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Intra-urban and peri-urban differences in cattle farming systems of Burkina Faso

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ABSTRACT

Little is known about the classification of urban and peri-urban cattle farming systems in West Africa. To contribute to filling this knowledge gap, we conducted a questionnaire-based survey in 137 and 133 cattle enterprises located, respectively, within and beyond the municipal boundaries of the city of Bobo Dioulasso in Burkina Faso. Categorical principal component and two-step cluster analysis techniques were used to group the different farms. The farmer's engagement in crop production, the area of cultivated land, his experience in cattle farming, the orientation of the cattle enterprises towards fattening or milk production and the feeding mode (zero-grazing, grazing only or grazing plus supplementation), among others, were relevant differentiating factors. Overall nine distinct clusters reflecting different farming systems in the intra-urban and peri-urban areas were identified. Farm types in the intra-urban area were mainly oriented towards meat production and included intensive landless cattle fattening (n = 30; 21.9%), semi-intensive grassland-based cattle farming (n = 40; 29.2%), extensive cattle farming (n = 20, 14.6%), semi-intensive maize-cattle farming (n = 37, 27.0%) and intensive maize-cattle farming (n = 10, 7.3%). In contrast, farms in the peri-urban area were mostly oriented towards milk production and classified as semi-intensive pastoral (n = 11; 8.3%), semi-sedentary pastoral (n = 38; 28.6%), medium-scale agro-pastoral maize-dairy farming (n = 40, 30.1%), and small-scale agro-pastoral dairy-maize farming (n = 44; 33.1%). The intensive landless fattening enterprises seem to be most promising for the future exploitation of the growing demand of urban customers for beef, whereas small dairy herds integrated or not with crop production appear to be the most adapted to the continuously changing peri-urban environment.

1. Introduction

During the past two decades, numerous papers were published on urban and peri-urban agriculture (UPA). A variety of definitions for UPA have been suggested. The most widely cited ones (Mougeot, 2000; Jacobi et al., 2000; Smit et al., 2001) refer to any form of farming or livestock keeping that takes place within and around cities, whereby a subdivision into “intra-urban” (or urban) and “peri-urban” agriculture has been controversial, given unclear boundary definitions (Willis, 2007; Simon, 2008; Stewart et al., 2013). Binns and Lynch (1998) argued that it is unnecessary to differentiate between urban and peri-urban agriculture because producers, regardless of their location, have largely the same motivations, usually share a common market and face similar production and marketing challenges. While the intra-urban area is defined as the heart of the built-up or the fully urbanized area of a city, most scholars define the peri-urban area as the zone around cities and urban agglomerations that stretches into the rural hinterlands (McGranahan et al., 2004), the peri-urban being, in contrast to the urban, characterized by fast changes of land use and social, economic and environmental settings (Belevi and Baumgartner, 2001; Douglas, 2006; Galli et al., 2010; Piorr et al., 2011).

The presence of such invisible boundaries strongly affects the local farming systems (Galli et al., 2010), and a recent study revealed that farming systems significantly differ and perform dif-

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ferently depending on their intra-urban or peri-urban location (Aubry et al., 2011). It has also been argued that within a single urban area, a high diversity of farm types and farm strategies exist (Douglas, 2006). This may also hold true for peri-urban areas, which, even though they contain both rural and urban elements, may have their own distinctive characteristics (Birley and Lock, 1998; Drechsel et al., 1999; Adams et al., 2000).

With respect to livestock keeping within and around cities, a functional understanding of the prevailing production systems in both areas is needed to analyse how the degree of urbanization influences animal enterprises across the interface (Brook and Dávila, 2000; Mougeot, 2000). Compared to gardening and crop farming, keeping various types of livestock in and around the major and secondary cities has in many sub-Saharan African countries received little systematic attention by scientists and policy makers. Despite official by-laws limiting its practice in many countries (Assemblée Nationale du Burkina Faso, 2005; Geyer, 2011; Simiyu and Foeken, 2011; Schmidt, 2012), this activity is flourishing (Masters et al., 2013). In the West African Sudano-Sahelian region, more than 70% of UA practitioners are livestock keepers (Dossa et al., 2011a), of which 82% raise cattle (Amadou et al., 2012).

Yet, all previous studies in Burkina Faso (Hamadou et al., 2003, 2008; Marichatou et al., 2003; Hamadou and Kiendrebeogo, 2004; Sidibe et al., 2004), Niger (Vias et al., 2003; Boukary et al., 2007; Chaibou et al., 2011), and Mali (Bonfoh et al., 2003) diverged when defining the limits of intra- and peri-urban areas, which hampers their comparison. Furthermore, they mainly focused on dairy cattle and did not comprehensively consider the diversity of existing urban, peri-urban and rural cattle farming systems (Zorom et al., 2013). Also, despite its numerous benefits, city authorities are concerned about pollution and public health issues associated with keeping large farm animals in close proximity to human populations. Yet, the development and establishment of proper policy interventions to minimize public health risks that might ensue from urban livestock enterprises (Amadou et al., 2014) require a clear distinction between urban, peri-urban and rural locations as well as a better understanding of the diversity of production systems and their resources use efficiencies.

This study, therefore, aimed to identify and characterize the different cattle farming systems in the fully urbanized and the peri-urban areas of a typical secondary city in the West African Sudano-Sahelian region (Dossa et al., 2011b; Abdulkadir et al., 2012; Amadou et al., 2012).

