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Agricultural livelihood systems (ALS) typology for coping with socio-ecological diversity in ALS transition research: A demonstrative case in Pontieba, south-western Burkina Faso

Food security and better livelihoods
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Agricultural livelihood systems (ALS) typology for coping with socio-ecological diversity in ALS transition research: A demonstrative case in Pontieba, south-western Burkina Faso

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Abstract

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. The main objective of the present study was to formulate empirical agricultural livelihood typology in the village of Pontieba for the purpose of integrated farming livelihood modelling in West African drylands. We used a multivariate analysis combining PCA to K-CA, and expert knowledge to identify agricultural livelihood types in Pontieba. Based on the Sustainable Livelihood Framework, a multidimensional dataset of 108 households was collected through face-to-face interviews. The results showed that the main variables discriminating agricultural livelihoods in Pontieba were human (labor, labor age, education and dependency), natural (land holdings and livestock), financial (annual gross income, and non-fam income) assets, and production orientation (cotton and marketable food crops production). Three agricultural livelihood types were identified: *Poor, landless and subsistence-based farms*, *Medium-income, high-dependency, cotton-and livestock-turned farms*, and *Better-off, land-and labour-rich, cotton-and livestock-turned farms*. The study recommends the use of this typology for policy intervention and further systems analysis and modelling in the village of Pontieba.

Keywords: Agricultural livelihood typology, Smallholder farms, Sustainable livelihoods, semi-arid areas, integrated systems modelling, 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 & Le, 2015). 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, Section 7, page 85). 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 & Le, 2015) to improve farms' livelihoods.

Integrated system modelling offers the opportunity to better understand the issues farmers are facing and for identifying and testing potential solutions. However, capturing farming systems heterogeneity constitutes an important step in integrated farming systems modeling (Le, 2005). Indeed, smallholder farms in general (Tittonell *et al.*, 2005 ; Chikowo *et al.*, 2014) and those of West African drylands in specific (Thiombiano & Le, Submitted), are characterized by their heterogeneity. They exhibit different biophysical and socio economic settings in relation to their livelihood endowment and orientation which change over time.

The main objective of this paper is to analyze agricultural livelihood heterogeneity in the village of Pontieba for integrated agricultural livelihood systems modelling. The specific objectives are to (i) identify main factors discriminating agricultural livelihoods at village level and (ii) identify and characterize agricultural livelihood types in the village of Pontieba.

2. Methods and materials

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 & 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 village of Pontieba.

Study site

The study was conducted in the village of Pontieba located 11° 7' 0" North and 3° 7' 0" W in the Ioba province, South-western Burkina Faso (Fig.1). The village of Pontieba is part of the South-Sudanian climatic zone with an average annual rainfall of 900-965 mm. The vegetation cover is savannah. The main soil type encountered in the village is leached ferruginous tropical soils, hardened in some locations (Thiombiano, 2015). 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 only 7 km away from Dano, the main town of the province. The population of the village was estimated to be 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 identifying agricultural livelihoods types used multivariate analysis and expert knowledge. Therefore the choice of Pontieba for this study was guided by available background information and expert knowledge of the village.

