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Analysis of socio-ecological determinants for adoption of legume-cereals intercropping and improved seeds uses in the face of agricultural livelihood diversity in Satiri sub-district, Houet province, Burkina Faso

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2. Abstract

Following the identification of the different agricultural livelihoods systems (ALS) type in the Satiri sub-district, western Burkina Faso, the presented study aims at assessing behaviour of these different ALS types in adoption of cereal-legume association and improved seeds use, and adoption determinants. Based on the sustainable livelihoods framework capital, literature revue and expert knowledge were used to identify candidate variables affecting this adoption. The binary logit model was used for the analyses. A total number of 390 farm-households growing millet, sorghum and cowpea (i.e. main crops targeted by CRP GLDC). Bi-logistic regression models were run for whole population and individual ASL types. The results showed that factors determining farmers' adoption are related to labour availability, farmer remoteness from paved road and market, equipment level, income, policy intervention and farmer perception of the rainfall variability risk. The study identified determinants for all ALS types (common determinants) and specific determinants shaping adoption behaviour of each individual ALS type (ALS type-specific determinants). The existence of both common and type-specific determinants demonstrated that the presented ALS typology-based adoption analysis approach add new values compared to business-as-usual adoption analysis approaches that treat only sample whole population. The common determinants confirmed factors having wide effects on adoptions. The ALS type-specific determinants reflect new causal effects which the consideration of whole sample population alone cannot find. With the ALS typology-based approach, the number of identified causal relationships explaining adoption can increase 50% (improved seed uses) or 30% (cereal-legume intercropping practices) compared with the use of business-as-usual adoption analysis method. The study therefore recommends accounting for agricultural livelihoods systems heterogeneity in designing policy interventions and for conducting research studies.

Key words: Grain legumes dry cereals, cereal-legume association, improved seeds adoption, Agricultural livelihood systems heterogeneity, binary logit regression, Burkina Faso

1. Introduction

Smallholders in Sub-Saharan African semi-arid regions are facing important issues needing the support of farming systems research to propose innovative pathways and solutions. These issues range mainly from land degradation to food insecurity and poverty. The interrelated food insecurity and land degradation can be argued to be the most important threat to agricultural livelihood as it contributes to maintaining a poverty trap(Thiombiano and Le, 2015b). Indeed, the number of undernourished people continues to increase since 1990-92 (FAO, 2015). Studies support the existence of widespread soil nutrient depletion (Cobo *et al.*, 2010). In Burkina Faso in particular, successive studies have shown a worsening of soil nutrient depletion (Thiombiano, 2015). In most cases poverty constraints the investment in soil fertility, and wealthy farms which draw most of their income from soil nutrient mining (Van der Pol, 1992)are running into poverty trap in the near future if the nutrient mining process is not reversed (Thiombiano and Le, 2015b) to improve farms' livelihoods. Crop and animal production systems are still very extensive as inputs use (soil nutrient resources, animal feed and equipment) remain weak (Coulibaly, 2012).

The farming system in Burkina Faso is generally mixed crop-animals systems with a clear domination of crops. Millet and sorghum are the most cultivated cereals in Burkina Faso either in sole or in association with legumes. However, the yield remains low for these three crops like for all other crops in the country (MAAH, 2017). The low yield of these food crops are caused mainly by rainfall variability, low soil fertility, but also the poor farm management by producers. Improving food crops production for food and nutrition security requires addressing main issues undermining the production: poor farm management practices, rainfall variability, crop and animal diseases, and inefficiency of agricultural policies.

The use of improved varieties and affordable practices such as legumes-cereals association may help to boosting farm productivity. Beside fertility effects, legumes are dual crops used for feed human as well as forage. Synergies and positives feed-backs may contribute to improve smallholder farmers' livelihoods. However the conditions of consistent legumes-cereals association and use of improved seeds by smallholder farms with regards to their heterogeneity is still under investigated in sub-Saharan Africa and Burkina Faso in particular.

The present study performed in four villages of the sub-district of Satiri in Western Burkina Faso, aimed at conducting a behavioural analysis of different Agricultural Livelihood Systems (Thiombiano and Le, 2018) for the adoption of cereal-legumes association and the use of improved seeds. The specific objectives of the study are (i) to determine factors influencing the association of cereals and legumes in cropping systems by different agricultural livelihood system types identified in the study zone and (ii) to identify the determinants of the use of improved seeds by these agricultural livelihood system types.

2. Methods and materials

2.1. Conceptual framework

Households-farms are characterized by their settings comprising biophysical resources (e.g. land, water and trees), economic resources (e.g. financial and infrastructures) and socio-demographic resources (e.g. labour, capabilities and networks). These settings vary from household-farm to household-farm defining thereby the heterogeneity of a given population in a given region or location. Therefore, this heterogeneity needs to be captured for successfully designing efficient and profitable, adaptive or resilient farming systems as well as effective policy interventions. The Sustainable Livelihood Framework (Chambers and Conway, 1991; Sconnes, 1998) offers the possibility to holistically apprehending the household-farm as it considers all the settings of the household-farm. These settings are grouped into five types of capital: human capital (demography, education of household members and their profession), natural capital (e.g. land holdings and tenure, planted trees), physical capital (e.g. agricultural equipment, transportation means, farming and household tools), financial capital (livestock, off-farm employment remittance) and social capital (e.g. networks and membership to organization/association). The level of endowment in these capitals will define different livelihood strategies of household-farms. Our study therefore used the Sustainable Livelihood Framework as a guide for collecting a multidimensional dataset used for identifying the agricultural livelihood types in the sub-district of Satiri.

