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Diversification in Crop-Livestock Farming Systems and Its Effects on Farm Households' Livelihoods in Benin

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The objective of this study is to analyze the benefits of agricultural diversification for smallholder farmers. We use household survey data in Benin and consider not only crop diversification or livestock diversification, but also crop-livestock system diversification. The main outcomes are twofold. First, based on a Tobit regression model we find that farmers with more agricultural resources tend to diversify crops more, while such a relationship is not significant in the case of livestock or crop-livestock diversification. Second, OLS and PSM analyses find positive and significant associations between farm households' livelihood and diversification.

Key words: crop-livestock diversification, income, food security

1. Introduction

In the semi-arid tropical regions of Sub-Saharan Africa (SSA), agriculture usually takes on a mixed form, with farmers rearing livestock in addition to cultivating crops. According to Dixon *et al*. (2020), the mixed farming system in Africa is classified into two: cereal-root crop mixed system and maize mixed system. The former spreads from Senegal to South Sudan like a belt, including northern two thirds part of Benin.[1)] In terms of the area covered, cereal-root crop mixed system is one of the largest farming systems in Africa.[2)] Dixon *et al*. (2020) identify 15 distinct farming systems in Africa and highlight heterogeneity of African agriculture. Then, they emphasize the usefulness of farming system approach to address food security in Africa since within each farming system millions of households share similar livelihood patterns and similar development opportunities.[3)]

Although farming system is largely determined by agroecological factors that extend beyond country borders, we choose one country, Benin, as an example to analyze the association between crop-livestock farming system and food security at the household level because poverty and food insecurity remain serious problems in Benin like in other West African countries belonging to cereal-root crop mixed farming area. According to INSAE (2013), approximately 25% of rural households in Benin are highly food insecure and approximately 45% are at the risk of food insecurity.

The evolution and the current situation of cereal-root crop mixed farming system are thoroughly described by Kassam *et al*. (2020), which is generally applied to Benin since Benin is part of this farming system area. While Kassam *et al*. (2020) describe three key changes that the farming system has undergone: area expansion, increased importance of maize, rice, and soybean, and intensification of farming, they conclude that diversification including livestock intensification is one of pathways for future development. Following their conclusion, this study focuses on the diversification of crop-livestock farming system, and examines if it decreases poverty and enhances food security.[4)]

Crop diversification has been extensively studied in terms of risk management as well as income generation (for

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1) Remaining southern part of the country belongs to root and tuber crop farming system, which is dominated by roots and tubers (Dixon *et al*., 2020).

2) Cereal-root crop mixed farming system features a variety of cereals (maize, sorghum, millet, rice, etc.), root and tuber crops (yam, cassava, etc.), legumes, cattle, and small ruminants (Kassam *et al*., 2020).

3) Although crop production and livestock rearing coexisted traditionally in West Africa, their integration as a farming system is a relatively recent innovation. According to a classic publication of FAO (1985), most part of West Africa was classified as "rotational bush/grass land fallow" area and "mixed farming" area is very limited as of 1977. Powell *et al*. (2004) review the evolution of the linkage between crops and livestock in terms of income, animal power, feed, and manure, and conclude that the transition from extensive system to intensively integrated system is still a challenge although it is driven by human population pressure and urbanization. Kassam *et al*. (2020) add market access for grain and livestock as a recent factor driving the integration.

4) For poverty alleviation, the diversification of income sources to off-farm activities is also important and may be more effective than the within-farm diversification. However, since this study is to evaluate the potential role of farming system, off-farm income is not included.

example, a review by Feliciano (2019)). In the context of SSA, many studies like Adjimoti *et al*. (2018), Makate *et al*. (2016), and Mango *et al*. (2018) found that crop diversification is beneficial to farmers by generating income and/or enhancing food security. On the other hand, as for livestock diversification Megersa *et al*. (2014) concluded that diversification of livestock species is associated with shorter food deficit periods, better dietary intake, and lower food insecurity magnitude in the household, by increasing animal product to consume and sell and reducing the production risk.

However, there is a pronounced scarcity of studies on mixed farming. Exceptions are, for example, Waha *et al*. (2018); Mekuria and Mekonnen (2018); and Mulwa *et al.* (2020). However, none of them focuses on cereal-root crop mixed farming system in West Africa, where Benin's agriculture is categorized, even though it is a distinct and important farming system in SSA and its diversification is considered to be a development pathway. Accordingly, this study will contribute to the literature by investigating the association of crop and livestock diversification at the farm level with income and food security.