2. Materials and methods

2.1. Study area

The study was conducted in the city of Bobo Dioulasso (11°11′N and 4°17′W), the second largest city of Burkina Faso with about 490,000 inhabitants in 2006 (INSD, 2010) who grew to 800,000 by 2012 (UN-Habitat, 2014). Located at an altitude of 430 m above sea level, Bobo Dioulasso lies in the Southern Sudanian Savannah zone characterized by a sub-humid climate with three seasons: a rainy season (May–October), a cool dry season (November–February) and a hot dry season (March–May). The unimodally distributed average annual rainfall varies between 900 and 1200 mm. The official administrative boundaries of the city have been expanded in 2004 to include 25 administrative subunits in the contiguous built-up area, and 35 independent villages that are in the immediate periphery of the city but remain unconnected to the main contiguous built-up area (Werthmann and Sanogo, 2013). In this study, the contiguous built-up area is referred to as intra-urban area and its surroundings, including the 35 villages, as peri-urban area, with the physical boundary of the built-up area being the limit between the two (Fig. 1).

2.2. Data collection

Because lists of households keeping livestock were not available in both intra-urban and peri-urban areas, a fully randomized sampling was not feasible. We therefore conducted a preliminary exploratory survey in February and March 2013 with farmers from all 25 administrative units representing the intra-urban area and from the 35 villages representing the peri-urban area. Using a snowball sampling procedure, 400 livestock keeping households were approached in each area as primary sampling units and interviewed mainly on the livestock species owned.

As secondary sampling units, 150 cattle farming households were randomly selected in each area (six per administrative unit in the intra-urban area and five per village in 30 out of the 35 villages in the peri-urban area) and interviewed from May to September 2013 using a structured questionnaire. It included questions on general household characteristics, cattle herd size and structure, production objectives and management practices, and practices of other agricultural activities. The questionnaire was pretested in April 2013 on a sample of 15 farmers who are not included in the final sample.

2.3. Data analysis

Before processing, collected data was screened for consistency and completeness. This resulted in the removal of 13 intra-urban and 17 peri-urban cattle farm households (HH) from the sample. Subsequently, the data from the remaining 137 intra-urban and 133 peri-urban farms were analysed. After a general description of the sample, a farm typology was undertaken for each area separately. Categorical Principal Components Analysis (CATPCA) was used to eliminate redundancy caused by correlation between variables and to identify the main cluster-determining variables (Meulman and Heiser, 2004; Linting et al., 2007). HHSIZE, GRAZ and TLU were significantly ($p \leq 0.001$) correlated with AGE ($r = 0.472$), FEEDMOD (Pearson Chi-Square = 270 and Cramer's $V = 1$) and BCATSIZ ($r = 0.942$), respectively, and were therefore removed from the analysis (Table 1).

Since all farmers in the peri-urban area used crop residues to feed their animals, the variable "feeding crop residues" (CROP_RES) was removed for the CATPCA performed on the peri-urban farms. In the final CATPCA, we set the number of dimensions at a default value of two and retained those variables with a loading score ≥0.6 on one of the two components (Stevens, 1992) as the most discriminating ones. These variables were subsequently used as input variables in a two-step cluster analysis (Mooi and Sarstedt, 2011) to identify the most powerful discriminating variables for separate classification of the 137 intra-urban and the 133 peri-urban farms into homogeneous types of cattle farming systems. Although the two-step clustering approach determines an optimal cluster solution, several cluster solutions were explored and those with an overall silhouette measure of cohesion and separation >0.5 were accepted. They were then compared by their overall goodness-of-fit (Linting et al., 2007) to select the most appropriate one.

A dummy variable "cluster membership" was created that identified which farm belonged to which cluster. The final clusters were profiled by cross tabulating the variable "cluster membership" with both qualitative and quantitative explanatory variables used in the clustering algorithm; based on the outcome, a cluster name was assigned. Subsequently, we assessed the cluster solutions' validity and stability through discriminant and multinomial logistic regressions analyses performed on a set of variables that were not used in the cluster analysis. In the multinomial regression analysis, the chi-square (χ^2) statistic was used to assess the differences in likelihood of cluster membership between the final model and reduced model (the intercept-only model) and to ascertain the significance of pre-