2.2. Study site

The study was conducted in the sub district of Satiri, in the Houet province, Western Burkina Faso. The sub-district belongs to the South-Sudanian climatic zone with an average annual rainfall of 900-965 mm. The vegetation cover is savannah. The farming system is the Satiri department is characterized by mixed crop-livestock farming. The average annual rainfall is estimated to be 920 mm. Four villages were purposively selected based on the criteria of legume production in pure cultivation cropping system and associated to cereals crops cropping system. From literature review and information provided by agricultural extension services, the villages of Sissa, Neferelaye, Ramatoulaye and Kadomba were selected (Fig.1). These village are all located on a transect East-West with a distance gradient to the main road and Satiri, the main town of the sub-district. Kadomba is located 15 km away Satiri, Ramatoulye 20 km, Néférélaye and Sissa from 25 and 31 km, respectively.

The main cash crops are cotton and sesame for all three villages. Livestock production comprises mainly cattle goat and sheep. Poultry is raised by almost all farmers. Due to the existence of a small dam, irrigated crops are produced in Kadomba, mainly tomatoes, onion and a bit of maize. Farmers face the general issue of land degradation with soil and water conservation measures (stone bunds, compost) being inconsistently practiced. Natural tree regeneration is often encountered. The legislation on tree conservation in Kadomba is particularly strong with the monitoring system put in place the Ministry of environment to preserve the neighboring protected forest. Farmers are therefore encouraged to leave as much trees as possible in their fields.

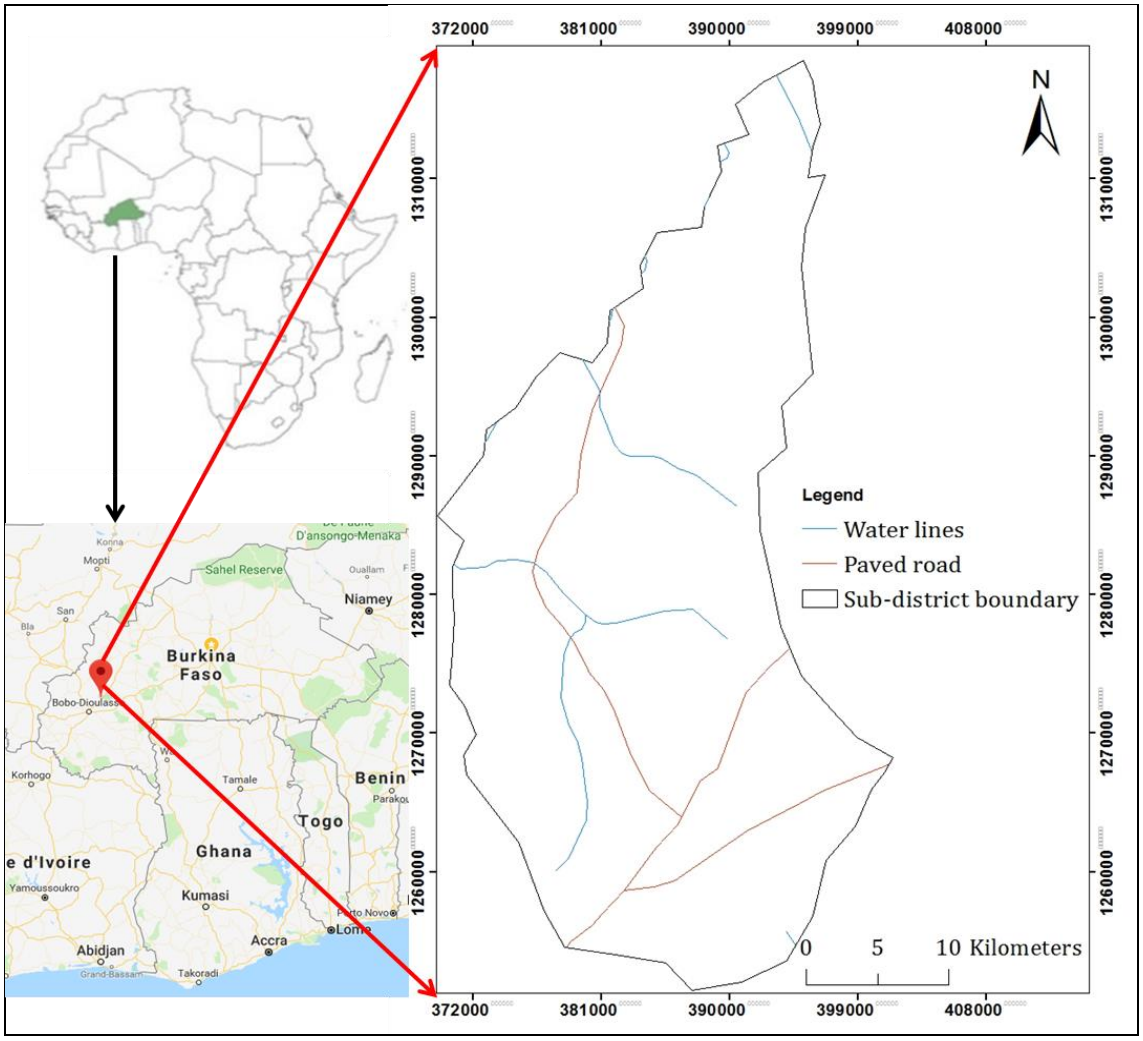

Fig. 1. Study site. The sub district of Satiri

2.3. Main agricultural livelihoods systems types in the study area

Four main agricultural livelihoods systems types were previously identified in the study area by Thiombiano and Le (2018).

