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Agricultural livelihood systems typology for coping with diversity in smallholder farming system research: A demonstrative case in South-western Burkina Faso

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Smallholder farms' populations are characterized by their heterogeneity giving the diversity of farms' livelihood settings. Integrated farming system modelling therefore requires a preliminary clear identification of the farm types in a location and for a given population. This study aims to formulate empirically agricultural livelihood system (ALS) typology for the purpose of integrated modeling of smallholder systems in West African drylands, taking Pontieba village in South-western Burkina Faso as a demonstration case. We used a multivariate analysis combining PCA to K-CA, and expert knowledge to identify agricultural livelihood system types in Pontieba. Based on the Sustainable Livelihood Framework, a cross-sectional dataset of 108 households was collected through household interviews. The results revealed the main variables discriminating agricultural livelihoods in Pontieba, which includes variables of human asset (labour, labour age, education and dependency), natural asset (land holdings and livestock), financial asset and livestock), financial (annual gross income, and non-farm income) assets, and production orientation (cotton and marketable food crops production). Three agricultural livelihood system types were identified: (i) Poor-income, landless and subsistence-based farms; (ii) Medium-income, high-dependency, cotton-and livestock-oriented farms, and (iii) better-off income, land-and labour-rich, cotton-and livestock-oriented farms. The study recommends the use of this typology for policy intervention and further systems analysis and modelling.

Key words: Agricultural livelihood typology, smallholder farms, sustainable livelihoods, semi-arid areas, integrated systems modelling, Burkina Faso.

INTRODUCTION

Food production is dominated by smallholder farming in Sub-Saharan African countries (Gassner et al., 2019). In semi-arid regions these smallholders are facing important issues needing the support of farming systems research

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to propose innovative pathways and solutions. These issues range mainly from land degradation to food insecurity and poverty. The inter-related 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 (Bjornlund et al., 2020; Nord et al., 2022b). Indeed, the number of undernourished people continues to increase since 1990 to 1992 (FAO, 2015; FAO et al., 2022). Studies support the existence of widespread soil nutrient depletion (Cobo et al., 2010; Nord et al., 2022b). In Burkina Faso in particular, successive studies have shown a worsening of soil nutrient depletion (Zougmoré et al., 2004; Diarisso et al., 2016). Rural poverty reduces farmers' investment in soil fertility, and wealthy farms often generate most of their income from soil nutrient mining (Van der Pol, 1992).
These phenomena make African smallholders running into poverty trap if the nutrient mining process is not reversed to improve farms' livelihoods.

These facts illustrate the failure of the current farming systems and policy intervention approaches aiming at supporting livelihood of rural population and ensuring satisfactory living conditions for populations in sub-Saharan Africa. The adoption of proven technologies that can help improve agricultural production remains low (Kanyama-Phiri et al., 2017; Nord et al., 2022b). The low performance of current farm systems, experience and lessons learned (Nord et al., 2022a) showed there is a need for holistic approaches (Kanyama-Phiri et al., 2017) that could lead to more successful farming systems and policy interventions. To that end, agricultural research has a key role to play. It can help in creating a better understanding of the condition for successful intervention. Interventions that lead to transforming the current farming systems as well as identifying pathways for transition to farming system designs that create and catalyze the resilience of farmers' livelihood.

Integrated system modeling offers the opportunity to better understand the issues farmers are facing and for identifying and testing potential solutions. For Stewart et al. (2019), integrated approach accounting for bio-physical and socio-economic factors is required for addressing soil fertility issue in Sub-Saharan African, and therefore for improving agricultural productivity and livelihood conditions of farmers. However, capturing farming systems heterogeneity constitutes an important step in integrated farming research and systems modelling (Le, 2005). Policy interventions wise, accounting for heterogeneity is crucial for ensuring the effectiveness of agricultural policies. Gassner et al.(2019) highlighted that developing agriculture in Africa goes through differentiating policy intervention based on smallholder heterogeneity. Indeed, smallholder farms in general (Tittonell et al., 2005; Chikowo et al., 2014) and those of West African drylands in specific, are characterized by their socio-economic and agro-ecological heterogeneity (Stewart et al., 2019). They exhibit different biophysical (Nord et al., 2022a) and socio-economic settings in relation to their livelihood endowment and orientation which change over time.

Objectives of the study

The overall objective of this study is to analyse agricultural livelihood heterogeneity in Pontieba for farming system design and integrated agricultural livelihood systems modeling. The specific objectives of the study are: (1) To identify main factors discriminating agricultural livelihoods in Pontieba (2) To identify main agricultural livelihood system types in the village of Pontieba (3) To characterize agricultural livelihood system types in the village of Pontieba

MATERIALS AND METHODS

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 system types in Pontieba.

Study site

The study was conducted in 2014 in Pontieba located 11° 7' 0" North and 3° 7' 0" W in the Ioba province, South-western Burkina Faso (Figure 1). Pontieba is part of the South-Sudan climatic zone with an average annual rainfall of 900 to 965 mm. The vegetation cover is savannah. The main soil type encountered in the village is leached ferruginous tropical soils, hardened in some locations. The main livelihood activities are subsistence rain-fed agriculture, animal husbandry, trade, handicraft, and traditional mining. Cereals and cotton are the main cultivated crops in the village. Livestock productions concerns mainly ruminants, pigs and poultry. Pontieba is situated at 7 km away from Dano, the main town of the province. The population of the village is 2,215 inhabitants at the last census in 2006 with growth rate of 2.5% and a population density of 71.4 inhabitants/km^2 (INSD, 2009). The methodological approach in