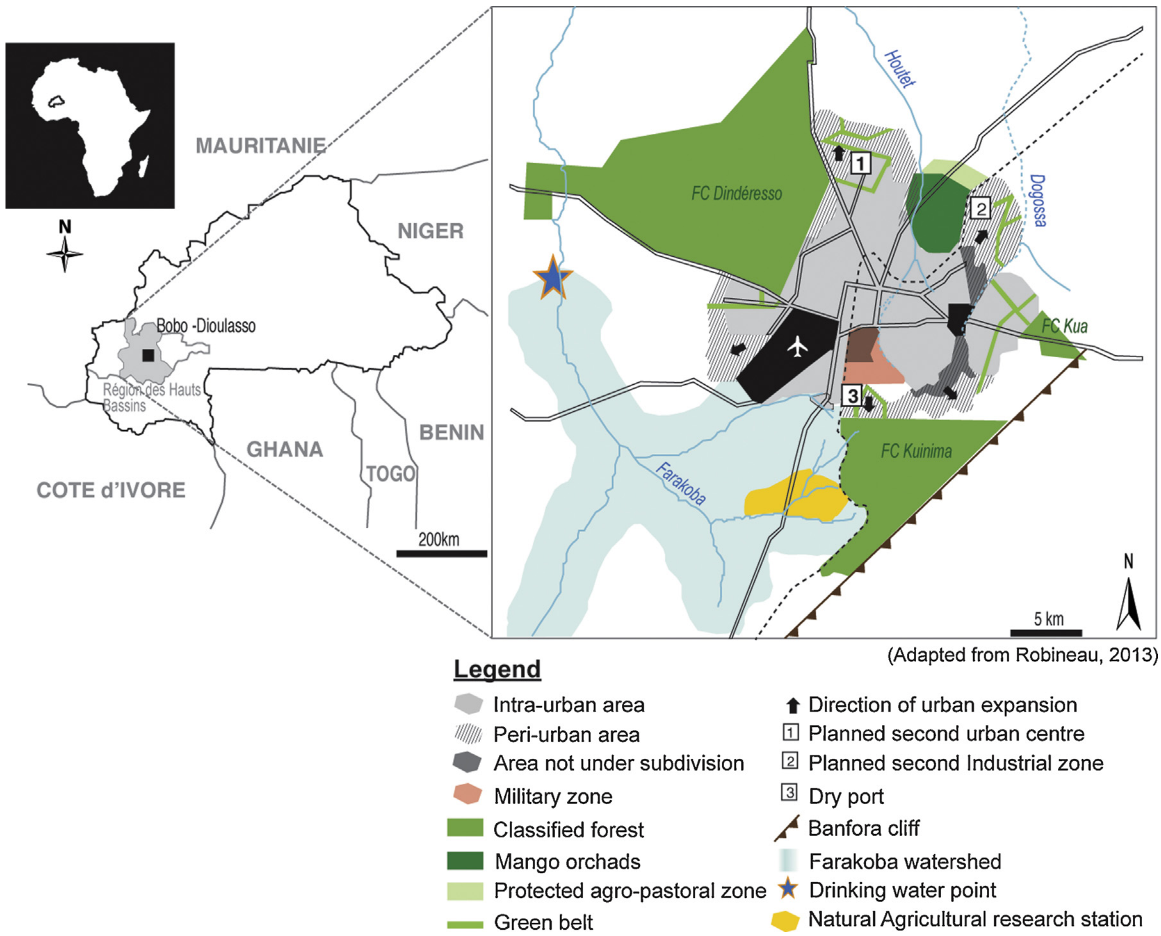

Fig. 1. Map of the city of Bobo Dioulasso with the physical boundaries between its intra- urban and peri-urban areas (adapted from Robineau, 2013).

Table 1
Description of the relevant variables used in the categorical principal component analysis (CATPCA) performed on 270 cattle enterprises in Bobo Dioulasso, Burkina Faso in 2013.

Variable	Type	Description
AGE	Continuous	Age of cattle owner (years)
SEX	Dichotomous	Gender of cattle owner (male = 1, female = 2)
MARIT	Dichotomous	Marital status of cattle owner (married = 1, single = 2)
HH_SIZE	Continuous	Number of persons who live in the household (n)
CROPIN	Dichotomous	Practice of crop cultivation (yes = 1, no = 2)
CULTLAND	Continuous	Total cultivated land size (hectares)
EXP	Continuous	Experience in urban cattle production (years)
TLU[a]	Continuous	Total number of owned tropical livestock unit (n)
BCATSIZ	Continuous	Breeding cattle herd size (n)
COWS	Continuous	Proportion of cows in the herd (%)
SHESIZ	Continuous	Sheep flock size (n)
GOASIZ	Continuous	Goat flock size (n)
OXENSIZ	Continuous	Number of oxen (n)
FEEDMOD	Nominal	Feeding mode (zero grazing = 1, grazing only = 2, grazing + supplementation = 3)
CROP_RES	Dichotomous	Feeding crop residues (yes = 1, no = 2)
FATT	Dichotomous	Practice of fattening (yes = 1, no = 2)
GRAZ	Dichotomous	Practice of grazing (yes = 1, no = 2)
TRANSHUM	Dichotomous	Practice of transhumance (yes = 1, no = 2)

[a] TLU, tropical livestock unit: a hypothetical animal of 250 kg live weight; used to standardize different livestock categories. TLU conversion factors used: camel = 1, cattle = 0.80, sheep/goats = 0.10, donkey = 0.50, pigs = 0.20, poultry/rabbit = 0.01.

dictors (independent variables) to the final model. The different clusters were then compared using the χ^2 test for the categorical and the non-parametric Kruskal–Wallis test followed by the Mann–Whitney U test for post hoc comparison of the continuous variables. Significance was declared at $p \leq 0.05$. All statistical analyses were performed with the IBM®-SPSS® software version 20 (IBM Corp., 2011).

3. Results

3.1. Farmers' socioeconomic characteristics

There were significant differences between intra-urban and peri-urban cattle farmers with respect to their main occupation, source of income, level of education, ethnicity, religion, and mem-

Table 2
Socio-economic characteristics of intra-urban (n = 137) and peri-urban (n = 133) cattle farmers in Bobo Dioulasso, Burkina Faso in 2013.