Livelihood type I. Pro-poor, landless and cereal-based

This livelihood system type (ALS) represented 47% of the total study sample. The main characteristics discriminating this ALS type with other are its level financial and natural assets endowment as well as crop production orientation. It comprises the least endowed farms in the study area. The annual gross income per household member was found to be 82,371 FCFA/Person/Year. Land ownership is very low as well as they cultivated 4.03 ha in total pour all crops, meaning 0.57ha per person. Their livelihood is dominated by cereals given that cereals crops (Sorghum, millet and maize) alone provide up to 49.25% of household annual

income. Cotton which is the main non-food cash crop of the region is not a major contributor to the farm income. Indeed only 18.92% of household incomes come from cotton production. They have low access to paved road with the mean distance from a paved road being 4.17 Km. This distance which is quite long giving the limited available transportation means in the rural areas and the importance played by permanent road in accessing market for buying factors and selling crop products.

Livelihood type II: Poor, landless and cereal-based livelihood

The livelihood type II concerne 32% of the total study sample. Farmers of this ALS type are Poor, landless, and cereal-based livelihood. They also have low annual gross income (131,438 FCFA/Person/Year) but statistically significatly higer than the Pro-poor, landless, and cereal-based livelihood type (ALS type I). They have slightly, but still significant higher area of cultivated land than ALS type I (5.82 ha in total, and 0.60 ha per capita). Their livelohood is also dominated by cereals income which contribute for 44.67% to the annual gross income of the household. This contribution is statiscally significantly lower than the contribution of cereals income to farm annual income of ALS type I. The contribution of cotton to the annual farm income (20.90%) is not significantly different from the contribution in ALS type I. However, livestock income contribution to the annual gross income of the household (11.15%) is significantly higher than this contribution for farms of ALS type I. In definitive ALS type II has better annual income, better libvestock income contribtion but are remoted from paved road (5.4km) and less based on cereal than farms of ALS type I.

Livelihood type III: Medium, land rich, cereal-based livelihood

The livelihood type III Medium, land rich, cereal-based livelihood was statistically significantly better endowed in financial and natural capital than the ALS types I and II which are pro-poor and poor. Farmers in ALS type III have annual gross income of 154,029 FCFA/Person/Year. They cultivate more lands: 9.87 ha in total, meaning 0.68 ha/Person. Though strong contribution from cereal income to household annual gross income, farmers of this ALS type statistically significantly rely less on cereal income (39.84%) than ALS type I (around 49%) and ALS type II (around 45%). However, no significant difference was found between this ALS type III and ALS types II for cotton income contribution and livestock income contribution to the household annual gross income. These differences (Cotton income and livestock income)

were significant only between this ALS type III and ALS type I (the pro-poor ALS). In terms of road access, ALS type III has similar access with ALS type I but better access than ALS type II.

Livelihood type IV: Better-off, land rich, diversified and livestock-preference livelihood

This ALS type is the better-off. It was named Better-off, land rich, diversified and livestock-preference livelihood and represent only 5% of the study population. Farmers of that ALS type have the highest annual gross income per person (188,914 FCFA/Person/Year). They also cultivate the biggest share of land area (12.91ha in total, meaning 0.68 ha/person). Compared to the three other ALS types, there are little differences between the three main sources of income (Cereal, Cotton and livestock) for the contribution to household annual gross income. Cereals income contributes for 32.81%, cotton income for 24.44% and livestock income for 24.63%. This make the ALS type IV a diversified agricultural livelihood system type. Farmers of ALS type IV are the closest to paved road with a mean distance of 3.18 km.

2.4. Method for adoption determinant analysis

The binary logistic regression method was used for analysing the factors affecting the adoption of legumes-cereals association on one hand and the adoption of the use of improved seeds on the other.

Dependent variables

The dependent variable for legumes-cereal association adoption model was coded as GLDC_ASSO. GLDC_ASSO =1 if the household is practicing sorghum-cowpea association and/or millet-cowpea association; GLDC_ASSO=0 if not.

As for the adoption of improved seeds for any crop on the farm, the dependant variable was coded SEEDS_GLDC with the value 1 if the household is using improved seeds on its farm; and 0 if not.

Explanatory variables

The candidate explanatory variables for both adoptions were selected from expert knowledge and contextualized results from literature (Table 1). The selected variables were entered into the models either as standing alone, or as interacting with another variable. These interactions are important to capture as smallholder farm decision making most often result from inter-acting factors. The explanatory variables are variables reflecting the five sustainable livelihood capitals assets (Human, physical, natural, social and financial assets) as well as variable related to risk management and policy intervention.

- **Human capital variables** was represented by the natural logarithm of the farm household size (LN_HSIZE), the number of workers of the farm (H_DEPEND), the number of wives of the

household head (H_POLYGAM) and the number of household members who were away for migration (H_MIGRATED). Only LN_HSIZE was considered in both models (GLDC association and use of improved seeds). Associating cereals to legumes diversifies crop production on the same land and requires more labour (for harvesting and weeding) as animal traction is difficult to use in such plots due to the mixing of cereals and rampant plants. Also, we suppose that large families are more inclined to use improved seeds due to the relative higher need in food production. The variables H_DEPEND, H_POLYGAM and H_MIGRATED most relate to the availability of labour for dealing with the high demand in labour when associating cereals and legumes. Moreover, women labour are the most used for cowpea harvesting in the area, therefore the number of wives is expected to affect the decision of associating or not GLDC crops.