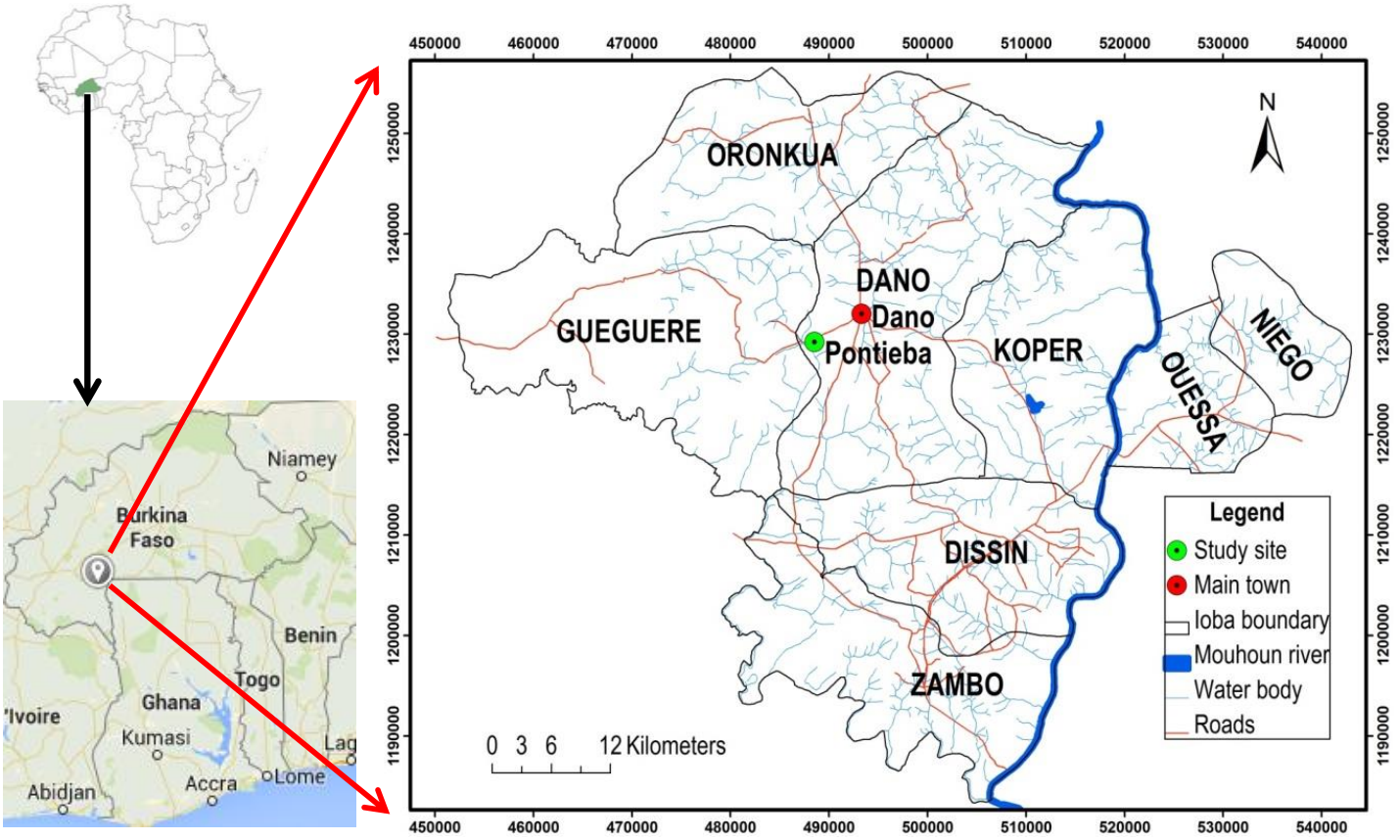

Figure 1. Study site. Text labels with capital and normal characters are for communes and villages, respectively. Dano is the main town of Ioba province.
Source: Thiombiano and Le (2015).

identifying agricultural livelihoods types used principal component analysis combined with cluster analysis and expert knowledge (key informants). Therefore, the choice of Pontieba for this study was guided by available background information and expert knowledge of the village.

Household-farm sampling and surveys

The household-farms were randomly sampled from a list of households of the village provided by local leaders. We sampled and surveyed 108 household-farms from 316 in the village, meaning 34% of the village's household-farms. The total population size of the village was 2,215 inhabitants. The surveys were conducted at the end of the cropping season 2013/2014, one to two months after harvest, in January and February 2014. The data was collected through face to face interview with the head of the household-farm helped by other key members of the household-farm. Field visits were organized with each farmer to measure the area of the farm's plots with GPS units and record geographic coordinates. The questionnaires were guided by the sustainable livelihood framework covered mainly household characterization (e.g. demography, education and profession), farm lands inventory and land tenure, agricultural and farm tools inventory, crop and livestock production, off-farm income and remittance. The proximity of households from permanent roads was extracted from map reading.

Identification of household-farm types

The identification of the agricultural livelihood system types in Pontieba combined multivariate analysis and expert knowledge. The methodological flowchart is shown in Figure 2. The multivariate analysis consisted in two steps. The first step used Principal Components Analysis (PCA) for identifying the main factors that discriminate household-farms. The collected multidimensional dataset was prepared by selecting main variables per capital in reference to the sustainable livelihood framework (Table 1). The PCA was run with the varimax option and only Principal Components (PC) with Eigen values of at least 1 (>=1) were considered. The second step consisted in K-mean cluster analysis (K-CA). The key variables contributing most to the factors loadings (Loadings>=0.6) from the PCA results were used. The knee method was employed to decide on the optimal number of clusters. ANOVA was used to characterize identified agricultural livelihood system types and the results were confronted to expert knowledge.