Variable	Frequency (%)		χ^2	$P\leq$
	Intra-urban	Peri-urban		
Sex			4.90	0.026
Male	96.4	100.0		
Female	3.6	0.0		
Religion			9.20	0.010
Christian	10.9	13.5		
Muslim	89.1	80.5		
Traditional	0.0	6.0		
Ethnicity			61.95	0.001
Dioula	6.6	0.0		
Peul	12.4	45.9		
Bobo	12.4	24.8		
Mossi	51.1	23.3		
Other	17.5	6.0		
Education level			61.50	0.001
Kuranic	38.0	9.0		
Primary school	17.5	9.0		
Secondary school	18.2	9.0		
None	26.3	73.0		
Main occupation			98.81	0.001
Livestock keeping	24.1	56.4		
Crop farming	14.6	39.1		
Trade	26.3	2.3		
Handicraft	12.4	0.0		
Public service	9.5	1.5		
Paid labour	8.8	0.8		
Other	4.4	0.0		
Main source of income			58.06	0.001
Livestock keeping	42.3	60.9		
Crop farming	14.6	34.6		
Trade	20.4	2.3		
Handicraft	8.0	0.0		
Salary	11.7	2.3		
Other	3.0	0.0		
Livestock keepers' association membership			27.35	0.001
Yes	2.9	24.8		
No	97.1	75.2		

bership in a livestock keepers' association (Table 2). Peri-urban farm households had a significantly ($p\leq0.001$) higher number of members (13 ± 7 persons) than their intra-urban counterparts (7 ± 4 persons).

3.1.1. Livestock species kept, herd sizes and composition

Compared with their intra-urban counterparts, a significantly higher proportion of peri-urban farmers owned sheep (67% against 55%, $p\leq0.05$), goats (55% against 28%, $p\leq0.001$) and oxen (27% against 9%, $p\leq0.001$). However, the ownership of donkey (peri-urban: 29%; intra-urban: 23%) was similar between locations. Except for oxen and donkey, peri-urban farmers owned significantly ($p<0.001$) larger number of breeding cattle (23.6 ± 15.22 against 5.3 ± 7.76), sheep (14.5 ± 7.26 against 6.7 ± 4.90), goats (11.5 ± 5.68 against 4.3 ± 3.76) and a higher TLU (20.1 ± 12.90 against 5.2 ± 6.65). Furthermore, there were also significant ($p<0.001$) differences between the two locations in terms of cattle herd composition, with male animals representing 55% and 37% of the intra-urban and peri-urban herds, respectively.

3.1.2. Production objectives and management practices

Farmers' production objectives and management practices with respect to cattle differed significantly between the two locations (Table 3). Cattle were kept for dual purpose (milk and meat) in more than half of the peri-urban farms, whereas fattening was common practice in the large majority of intra-urban farms.

3.1.3. Cattle farm typologies

In the CATPCA analysis the original variables were grouped into two dimensions that accounted for 36.7% and 52.0% of the total variance within the intra-urban and peri-urban farms, respectively (Table 4). The indicator variables that showed high loadings (>0.6) on one of the two dimensions were practice of crop cultivation, total cultivated land size, practice of fattening, experience in urban cattle production and feeding mode for the intra-urban farms, and number of oxen, total cultivated land size, sheep flock size, experience in urban cattle production, practice of transhumance, practice of crop cultivation and goat flock size for the peri-urban farms. The two-step cluster analysis performed on these variables suggested for both locations a four-cluster solution with a satisfactory average silhouette measure of 0.6. A five-cluster solution was finally retained for the intra-urban farms because it had a higher average silhouette measure (0.7) and provided maximum differentiation of the farms as well as better interpretability (Table 5).

Quantitative variables that showed significance in the bivariate analyses (Table 6), but were not used in the final two-step cluster analysis were selected for further validation of the cluster solutions through discriminant analysis. In general, 71.4% of the peri-urban and less than 50% of the intra-urban cattle farms were correctly classified. These results indicated modest to low ability to discriminate among farms and suggested that discriminant analysis was ill suited to predict class membership of the individual intra-urban cattle farms. Multinomial logistic regression analyses using main occupation, main source of revenues, source of drinkable water, manure handling, feeding crop residues, origin of labor for herding and ownership of donkey as predictor variables resulted in better overall accuracy for both intra-urban and peri-urban farms (respectively, 75.2% and 77.4% correct classification). The Cox and Snell pseudo R-square of the model (Meuleman et al., 2004) was 0.863 and 0.723 for intra-urban and peri-urban farms, respectively. For

Table 3
Cattle management practices of intra-urban ($n = 137$) and peri-urban ($n = 133$) farmers in Bobo Dioulasso, Burkina Faso in 2013.

Variable	Frequency (%)		χ^2	$P\leq$
	Intra-urban	Peri-urban		
Main production purposes				
Milk	0.0	3.3	62.70	0.001
Meat	86.1	39.8		
Milk and meat	13.9	57.9		
Practice of fattening				
Yes	78.1	5.3	146.77	0.001
No	21.9	94.7		
Practice of transhumance				
Yes	0.0	28.6	45.25	0.001
No	100.0	71.4		
Feeding mode				
Zero grazing	28.5	0.0	200.80	0.001
Grazing only	0.0	84.2		
Grazing + supplementation	71.5	15.8		
Feeding crop residues				
Yes	81.8	100.0	26.75	0.001
No	18.2	0.0		
Source of drinking water				
Natural sources	1.5	73.0	160.85	0.001
Well/borehole	13.1	9.0		
Tap	31.4	0.0		
Combinations	54.0	18.0		
Ownership of stable				
Yes	43.1	95.5	86.53	0.001
No	56.9	4.5		
Manure handling				
Sale	40.9	12.0	106.74	0.001
Use as fertilizer	33.6	46.6		
Dumping (partial)	25.5	41.4		

Table 4
Summary of the final CATPCA model and component loadings for 137 and 133 cattle farms in the intra-urban and peri-urban areas, respectively, of Bobo Dioulasso, Burkina Faso in 2013.