- **Physical capital variables:** the variables indicating the physical capital of the households were the variable resulting from the interaction between Household mean distance to paved road and the Household mean distance to nearest important market extracted from map (LN_DROAD x LN_DMARK), the Number of bullock for drought (H_BULLOCK), the Number of bikes and motorbike in the household (H_VEHICLE) as well as the Number of cellular phones in the household (H_CELL). The first two variables (LN_DROAD x LN_DMARK and H_BULLOCK) were considered only in the GLDC association model. In effect, the distance road and market represents farm isolation and prevent it to co-learn from other farmers. As for H_BULLOCK, farmers told during screen survey that ploughing with bullock is rendered difficult in mixed cereals cowpea plots with the high risk of destroying cowpea crops which are rampant. The variables H_VEHICLE and H_CELL were considered only in improved seeds adoption model as they facilitated farmer access to seeds selling points and facilitate farmer access to information on seeds availability.

- **Natural capital variables:** three variables represented natural capital. These are Cultivated land area (H_CULT_LAND), Total area allocated to GLDC targeted crops (millet, sorghum and cowpea) (H_GLDC_AREA) and the variable resulting from the interaction between Area allocated to GLDC targeted crops and Use of improved seeds (H_GLDC_AREA x SEEDS_GLDC). H_CULT_LAND is expected to have negative effect on the adoption of GLDC crops association and the use of improved seeds. Indeed the more land area a farm is cultivating (meaning land rich) the less it will be intensive and tend to not associate crops and not use improved seeds. H_GLDC_AREA was included only in the model analysing improved seeds adoption and its expected effect is undermined. As for H_GLDC_AREA x SEEDS_GLDC, it was considered only in the model GLDC crops association and has an undetermined expected effect.

- Social capital variables: The variable Household membership to a farmer organisation or credit association (H_MEMB), and the variable resulting from the Interaction between Household access to credit and Household head attendance to classic education (H_CRED x H_EDUCL) represented the social capital of the households. H_MEMB included only in the cereals-legumes association analysis model is expected to have a positive effect on the

adoption of GLDC crops association. In effect, membership to organization/association gives opportunity to the farmer to exchange knowledge and therefore provides learning opportunities. Training sessions on cropping management and practices offered by extension services or developmental agencies are generally organized for farmer organisations rather than for individual farmers. As for H_CRED x H_EDUCL, it was included only in the improved seeds adoption model. Though seeds for all GLDC crops are subsidized in Burkina Faso, the access in time is often limited due to programme malfunctioning (late availability of the seeds at extension service office, lack of information on seed availability). In this context the access to improved seeds out of the subsidy programme in affected by the availability of financial resources and therefore the access to credit. Classic education plays a key role in creating the condition for farmers to understand the need for using improved seeds. Interaction of both variables is crucial to improved seeds adoption and is expected to have a positive effect.

- Financial capital variables: Most financial capital variables considered in the adoption analyses were included in their natural logarithmic form. The variables Natural logarithm of the household annual gross income (LN_H_GROSINC) and Natural logarithm of the household annual income drawn from cereal crops (LN_H_CER_INC) were considered in both adoption models as the level of annual gross income and income drawn from cereals affect in one way or another the decision making of cereal-based farms. Their expected effects were undetermined. However, the variables Natural logarithm of the household annual income drawn from marketable food crops (LN_H_MFCRP_INC) and Natural logarithm of the household annual income drawn from regenerated/planted trees (LN_H_FMNR_INC) were included only in the GLDC crops association model. The expected sign of both variables was negative. Indeed, the level of income drawn from marketable food crops (including cowpea) may drive farmer to avoid associating crops in the aim to harvest as much marketable food crop as possible and not immediately consider the beneficial effect the association with cowpea on soil fertility. In the same logic, the higher the revenue drew from trees the less the farm will tend practice cereal-cowpea association. The last two financial capital variables, Share of non-farm income within household annual gross income (H_SHNF_INC) and Natural logarithm of the household annual income drawn from cotton crops (LN_H_COT_INC) was included only in improved seeds adoption model. Their expected effects were positive as they increase farmer financial resources and may increase farmer capacity to purchase improved seeds on the market.

- Uncertainty perception and Policy intervention variables: In the addition to the five capital assets we also considered uncertainty perception and policy intervention variables. Indeed in perceiving the uncertainty facing the farming system, farmer may decide to intensify by used improved seeds. Therefore we included the variable Interaction between Legumes-cereals association and Perception of rainfall decrease over the last 10 years (H_GLDCAS x H_RAIN). The variable has an expected positive effect on improved seed adoption. The policy intervention was captured through the extension visits to famers. The Number of visits to the farm by extension services during the last 12 months (H_EXTENSION) was included in the

model analysis improved seeds adoption. The expected sign of the variable is positive as extension services visits to farmers are expected to improve adoption of good agricultural practices like improved seeds adoption.