Testing the heterogeneity amongst the identified agricultural livelihood systems

The heterogeneity amongst the different agricultural livelihood systems in the Pontieba was tested. Analysis of variance (ANOVA) was used to detect differences amongst the ALS. According to whether the equal variance across groups is assumed or not,

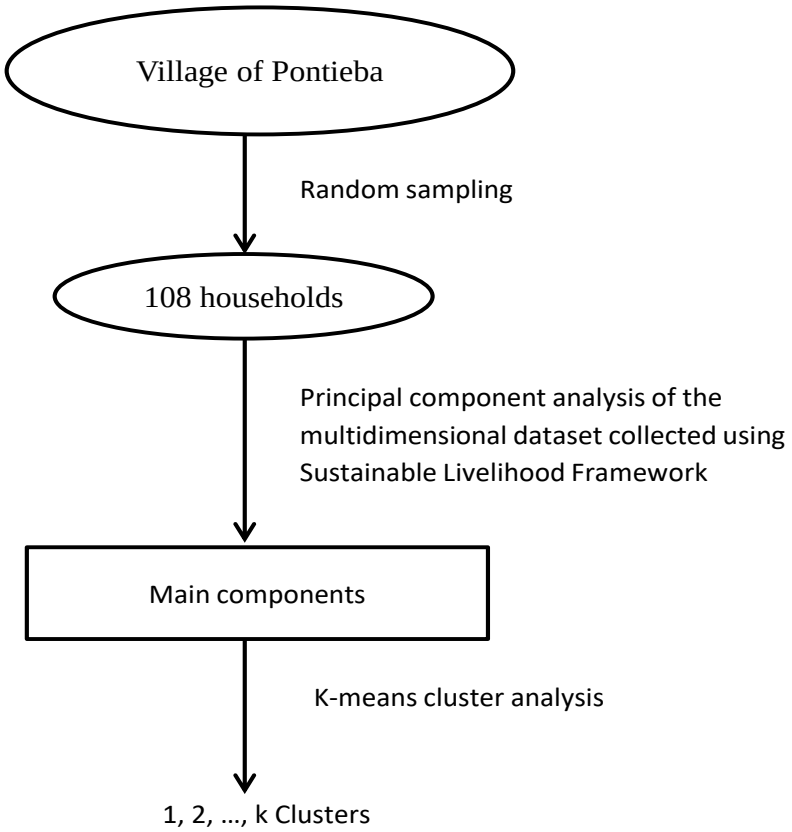

Figure 2. Methodological flow chart of household livelihood typology analysis.
Source: Authors

different post-hoc tests are used to decide on the groups' heterogeneity. For deciding on the post-hoc test to use, the Levene's test of variance equality was first run. This test indicates if the null hypothesis of equal variance across the different groups can be rejected. When the p-value of the Levene's test is lower than the chosen threshold p-value (0.05), the null hypothesis is rejected and the equal variance is not assumed. The least square difference (LSD) test was used when the Levene's test of equal variance indicates that there is equal variance. When the Levene's test suggested that the equal variance cannot be assumed; the Games-Howell test was used instead of the LSD. Two main indicators were used for testing the difference amongst ALS; the yield performance of main crops and the land use choice through the land area allocated to each land use type (crop).

RESULTS AND DISCUSSION

Characteristics of farming settings in Pontieba

Table 2 presents the characteristics of farming settings in Pontieba. It shows that households have an average size of 7 members dominantly headed by males, as females' heads are 7%. Around 60% of household's heads were illiterate reflecting the low literacy rate in the country and particularly in rural areas. This situation is a potential constraint to the adoption of good practices/innovations susceptible of improving farms' livelihood. The networking amongst farmers appeared to be relatively low as up to 58% of farmers did not belong to farmer or credit organization (Table 2). Farms possessed less than 1 ha of land per person (0.55 ha/person). Land pressure is likely to increase dramatically in the village in short term giving the population growth rate of 2.5% (INSD, 2009). The cropping system is subsistence based with 55% of household's farmed land allocated to basic cereals (sorghum, millet and maize). The level of equipment among farmers was very low: The average number of bullocks for land ploughing is only 0.15 per farm. The ratio livestock to land is low (0.45) suggesting a low potential for crop-livestock integration found to be the most promising way for affordably improving sustainable soil nutrient management in the region.

Main factors discriminating agricultural livelihood system types in Pontieba

The PCA results revealed 10 factors with total Eigen values of at least 1 (Table 3). The 10 factors beard 80.87% of initial total variance. Using the rotated component matrix, the factors were named after variables

Table 1. Household variables for principal component analysis.