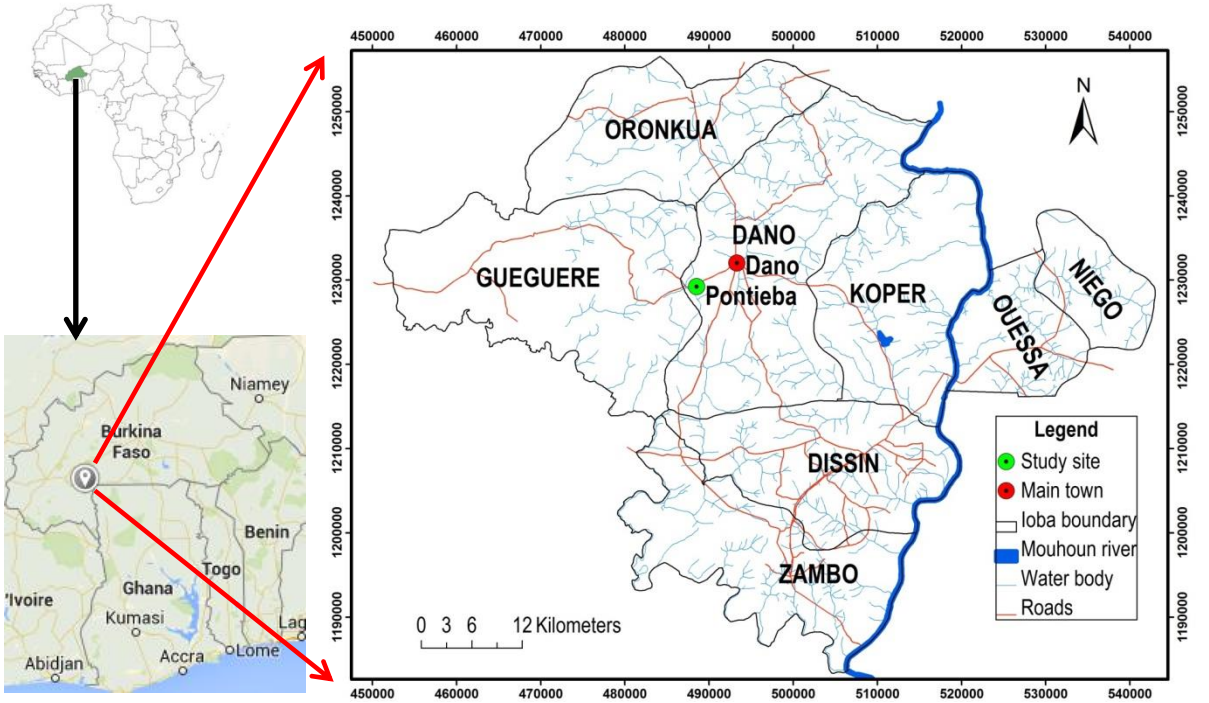

Fig. 1. Study site. The village of Pontieba in Dano commune was selected out of the six villages surveyed in a previous study (Thiombiano and Le, Submitted). Notes: Text labels with capital and normal characters are for communes and villages, respectively. Dano is the main town of Ioba province.

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 over 316 in total in the village, meaning 34% of the village's household-farms. 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 was 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 types in Pontieba combined multivariate analysis and expert knowledge. The methodological flowchart is shown in Fig.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 types and the results were confronted to expert knowledge.

