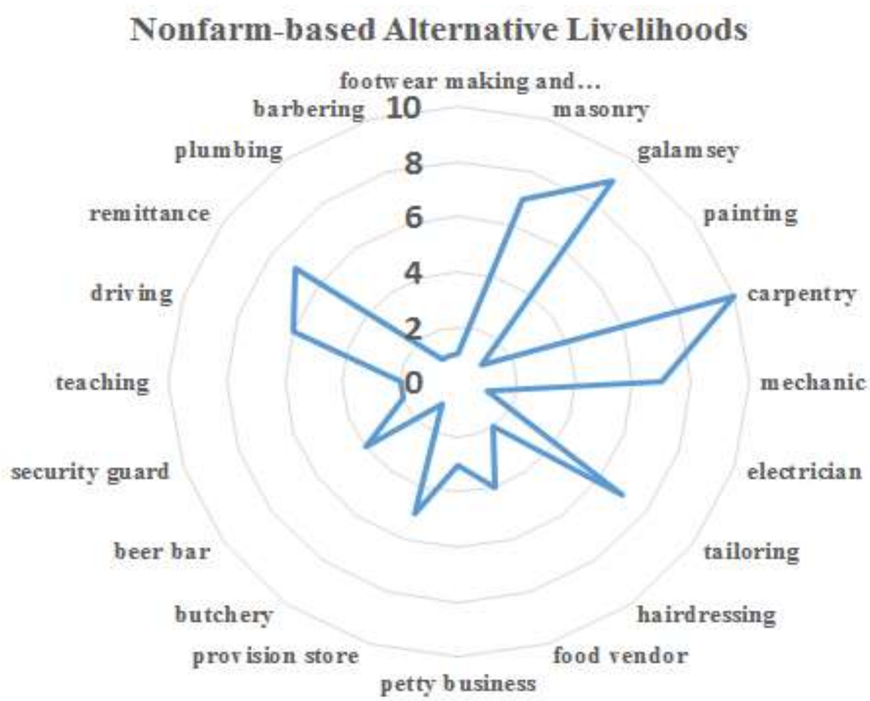

Figure 4. Nonfarm-based alternative livelihoods.
Source: Field Survey (2019).

livelihoods, followed by galamsey which explains the high incidence of mining in the study area. Most of the nonfarm-based alternative livelihoods of the cocoa farmers including carpentry and tailoring, among others, were skill-based. This shows that possessing a technical skill enhances the chance of a household to have a

Table 5. Relationship between cocoa farmers' socioeconomic characteristics and alternative livelihoods.

Variable	None [N (%)]	Farm-based [N (%)]	Nonfarm-based [N (%)]	Both [N (%)]	Total [N (%)]	Pearson chi^2 (3)	Prob.
Sex							
Female	15 (37)	7 (17)	13 (32)	6 (15)	41 (100)	1.32	0.73
Male	70 (41)	31 (18)	54 (32)	15 (9)	170 (100)		
Formal education							
No	41 (57)	18 (25)	12 (17)	1 (1)	72 (100)	**26.38*** **	**0.00*** **
Yes	44 (32)	20 (14)	55 (40)	20 (14)	139 (100)		
Marital status							
Unmarried	29 (41)	14 (20)	20 (29)	7 (10)	70 (100)	0.60	0.90
Married	56 (40)	24 (17)	47 (33)	14 (10)	141 (100)		
Technical skills							
No	80 (54)	37 (25)	21 (14)	9 (6)	147 (100)	**91.56*** **	**0.00*** **
Yes	5 (8)	1 (2)	46 (72)	12 (19)	64 (100)		
Farm ownership							
Tenant	11 (46)	4 (17)	7 (29)	2 (8)	24 (100)	0.36	0.95
Landlord	74 (40)	34 (18)	60 (32)	19 (10)	187 (100)		
Extension access							
No	41 (38)	19 (18)	41 (38)	6 (6)	107 (100)	**7.28***	**0.06***
Yes	44 (42)	19 (18)	26 (25)	15 (14)	104 (100)		
Access to credit							
No	45 (40)	20 (18)	37 (33)	11 (10)	113 (100)	0.11	0.99
Yes	40 (41)	18 (18)	30 (31)	10 (10)	98 (100)		

N = frequency Prob = Probability (* = significant at 10%, *** = significant at 1%).
Source: Field Survey, 2019.

nonfarm-based alternative livelihood. There is therefore the need to promote skills acquisition and market access for cocoa farmers in the district.

Relationship between cocoa farmers' socioeconomic characteristics and alternative livelihoods

Table 5 presents the results from the Chi-square test of independence on the relationship between the alternative livelihoods and socioeconomic characteristics of cocoa farmers in the district. The socioeconomic variables included sex, formal education, marital status, technical skills, farm ownership, access to credit and extension services (Table 5). The results showed that there is an association between formal education and choice of alternative livelihood. Household heads having no formal education were found to be more likely to have no alternative livelihood whereas household heads having formal education were more likely to engage in nonfarm-based alternative livelihoods. This is mainly because formal education creates opportunities for employment outside agriculture. This supports the assertion by Adi (2007) that literates have skills that can secure them employment off-farm. Again, Khatun and Roy (2012) stated that lack of education is a major barrier to entry into the nonfarm sector. Similarly, the results showed that there is an association between the alternative livelihood choice of a cocoa farming household and whether the household head possesses a technical skill or not. Household heads who do not possess technical skills were more likely to have no alternative livelihood whilst household heads with technical skills were found to be more likely to be engaged in nonfarm-based alternative livelihoods. This is because technical skills improve a person's chances of having a job in the nonfarm sector. This finding is consistent with Njuguna (2015) who found that possession of technical skills influences a household to diversify into a non-agricultural livelihood. Moreover, a cocoa farming household's choice of an alternative livelihood option and access to agricultural extension services was found to be associated. Households without access to agricultural extension services were found to be more likely to be engaged in nonfarm-based alternative livelihood or have no alternative livelihood. However, households having access to agricultural extension services were more likely to have no alternative livelihoods. Access to extension services improves farm productivity and income, and it is assumed that farmers with extension services have adequate income from their farm activities.