Livelihood asset	Variable	Variable definition	Source[a]
Human	$H_{HEADAGE}$	Household head age (year-old)	D
	$H_{MEANAGE}$	Average age of the household members	C
	H_{LABAGE}	Average age of the household labour	C
	H_{HEDUYR}	Number of years of classic education of household head	C
	H_{NBEDUC}	Number of educated members in the household	C
	H_{SIZE}	Household size (no. of people in the household)	D
	H_{LABOUR}	Number of workers of the household (labour)	C
	H_{DEPEND}	Dependency ratio of the household	C
Physical	$H_{DMARKET}$	Distance to important market (Main town) from household house	D
	H_{DROAD}	Distance to permanent road from household house (m)	R
	$H_{VEHICLE}$	Number of transportation means (bicycle and motorbike) possessed by the household	C
	$H_{BULLOCK}$	Number of bullocks possessed by the farm	D
Natural	$H_{HOLDINGS}$	Farm land holdings (ha)	D
	$H_{HOLDINGCP}$	Farm land holdings per capita (ha/person)	C
	$H_{FALLOWCP}$	Farm fallow land per capita (ha/person)	C
	$H_{CULTLANDCP}$	Farm cultivated land per capita (ha/person)	C
	$H_{SHFALLOW}$	Share of fallow area in land holdings (%)	C
	$H_{SHCOTTON}$	Share of cotton area in land holdings (%)	C
	$H_{SHCEREAL}$	Share of cereals area in land holdings (%)	C
	$H_{SHMFCRP}$	Share of marketable food crops area in land holdings (%)	C
	H_{TLUCP}	Tropical livestock unit per capita (TLU/capita)	C
	H_{TLUHA}	Tropical livestock unit per ha of cultivated land (TLU/ha)	C
Financial	$H_{GROSSINC}$	Household annual gross income (FCFA)	C
	$H_{GROSSINCCP}$	Household annual gross income per capita (FCFA/capita)	C
	$H_{SHREMITINC}$	Share of remittance income in household annual gross income (%)	C
	$H_{SHNFINC}$	Share of off-farm income in household annual gross income (%)	C
	$H_{SHLIVESTINC}$	Share of livestock income in household annual gross income (%)	C
	$H_{SHCOTINC}$	Share of cotton income in household annual gross income (%)	C
	$H_{SHCERINC}$	Share of cereals income in household annual gross income (%)	C
	$H_{SHMFCRPINC}$	Share of marketable food crops income in household annual gross income (%)	C

[a] D = Direct extracted from the questionnaire; C = Compound information calculated based on information coded in the questionnaire; R = Extracted from map reading.
Source: Authors

with greater loadings and most correlated to the factors as shown in Table 4. The most discriminating factors of household-farms in Pontieba, with at least 10% of initial total variance, were PC1, PC2 and PC3 which were highly correlated with natural capital ($H_{HOLDINGS}$ with loadings b=0.88 and H_{TLUCP} with loadings b=0.92), human capital (H_{LABOUR} with loadings b=0.90). The PC1 was named Land PC as it was highly associated with land variables. This PC is a measure of land abundance as the loading was positive. The PC2 was named Livestock PC for it was highly associated with livestock, indicating it is a measure of livestock endowment because the loading was positive. As for the PC3, it was named Labour PC for it is highly associated with labour, hinting that the PC is a measure of labour resource abundance given that the loading was positive. These three factors represented 16, 12 and 11% of initial total variance, respectively. Other discriminating factors were PC4 to PC8 which carried less than 10% of initial total variance (6-8%) each. The PC4 was most correlated with human capital (H_{LABAGE} and $H_{MEANAGE}$ with loadings b=0.91 for both) with positive loading. This PC reflects the aging of human resource. The PC4 was therefore named Age PC. It carried 8% of initial total variance. The PC5 and PC6 were most correlated with Financial capital ($H_{GROSSINCCP}$ with loadings b=0.75 for PC5 and $H_{SHCOTINC}$ with loadings b= -0.90 for PC6). The PC5 carried 8% of initial total variance. It has a positive loading and indicated the level

Table 2. Main farming system characteristics in Pontieba.

Variable	Mean / value	Minimum	Maximum
Household size	7	1	14
Household female head (%)	7	-	-
Household head illiteracy (%)	60	-	-
Litteracy level (%)			
Primary school	19	-	-
High school	21	-	-
Network membership (%)	42	-	-
Land holdings (ha/person)	0.55	0.03	3.43
Share of basic cereals[a] in cropped land (%)	55	0	100
Number of bullocks possessed by the farm	0.15	0	2
Livestock farmed land ratio (TLU[b]/ha)	0.45	0	3.51

[a]Basic cereals: Sorghum, millet and maize; [b]TLU: Tropical Livestock Unit.
Source: Authors' own calculation

Table 3. Total variance explained by extracted components, using principal component analysis (PCA) as extraction method.

PC	Initial Eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumul.[a] %	Total	% of Variance	Cumul.[a] %	Total	% of variance	Cumul.[a] %
1	4.78	15.94	15.94	4.78	15.94	15.94	3.80	12.66	12.66
2	3.74	12.45	28.39	3.74	12.45	28.39	3.24	10.81	23.47
3	3.39	11.30	39.69	3.39	11.30	39.69	3.16	10.54	34.01
4	2.52	8.40	48.09	2.52	8.40	48.09	2.86	9.52	43.53
5	2.29	7.62	55.71	2.29	7.62	55.71	2.47	8.23	51.76
6	1.99	6.64	62.36	1.99	6.64	62.36	2.29	7.62	59.38
7	1.73	5.77	68.13	1.73	5.77	68.13	1.98	6.59	65.97
8	1.68	5.61	73.74	1.68	5.61	73.74	1.84	6.14	72.11
9	1.12	3.73	77.47	1.12	3.73	77.47	1.38	4.59	76.70
10	1.02	3.40	80.87	1.02	3.40	80.87	1.25	4.17	80.87

Only PC was retained with Eigen value ≥ 1. The principal components with Eigenvalues less than 1 are not shown. [a]Cumul.= Cumulative.
Source: Authors' own calculation

of income per capita. It can be seen as a measure of the wealth of farm members. The PC5 was then named Income PC. The PC6 was highly associated with share of cotton income but has a negative loading. This means the PC reflects low income from cotton. It was named Cotton PC and carried 7% of initial total variance.