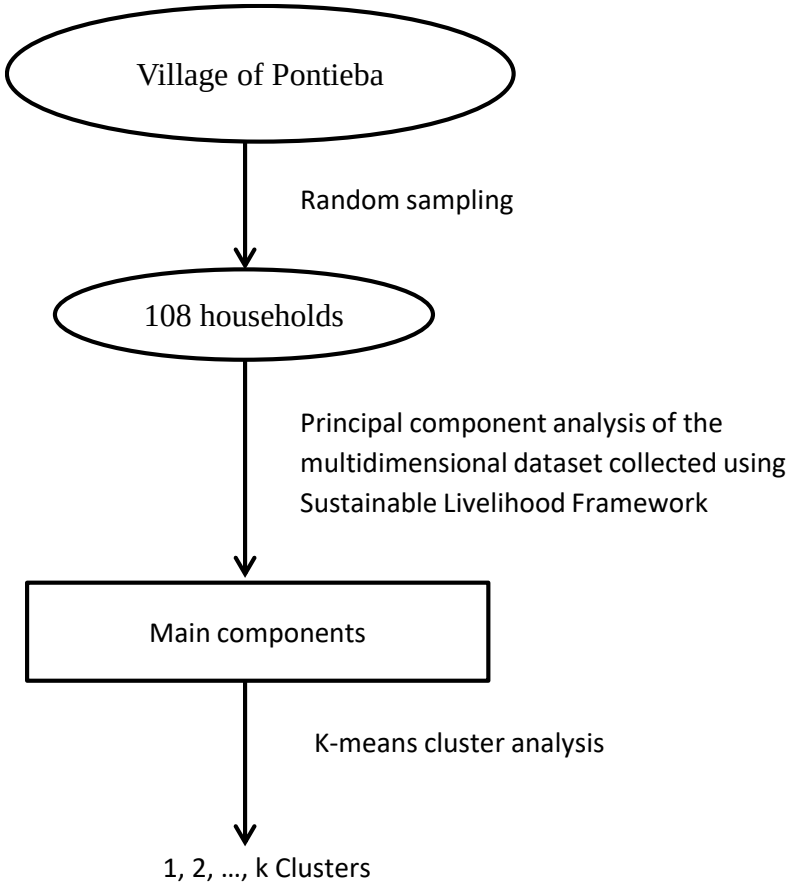

Fig.2. Methodological flow chart of household livelihood typology analysis. We used a multi-dimensional dataset collected based on the Sustainable Livelihood Framework (SLF), to run a Principal Component Analysis (PCA) followed by a K-mean Cluster Analysis to identify the main agricultural livelihood farm types in the village of Pontieba.

Table 1. Household variables for Principal Component Analysis. The main variables representing the livelihood assets of households based on the SLF were extracted from a multi-dimensional dataset and used to run the PCA. It allowed identifying key variables discriminating farms in Pontieba.

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 bullock 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

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

Testing the heterogeneity amongst the identified agricultural livelihood systems

The heterogeneity amongst the different agricultural livelihood systems in the Pontieba was tested. We used analysis of variance (ANOVA) to detect differences amongst the ALS. According to whether the equal variance across groups is assumed or not different post-hoc tests are used to decide on the groups' heterogeneity. For deciding on the post-hoc test to use, we first run the Levene's test of variance equality. 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).

3. Results

Farming main settings in Pontieba

In Pontieba, households have an average size of 7 members and are dominantly headed by males: only 7% of households' heads were female. 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 S1). Farms possessed less than 1 ha of land per person (0.6 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 households' farmed land allocated to basic cereals (sorghum, millet and maize). The equipment among farmers was very low: only 9% of the sample was equipped with bullocks for land ploughing. 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 (Thiombiano & Le, 2015).

Main factors discriminating agricultural livelihood types in Pontieba

The PCA results revealed 10 factors with total Eigen values of at least 1 (Table S2). The 10 factors beard 80.87% of initial total variance. Using the rotated component matrix, the factors were named after variables with greater loadings and most correlated to the factors as shown in Table 2. 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 while the PC2 was named Livestock PC and the PC3 was named Labour PC. 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). 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).

Table 2. Rotated Component Matrix (i.e., loadings) using Varimax rotation method and Kaiser Normalization of first ten PCs

		Principal Components									
Livelihood asset	Variable	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

Note: ***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 the principal components. Bold and underlined are the high loadings, indicating most important original variables representing the principal components and used for clusters analysis.*

The PC5 was then named Income PC and carried 8% of initial total variance while PC6 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, respectively. PC7 was most correlated with $H_{SHMFCRP}$ (with loadings b=0.91). It was 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. As for PC10, it was most correlated with H_{DEPEND} (with loadings b=0.85). This last PC was named dependency PC and it carried also only 4% of initial total variance.

Agricultural livelihood types in Pontieba

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

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

The agricultural livelihood type I (*Poor, landless and subsistence-based farms*) represented 40% of the study sample. This livelihood 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[1]/person). Livelihoods of 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).