Table 1. Definition of explanatory variables for adoption analysis of cereal-legume association and improved seeds used

Asset type	Variable name	Brief definition	Considered in (Expected sign)	
			Legume-cereals association adoption analysis	Improved seeds adoption analysis
Human capital	LN_HSIZE	Natural logarithm of the farm household size *(Numb. of. Pers.)*	X (+)	X (+)
	H_DEPEND	Number of workers of the farm *(Numb. of. Pers.)*	X (-)	
	H_POLYGAM	Number of wives of the household head *(Numb. of. Pers.)*	X (±)	
	H_MIGRATED	Number of household members who are currently away for migration *(numb. of pers.)*	X (-)	
Physical capital	LN_DROAD x LN_DMARK	Interaction between Household mean distance to paved road extracted from map *(m) and* Household mean distance to nearest important market extracted from map *(m)*	X (±)	
	H_BULLOCK	Number of bullock for drought *(Numb. of animals)*	X (-)	
	H_VEHICLE	Number of bikes and motorbike in the household (*Numb. of .units)*		X (+)
	H_CELL	Number of cellular phones in the household *(Numb. of .units)*		X (+)
Natural capital	H_CULT_LAND	Cultivated land *(ha)*	X (-)	X (-)
	H_GLDC_AREA	Total area *(ha*) allocated to GLDC targeted crops (millet, sorghum and cowpea)		X (±)
	H_GLDC_AREA x SEEDS_GLDC	Interaction between Land area *(ha*) allocated to GLDC targeted crops (millet, sorghum and cowpea) and Use of improved seeds (not only for GLDC crops) on the farm	X (±)	

Social capital	H_MEMB	The household is member of a farmer organisation or credit association *(1=Yes, 0=No)*	X (+)	
	H_CRED x H_EDUCL	Interaction between Household access to credit (Y/N) and Household head attendance to classic education (Y/N)		X (+)
Financial capital	LN_H_GROSINC	Natural logarithm of the household annual gross income	X (±)	X (±)
	LN_H_CER_INC	Natural logarithm of the household annual income drawn from cereal crops	X (±)	X (±)
	LN_H_MFCRP_INC	Natural logarithm of the household annual income drawn from marketable food crops	X (-)	
	LN_H_FMNR_INC	Natural logarithm of the household annual income drawn from regenerated/planted trees	X (-)	
	H_SHNF_INC	Share of non-farm income within household annual gross income		X (+)
	LN_H_COT_INC	Natural logarithm of the household annual income drawn from cotton crops		X (+)
Uncertainty perception	H_GLDCAS x H_RAIN	Interaction between Legumes-cereals association and Perception of rainfall decrease over the last 10 years		X (+)
Policy intervention	H_EXTENSION	Number of visits to the farm by extension services during the last 12 months		X (+)

Note: - the signs +, - and ± mean expected positive, negative and undetermined (difficult to anticipate) effect on adoption, respectively.

- Access to subsidy was not considered as variable as all farmer have access to government subsidy which the sole subsidy program for food crops.

3. Results and discussions

3.1. Evaluation of models' performance

To avoid multicollinearity (i.e. auto-correlations among explanatory variables at a degree violating the assumption of their independency in the statistical model), we used Variance Inflation Factor (VIF) and contingency coefficient to check the existence of multicollinearity. There is risk of multi-collinearity when VIF is greater than 5 and contingency factor is less than 0.2 (DeFries *et al.*, 2010). The Chi-square test was used to evaluate models' overall performance of logistic regressions. The models' goodness-of-fit was evaluated using area under the Receiver Operating Characteristic (ROC) curve (Hosmer and Lemeshow, 2000). For values of area under ROC less than 0.70, the model's performance is appreciated to be poor. For values of area under ROC between 0.70 and 0.80, the performance of the model is considered to be good enough. It will be very good if the area under ROC is between 0.8 and 0.90. When values are between 0.90 and 1, the performance of the model is excellent.

In a first step, all models were estimated for the whole population (all 4 ALS types) without distinguishing separate agriculture livelihood systems (ALS). In a second step, the models were estimated for each ALS type. At this second step, ALS IV was left out of the regression analyses due to low sample size (19 household). For analysing affecting factors of the cereals-legumes association and adoption of improved seeds by this ALS type IV, non-parametric method should be used to deal with the low sample size. The summary of population size per ALS type is shown in Table 2. Out of the 428 households forming the study sample(Thiombiano and Le, 2018), 390 households cropped at least one of the GLDC targeted crops. The distribution of these 390 households across ALS type is giving in Table 2.

Table 2. Cereal-cowpea association by households across ALS types

	Household is practicing sorghum-cowpea or Millet-cowpea association (Y/N)		
ALS type	No	Yes	Total
ALS I	125	60	185
ALS II	101	22	123
ALS III	51	12	63
ALS IV	15	4	19
TOTAL	292	98	390

3.2. Determinants for adoption of cereals-legume association

The estimation results of the cereals-cowpea adoption model are given in Table 3. The Hosmer and Lemeshow test shows that the model was globally statistically significant for whole population and individual ALS types (1-3). The value of the Nagelkerke Pseudo R^2 varied from 0.13 (ALS type II) to 0.40 (ALS type III). As for the area under ROC, its values showed that

the model performed well for Whole population (0.70), ALS type I (0.76) and ALS type II (0.74). It performed very well for the ALS type III (Area under ROC=0.84). The screening of the individual variable significance showed common and individual affecting factors as previously shown by Thiombiano and Le (2015a; 2015c) for sustainable nutrient management in the south-western of Burkina Faso.