Factors influencing the choice of alternative livelihoods

The results of the multinomial logit regression on factors influencing the choice of alternative livelihood are presented in Table 6. The empirical results show a Pseudo R^2 value of 0.29 which indicates that the explanatory variables explain the variations in the dependent variable by 29%. The empirical results also show that the LR Chi-square value (155.72) is statistically significant at 1% which indicates that the independent variables included in the model jointly explain the variation in the choice of alternative livelihoods by cocoa farming households in the district. The cocoa farming households were grouped into four categories according to their engagement in alternative livelihoods, namely none; farm-based; nonfarm-based, and both farm and nonfarm- based (Figure 2). The odds ratio (OR) was used to determine the influence of the independent variables on the likelihood of a household choosing a certain livelihood option compared to having no alternative livelihood. Having no alternative livelihood (solely cocoa farming) was used as the base category. The regression results revealed that a cocoa farmer's choice of an alternative livelihood is influenced by sex, possession of technical skills, access to extension services, years of formal education, farm income, perception that mining has reduced farm sizes and perception that mining has reduced farm outputs (Table 6). The results show that the relative probability of a household head to engage in a farm-based alternative livelihood was 67% more likely than having no alternative livelihood as the respondent perceives that mining has reduced farm sizes. On the other hand, households which perceive that mining has reduced farm outputs were 34% less likely to choose farm-based alternative livelihood compared to having no alternative livelihood. This implies that as a cocoa farming household perceives that mining has reduced farm outputs, the household would rather not have any farm-based alternative livelihood.

Also, households which perceive that mining has reduced farm sizes were 1.5 times interested in choosing a nonfarm-based alternative livelihood relative to having no alternative livelihood. This is because the non farm-based alternative livelihoods require very little or no land space for operations. Thus, a cocoa farming household would rather engage in a nonfarm-based alternative livelihood such as carpentry or driving which requires no land if the household perceives that mining has reduced farm sizes. This finding is consistent with that of Khatun and Roy (2012), who found that limitation of land suitable for agricultural production influences the choice of income and livelihood diversifications. Moreover, a household head was about 27 times more interested to engage in a nonfarm-based alternative livelihood in comparison with having no alternative livelihood if he or she possesses a technical skill. Thus, a household head would rather engage in an activity in which he or she has a technical skill to earn additional income compared to having no alternative livelihood. This result agrees with literature as a similar finding was made in Eastern Tigray, Ethiopia (Zerai and Gebreeziabher, 2011). Furthermore, a household which has access to agricultural extension services was about five times interested to engage in both farm and nonfarm-based alternative livelihoods relative to having no alternative livelihood. This finding agrees with the assertion by Hofs et al. (2006) that lack of extension service leads to poor performance of farmers. They found that access to extension services improve farm productivity and income. Thus, having access to extension services can improve the income from the cocoa farming thereby affording the cocoa farmers the financial capital to invest into farm-based and nonfarm-based alternative livelihoods in addition to cocoa farming. In addition, it was found that a household with the household head possessing a technical skill was about 22 times interested to engage in both farm-based and nonfarm-based alternative livelihoods as compared to having no alternative livelihood. The estimated model also indicates that the relative probability of a male-headed household to engage in both farm and nonfarm-based alternative livelihoods rather than having no alternative livelihood was about 91% less likely. This can be attributed to the fact that per the culture of Ghanaians, males are mostly family heads. Family heads are responsible for sharing family lands; thus, males have easier access to more farm sizes (FAO, 2012). This result disagrees with the finding by Njuguna (2015) that male-headed households are more likely to be engaged in a nonfarm-based alternative livelihood rather than having no alternative livelihood. This result also disagrees with the finding by Babatunde and Qaim (2009) that males are more likely to have alternative livelihoods because males have more access to employment opportunities both on and off the farm.

Again, as the farm income of a household increases, the less likely the household was engaged in both farm and nonfarm-based alternative livelihoods. However, the influence of farm income on the decision by a cocoa farming household to choose both farm and nonfarm-based alternative livelihoods compared to having no

Table 6. Multinomial regression results on farmers' choice of alternative livelihood.

Variable	Odds ratio	Std. error	z-value	p-value	(95% Conf. Interval)	
Farm-based						
Per_fsize	**1.669****	0.418	2.05	0.041	1.022	2.726
Per_foutput	**0.663***	0.156	-1.75	0.080	0.418	1.051
Sex	1.411	0.972	0.50	0.617	0.366	5.446
Eduyears	0.999	0.038	-0.01	0.995	0.928	1.077
Age	0.977	0.021	-1.07	0.284	0.936	1.020
Maritalstat	0.648	0.367	-0.76	0.444	0.213	1.969
Techskills	0.261	0.309	-1.14	0.256	0.026	2.652
Hhsize	1.005	0.085	0.06	0.951	0.851	1.187
Depratio	1.077	0.190	0.42	0.675	0.761	1.523
Farmownership	1.411	0.949	0.51	0.609	0.377	5.276
Farmsize	1.020	0.038	0.54	0.591	0.948	1.098
Extser	0.897	0.396	-0.25	0.805	0.377	2.131
Credit	0.931	0.393	-0.17	0.866	0.407	2.130
Farmincome	0.999	0.000	-0.19	0.849	0.999	1.000
Constant	0.723	1.359	-0.17	0.863	0.018	28.791
Nonfarm-based						
Per_fsize	**1.531***	0.376	1.74	0.083	0.946	2.476
Per_foutput	1.151	0.328	0.49	0.622	0.659	2.011
Sex	0.376	0.295	-1.25	0.213	0.081	1.750
Eduyears	1.009	0.049	0.18	0.861	0.917	1.109
Age	0.959	0.026	-1.53	0.125	0.901	1.012
Maritalstat	2.414	1.676	1.27	0.205	0.619	9.417
Techskills	**26.934*****	16.197	5.48	0.000	8.287	87.54
Hhsize	1.012	0.107	0.11	0.911	0.822	1.246
Depratio	0.776	0.164	-1.20	0.232	0.513	1.175
Farmownership	1.719	1.231	0.76	0.449	0.423	6.993
Farmsize	0.946	0.055	-0.95	0.342	0.845	1.060
Extser	0.780	0.379	-0.51	0.609	0.301	2.021
Credit	1.242	0.574	0.47	0.639	0.502	3.071
Farmincome	0.999	0.000	-1.17	0.243	0.999	1.000
Constant	0.689	1.405	-0.18	0.855	0.013	37.485
Both						
Per_fsize	1.479	0.459	1.26	0.208	0.804	2.718
Per_foutput	1.481	0.555	1.05	0.295	0.711	3.088
Sex	**0.086****	0.086	-2.45	0.014	0.012	0.612
Eduyears	**1.133***	0.083	1.69	0.091	0.981	1.308
Age	0.972	0.036	-0.78	0.433	0.904	1.044
Maritalstat	2.259	1.993	0.92	0.356	0.401	12.731
Techskills	**22.179*****	17.004	4.04	0.000	4.936	99.663
Hhsize	1.107	0.145	0.78	0.436	0.856	1.432
Depratio	0.692	0.196	-1.30	0.195	0.397	1.207
Farmownership	2.417	2.582	0.83	0.409	0.298	19.616
Farmsize	0.978	0.060	-0.36	0.717	0.867	1.102
Extser	**4.682****	3.311	2.18	0.029	1.171	18.720
Credit	1.404	0.869	0.55	0.584	0.417	4.724
Farmincome	**0.999***	0.000	-1.88	0.060	0.999	1.000
Constant	0.013	0.037	-1.56	0.118	0.000	3.003