2. Data and Methods

1) Data

Data used in this paper were collected by the National Agricultural Research Institute of Benin (INRAB) in 2017. The survey covered almost all the departments in Benin. It had a sample size of 1,874, out of which we considered 1,303 farm households after data cleaning and restrictions.

2) Diversification Index

Agricultural diversification at the farm level is captured by several indices in the literature. Among them, we choose the Herfindahl-Hirschman index (HHI) for this study since the index interpretation is straightforward and perfectly fits this analysis on diversification.

We compute three different indices for crop, livestock, and crop-livestock system using the same standard HHI formula:

$$HHI_j = \sum_{k=1}^{n} P_{jk}^2 \quad (1)$$

$$P_{jk} = \frac{V_{jk}}{\sum_{k=1}^{n} V_{jk}} \quad (2)$$

where j stands for either crop, livestock, or crop-livestock. V_{jk} is output value of the k^{th} crop or stock value of the k^{th} livestock evaluated by the market price, and P_{jk} is the value share of k^{th} crop or livestock. Then, HHI is defined as the sum of squared value share of each crop/livestock.[5)]

To obtain the actual diversification indices to be used in the analysis, we subtracted each one of the computed HHI from one, thereby obtaining the crop, livestock, and crop-livestock diversification indices (respectively CD, LD, and CLD). The obtained diversification indices, therefore, vary from 0 or "perfect specialization" to 1 or "infinite diversification". This makes the interpretation of diversification in the sample more intuitive. The description of these diversification indices is given in Table 1.

3) Determinants of diversification

In order to identify factors determining crop and livestock diversification, we use Tobit model as below.

$$D_i^* = \delta X_i + \nu_i \;;\quad D_i = D_i^* \quad if\ D_i^* > 0 \quad \text{and} \quad D_i = 0 \quad if\ D_i^* \leq 0 \quad (3)$$

where i stands for household i. D_i is the observed level of diversification, which can be either crop diversification (CD_i), livestock diversification (LD_i), or crop-livestock system diversification (CLD_i). X_i is a vector of independent variables affecting the diversification, including observable characteristics of household and its head. Identifying such factors could be useful for policy targeting.

4) Effect of diversification

To examine the association of diversification with income and household food security, this study estimates the OLS model specified below.

$$L_i = \delta_o + \alpha CD_i + \beta LD_i + \theta X_i' + \mu_i \quad (4)$$

$$L_i = \delta_o + \gamma CLD_i + \vartheta X_i' + \varepsilon_j \quad (5)$$

where i stands for household i. Equation (4) is for the relationship of both crop diversification and livestock diversification with the livelihood outcome variables (L), which are either cash income, household food security, or food expenditure per capita. As for equation (5), it is the same for crop-livestock system diversification. We also conduct propensity score matching (PSM) to check the consistency of OLS results.

Household food security is assessed based on Household Food Insecurity Access Scale (HFIAS) in the dataset. The HFIAS is constructed from a series of questions about the occurrence/experience related food insecurity posed to farmers with a recall period of four weeks. Then, our food security index is a kind of inverse HFIAS, defined as follows:

Food Security of household i =

max HFIAS observed in the sample – HFIAS of i

5) In the case of crop-livestock system, output value of each crop and stock value of each livestock are equally treated and applied to equations (1) and (2).

Table 1. Descriptive statistics (N=1,303)

	Mean	S. D.
Outcome Variables		
Household cash income (10^4 FCFA)	189.7	1367
Food security index	15.0	3.7
Food expenditure per capita (FCFA)	1967	1518
Diversification Index (from 0 to 1)		
Crop diversification (CD)	0.52	0.22
Livestock diversification (LD)	0.32	0.22
Crop-Livestock System diversification (CLD)	0.64	0.17

Note: 1) Correlations among diversification index are 0.05 (CD-LD), 0.63 (CD-CLD), and 0.37 (LD-CLD).
2) FCFA is the common currency of member countries of the West African Economic and Monetary Union (WAEMU), to which Benin belongs.

The description of these household livelihood outcome variables is given in Table 1.

3. Results and Discussion

1) Determinants of diversification

Table 2 shows the results of Tobit regression on the determinants of the extent of diversification, combined with descriptive statistics of explanatory variables.

First, we find that households rich in resources for agriculture tend to diversify crop production, namely it is associated with larger family size, larger farm size, having irrigated plots, and receiving visits of extension officers. The results are largely consistent with existing literature such as Asante *et al*. (2018), Baba and Abdul-Malik (2020), Mofya-Mukuka and Hichaambwa (2018), and Sichoongwe *et al*. (2014). Owing to the same reason, off-farm income significantly decreases crop diversification as found by Baba and Abdul-Malik (2020). Finally, closeness to the market and the main road has a significantly negative association with crop diversification, which is also consistent with recent studies such as Sichoongwe *et al*. (2014). The result indicates that households with poor access to the market rely on their own production of foods for family consumption.