Variable	Intra-urban farms		Peri-urban farms	
Total Cronbach's alpha[a]	0.843		0.908	
Total eigenvalue	4.404		5.719	
Total variance explained (%)	36.698		51.989	
	Dimension			
	1	2	1	2
Cronbach's alpha	0.717	0.355	0.768	0.642
Total eigenvalues	2.921	1.483	3.318	2.401
Total variance explained (%)	24.339	12.359	30.166	21.823
Variable name[b]	Component loadings			
AGE	−0.496	0.355	0.473	0.391
GOASIZ	−0.484	−0.212	0.605	0.365
EXP	−0.691	−0.263	0.763	0.006
COW	−0.388	−0.034	0.479	−0.312
OXENSIZ	−0.539	0.064	−0.043	0.830
SHESIZ	−0.300	−0.501	0.789	0.006
CULTLAND	−0.761	0.048	−0.023	0.823
FEEDMOD	−0.232	0.637	−0.525	−0.257
CROPIN	0.762	−0.095	−0.638	−0.422
CROP_RES	0.252	−0.016	n.a.[c]	n.a.
BCATSIZ	−0.394	−0.075	0.551	−0.425
FATT	−0.009	0.751	0.250	−0.173
TRANSHUM	n.a	n.a.	−0.630	0.468

[a] Total Cronbach's alpha is based on the total eigenvalue.
[b] See Table 1 for explanation of the variables.
[c] n.a.: not applicable.

Table 5
Profiles of the different types of farms[1] differentiated by the two-step clustering algorithm performed on 137 and 133 cattle farms, respectively, in the intra-urban and peri-urban areas of Bobo Dioulasso, Burkina Faso in 2013.

Variable	Intra-urban area					Peri-urban area			
	ILBF (n = 30)	SICF (n = 40)	EXCF (n = 20)	SIMBF (n = 27)	IMBF (n = 10)	SIP (n = 11)	SSP (n = 38)	MAPMD (n = 40)	SAPDM (n = 44)
Practice of crop cultivation (%)									
Yes	0.0	0.0	0.0	100.0	100.0	0.0	100.0	100.0	100.0
No	100.0	100.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0
Practice of fattening (%)									
Yes	100.0	100.0	0.0	75.7	90.0	18.2	0.0	7.5	4.5
No	0.0	0.0	100.0	24.3	10.0	81.8	100.0	92.5	95.5
Feeding mode (%)									
Zero grazing	100.0	0.0	0.0	0.0	90.0	0.0	0.0	0.0	0.0
Grazing only	0.0	0.0	0.0	0.0	0.0	45.5	100.0	87.5	77.3
Grazing + supplementation	0.0	100.0	100.0	100.0	10.0	54.5	0.0	12.5	22.7
Practice of transhumance (%)									
Yes	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
No	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0
	Mean ± SD								
CULTLAND[2] (ha)	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	$1.4^a \pm 1.21$	$3.7^b \pm 3.11$	0.0 ± 0.00	$0.7^a \pm 0.30$	$2.8^b \pm 1.17$	$1.2^{ac} \pm 0.67$
EXP (years)	$7.0^{ab} \pm 4.44$	$6.8^b \pm 3.93$	$4.1^c \pm 3.36$	$9.6^a \pm 4.49$	$10.1^a \pm 9.76$	$4.2^a \pm 3.87$	$26.9^a \pm 9.87$	$17.5^{cd} \pm 10.79$	$14.9^d \pm 10.68$
OXENSIZ (n)	0.0 ± 0.00	$0.2^a \pm 0.89$	0.0 ± 0.00	$0.6^b \pm 1.23$	0.2 ± 0.63	0.0 ± 0.00	0.0 ± 0.00	$1.5^a \pm 0.68$	$0.0^b \pm 0.15$

[abc]Means with different letter are significantly different at $P \leq 0.05$; non parametric Kruskall–Wallis test.
[1] ILBF = intensive landless beef cattle farming; SICF = semi-intensive grassland-based beef cattle farming; EXCF = extensive sedentary cattle farming; SIMBF = semi-intensive maize–beef cattle farming; IMBF = intensive maize–beef cattle farming; SIP = semi-intensive pastoral system; SSP = semi-sedentary pastoral system; MAPMD = medium-scale agro-pastoral maize-dairy system; SAPDM = small-scale agro-pastoral dairy-maize system.
[2] For abbreviations of continuous variable names see Table 1.

both locations, the model Chi-Squares were statistically significant at $p < 0.001$ and the goodness-of-fit equal to 1 (Table 7), indicating a good fit.

3.1.4. Intra-urban cattle systems

The following farm types were distinguished within the city's build-up area: "Intensive landless beef cattle farming" ILBF ($n = 30$; 21.9%); "semi-intensive grassland-based beef cattle farming" SICF ($n = 40$; 29.2%); "extensive sedentary cattle farming" EXCF ($n = 20$, 14.6%); "semi-intensive maize–beef cattle farming" SIMBF ($n = 37$; 27.0%) and "intensive maize–beef cattle farming" IMBF ($n = 10$, 7.3%).