The PC7 and the PC8 were most correlated with natural capital and financial capital,

Table 4. Rotated component matrix (that is, loadings) using varimax rotation method and Kaiser normalization of first ten principal components.

Livelihood asset	Variable	Principal components (PC)									
		1-Land PC (16%)	2-Liv. PC (12%)	3-Lab. PC (11%)	4-Age PC (8%)	5-Inc. PC (8%)	6-Cot. PC (7%)	7- MF PC (6%)	8-NF PC (6%)	9-Educ. PC (4%)	10-Dep. PC (3%)
Human	$H_{HEADAGE}$	0.03	0.05	0.30	**0.60**	-0.02	0.18	0.03	-0.16	-0.29	0.04
	$H_{MEANAGE}$	0.08	0.05	-0.18	**0.91**	0.12	0.04	0.01	0.06	0.05	-0.15
	H_{LABAGE}	0.06	0.08	-0.18	**0.91**	0.12	0.06	0.00	0.08	0.00	-0.07
	H_{HEDUYR}	0.21	-0.06	0.05	-0.24	0.04	0.13	0.02	0.11	**0.75**	-0.07
	H_{NBEDUC}	0.01	0.00	**0.68**	-0.38	-0.05	0.20	0.10	-0.07	0.35	-0.14
	H_{SIZE}	-0.01	0.00	**0.88**	-0.16	-0.23	-0.05	-0.11	0.01	-0.11	0.17
	H_{LABOUR}	-0.09	0.01	**0.90**	-0.10	-0.14	-0.05	-0.06	-0.06	-0.07	-0.23
	H_{DEPEND}	0.14	0.03	-0.09	-0.19	-0.11	-0.06	-0.15	0.13	-0.04	**0.85**
Physical	$H_{DMARKET}$	-0.15	0.00	0.06	-0.42	-0.13	0.14	0.10	0.06	-0.59	-0.12
	H_{DROAD}	-0.10	-0.06	0.13	0.24	0.50	-0.08	0.01	-0.07	0.05	0.39
	$H_{VEHICLE}$	-0.03	0.02	**0.67**	0.12	0.29	-0.07	0.02	0.09	0.02	0.04
	$H_{BULLOCK}$	0.03	**0.60**	0.10	-0.14	0.24	0.00	0.06	-0.07	-0.28	-0.02
Natural	$H_{HOLDINGS}$	**0.88**	0.02	0.27	-0.03	0.23	0.01	-0.01	-0.12	-0.06	0.03
	$H_{HOLDINGCP}$	**0.85**	-0.02	-0.22	0.07	0.39	0.05	0.00	-0.11	0.09	-0.09
	$H_{FALLOWCP}$	**0.91**	-0.06	-0.14	0.02	0.02	0.10	-0.05	0.04	0.14	0.04
	$H_{CULTLANDCP}$	0.17	0.05	-0.21	0.11	**0.78**	-0.07	0.08	-0.29	-0.06	-0.23
	$H_{SHFALLOW}$	**0.88**	-0.01	-0.04	0.13	-0.22	0.13	-0.08	0.12	0.16	0.12
	$H_{SHCOTTON}$	-0.14	0.10	0.09	-0.02	0.08	**-0.90**	-0.09	0.07	-0.04	0.02
	$H_{SHCEREAL}$	-**0.63**	-0.08	0.02	-0.11	0.13	0.48	-0.41	-0.22	-0.07	-0.08
	$H_{SHMFCRP}$	-0.16	0.02	-0.09	0.01	0.05	0.09	**0.91**	0.09	-0.10	-0.07
	H_{TLUCP}	0.03	**0.92**	-0.04	0.07	0.22	-0.04	-0.05	0.01	0.05	-0.08
	H_{TLUHA}	-0.24	**0.87**	0.03	0.02	-0.02	0.03	-0.09	0.15	0.10	0.08
Financial	$H_{GROSSINC}$	0.07	0.37	0.47	-0.02	**0.59**	-0.11	-0.10	0.36	0.00	0.08
	$H_{GROSSINCCP}$	0.17	0.29	-0.12	0.18	**0.75**	-0.05	-0.06	0.35	0.20	-0.07
	$H_{SHREMITINC}$	0.01	-0.17	-0.18	0.40	0.28	0.01	-0.01	-0.25	0.14	0.29
	$H_{SHNFINC}$	-0.05	-0.35	0.05	-0.09	-0.04	0.27	-0.26	**0.83**	0.02	-0.01
	$H_{SHLIVESTINC}$	0.11	**0.90**	-0.01	0.12	-0.13	-0.05	0.05	-0.14	-0.05	0.00
	$H_{SHCOTINC}$	-0.05	-0.07	-0.01	-0.17	0.08	**-0.90**	-0.16	-0.08	-0.02	0.04
	$H_{SHCERINC}$	-0.07	-0.20	0.04	-0.07	-0.03	0.40	-0.16	**-0.70**	-0.08	-0.16
	$H_{MFCRPINC}$	0.10	-0.06	0.01	-0.02	-0.03	0.11	**0.87**	-0.17	0.04	-0.08

Liv= Livestock, Lab= Labour, Inc.=Gross Income; Cot= Cotton, M.F= Marketable Food crops, NF=Non-farm income; Educ. = Education; Dep= Dependency. Numbers in parenthesis are percentages of total variance of original variables explained by PC. Bold and underlined are high loadings, indicating most important original variables representing the PC and used for CA.
Source: Authors' own calculation