LR chi^2 (42) = 155.72, Prob > chi^2= 0.0000, Pseudo R^2 = 0.2908, Log likelihood = -189.88 (* = significant at 10%, ** = significant at 5%, *** = significant at 1%).
Source: Field Survey (2019).

Table 7. Constraints faced in farm-based alternative livelihoods (n = 59).

Constraint	1*F	2*F	3*F	4*F	5*F	Mean score	Rank
Access to water supply	2	14	57	76	60	3.54	1st
Access to land	5	18	27	100	55	3.47	2nd
Access to extension services	10	8	36	68	80	3.42	3rd
Housing for livestock	4	18	57	84	30	3.27	4th
Access to credit	11	20	51	52	40	2.95	5th
Access to reliable markets	10	20	69	52	15	2.81	6th
Theft	22	20	27	60	15	2.44	7th
Pests and diseases	611	58	51	8	0	2.17	8th
Perishability of produce	53	0	0	8	20	1.37	9th

1=Very Low, 2=Low, Moderate=3, High=4, Very High=5 and F=Frequency.
Source: Field Survey (2019)

Table 8. Constraints faced in nonfarm-based alternative livelihoods (n= 88).

Constraint	1*F	2*F	3*F	4*F	5*F	Mean score	Rank
Access to credit	12	20	66	108	85	3.31	1st
Access to water supply	21	30	60	80	60	2.85	2nd
Access to reliable markets	18	40	108	40	20	2.57	3rd
Access to land	34	50	15	68	35	2.30	4th
Access to reliable electricity	47	42	39	28	0	1.77	5th
Legal Issues	75	0	0	24	35	1.52	6th
Fuel Prices	76	4	6	28	5	1.35	7th

1=Very Low, 2=Low, Moderate=3, High=4, Very High=5 and F=Frequency.
Source: Field Survey (2019).

alternative livelihood was almost at par. Lastly, it was also found that as the years of formal education of the household head increased, the more likely the household head was engaged in both farm and nonfarm-based alternative livelihoods compared to having no alternative livelihood. The relative probability for a household to choose both farm and nonfarm-based alternative livelihoods compared to having no alternative livelihood was 13% more likely as the years of formal education increases. Formal education creates the opportunity for a person to diversify the use of his/her resources; thus, a household head with formal education is likely to have an alternative livelihood in both formal and informal sectors aside the cocoa farming.

Constraints faced in farm-based alternative livelihoods

Table 7 shows the constraints faced by the respondents who were engaged in farm-based alternative livelihoods. From the study, the highest and lowest ranked constraints were access to water supply and the perishability of their food crop produce, mostly vegetables, respectively. The respondents complained that they face difficulties in accessing water to irrigate their farms. They mentioned that the waterbodies in the District have been polluted so they depend heavily on the rain to irrigate their crops. The farmers attributed this problem to the increasing activities of miners in the district. Findings by Babulo et al. (2008) revealed that infrastructure such as water supply affects intensity and the variety of agricultural produce cultivated in rural communities. Moreover, access to land for grazing and also cultivating arable food crops was found to be the second highest constraint since the farmers in this category were into livestock farming and crop farming as alternative livelihoods. They attributed this problem to the increasing houses being constructed as well as mining in the district.

Constraints faced in nonfarm-based alternative livelihoods

Table 8 shows the constraints faced by the cocoa farming households which were engaged in nonfarm-based alternative livelihoods. The highest and lowest ranked constraints faced by farmers in this category were access to credit and fuel prices respectively. The farmers attributed the access to credit being a major constraint to the fact that requirements of the financial institutions in giving them loans are too stringent such as requesting for collaterals. They also attributed it to the fact that they themselves fear the risk of defaulting loan repayment. Moreover, access to water supply was ranked as the second highest constraint faced by the respondents. The respondents which were engaged in galamsey activities stated that they face legal complications due to the illegality of their alternative livelihood.

CONCLUSION AND RECOMMENDATIONS

This study sought to assess the perception of cocoa farming households on the impact of mining on their socioeconomic activities and the factors that influence their choice of alternative livelihoods. The results showed that cocoa farming households agree that mining has negative impacts on socioeconomic activities in the study area. They agreed that mining has negatively impacted agriculture, health, security and education in the district. The study also found that majority of the cocoa farming households were engaged in alternative livelihoods in addition to their cocoa farming. The alternative livelihoods identified were farm-based only, nonfarm-based only, and a combination of both. A Chi-square test of association between socioeconomic factors of cocoa farmers and the alternative livelihood options revealed that formal education, possession of technical skills and access to extension services have associations with the choice of an alternative livelihood by cocoa farmers. The multinomial regression results showed that sex, years of formal education, possession of technical skills, access to extension services, farm income, perception that mining has reduced farm sizes and farm outputs are factors that influence a cocoa farming household to choose a particular alternative livelihood as against having no alternative livelihood. The study found that the respondents face some constraints with regards to the alternative livelihoods they are engaged in. With regards to farm-based alternative livelihoods, the highest ranked constraint the respondents face was access to water supply for irrigation whilst the highest ranked constraint faced by respondents who were into nonfarm-based alternative livelihoods was access to credit.