Farmers practicing intensive landless beef cattle farming (ILBF) were not involved in any cropping activity. All of them reported the practice of fattening cattle as the only production objective and meat as the only product. They generally bought lean mature animals from agro-pastoralists in rural and peri-urban areas and/or from the markets and sold them after three to four months of feeding. The herds were exclusively stall-fed with purchased feeds including crop residues and agro-industrial by-products. This farming system included the smallest farms both in terms of number of cattle and TLU. Farmers in this group were significantly ($p < 0.001$) younger than those in the four other intra-urban farm types. In the majority (70%) of farms, tap water was used to water the animals. The dung collected was mainly sold or dumped as household waste. Only family labor was used for tending the animals.

Farmers engaged in semi-intensive grassland-based beef cattle farming (SICF) shared similar characteristics with the ILBF, but the feeding mode differed, because cattle feeding depended largely on grazing. The animals grazed year round on natural vegetation on vacant plots and along road sides and were supplemented with purchased crop residues and agro-industrial by-products. Furthermore, although fattening was of primary importance, 12.5% of SICF farmers considered milk as an additional product. Only 10% of farmers watered the animals with tap water, 22% used water from wells and the large majority (67%) combined both sources. Herding was done either by a hired herder (70%) or by a family member (30%), whereas exclusively family labor was used to supplement animals at the homestead.

Farmers practicing extensive sedentary cattle farming (EXCF) were not involved in cropping activities, but in contrast to the two previous types did not engage in cattle fattening activities. Furthermore, they had the least ($p < 0.001$) experience in cattle farming. Feeding was almost exclusively based on grazing natural vegetation on vacant land plots and along road sides during the rainy season, whereas in the dry season all farmers supplemented their animals with purchased crop residues and agro-industrial by-products. Only family labor was used for tending the animals at the homestead while herding was done either by a family member (35%) or by a hired herder (65%). Herders did not graze their animals in the same place on consecutive days and therefore did not follow the same itinerary from day to day while trekking the animals. They estimated the total daily time spent walking and grazing to range from 9 to 12 h.

All farmers engaged in semi-intensive maize–beef cattle farming (SIMBF) also cultivated subsistence crops, mainly maize. In comparison to the other four intra-urban farm types, this type included the largest livestock holdings both in terms of cattle numbers and TLU. Farmers of this group were significantly ($p < 0.001$) older and had the largest family size, thus the highest potential family work force. Similar to SICF and EXCF, feeding cattle depended largely on grazing natural vegetation. However, since cattle were integrated with crop production, crop residues and crop by-products were used for livestock feeding, and animal excreta were collected and applied as manure on crop fields. The manure was transported to the fields, and crop residues to the barns, by using oxen (24%) and/or donkeys (49%) drawn carts. Herding was either done by a family member (43%) or by a hired herder (57%), whereas only family labor was used for tending the animals at the homestead.

Farmers engaged in intensive maize-beef cattle farming (IMBF) shared many characteristics with the SIMBF type. For instance, all farmers grew maize and used cattle manure to fertilize their maize fields. However, major differences existed between both systems in terms of cultivated cropland size and cattle feeding mode. Farmers

Table 6
Major characteristics of the livestock holdings, livestock management practices and of general household characteristics of intra- and peri-urban cattle farm types in Bobo Dioulasso, Burkina Faso in 2013 (means ± SD for continuous variables, percentages for nominal variables).