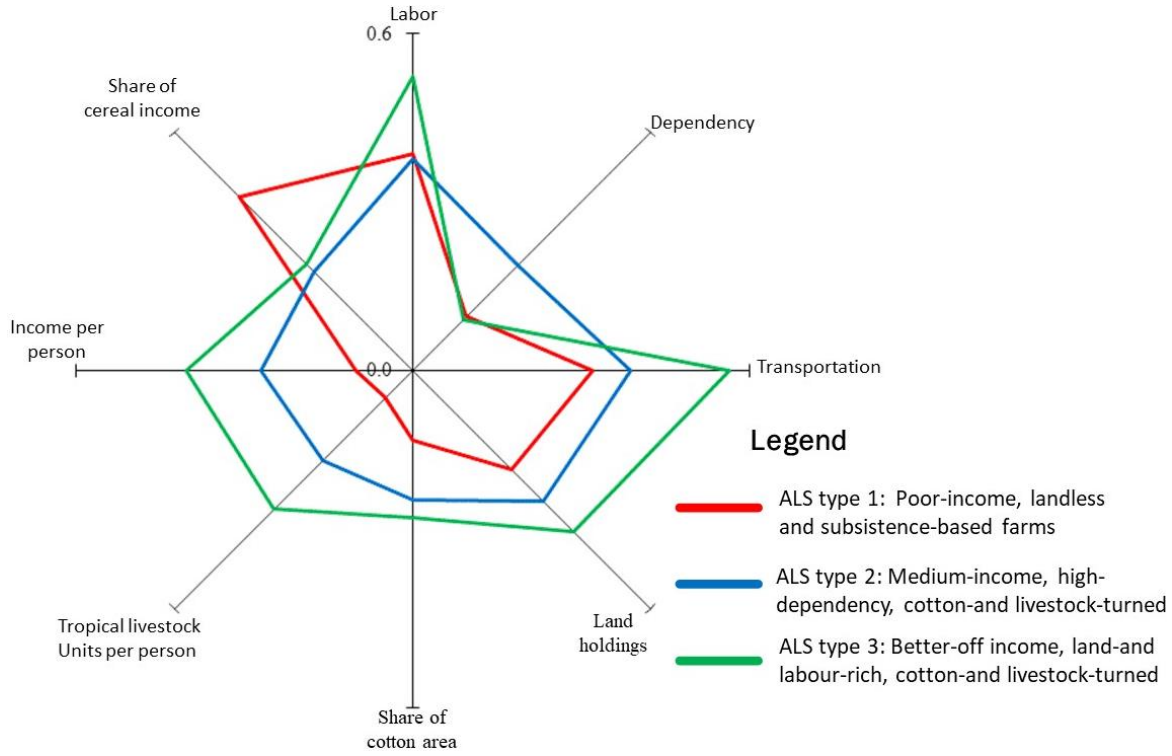

Figure 3. Key indicators (standardized) of the three main agricultural livelihood system (ALS) types. Three main agricultural livelihood system types in the village of Pontieba: Agricultural Livelihood System type I [Poor-income, landless and subsistence-based farms] (red colour curve), Agricultural Livelihood System type II [Medium-income, high-dependency, cotton-and livestock-oriented] (dark blue colour curve), agricultural livelihood system types III [Better-off income, land-and labour-rich, cotton and livestock-oriented] (dark green colour curve) were identified.
Source: Authors' own calculation

respectively. PC7 was most correlated with $H_{SHMFCRP}$ (with loadings b=0.91). It reflects the orientation toward marketable food crop production since the loadings is positive. It was therefore named marketable food crops PC. It carried 6% of initial total variance. The PC8 was most correlated with $H_{SHNFINC}$ (with loadings b=0.83). This PC was named Off-farm income PC. It carried 6% of initial total variance. The last two PCs, PC9 and PC10 were both most correlated to human capital. PC9 was most correlated with H_{HEDUYR} (with loadings b=0.75). It was named education PC and carried only 4% of initial total variance. This PC reflects the level of education. As for PC10, it was most correlated with H_{DEPEND} (with loadings b=0.85). This last PC reflects the level of dependency within the farm and was therefore named dependency PC. It carried 4% of initial total variance.

Agricultural Livelihood System types in Pontieba

The typology analysis results revealed three agricultural livelihood system types in the village of Pontieba. These agricultural livelihood system types were characterized using a radar diagram showing the livelihood dimension structure built from standardized values of key variables (Figure 3), in addition to the income composition and the livelihood orientation. The Table 5 shows keys variables for which the three Agricultural Livelihood System type were found significantly different at 5% using ANOVA.

Agricultural Livelihood System type I: Poor-income, landless and subsistence-based farms

The agricultural livelihood system type I (Poor-income, landless and subsistence-based farms) represented 40% of the study sample. This agricultural livelihood system type had the lowest asset endowment. It had in average 2.67 ha of total land holdings, meaning 0.47 ha per person. The livelihood orientation was subsistence-based as income from basic cereals (sorghum, millet and maize) formed 32.47% of annual gross income with 60.85% of cultivated land dedicated to these cereals. Only 10.74% of cultivated lands were allocated to cotton which is the main local and regional cash crop. These farms also have low labour and less transportation. They have the lowest annual gross income. Only 46,152 FCFA per person was found (USD 93.35/person). Livelihoods of

Table 5. Descriptive statistics of the agricultural livelihood system types in Pontieba.