[1] Year 2014 annual average exchange rate: USD 1=494.421 FCFA.
Source: http://www.oanda.com/currency/historical-rates/

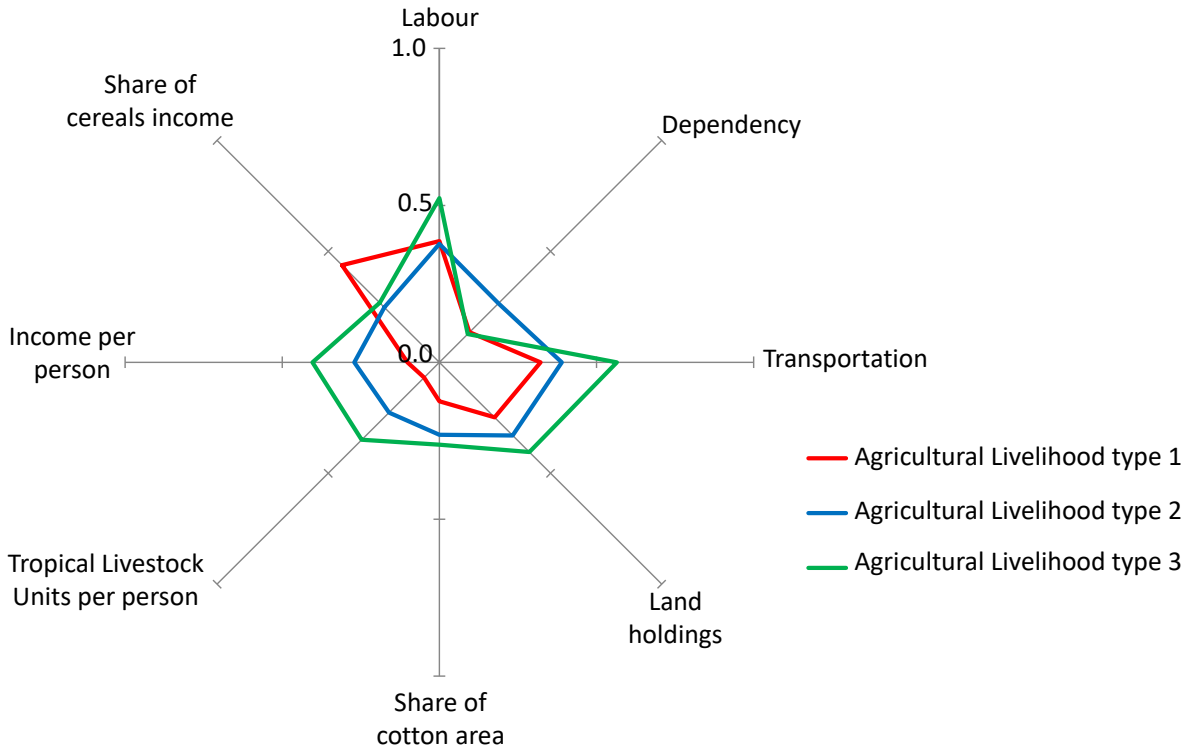

Fig. 3: Key indicators (standardized) of the three main livelihood types. We identified three main agricultural livelihood types in the village of Pontieba: livelihood type I [Poor, landless and subsistence-based farms] (red colour curve), livelihood type II [Medium-income, high-dependency, cotton-and livestock-turned] (dark blue colour curve), livelihood types III [Better-off, land-and labour-rich, cotton and livestock-turned] (dark green colour curve).

Livelihood type II: Medium-income, high-dependency, cotton-and livestock-turned

The agricultural livelihood type II (*Medium-income, high-dependency, cotton-and livestock-turned*) 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 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 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.

Livelihood type III: Better-off, land-and labour-rich, cotton-and livestock-turned

The third farm type, agricultural livelihood type III (*Better-off, land-and labour-rich, cotton-and livestock-turned*) 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 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 type I, but were not significantly different from agricultural livelihood type II. The agricultural livelihood 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).

Table 3: Descriptive statistics of the agricultural livelihood types in Pontieba. ANOVA was used to test the difference amongst identified agricultural livelihood types. Highlights in colour show variables for which the farm types were found significantly different. Variables highlighted in green colour were used for constructing the spider diagram. Highlights in yellow colour are other key variables.