Second, as for livestock diversification, only three variables are significantly related with it. Unlike crop, off-farm income is positively associated with livestock diversification. It may suggest that off-farm activities and livestock rearing should have a similar role in household income diversification. The correlation between crop diversification index and livestock diversification index is very low as shown in the footnote of Table 1, and factors influencing livestock diversification is very different from those about crop diversification as shown in Table 2. These results indicate that the two diversifications are quite different.

Third, Table 2 shows that factors affecting crop-livestock diversification are not necessarily the same as those affecting

Table 2. Determinants of diversification with descriptive statistics of explanatory variables

	Description of variables			Determinants of Diversification[3]					
				Crop		Livestock		Crop-Livestock	
Household Characteristics[1]	Mean	S.D.	Trans-formation[2]	Marginal effect	S.E	Marginal effect	S.E	Marginal effect	S.E
Sex of household head (male=1)	0.97	0.18	none	-0.037	0.030	-0.037	0.025	0.022	0.031
Age of household head (years)	48.2	12.5	none	-0.004	0.003	-0.002	0.002	-0.002	0.003
			squared (sq)	0.000	0.000	0.000	0.000	0.000	0.000
Education of household head (years)	3.5	4.0	none	-0.003	0.002	0.000	0.001	-0.001	0.001
Family size (number)	11.6	6.0	none	0.003	0.001**	0.001	0.001	0.002	0.001
Total land holdings (ha)	14.3	20.7	natural log.	0.073	0.025***	0.019	0.019	0.003	0.017
			natural log. sq	-0.010	0.004**	-0.006	0.003*	0.001	0.003
Irrigation (1=at least one irrigated plot)	0.07	0.25	none	0.054	0.022**	-0.005	0.018	0.011	0.017
Livestock holdings (TLU)	4.86	11.7	none	-0.001	0.001	0.000	0.001	-0.007	0.001***
			squared	0.000	0.000	0.000	0.000	0.000	0.000***
Off-farm income (10^4 FCFA)	51.0	87.4	natural log.	-0.003	0.001**	0.003	0.001**	0.000	0.001
Household asset value (10^4 FCFA)	543	1065	natural log.	0.005	0.005	0.003	0.004	0.005	0.003
Distance to markets (km)	6.2	9.2	none	0.001	0.001*	0.000	0.000	0.001	0.000***
Distance to main road (km)	2.7	6.4	none	0.002	0.001**	0.001	0.001	0.002	0.001**
Farmer organizations (member=1)	0.11	0.31	none	-0.028	0.018	-0.004	0.017	-0.017	0.016
Farm practices training (received=1)	0.21	0.41	none	-0.008	0.016	0.043	0.013***	0.011	0.012
Input subsidies in the past (received=1)	0.36	0.48	none	0.022	0.013*	0.012	0.012	0.017	0.010*
Credit access in past 5 years (yes=1)	0.14	0.34	none	-0.011	0.017	-0.007	0.015	-0.002	0.012
Visits by agricultural extension (yes=1)	0.38	0.48	none	0.060	0.013***	0.002	0.013	0.032	0.011***
Number of observations	1,303			1,303		1,303		1,303	

Note: 1) TLU is tropical livestock unit. Please refer to footnote to Table 1 for the explanation of FCFA.
2) Transformation column shows how each variable is transformed to use in the regression.
3) Tobit model is used for the estimation. Robust standard errors clustered at village-level are shown. * P <0.1, ** P<0.05., *** P<0.01.

crop diversification or livestock diversification, although their correlations are not so low as shown in the footnote of Table 1. The significantly positive association of livestock holdings may imply that households with less livestock cannot diversify crop-livestock system.

2) Effects of diversification on livelihood

Table 3 presents the OLS regression results for the estimates the effects of crop, livestock, and crop-livestock diversification strategies on income and food security.

In addition to the diversification variable, all the household characteristics shown in Table 2 are included as control variables in the OLS regression. We hope that those variables can capture even unobserved household characteristics such as household head's ability and preferences. In addition, we include village dummies[6] to control for community level unobserved factors such as natural resource endowments, traditional culture and customs, social capital, etc.