Livelihood asset	Farm type (size)	Poor-income, landless and subsistence-based farms (40)					Medium-income, high-dependency, cotton and livestock-oriented (40)					Better-off income, land-and labour-rich,cotton and livestock-oriented (20)				
		Mean	Std. Dev	Std. Error	95% Conf.Interval		Mean	Std. Dev	Std. error	95% Conf.Interval		Mean	Std. Dev	Std. Error	95% Conf.Interval	
					Lower Bound	Upper Bound				Lower Bound	Upper Bound				Lower Bound	Upper Bound
Human	H_HeadAge	47.03	12.24	1.94	43.11	50.94	44.23	14.53	2.30	39.58	48.87	50.55	14.85	3.32	43.60	57.50
	H_MeanAge	26.53	8.96	1.42	23.66	29.39	25.65	9.14	1.45	22.73	28.57	27.50	9.98	2.23	22.83	32.17
	H_LabAge	28.08	8.62	1.36	25.32	30.83	26.95	8.58	1.36	24.20	29.70	29.20	10.22	2.29	24.42	33.98
	H_HEduYr	1.03	2.50	0.40	0.23	1.82	2.18	3.46	0.55	1.07	3.28	0.75	2.36	0.53	-0.35	1.85
	H_NbEduc	2.68	1.98	0.31	2.04	3.31	2.63	1.50	0.24	2.15	3.10	3.25	1.94	0.44	2.34	4.16
	H_Size	6.20	2.70	0.43	5.34	7.06	6.85	2.53	0.40	6.04	7.66	7.70	2.03	0.45	6.75	8.65
	H_Labour	5.25	2.37	0.38	4.49	6.01	5.15	1.98	0.31	4.52	5.78	**6.75**	2.27	0.51	5.69	7.81
	H_Depend	0.19	0.18	0.03	0.13	0.25	**0.37**	0.36	0.06	0.26	0.49	0.18	0.21	0.05	0.08	0.28
Physical	H_DMarket	6.66	2.09	0.33	6.00	7.33	6.14	1.80	0.28	5.57	6.72	6.51	1.97	0.44	5.59	7.43
	H_Vehicle	2.25	1.34	0.21	1.82	2.68	2.73	1.34	0.21	2.30	3.15	**3.95**	1.70	0.38	3.15	4.75
	H_Bullock	0.00	0.00	0.00	0.00	0.00	0.15	0.48	0.08	0.00	0.30	0.45	0.83	0.19	0.06	0.84
Natural	H_Holdings	**2.67**	2.00	0.32	2.03	3.31	3.50	2.44	0.39	2.72	4.28	**4.25**	1.94	0.43	3.35	5.16
	H_HoldingCp	0.47	0.35	0.06	0.36	0.58	0.60	0.58	0.09	0.41	0.78	0.60	0.36	0.08	0.43	0.77
	H_FallowCp	0.12	0.32	0.05	0.02	0.22	0.21	0.49	0.08	0.06	0.37	0.10	0.25	0.05	-0.02	0.21
	H_CultLandCp	0.35	0.23	0.04	0.27	0.42	0.38	0.18	0.03	0.32	0.44	0.51	0.27	0.06	0.38	0.63
	H_ShFallow	14.32	24.59	3.89	6.46	22.19	18.87	27.49	4.35	10.08	27.66	10.08	21.01	4.70	0.25	19.92
	H_ShCotton	10.74	18.60	2.94	4.79	16.69	**19.93**	20.40	3.22	13.41	26.46	**22.63**	16.96	3.79	14.69	30.57
	H_ShCereal	60.85	27.37	4.33	52.09	69.60	50.73	26.99	4.27	42.10	59.36	54.31	22.94	5.13	43.58	65.05
	H_ShMFCrp	14.09	20.90	3.30	7.40	20.77	10.47	11.99	1.90	6.63	14.30	12.97	11.13	2.49	7.77	18.18
	H_TLUCp	0.07	0.08	0.01	0.04	0.10	**0.23**	0.24	0.04	0.15	0.30	**0.35**	0.28	0.06	0.22	0.49
	H_TLUha	0.21	0.26	0.04	0.12	0.29	0.50	0.43	0.07	0.36	0.64	0.81	0.95	0.21	0.37	1.26
Financial	*H_GrossInc*	251,594	101,685	16,078	219,074	284,114	591,671	109,395	17,297	556,685	626,657	1,062,780	134,101	29,986	1,000,019	1,125,541
	H_GrossIncCp	**46,152**	28,676	4,534	36,981	55,323	**101,295**	53,319	8,430	84,242	118,347	**144,428**	30,603	6,843	130,105	158,751
	H_ShRemitInc	3.72	14.41	2.28	-0.89	8.33	1.47	5.53	0.87	-0.30	3.24	2.21	8.26	1.85	-1.65	6.08
	H_ShNFInc	26.60	21.89	3.46	19.60	33.60	36.19	25.35	4.01	28.08	44.30	32.31	26.51	5.93	19.90	44.72
	H_ShLivestInc	17.25	14.51	2.29	12.61	21.89	21.27	17.27	2.73	15.75	26.79	26.04	20.92	4.68	16.24	35.83
	H_ShCotInc	8.17	17.58	2.78	2.55	13.79	14.99	14.86	2.35	10.23	19.74	11.46	11.89	2.66	5.89	17.02
	H_ShCerInc	**32.47**	19.97	3.16	26.08	38.85	18.33	12.17	1.92	14.44	22.23	19.91	11.00	2.46	14.76	25.05
	H_ShMFcrpInc	11.67	16.50	2.61	6.39	16.95	7.76	8.10	1.28	5.17	10.35	8.08	8.29	1.85	4.19	11.96

ANOVA was used to test the difference amongst identified agricultural livelihood system types.
Source: Authors' own calculation

Table 6. Main land use and yield performance of identified ALS.