	Farm type (Size)	Poor, landless and subsistence-based farms (40)					Medium-income, high-dependency, cotton and livestock-turned (40)					Better-off, land-and labour-rich, cotton and livestock-turned (20)				
Livelihood asset	Descriptives	Mean	Std. Dev	Std. Error	95% Conf.Interval Lower Bound	95% Conf.Interval Upper Bound	Mean	Std. Dev	Std. Error	95% Conf.Interval Lower Bound	95% Conf.Interval Upper Bound	Mean	Std. Dev	Std. Error	95% Conf.Interval Lower Bound	95% Conf.Interval 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

Agricultural livelihood systems heterogeneity in Pontieba

The results of the ANOVA test are summarized in Table 4. 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 were 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.

Table 4: Main land use and yield performance of identified ALS

		Land use (ha)			Crop yield (kg/ha)		
Agricultural Livelihood System		Cotton	Maize	Sorghum	Cotton	Maize	Sorghum
ALS 1: *Poor, 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-turned*		0.85 [a]	0.43 [ab]	1.18 [a]	753 [b]	1266 [a]	401 [a]
ALS 3: *Better-off, land-and labour-rich, cotton and livestock-turned*		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

Note: Number in the same column and with the same letter are not significantly different at 0.05 (95% confidence).

4. Discussion

The study findings on factors discriminating among smallholder farms in Pontieba (local typology) corroborated with those of Thiombiano and Le (Submitted). They formulated empirical typology of smallholder farms in 6 villages of Ioba province (regional typology) including the village of Pontieba. They found the same number of discriminating factors (10) with same names following a similar methodological procedure. Only Income PC, out of the 10 factors, was new in the discriminating factors identified in the present study. This similarity of the results of the two studies demonstrates that the identified discriminating factors can be successfully used for scaling out studies from local to regional level in similar drylands.

The study locally identified three farm types against five for the regional typology formulated by Thiombiano and Le (Submitted). When looking at the distribution of the farm types across the 6 villages of the regional typology study, we can observe that two farm classes had size less than 30 farms (Table S3). These two farm classes recorded low number of farms (2 and 4) in Pontieba, attesting of their scarcity in the village. In addition, a farm typology is a picture of the distribution of farm classes at a given time in a given location. The change in one of the five dimensions of the Sustainable Livelihood Framework can lead to a restructuration of the farm livelihood settings due to the interactions between the five dimensions (DFID, 1999). Hence, from one year to another some farms can migrate from one class to another according to the amplitude of the changes in livelihood dimensions (Le *et al.*, 2012). Therefore, the results of the local typology in this study are in agreement with the findings of the regional typology formulated by Thiombiano and Le (Submitted) one year earlier. Indeed, the three farm types found in this study share common characteristics with the three largest farm types of the regional typology, in terms of wealth, land and livestock endowment, and crop production orientation.

5. Conclusion

The failure to consider farm heterogeneity in a location hampers the effectiveness of interventions aiming at improving rural livelihood. Accounting for farms' heterogeneity is key to farming design studies, in particular for integrated farming systems modelling seeking to propose innovative solutions for adaptive and sustainable agricultural livelihoods. Combining PCA and CA, 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. The main variables discriminating agricultural livelihoods in Pontieba were human (labor, labor age, education and dependency), natural (land holdings and livestock), financial (annual gross income, and non-fam income) assets, and production orientation (cotton and marketable food crops production). The study identified three agricultural livelihood types in the village of Pontieba: *Poor, landless and subsistence-based farms*, *Medium-income, high-dependency, cotton-and livestock-turned farms*, and *Better-off, land-and labour-rich, cotton-and livestock-turned farms*. The results of this study can be used for policy intervention. They are also useful for further studies in the village and for integrated farming systems modelling.