Common determinants

The common affecting factors are variables found significant for whole population and individual ALS types. These variables were (Table 3):

- The number of workers which were found statistically significant for whole population (at 5%), ALS type I (at 5%) and ALS III (at 10%). It had a positive effect on the cereals-legume association adoption in the three cases. This means that the availability of labour drives farms to associate cereals to legume crops on the same plot;
- The number of household members on migration found to be statistically significant for whole population (at 10%) and ALS type III (at 5%). It had a negative effect on cereals-legumes association adoption by farmers in both cases. The migration phenomenon reduces labour availability and therefore reduce the chance of adopting cereals-legume association by farmers;
- The interaction Household mean distance to paved road *and* Household mean distance to nearest market was found significant at 10% for whole population and 1% for ALS type I. The affecting direction was negative, indicating that the remoteness from paved road and important market reduce the chance for farmers to adopt cereals-legumes association.
- The number of bullock which was found to be statistically significant for whole population (at 1%) and ALS type II (at 10%). It had same negative affecting direction in both cases. Having bullock for ploughing tend to prevent farmers to adopt cereals-legume association. Farmers explained during field visits that plots cannot be easily ploughed using animal traction as it destroys cowpea crops which are crawling plant;
- The cultivated land which was also statistically significant for whole population (at 5%) and ALS type I (at 1%). The affecting direction was also negative. In land availability situation, farmers mostly use extensive agricultural practices and are less inclined to associate cereals to legumes. Land availability constrains the adoption of cereal-legume association practice;
- The Interaction between Land area allocated to GLDC targeted crops and Use of improved seeds on the farm positively affect the association decision making by whole population (at 5%) and ALS type (at 5%). This means that farmers having large land area allocated to GLDC crops and using at the same time improved seeds tend to associate cereal to legume crops. These farms are GLDC crop based and from

experience may understand the benefit from associating cereals to legumes compared to farms more based on other crops such maize or cotton;

- The last common affection factor for cereals-legumes association adoption was the household annual income drawn from regenerated/planted trees. It was found significant at 10% for whole population and at 1% for ALS type I. It had negative effect on cereals-legume association. This means that the highest the income drawn from regenerated/planted trees, the less they have the chance to adopt cereals-legumes association.

ALS type-specific determinants

An ALS type-specific affecting factor is a factor that does not appear significant for whole population, but only for specific ALS types. From the regression results shown in Table 3, two variables were type-specific affecting factor for the adoption of cereal-legume association practice:

- The Natural logarithm of the household annual gross income: It was found significant for ALS type I only (at 5%). And it increases the chance for a farmer to adopt the cereal-legume association practice. ALS type I is the pro-poor ALS type which is land constrained and therefore tend to associate cereals and legume on same plot to diversify crop production. It may also be the fact that these farmers perceived the beneficial effects of the association on soil fertility and therefor on crop productivity;
- The Natural logarithm of the household annual income drawn from cereal crops which was found statistically significant at 10% for ALS type I and ALS type II. However the affecting pattern is different for the two ALS types. Indeed, the variable is negatively affecting the adoption of cereal-legume association for ALS type I while it positively affects it for ALS II. The two ALS type are pro-poor and poor respectively.

Table 3: Bi-logistic regression results for determinants of improved seeds uses for whole smallholder farms population and different ALS types.

Explanatory variables	Whole population	ALS I	ALS 2	ALS 3
Size of the farm household	0.45 (0.32)	0.27 (0.47)	1.07 (0.74)	-0.26 (1.12)
Number of workers of the farm	0.79 ** (0.4)	1.1** (0.5)	-0.36 (1.16)	5.09* (3.02)
Number of wives of the household head	-0.36 (0.27)	-0.17 (0.37)	-0.64 (0.61)	-0.07 (0.99)
Number of household members on migration	-0.17* (0.10)	-0.13 (0.15)	-0.08 (0.2)	-0.97** (0.48)
Interaction between Household mean distance to paved road *and* Household mean distance to nearest market	-0.01* (0.01)	-0.03*** (0.01)	$2.43\ 10^{-4}$ (0.02)	$4.00\ 10^{-3}$ (0.02)
Number of bullock for drought	-0.31*** (0.11)	-0.11 (0.16)	-0.5* (0.3)	-0.45 (0.39)
Cultivated land *(ha)*	-0.14** (0.06)	-0.32*** (0.12)	-0.16 (0.17)	$3.00\ 10^{-3}$ (0.14)
Interaction between Land area allocated to GLDC targeted crops and Use of improved seeds on the farm	0.21** (0.10)	0.4** (0.18)	0.06 (0.21)	-0.13 (0.27)
Household membership to farmer or credit association	0.13 (0.33)	-0.23 (0.58)	0.23 (0.59)	1.04 (1.2)
Natural logarithm of the household annual gross income	0.44 (0.30)	1.59** (0.64)	0.45 (1.63)	-0.61 (3.29)
Natural logarithm of the household annual income drawn from cereal crops	-0.21 (0.15)	-0.33* (0.4)	1.44* (0.85)	-1.1 (1.65)
Natural logarithm of the household annual income drawn from marketable food crops	-0.02 (0.03)	-0.02 (0.04)	-0.01 (0.05)	0.06 (0.13)
Natural logarithm of the household annual income drawn from regenerated/planted trees	-0.08** (0.03)	-0.16*** (0.05)	-0.06 (0.09)	0.3 (0.33)
Constant	-2.62 (3.34)	-14.06 (5.94)	-25.95 (21.97)	19.12 (49.53)
Fitness and accuracy of the models				
-2 Log likelihood	399.89	200.16	105.16	43.19
Pseudo R 2 (Nagelkerke)	0.15	0.23	0.13	0.40
Hosmer and Lemeshow test	0.794	0.875	0.458	0.868
Area under ROC	0.70	0.76	0.70	0.84

Note: Signs ***, **, and * indicate statistical significance at the 99% (P<0.01), 95% (P<0.05), and 90% levels (P<0.1), respectively.

3.3. Determinants of improved seed uses

The estimation results of the improved seeds adoption model are shown in Table 4. The Hosmer and Lemeshow test indicates that the model was globally statistically significant for whole population and individual ALS types (1-3). The value of the Nagelkerke Pseudo R^2 varied from 0.17 (whole population) to 0.34 (ALS type III). As for the area under ROC, its values showed that the model performed well for Whole population (0.71), ALS type I (0.71) and ALS type II (0.76). It performed very well for the ALS type III (Area under ROC=0.80). The individual variable significance showed common and individual affecting factors as for the adoption of cereal-legume association practice.