Variable[a]	Intra-urban farms						Peri-urban farms				
	ILBF ($n = 30$)	SICF ($n = 40$)	EXCF ($n = 20$)	SIMBF ($n = 27$)	IMBF ($n = 10$)	$P\leq$	SIP ($n = 11$)	SSP ($n = 38$)	MAPMD ($n = 40$)	SAPDM ($n = 44$)	$P\leq$
Livestock holdings and management practices											
TLU (*n*)	$3.1^{a} \pm 1.73$	$5.3^{ab} \pm 5.65$	$5.3^{a} \pm 10.45$	$6.7^{b} \pm 7.74$	$5.1^{ab} \pm 5.03$	0.001	$12.1^{a} \pm 7.21$	$27.3^{b} \pm 10.29$	$16.4^{a} \pm 8.91$	$19.3^{a} \pm 16.09$	0.001
BCATSIZ (*n*)	3.0 ± 1.75	5.7 ± 6.34	6.2 ± 13.10	6.5 ± 8.76	4.7 ± 5.46	0.076	$18.7^{ac} \pm 10.58$	$31.1^{b} \pm 12.05$	$17.4^{c} \pm 10.42$	$24.2^{c} \pm 19.21$	0.001
COW (%)	25.1 ± 29.69	22.4 ± 27.15	18.6 ± 24.03	37.8 ± 29.71	17.3 ± 22.87	0.086	$17.6^{ac} \pm 14.86$	$31.2^{bd} \pm 7.66$	$22.5^{c} \pm 11.12$	$20.0^{dc} \pm 11.29$	0.001
SHESIZ (*n*)	3.5 ± 4.92	3.5 ± 3.93	2.0 ± 4.2	4.3 ± 5.53	6.1 ± 6.92	0.248	$1.5^{a} \pm 5.12$	$15.2^{b} \pm 9.54$	$8.5^{a} \pm 7.16$	$8.4^{a} \pm 8.57$	0.001
GOASIZ (*n*)	0.9 ± 2.37	0.7 ± 1.35	0.4 ± 1.05	2.0 ± 3.73	2.6 ± 4.83	0.259	0.0 ± 0.00	8.8 ± 8.23	7.0 ± 5.54	5.1 ± 7.14	0.001
Donkey (*n*)	$0.4^{a} \pm 1.24$	$0.2^{ab} \pm 0.58$	$0.1^{ac} \pm 0.45$	$0.7^{d} \pm 0.91$	$0.6^{ad} \pm 1.26$	0.008	0.0 ± 0.00	0.0 ± 0.00	$1.0^{a} \pm 0.83$	$0.2^{b} \pm 0.39$	0.001
Manure handling (%)											
Sale	53.3	57.5	60.0	13.5	0.0	0.001	45.5	0.0	10.0	15.9	0.001
Use as fertilizer	3.3	7.5	0.0	86.5	100.0		18.1	7.9	87.5	50.0	
Dumping (partial)	43.3	35.0	40.0	0.0	0.0		36.4	92.1	2.5	34.1	
Production orientation (%)											
Milk	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	5.0	2.3	0.001
Meat	100.0	87.5	95.0	70.3	80.0		45.5	100.0	12.5	31.8	
Milk and meat	0.0	12.5	5.0	29.7	20.0		54.5	0.0	82.5	65.9	
Farmer's/household's socio-economic characteristics											
AGE (years)	$38.0^{a} \pm 9.30$	$42.3^{ab} \pm 11.66$	$45.8^{ab} \pm 13.67$	$49.1^{b} \pm 12.52$	$46.7^{ab} \pm 17.25$	0.010	$31.8^{ad} \pm 12.56$	$45.5^{b} \pm 10.29$	$47.1^{cb} \pm 8.97$	$41.9^{cbd} \pm 8.47$	0.001
HHSIZE (*n*)	$6.3^{ab} \pm 3.74$	$6.6^{ab} \pm 3.93$	$5.5^{a} \pm 2.63$	$9.5^{b} \pm 5.79$	$8.4^{ab} \pm 7.63$	0.042	$2.7^{a} \pm 4.56$	$16.9^{bc} \pm 5.97$	$15.9^{c} \pm 8.11$	$11.2^{d} \pm 5.87$	0.001
Main occupation (%)											
Livestock keeping	16.7	27.5	20.0	27.0	30.0	0.001	81.8	100.0	10.0	54.5	0.001
Crop farming	3.3	2.5	10.0	35.1	30.0		0.0	0.0	85.0	40.9	
Trade	40.0	32.5	30.0	8.1	20.0		9.1	0.0	2.5	2.3	
Public service	3.3	2.5	20.0	18.9	0.0		9.1	0.0	0.0	2.3	
Paid labor	10.0	12.5	10.0	2.7	10.0		0.0	0.0	2.5	0.0	
Handicraft	26.7	15.0	5.0	5.4	0.0		–	–	–	–	
Other	0.0	7.5	5.0	2.7	10.0		–	–	–	–	

[a] For abbreviations of continuous variable names see Table 1.

Table 7
Results of the likelihood-ratio tests of multinomial logistic regression performed with variables not used in the two-step cluster analysis on cattle farms in the intra-urban ($n = 137$) and peri-urban ($n = 133$) areas of Bobo Dioulasso, Burkina Faso in 2013.

Variable[a]	Intra-urban farms −2 Log-likelihood[b]	χ2	df	P≤	Peri-urban farms −2 Log-likelihood	χ2	df	P≤
Intercept	106.80	0.00	0		44.84	0.00	0	
Manure handling	214.73	107.93	8	0.001	89.56	44.72	6	0.001
Source of drinking water	182.80	75.98	12	0.001	65.70	20.86	6	0.002
Ownership of donkey	118.60	11.78	4	0.019	55.78	10.94	3	0.012
Feeding crop residues	114.83	8.03	4	0.091	Not applicable[c]	n.a.	–	–
Main occupation	136.88	30.08	24	0.182	46.45	1.65	6	0.949
Main source of revenues	127.32	20.51	20	0.426	45.07	0.23	3	0.972
Origin of labour for herding	Not applicable[d]	Not applicable	–	–	91.70	46.86	3	0.001
Model		271.05	72	0.001		212.91	33	0.001
Goodness-of-fit		117.27	272	1.000		23.37	75	1.000

[a] Manure handling (sale = 1, use as fertilizer = 2 and dumping = 3); source of drinking water (natural sources = 1, well/borehole = 2, tap = 3, combinations = 4); ownership of donkey (yes = 1, no = 2); feeding crop residues (yes = 1, no = 2); main occupation (livestock keeping = 1, crop farming = 2, trade = 3, public service = 3, paid labour = 4, handicraft = 5, other = 6); main source of revenues (livestock keeping = 1, crop farming = 2, trade = 3, handicraft = 4, salary = 5, other = 6); origin of labor for herding (family = 1, hired = 2).