The study recommends the need for the media and educational institutions to intensify education on the negative effects of mining activities on socioeconomic activities in the district. Increased education will help shape the idea of the people engaged in mining activities, especially illegal miners to help improve the quality of water sources and other resources in the district. It is also expedient to create job opportunities for the youth who are into mining in order to mitigate mining activities in the study area. The study showed that technical skills were associated with engagement in alternative livelihoods. It is therefore recommended that policy makers initiate a policy for promoting skills acquisition as well as facilitating access to markets for products of alternative livelihoods in the district. This will help lessen engagement in illegal mining activities. Moreover, the Ministry of Food and Agriculture should improve extension services in the district. An improvement in extension services, especially to the food crops will ensure that the cocoa farmers can increase their engagement in production of food crops to supplement their income from cocoa.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Analysis of labor opportunity cost on the economic profitability of fertilizer microdosing (FM) in Burkina Faso

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This paper analyses the effect of labor opportunity cost on economic profitability of fertilizer microdosing (FM) in Burkina Faso. In order to assess the incremental change in net income when the investment cost increases and takes into account labor opportunity cost, the marginal value cost ratio (MVCR) approach is used. Using data from farmer's field, the results showed that for both crops, the median yield of the fertilizer microdosing plots is 500 kg.ha^{-1}, which is slightly higher than yield from recommended dose plots. Moreover, the rate of fertilizer microdosing plots of millet with a marginal value cost ratio above 2 shifts from 50% (without labor opportunity cost) to 41% (with labor opportunity cost) and not even one recommended dose plots reached this threshold. These findings argued that fertilizer microdosing adopters remain economically profitable for farmers compared to traditional practices despite the opportunity cost of labor. However, because of its importance in the process of fertilizer microdosing adoption, labor costs must be included in its economic evaluation. The results of this study confirm the need to accelerate mechanization of fertilizer microdosing application.

Key words: Fertilizer microdosing (FM), labor, marginal value cost ratio, Burkina Faso.

INTRODUCTION

Agricultural innovation, which is defined as a new idea, technique or often modification of a traditional practice seem to offer opportunities that substantially increase farmers' agricultural production and income (Adams,

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1982). The objective of fertilizer microdosing (FM) promoted throughout the semi-arid countries of West Africa since the 1990s was to achieve that outcome through an improvement in the fertilizer use efficiency and reduction in investment costs (Bationo et al., 1998).

Fertilizer microdosing is the application of mineral fertilizers in small doses per hill (Hayashi et al., 2008). This technology was developed to remove some obstacles due to the low rate of adoption of agricultural technologies, particularly mineral fertilizers, which have long been recognized as essential components for increasing agricultural productivity in semi-arid countries such as Burkina Faso (FAO, 2013; Crawford et al., 2006). One of the main problems was the high cost of fertilizer, which is often unaffordable for farmers, particularly smallholder's farmers (Holtzman et al., 2013; Abdoulaye and Sanders, 2005). Some studies further identified imperfect input and credits markets along with high transportation costs as impediments to the adoption and intensification of agricultural innovations (Liverpool-Tassie et al., 2015; Holtzman et al., 2013). Thus, Twomlow et al. (2011) perceived fertilizer microdosing as a pathway towards green revolution in Africa. Further, Aune and Bationo (2008) highlighted that the use of low-cost technologies like microdose could prompt farmers towards participating in agricultural intensification.

In terms of impacts, the results of previous studies showed a significant income increase for farmers who adopted fertilizer microdosing as well as an improvement of their food security (Okebalama et al., 2016; Fatondji et al., 2016; Bagayoko et al., 2011). However, the analysis of these studies revealed that not all the additional costs such as labor cost were taken into account particularly in the economic profitability evaluation of fertilizer microdosing. Indeed, the application of fertilizer microdosing generates an additional cost in terms of labor due to the greater effort needed to bury the fertilizer compared to the traditional practices (Liverpool-Tasie et al., 2015; Pender et al., 2008; Tovihoudji et al., 2018). In addition, analysis of the results of empirical studies indicated that labor availability would be one of the main constraints affecting fertilizer microdosing adoption (Okebalama et al., 2016; Tabo et al., 2007). This labor constraint led researchers to work on how to mechanize the application of fertilizer microdosing for a wider adoption by farmers (Tabo et al., 2007). Thus, an assessment of the economic profitability of hill placement technology without this factor could lead to an overestimation of its effect on yield level or even on economic profitability. To our knowledge, previous economic evaluation studies on fertilizer microdosing in Burkina Faso did not include this variable in their economic profitability analysis. Thus, the objective of this study is to analyze the effect of labor opportunity cost on the economic profitability of fertilizer microdosing in Burkina Faso.

MATERIALS AND METHODS

Study areas and data

The study was conducted in the municipalities of Nagreongo and Kaya in the provinces of Oubritenga (Plateau Central region) and Sanmatenga (Centre Nord region) respectively. The annual rainfall in Nagreongo is 700 - 800 mm and 450 -750 mm in Kaya. The areas are characterized by low fertility soil and degradation; in addition, sorghum and millet are staple crop. The data used are from a research project called TARGET implemented in Burkina Faso from 2002 to 2003. One hundred and sixteen (116) farmers were chosen on a voluntary basis to conduct agronomic trial. The test crops were sorghum and millet. Both seeds were mostly local varieties and the choice was left to the farmers. The test consisted of three (3) plots per farmer and each plot was 300 m². The three (3) treatments were the control plot, the fertilizer microdosing plot and the recommended fertilizer dose plot (as recommended by extension services for broadcasting fertilization). For the sorghum and millet fertilizer microdosing plots, the quantity of NPK (14-23-14) fertilizer was 62.5 $kg.ha^{-1}$ and 125 $kg.ha^{-1}$, respectively. Urea quantity per hectare was 50 kg and NPK was 75 $kg.ha^{-1}$ for recommended plots. The dose of fertilizer per hill was 4 g. The fertilizer and labor opportunity costs were obtained from a survey conducted by the project in 2003 for impact assessment (270 FCFA for NPK and 250 FCFA for urea). The selling prices of sorghum and millet were 120 $CFA.kg^{-1}$ in the Northern region and 115 $CFA.kg^{-1}$ in the North-Central. For labor opportunity costs, the average cost was 7950 FCFA for fertilizer microdosing in both regions, 6400 FCFA, and 3000 FCFA for the recommended dose in the Northern and North-central regions respectively. For urea, the costs were 4000 FCFA and 2000 FCFA in the Northern and North-Central regions respectively. The high cost of recommended dose plot in Northern region is due to additional cost generated by the application of organic manure at tillage.