Common affecting factors

A total of 6 variables were found statistically significant for either whole population or the different ALS types. Amongst these 6 variables 4 were common affecting factors (Table 4):

- The Number of cellular phones in the household statistically significant at 5% and 10% for whole population and ALS type 3. It had a positive sign. This means that the farm household access to cellular phone increases the farm chance to adopt improved seeds. Indeed, access to timely information on seeds availability at extension services office remains a constraint that may reduce the chance of adopting improved seeds. The development of communication technology reduces the cost of information acquisition;
- The share of non-farm income within household annual gross income also had a positive effect on improved seeds adoption for whole population, ALS types II and III. The variable was statistically significant at 1% for Whole population and ALS type II, and at 10% for ALS type III. This indicates that income level increase the chance of adopting improved seeds use for these ALS types and whole population;
- The interaction between Legumes-cereals association and Perception of rainfall decrease over the last 10 years which indicate risk perception was found statistically significant for whole population (at 5%) and ALS type I only (at 5%). This shows that for these farms, the perception climate risk drive farmers to use improved seeds such drought resistant or short cycle improved seeds to mitigate climate variability effects on crop production;
- The number of visits to the farm by extension services during the last 12 months was statistically significant at 1% for whole population, ALS I and II. Access to extension service is usually seen as an opportunity for farmers to learn about good agricultural practices and have access to capacity building necessary to increase their knowledge and understanding farming issues and challenges.

Table 4: Bi-logistic regression results for determinants of practicing cereal-legumes intercropping for whole population and different ALS types.

Explanatory variables	Whole population	ALS I	ALS 2	ALS 3
Size of the farm household	-0.25 (0.29)	-0.55 (0.47)	0.17 (0.57)	-0.81 (0.84)
Number of cellular phones in the household	0.17** (0.07)	0.09 (0.14)	0.11 (0.16)	0.28* (0.17)
Number of bikes and motorbike in the household	-0.06 (0.08)	-0.13 (0.17)	$4.79\ 10^{-4}$ (0.18)	0.21 (0.18)
Cultivated land *(ha)*	0.02 (0.05)	0.33** (0.16)	0.09 (0.14)	0.03 (0.14)
Total area *(ha)* allocated to GLDC targeted crops (millet, sorghum and cowpea)	0.07 (0.11)	-0.54** (0.24)	0.05 (0.26)	-0.03 (0.31)
Interaction between Household access to credit and Household head attendance to classic education	0.91 (0.64)	1.54 (1.5)	1.25 (0.9)	38.2 (13.35)
Natural logarithm of the household annual gross income	0.16 (0.29)	-0.5 (0.78)	-1.82 (1.66)	-0.4 (2.41)
Natural logarithm of the household annual income drawn from cereal crops	-0.03 (0.14)	0.62 (0.57)	1.02 (0.74)	0.91 (0.99)
Natural logarithm of the household annual income drawn from regenerated/planted trees	-0.01 (0.03)	-0.02 (0.05)	-0.05 (0.07)	0.11 (0.12)
Share of non-farm income within household annual gross income	0.02*** (0.01)	0.02 (0.02)	0.06*** (0.02)	0.06* (0.03)
Natural logarithm of the household annual income drawn from cotton crops	0.03 (0.03)	-0.02 (0.05)	0.07 (0.06)	-0.06 (0.09)
Interaction between Legumes-cereals association and Perception of rainfall decrease over the last 10 years	0.75** (0.32)	1.04** (0.43)	0.23 (0.82)	1.71 (1.61)
Number of visits to the farm by extension services during the last 12 months	0.45*** (0.1)	0.5*** (0.16)	0.78*** (0.23)	0.32 (0.25)
Constant	-3.58 (3.17)	-1.88 (5.69)	8.52 (19.92)	-8.64 (34.4)
Fitness and accuracy of the models				
-2 Log likelihood	450.46	191.09	132.90	68.51
Pseudo R 2 (Nagelkerke)	0.17	0.18	0.29	0.34
Hosmer and Lemeshow test	0.814	0.239	0.290	0.396
Area under ROC	0.71	0.71	0.76	0.80

Note: Signs ***, **, and * indicate statistical significance at the 99% (P<0.01), 95% (P<0.05), and 90% levels (P<0.1), respectively.

ALS type-specific determinants

While financial capital variables were the type-specific affecting factor for the adoption of cereals-legumes association practices by farmers, the adoption of improved seeds has natural capital variables as type-specific variables. In effect, identified type-specific affecting factor for seed adoption were:

- Cultivated land which was found statistically significant at 5% for ALS type I only. It was not significant for whole population or the other ALS types. The cultivated land size surprisingly increased the adoption of improved seeds by ALS type I which is the pro-poor ALS type.
- The total area allocated to GLDC targeted crops (millet, sorghum and cowpea). The variable had a negative effect on improved seed adoption and was found significant only for ALS type I at 5%. This indicates that the larger the area to be covered by improved seed the less chance the farmer will adopt improved seeds. This variable in its affecting direction seems complementary to the variable cultivated land with indicates all crops including non GLDC crops. So if GLDC crop area has a negative effect on improved seeds adoption, the positive effect of cultivated land (all crops) may be understood as the effect of the income from non GLDC crop which allows purchasing improved seeds for GLDC crops.