Agricultural livelihood system		Land use (ha)			Crop yield (kg/ha)		
		Cotton	Maize	Sorghum	Cotton	Maize	Sorghum
ALS 1: Poor-income, landless and subsistence-based farms		0.79[a]	0.34[a]	1.27[a]	436[a]	1206[a]	335[a]
ALS 2: Medium-income, high-dependency, cotton and livestock-oriented		0.85[a]	0.43[ab]	1.18[a]	753[b]	1266[a]	401[a]
ALS 3: Better-off income, land-and labour-rich, cotton and livestock-oriented		1.24[b]	0.53[b]	1.45[a]	546[a]	2074[a]	531[b]
Levene's test p-value		0.875	0.31	0.664	0.403	0.041	0.293
ANOVA Test	F	4.843	2.736	0.859	3.538	3.082	4.944
	p	0.012	0.070	0.427	0.034	0.049	0.008

Number in the same column and with the same letter is not significantly different at 0.05 (95% confidence).
Source: Authors' own calculation

these farms can be considered to be vulnerable as the annual income per person is below the national poverty line estimated to be 108,454 FCAF (USD 219.36/person/year).

Agricultural Livelihood System type II: Medium-income, high-dependency, cotton-and livestock-oriented

The Agricultural Livelihood System type II (*Medium-income, high-dependency, cotton-and livestock-oriented)* represented 40% of the study. This farm type had the highest dependency ratio (0.37). The livelihood orientation is market-turned. In effect, around 20% of the cultivated land is allocated to cotton cropping. In addition, the contribution of basic cereals income to the annual gross income (18.33%) is lower than in the case of Agricultural Livelihood System type I. It also had a better endowment in livestock than the farm type I. The number of Tropical Livestock Unit (TLU) per capita was 0.23. The labour endowment and transportation were not significantly different for farm types I and II. The Agricultural Livelihood System type II showed a medium annual income estimated to 101,295 FCFA/person, equivalent to USD 204.88/person/year. This amount is nearly the poverty line in Burkina Faso, USD 219.36/person/year.

Agricultural Livelihood System type III: Better-off income, land-and labour-rich, cotton-and livestock-oriented

The third farm type, Agricultural Livelihood System type III (*Better-off income, land-and labour-rich, cotton-and livestock-oriented)* represented the best endowed and wealthiest farm type out of the three. It had the highest labour endowment (7 workers), the highest land holdings (4.25 ha) and the highest number of transportation (4). This last setting might play an important role in facilitating the farmer access to market, to other farmers and villages, and thereby increases his exposure to innovations and opportunities. This farm type is also market-turned like in the case of Agricultural Livelihood System type II. The land area dedicated to cotton cropping was around 23% of cultivated. As for the livestock endowment, it was 0.35 TLU per person. The values for cotton and livestock as well as the contribution of cereal income to annual gross income (19.91%) were higher than in the case of Agricultural Livelihood System type I, but were not significantly different from Agricultural Livelihood System type II. The Agricultural Livelihood System type III was the only one farm type with annual income above the poverty line in Burkina Faso. This annual income was 144,428 FCFA/person (USD 292.12/person).

Agricultural livelihood systems heterogeneity in Pontieba

The results of the ANOVA test are summarized in Table 6. The ANOVA test showed that there were significant differences amongst Agricultural Livelihood Systems for cotton and Maize land use. Indeed, the cotton land area of ALS 3 was larger than the two other ALS while for maize; the ALS 3 had the largest farmed area compared to ALS 1. No significant difference was found amongst ALS for sorghum land use. The analysis of the yield performance also revealed heterogeneity across ALS. The ALS 1 had the highest cotton yield. Though the p-value of the ANOVA test indicated a significant difference amongst ALS1, the Levene's test rejected the null hypothesis of equal variance.

The post-hoc test under this condition of non-equal variance across ALS revealed no significant difference amongst ALS. The different ALS was found significantly different for the sorghum which is to the most cultivated cereal in the study region. The ALS 3 showed the highest yield. These results demonstrated that clusters identified in Pontieba are functional clusters regarding land use and crop yield. The performance and land choice analyses of the three Agricultural livelihood systems will be further analysed in subsequent work.

Conclusion

By combining principal component analysis and cluster analysis, the present study succeeded in clearly identifying main discriminating factors among smallholder farms in the village of Pontieba, Ioba province in south-western Burkina Faso. Variables discriminating agricultural livelihoods in Pontieba are labor, labor age, education and dependency (human asset); land holdings and livestock (natural asset); annual gross income and non-fam income (financial asset), and production orientation (cotton and marketable food crops production). The study identified three agricultural livelihood system types in the village of Pontieba: Poor-income, landless and subsistence-based farms, medium-income, high-dependency, cotton-and livestock-oriented farms, and better-off income, land-and labour-rich, cotton-and livestock-oriented farms. This farm types showed different livelihood settings and production performance. Therefore, the failure to consider farm heterogeneity in a location hampers the effectiveness of interventions aiming at improving rural livelihood. Accounting for farms' heterogeneity is keys to farming design studies, in particular for integrated farming systems modeling and analysis seeking to propose innovative solutions for adaptive, sustainable and resilient agricultural livelihoods in a changing biophysical and socio-economic context. The results of this study can be used for policy intervention.

Further studies should test the framework of the current study by performing behavioral analysis in terms of land use decision making, yield function of main crops and livestock for identified different agricultural livelihoods systems.

Limitation of the study

The study was conducted in one village with a population of 306 households. There a need to conduct a similar study at a larger geographical area and with a larger population size.

CONFLICT OF INTERESTS

The authors have no relevant financial or non-financial interests to disclose

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