Theoretical framework and empirical approach

Several studies analyzed the relationship between labor availability and the decision of farmers to adopt agricultural technologies (Mwangi and Kariuki, 2015; Jack, 2013; Feder, 1985). These studies argued that adoption depends on the intensity of the technology in terms of labor demand. For labor-intensive technologies such as fertilizer microdosing, studies found that households with labor constraints or access to opportunities from labor market are likely not to adopt it. On the other hand, farmers engaged in non-agricultural activities could adopt less labor-intensive technologies. Using household size as a proxy for labor availability, Samboko (2011) obtained a negative effect of labor on the economic profitability of improved cowpea seeds production because most family members were engaged in off-farm activities. The results of the study carried out by Akinola and Owombo (2012) showed that availability of hired labor had a positive effect on the decision to apply the dry straw spreading technique for Nigerian farmers because of the lack of opportunities on labor market. Moreover, some farmers opt for income diversification through off-farm activities as production risk management strategy (Cervantes-Godoy et al., 2013). This requires that available labor be shared between on-farm and off-farm activities. Thus, some households will tend to allocate more time to off-farm activities because they are well-paid (Venance et al., 2016). In addition, they may only apply agricultural technologies that require little working time. As for fertilizer microdosing, Liverpool-Tassie et al. (2015) noted that labor costs for fertilizer application are a key factor for low adoption rate in Niger.

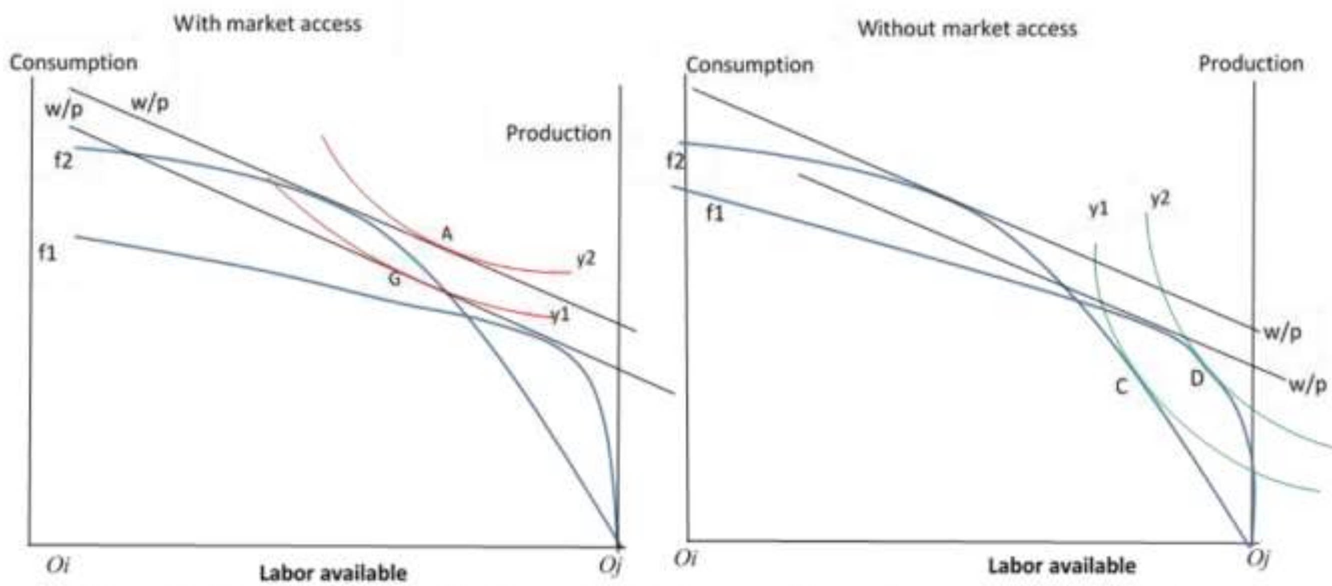

Figure 1. Decision to apply fertilizer microdosing according to the nature of labor market.
Source: Authors (2019).

Indeed, findings of these studies highlighted that households in developing countries often take into account opportunity cost of agricultural technology in their adoption decisions, particularly for labor-intensive technologies. With regard to fertilizer microdosing in Burkina Faso, the opportunity cost is likely to be decisive for many reasons. Firstly, in fertilizer microdosing dissemination areas, the market sometimes offers opportunities (daily worker, off-farm activities and mining activities) which could help farmers to meet their needs during agricultural season. Secondly, because farmers are risk averse, they sometimes adopt strategies to prevent production losses such as crop diversification and spatial diversification of fields. In the event of overlapping crop calendars and imperfect labor markets, they could favor traditional practices over fertilizer microdosing for an efficient allocation of available labor.

Furthermore, in developing countries, family labor requirements, which are the main source of labor, are sometimes difficult to assess due to the small size of plots and the particular requirements for agronomic trial (Crawford and Kamuanga, 1991). This is why in some studies, labor costs are not included in economic profitability analyses. However, for agricultural labor-intensive technologies such as fertilizer microdosing where the difference in application labor is substantial, it is crucial to estimate and include it into the analysis of economic profitability (Crawford and Kamuanga, 1991). Thus, the labor cost for fertilizer spreading is estimated in terms of opportunity cost. The opportunity cost of labor is defined as the wage received for off-farm work, or the estimated value of working time spent on an activity on the farm (Perrin et al., 1976). Based on this meaning, the labor opportunity cost to apply fertilizer microdosing could be the value of sowing time on one of farmers' plot. Indeed, the time required to apply fertilizer microdosing on one hectare is approximately similar to the time required to sow the same area.

From the aforementioned, using a farm household model, let us show the influence of labor opportunity cost in the decision to adopt fertilizer microdosing. Due to imperfect markets in developing countries, production and consumption decisions are often not separable (Sadoulet and De Janvry, 1995). Figure 1 is a representation of the household model to explain the adoption of fertilizer microdosing. Let *w/p* be the same relative labor wage for all farmers, *f1* the production function with fertilizer microdosing, *f2* the production function without fertilizer microdosing and *U(.)* the utility function. Consider the following cases.

Firstly, assume the farmer has access to labor market. The application of fertilizer microdosing is desirable because *U(A)>U(G)* but involves an adjustment. Indeed, if the farmer decides not to apply fertilizer microdosing, his production is *y1* and *G* the consumption. The current production does not suffice for his consumption needs. In this case, he will have to work as an off-farm worker to satisfy his remaining consumption needs. Thus, his time is devoted on the one hand, to his field *(t1=y2-Oj)* and on the other hand to off-farm activities or to work as an employee *(t2=G-y2)*. By applying fertilizer microdosing, its production level shifts from y1 to *y2*, which totally responds to the consumption needs *A*. This requires him to allocate all his labor time to his field and hire labor.