4. Conclusion

The present study focused on behavioural analysis of different Agricultural livelihoods system (ALS) types in terms of cereal-legume association practice and improved seeds adoption. The results showed that these adoptions are influenced by livelihood assets as well as farmer perception of climatic risks and policy intervention. The main affecting factors related to labour availability, farmer remoteness from paved road and market, the level of equipment, the income and its sources as well as policy intervention and farmer perception of the rainfall variability risk he is facing. These variables are not only affecting the decision making alone, but also have interaction effects that need to be considered.

Most importantly in terms of guiding policy intervention aiming at improving adoption of good practices and agricultural livelihoods, common and ALS type specific factors were identified for both cereal-legumes association and improved seeds use adopting. The common factors are affecting factors usually captured in uniform policy intervention approach. As for type specific affecting factors, they are usually missed when considering whole population and not screening the heterogeneity's effects of agricultural livelihoods

system types. This result more likely in the failure of policy intervention and inefficient policy design. In the present study ALS type specific affecting factors related to financial capital variables for the cereal-legume association adoption. Those of the adoption of improved seeds related to land area which challenges the capacity of farmer to afford using improved seeds for all land area in a general poverty context and inefficient seeds subsidy programmes.

The findings of the present study support on livelihood heterogeneity on household-farm behaviour, supports previous findings on the agricultural livelihoods system heterogeneity effects on soil nutrient management by heterogeneous agricultural livelihood system types. Findings of these studies are useful for policy design and methodological purpose.

The way forward

After identifying main agricultural livelihood systems types in the Satiri sub-district, and performing behavioural analysis, the next step will consist in conducting efficiency analysis and presenting monitory surveys results.

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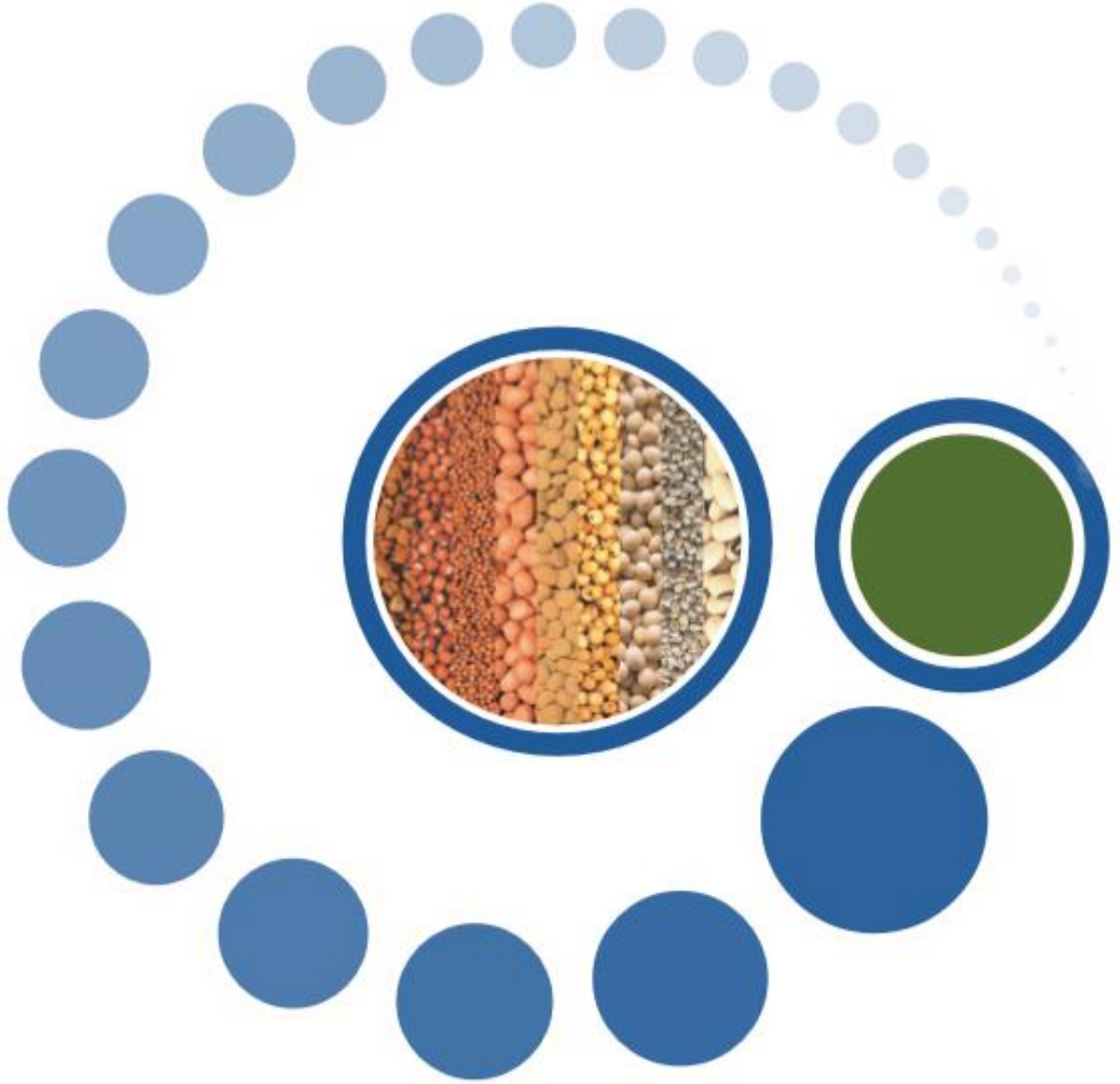

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