6. The ways forward

The present work formulated Agricultural Livelihood Systems typology in the village of Pontieba. It serves as a preliminary work to the upcoming work toward achieving the main objective of this research which the agent-based modelling (ABM) of sustainable agricultural livelihood systems in Pontieba using the LUDAS model (Le, 2005). The ways forward consist mainly of:

- Performing behavioural analysis in terms of the land use decision making by the identified ALS which will form the agent types in the ABM work;
- Analysing yield function of main crops and livestock;
- Performing the agent-based modelling of the agricultural livelihood systems in Pontieba by adapting the LUDAS model.

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Appendices (Support materials)

Table S1. Main farming system characteristics in Pontieba

H_Size	7
H_Female Head (%)	7
H_Illiteracy (%)	60
H_Network membership (%)	42
H_Holdings (ha/person)	0.55
H_Basic cereals[a] (%)	55
H_bullock	0.15
H_Livestock farmed land ratio (TLU[b]/person)	0.45

Note: [a] Basic cereals: Sorghum, millet and maize
[b]TLU: Tropical Livestock Unit

Table S2. Total variance explained by extracted components, using Principal Component Analysis (PCA) as extraction method. We retained only PC with Eigen value >= 1. Note: The Principal Components with Eigenvalues less than 1 are not showed.

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

Note: [a] Cumul.= Cumulative

Table S3: Distribution of regional farm typology. Compiled from Thiombiano and Le (submitted)

Village	**Farm type I** *(Better-off, cotton- and livestock-based farms)*	**Farm type II** *(Better-off, non-farm preference)*	**Farm type III** *(Pro-poor, labourless and landless)*	**Farm type IV** *(Medium-income, labor-rich, marketable food crop oriented, educated)*	**Farm type V** *(Poor, insecure land tenure, livestock-based)*
Loffing	31	14	8	5	2
Pontieba	18	24	8	2	4
Babora	12	17	17	4	5
Dibogh	21	15	7	10	3
Kolinka	9	16	15	4	11
Bekotenga	15	16	16	4	3
Total	106	102	71	29	28

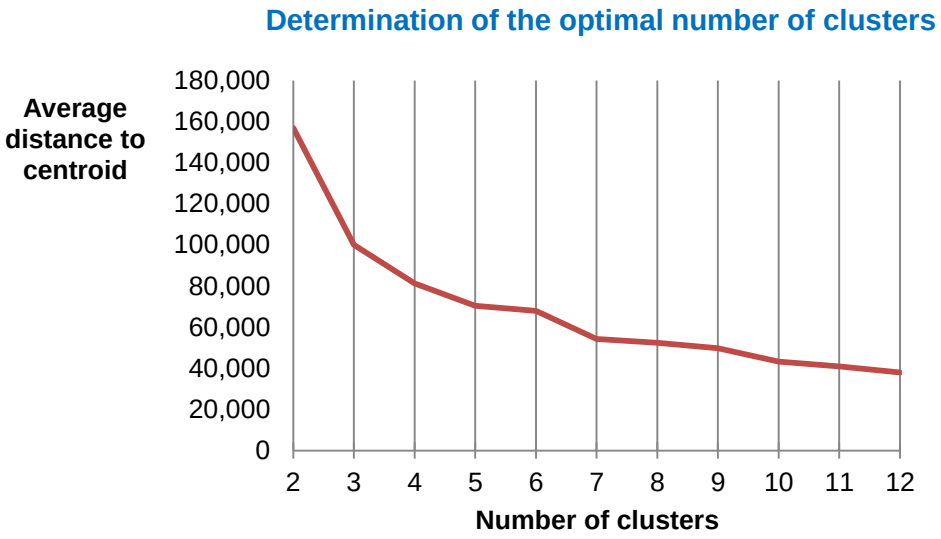

Fig.S1. Knee curve showing relationship between the Mean Distance to Cluster Centroids versus number of cluster k. The number of optimal clusters is decided at the point of inflexion of the curve (knee). We decided the number of clusters at k = 3.

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