Secondly, the farmer does not have access to labor market. As the opportunity cost of labor is high, he does not apply the fertilizer microdosing because *U(D)>U(C).*

Marginal value cost ratio approach

Previous studies examined the economic profitability of fertilizer microdosing using various approaches. Some studies used net income (Tabo et al., 2007), the benefit-cost ratio (Bielders and Gérard, 2015; Sime and Aune, 2014) and marginal value cost ratio (Camara et al., 2013; Liverpool-Tassie et al., 2015; Tovihoudji et al., 2018). Compared to other approaches, marginal value cost ratio (MVCR) examines the incremental change in net income when the investment cost increases and it takes into account additional costs generated by the new technology (Kelly, 2006; Boughton et al., 1990). In other words, it is the ratio (in percentage) between marginal net profit and marginal net cost (Tefft, 1991; Crawford and Kamuanga, 1991). For this study, we use the MVCR.

The marginal value cost ratio is formulated as:

$$\mathrm{MVCR} = \frac{(Y_m - Y_t)\, p_y}{CT_m - CT_t}$$

with Y_m, yield of fertilizer microdosing plot, Y_t yield of control plot, p_y price of agricultural product, CT_m total cost of applying fertilizer microdosing, CT_t total cost related to control plot. The total cost is equal to the fertilizer acquisition cost and the average labor opportunity cost. The average labor opportunity cost is equal to average number of hours needed to apply the fertilizer times the hourly cost of labor. We used the average costs of labor of each study area because the cost differs from one region to another.

For the MVCR threshold, the researcher must set the rate with farmers based on available information (Kelly, 2006). Crawford and Kamuanga (1991) suggest that the threshold can be set taking into account the current interest rate and risk premium of the study area. The treatment with the highest net benefit and high MVCR could be recommended (Kelly, 2006). Previous studies conducted in similar countries like Burkina Faso, suggest the threshold be set up at 2, especially for risk-averse farmers (Kelly, 2006). Indeed, at that threshold, the risk-averse farmers can be able to achieve a return on investment and to hedge against possible production and market risks. The MVCR is compared to 1 for risk-neutral farmers.

RESULTS AND DISCUSSION

Sorghum and millet yield analysis

The box plots (a) and (b) of Figure 2 represents respectively the yield distribution of millet and sorghum plots. The graphs show that 50% of fertilizer microdosing plots of millet have more than 500 $kg.ha^{-1}$ compared to control plots. For both crops, based on the result of mean difference test that is not significant (*p>0.05*), the difference of yield fertilizer microdosing over recommended dose plot is relatively low. Nevertheless, the both crop yield compared to control plots yield is statistically significant. It is also noted that almost all plots, regardless of the treatment, have yields less than 1000 $kg.ha^{-1}$. In addition, the median yield of the fertilizer microdosing is 500 $kg.ha^{-1}$, which is slightly higher than the recommended dose plots. About 25% of fertilizer microdosing plots of sorghum have a yield close to 1000 $kg.ha^{-1}$ compared to 75% for control plots with more than 500 $kg.ha^{-1}$. Compared to control plots, the use of fertilizer contributed to increasing millet and sorghum yields. These results could be explained by the agro-ecological characteristics of the areas such as annual precipitation and soil texture as well as its fertility level (Tabo et al., 2007; Garner et al., 2014; Bielders and Gérard, 2015). According to Tabo et al. (2007), better yields from fertilizer microdosing were found where an annual precipitation is more than 1000 mm (sorghum) and between 600 and 1000 mm (millet). In addition, the results of a study carried out in Niger by Bielders and Gérard (2015) argued that the low millet yield was not only due to low soil fertility but also to farmer's crop management strategies. That means that beyond some factors sometimes out of their control, farmers have to adopt the best agricultural innovations in order to get better yield.

The results of this finding are consistent with the results of some studies, which noted that the difference between sorghum and millet grain yields from fertilizer microdosing and recommended dose plots is not significant (Saba et al., 2017; Fatondji et al., 2016; Tabo et al., 2007; Hayashi et al., 2008). Similar results found that millet yields from fertilizer microdosing plots could reach 1000 kg or even about 2000 kg per hectare (Saba et al., 2017; Tabo et al., 2007).

Analysis of the economic profitability of fertilizer microdosing

Figure 3 represents the cumulative distributions of the MVCR of millet. The difference between both technologies in terms of economic profitability is significant at the 1% threshold with or without the opportunity cost of labor. Without taking into account labor opportunity cost, the results show that 70% of fertilizer microdosing plots have a MVCR higher than 1 compared to 35% for recommended dose plots. Considering the risk aversion of farmers compared to recommended dose plots, we note that 50% of fertilizer microdosing plots have a MVCR above 2, the conventional profitability threshold assumed to cover themselves against possible production risks. However, including the opportunity cost of labor, the rate of fertilizer microdosing plots with a MVCR above 2 shifts from 50 to 41% and not even one recommended dose plots reached the threshold of 2.

In Niger, Hayashi et al. (2008) obtained MVCR up to 5 when fertilizer microdosing is applied 57 days after planting on millet plots compared to plots with different application dates after planting. However, in Niger, Liverpool-Tassie et al. (2015) noted that the MVCR of fertilizer microdosing to millet could be slightly below MVCR of mixing fertilizer and seed estimated at 8. Taking into account all costs as well as the additional costs of fertilizer microdosing, Camara et al. (2013) showed that the marginal rate of return on fertilizer microdosing applied to millet is between 1 and 2 in Mali. On the other hand, the benefit-cost ratio of millet can reach up to 18 during the dry season in Mali where the market price is higher (Fatondji et al., 2016).