However, we cannot deny the possibility of existing unobserved factors that affect both diversification and outcome variables, that is, there can be problems of endogeneity due to omitted variables. Moreover, there would be endogeneity problems caused by reverse causality as higher farm livelihood could also somehow affect diversification behavior. However, because there are no suitable instrumental variables for the diversification (due to data limitation), we cannot solve those problems. Our approach, although admittedly imperfect, is to do OLS regression with village dummies, and then to perform propensity-score matching (PSM) for addressing potential reverse causality. PSM is not very appropriate in this situation where unobserved factors can be remaining, but assuming that it is not so serious, we add it to OLS regressions.[7]

We find a significant and positive association of crop and livestock diversification with cash income. It is confirmed by PSM as well. Our results are consistent with those of Makate *et al*. (2016) with respect to crop diversification. As for crop-livestock diversification, it is not significant by OLS, but significant by PSM. Since we cannot know which is correct, we should be careful of the interpretation.

As for food security, no significant estimation is obtained by OLS, but PSM gives marginally significant and positive results. Although there is no evidence, we consider that livestock diversification has little correlation with food security because PSM's significance level is not so high.

On the other hand, both OLS and PSM show that household food expenditure per capita is associated significantly with crop diversification. But livestock diversification does not seem to have a significant association with it, and the results of crop-livestock diversification are mixed. Thus, the increased income due to crop diversification and maybe crop-livestock diversification as well will contribute to households' purchase of food from the market.[8] Mulwa *et al*. (2020) also found a positive effect of crop diversification on food expenditure in Namibia.

4. Conclusion and Policy Implications

In this study, we examine the association of diversification of crop and livestock mixed farming system with household income and food security using data collected in Benin.

First, we identify the determinants of agricultural diversification, namely crop, livestock, and crop-livestock diversification. Our results show that the crop and livestock diversification strategies are characterized by a different set of factors when considered respectively. We should note this fact to promote agricultural diversification at the farm level among rural households: there will be no single policy that works for all kinds of diversification.

As for the effect of agricultural diversification, we find a positive association of mainly crop diversification with cash income and food expenditure. It may be also true with crop-livestock diversification to some extent. The OLS as well as PSM results suggest that cash income due to diversification may increase in household food expenditure per capita. Therefore, our findings urge policymakers to adopt more effective ways to promote diversification strategies to address poverty and food insecurity. This study unfortunately does not show which specific policies are more effective.

Our analysis could not deal with the potential endogeneity problems. This is the most significant limitation of this study, requiring future research.

6) Commune is the smallest administrative unit of the country, and each commune consists of several villages. There are 347 villages in the data.

7) We divide the sample into two: treatment and control groups. The treatment consists of highly diversified households, whose diversification index is above 75th percentile, and the control consists of less diversified households whose diversification index is below 75th percentile. Then, we obtain propensity score by probit regressions using the same variables shown in Table 2.

8) The analysis does not tell why livestock diversification has insignificant influence on household's food expenditure, although it is associated with higher cash income like crop diversification. Our interpretation is that livestock income, particularly that from cattle or even sheep and goats, is relatively large amount and arises less frequently, and hence it is used for something other than daily requirements like foods.

Table 3. Effect of diversification on household livelihoods

	Cash Income			Food Security			Food Expenditure		
	Eq. 4	Eq. 5	PSM	Eq. 4	Eq. 5	PSM	Eq. 4	Eq. 5	PSM
Crop	3.77*		2.32***	-0.04		0.02	0.31**		0.12**
Diversification (CD)	(2.08)		(0.69)	(0.06)		(0.02)	(0.12)		(0.05)
Livestock	3.32*		1.80***	0.03		0.03*	-0.08		-0.05
Diversification (LD)	(1.76)		(0.61)	(0.05)		(0.02)	(0.13)		(0.06)
Crop-Livestock		3.69	2.32***		-0.04	0.02		0.17	0.12**
Diversification (CLD)		(2.64)	(0.69)		(0.07)	(0.02)		(0.15)	(0.05)
Household Characteristics	Yes	Yes	-	Yes	Yes	-	Yes	Yes	-
Village dummies	Yes	Yes	-	Yes	Yes	-	Yes	Yes	-
R-squared	0.35	0.35	-	0.44	0.44	-	0.47	0.46	-
Observations	1,303	1,303	1,303	1,303	1,303	1,303	697	697	697

Note: Outcome variables are transformed to natural logarithm. OLS model is used for the estimation of equations (4) and (5). For the method of PSM, please refer to footnote 7. Standard errors clustered at village-level in the case of OLS and Abadie-Imbens robust standard errors in the case of PSM are in the parenthesis. * P<0.1, ** P<0.05, *** P<0.01.

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