Figure 4 represents the cumulative distributions of the MVCR of sorghum. The difference between both technologies in terms of economic profitability is significant at the 1% threshold with or without the

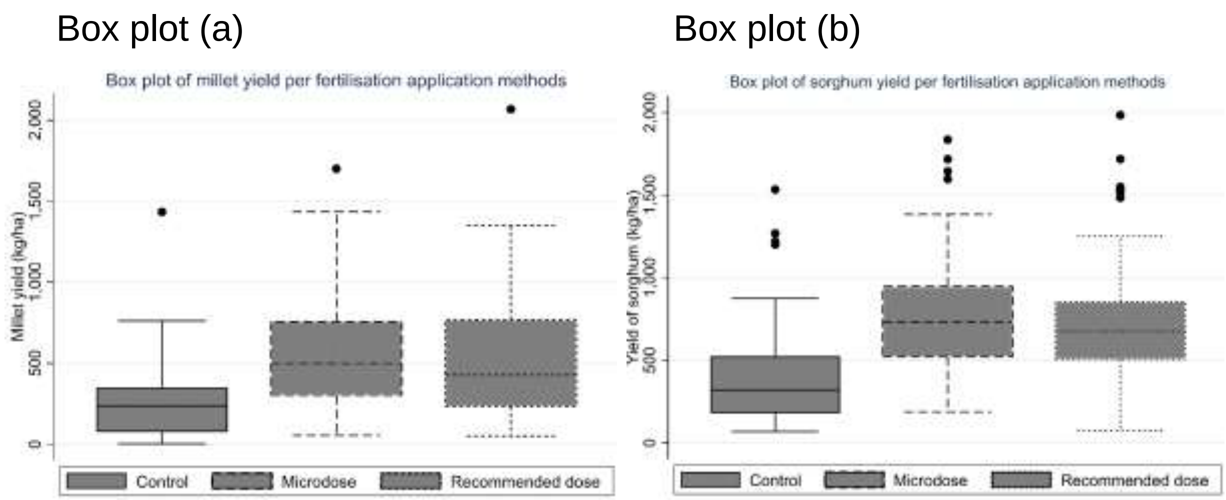

Figure 2. Sorghum and millet plot yield distribution.
Source: Authors' Computation from Survey Data (2019).

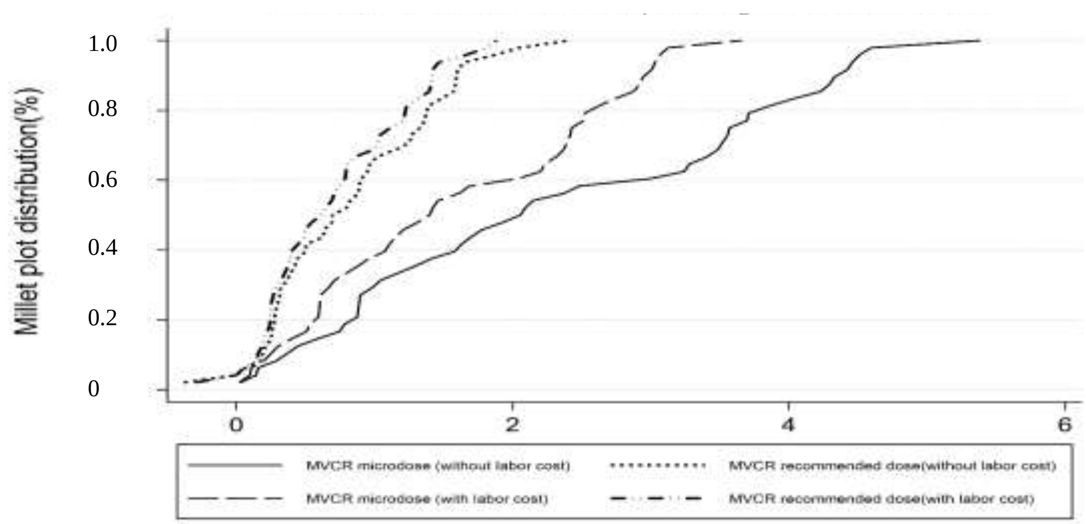

Figure 3. Cumulative distribution of the MVCR of millet plots.
Source: Authors' Computation from Survey Data (2019).

opportunity cost of labor. Some plots have a negative MVCR regardless of the fertilization technique. Without the labor opportunity cost, the rate of MVCR of fertilizer microdosing plots can be as high as 5 to 3 for recommended dose plots over control. The inclusion of labor cost induces 1 point decrease in fertilizer microdosing plots. In addition, without labor costs, the proportion of fertilizer microdosing plots and recommended dose plots greater than 1 are the same, that is, 63%. By setting the threshold at 2, the proportions slightly differ, that is, 28% (fertilizer microdosing plots) and 22% (recommended dose plots). On the other hand, by including the opportunity cost of labor, the proportion of fertilizer microdosing plots with MVCR above 2 decreased from 28 to 15% compared with 22% to 19% for recommended dose plots. Moreover, the difference between the MVCR of both plots is significant at 5%.

Using the benefit-cost ratio, Saba et al. (2017) noted that the ratio could reach 7.3 for fertilizer microdosing versus 4.3 for recommended dose method for soghum. In that analysis, only the acquisition cost of the fertilizer was recorded. In contrast, in Mali, Fatondji et al. (2016) obtained a benefit-cost ratio of 3 and 7 for sorghum under fertilizer microdosing at harvest and during the dry season respectively.

From the analysis of Figures 3 and 4, fertilizer

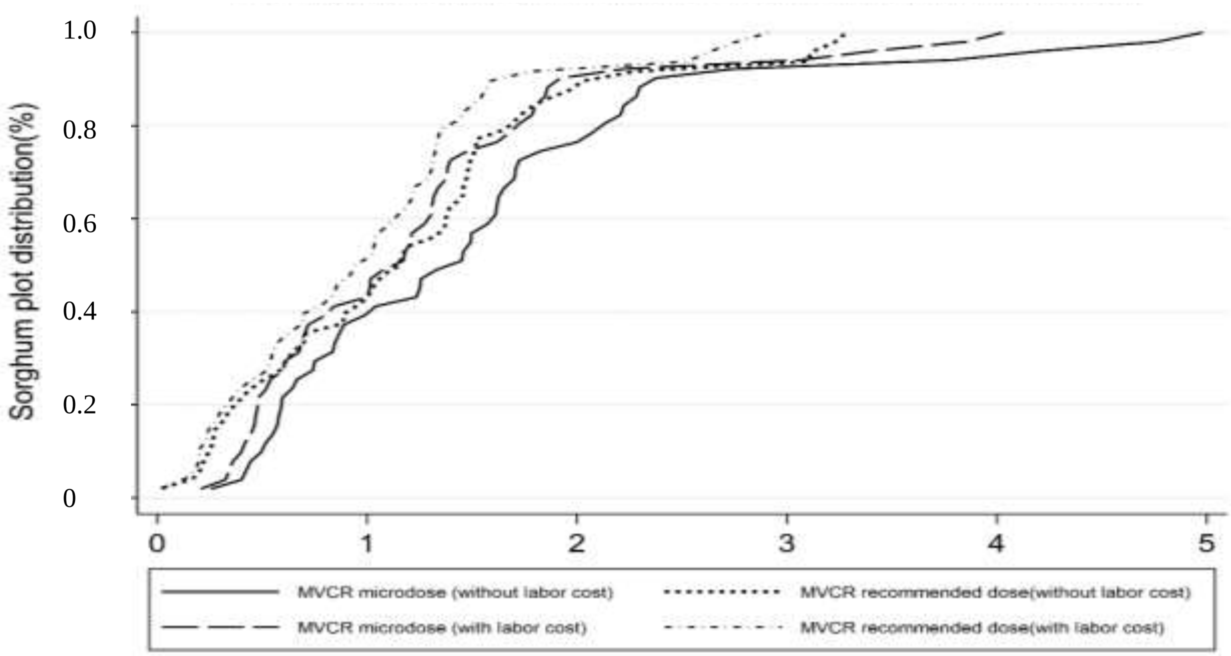

Figure 4. Cumulative distribution of the MVCR of sorghum plots.
Source: Authors' Computation from Survey Data (2019).

microdosing was found to be a more labor-intensive technology than recommended dose. That is consistent with the findings of some studies, which highlighted that fertilizer microdosing application needs additional labor (Pender al., 2008; Sime and Aune, 2019). By contrast, in Niger, Liverpool-Tassie et al. (2015) found that fertilizer mixed with seed is more labor-intensive than fertilizer microdosing. In addition, it appears that including labor opportunity cost decreases the economic profitability rate of fertilizer microdosing regardless of the crop in Burkina Faso. However, despite the labor opportunity cost, the fertilizer microdosing remains economically profitable compared to the recommended dose. These results could be explained by the quantity of fertilizer applied on fertilizer microdosing plots, which is 12 kg less per hectare compared to the recommended dose plots. In other words, application of this technique reduces the fertilizer purchased cost, which is consistent with previous studies (Aune and Ousman, 2011; Camara et al., 2013; Tabo et al., 2007). Another explanation could be the high labor cost of recommended dose application. For example, in the Northern region, this cost does not include fertilizer microdosing labor cost because of organic manure application cost during tillage. Indeed, the tillage is usually carried out manually and that leads to an additional cost (Barro et al., 2002). Williams (1999) showed that the use of manure in West Africa is labor-intensive and thus results in higher labor costs.

This finding seems inconsistent with the results of Liverspool-Tassie et al. (2015) in Niger, who found that the marginal product of labor does not vary significantly with fertilization techniques. Thus, despite the decrease in investment cost associated with the application of fertilizer microdosing, it generates an additional cost including labor cost that must necessarily be assessed in economic profitability studies.

Conclusion

Unlike other studies, this paper focuses on understanding the effect of labor opportunity cost on the economic profitability of fertilizer microdosing in Burkina Faso. Using experimental farm field data, the results indicate that yields vary from one plot to another for any fertilizer technique. This result also shows that despite the control of variability factors, some heterogeneity factors did not include socio-economic factors, which should have been necessary during yield analysis, owing to their interaction with agronomic factors.

In terms of economic profitability, analysis of the marginal value cost ratio reveals that fertilizer microdosing remains economically profitable for some farmers despite the opportunity cost of labor. Thus, the opportunity cost of labor should be included in economic profitability analysis of fertilizer microdosing because of its significant effect on farmers' decision to adopt it. In addition, the results show that farmers who applied fertilizer microdosing could realize a return on investment. For future studies on fertilizer microdosing, the labor opportunity cost should be included in the analysis of economic profitability. In addition, mechanization of fertilizer microdosing has become undeniable for large adoption and one of *sine qua none* conditions of its sustainability.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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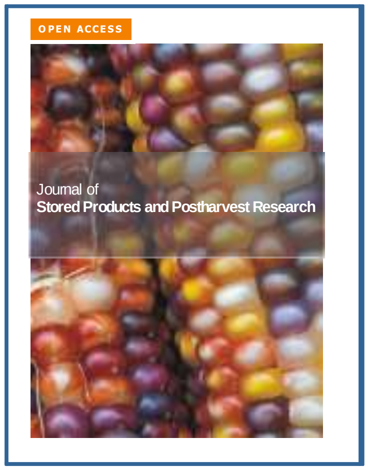

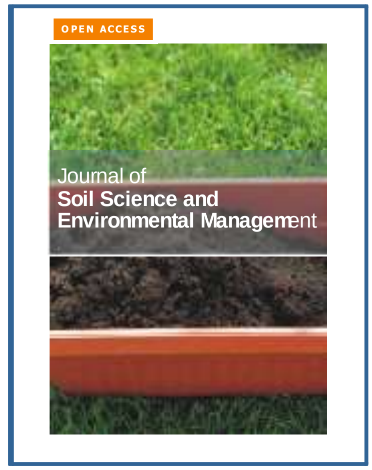

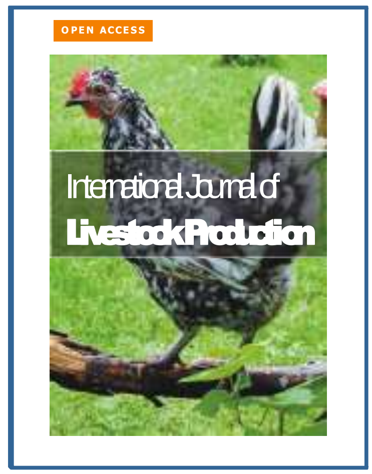

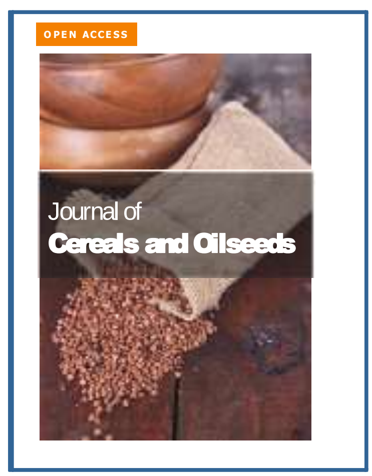

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