[b] The −2 log likelihood is a measure of whether a given independent variable has a relationship to the dependent variable. The initial value of 106.80 is a measure of a model with no independent variables. The value for a given independent variable is the measure computed after the independent variable has been entered into the logistic regression. If the given independent variable is associated with the dependent variable, the −2 log likelihood measure decreases. The difference between these two measures is the model chi-square value which tests whether or not the improvement in the model associated with the independent variable is statistically significant.

[c] Crop residues were used for feeding cattle in all peri-urban farms.

[d] Only family labour was used.

in the IMBF group cultivated significantly ($p < 0.001$) larger fields but owned fewer working oxen or/and donkeys. In almost all IMBF farms, cattle were intensively stall-fed with purchased feed, mainly agro-industrial by-products. Furthermore, in contrast to the other four farm types, significantly ($p < 0.05$) fewer farmers in this group used crop residues for feeding their cattle. Only family labor was used for tending the animals.

3.1.5. Peri-urban cattle systems

In the peri-urban area, the "semi-intensive pastoral system" SIP ($n = 11$; 8.3%); the "semi-sedentary pastoral system" SSP ($n = 38$; 28.6%), the "medium-scale agro-pastoral maize-dairy system" MAPMD ($n = 40$, 30.1%) and the "small-scale agro-pastoral dairy-maize system" SAPDM ($n = 44$; 33.1%) were distinguished.

The semi-intensive pastoral system (SIP) shared similarities with the intra-urban EXCF group (no cropping, no or very little practice of fattening). But in contrast to EXCF, livestock keeping was the main occupation and source of revenues for most farmers (82%) in the SIP cluster, and they possessed higher ($p \leq 0.001$) TLU and breeding cattle than EXCF farmers. Furthermore, in contrast to the three other peri-urban farm types, this group comprised cattle farmers with least livestock keeping experience, but at the same time a significantly higher ($p \leq 0.001$) proportion of SIP farmers provided feed supplementation to their animals in all seasons before and after grazing. Their herds were exclusively managed by hired herders.

Farms practicing a semi-sedentary pastoral system (SSP) were mainly found in villages located North–West of the city. They significantly ($p \leq 0.001$) contrasted with the other three peri-urban farm types by their practice of seasonal transhumance from January to May notably towards the county of Diaradougou located at an average distance of 16.1 ± 5.60 km from their dwellings. This cluster included the most experienced cattle farmers and the largest livestock holdings both in terms of cattle numbers and TLU. Cattle were exclusively grazed on natural pastures near their homestead during the dry season and mostly in the Dinderesso protected forest (18 km in North West of the city) during the rainy season from May to December. Herding was exclusively done by family members. Livestock keeping was the main occupation and source of revenues of all SSP farmers. Cattle production was oriented towards meat although none of the farms practiced fattening.

Farmers engaged in medium-scale agro-pastoral maize-dairy farming (MAMD) cultivated cropland and grew maize as their main activity and source of income. Cattle production was for dual purpose with milk being the main product, and feeding was based on grazing. Herding was ensured by family members. Most of the farms used manure for fertilizing their crop fields and owned and used oxen for ploughing the fields.

Farmers of the small-scale agro-pastoral dairy-maize system (SAPDM) shared many similarities with the MAMD type. Yet, a significantly higher ($p \leq 0.001$) proportion of farms in this group identified livestock keeping as their main occupation and income source, and cultivated a significantly ($p \leq 0.001$) smaller area of field, which were worked by hand.

4. Discussion

4.1. Cattle farming systems

In general, cattle farming in Bobo Dioulasso was mainly oriented towards beef production in the intra-urban area and milk production in the peri-urban area. In the intra-urban area cattle fattening was practiced by all farm types except EXCF, albeit to a widely varying degree.

In the ILBP system, the animals were managed intensively by stall-feeding them exclusively with purchased feeds such as concentrate meal, crop residues and agro-industrial by-products. This production system shares similarities with the landless metropolitan systems previously described by Thornton et al. (2002), and represents the most important intra-urban system in our study. Our findings clearly highlight the increasing shift of cattle production in both intra-urban and peri-urban areas from the traditional extensive grazing-based systems (EXCF in the intra-urban and SSP in the peri-urban areas) to more intensive stall feeding systems. This likely is a response to increased urbanization and thus to shrinkage of grazing areas and increasing distances and difficulties for herds to cross city quarters before arriving at sites for grazing. At the same time, this development also points to increased market opportunities for meat within and beyond the city of Bobo Dioulasso.

In the future, such intensified systems are expected to grow in importance given the young age of its entrepreneurs and the current annual growth rate of the urban population estimated at 7% in Bobo Dioulasso (Traoré et al., 2013), but also in other African cities.

Because the practice of fattening is associated to high demand of animal feeds and feedstuffs, the development of the intensive zero grazing system provides entrepreneurs with investment opportunities in feed milling enterprises. While the major constraints of the system were identified as limited availability and high prices of feed resources (Schiere and van der Hoek, 2001; Thys et al., 2005), a study by Diogo et al. (2010) in Niamey (Niger) revealed that farmers operating in this system provide excessive feed and nutrients to their animals.

A negative externality of intra-urban and peri-urban system is thus associated with the likely excess of nutrient supply through feed, and the reportedly poor disposal of animal waste, given that only a small portion of these nutrients are converted into meat (and/or milk), while the rest is excreted. Although 55% of the ILBP farmers sold manure to urban gardeners and peri-urban crop farmers, the remaining 45% mainly dumped it in open spaces within the city. Furthermore, continued housing and zero-grazing might predispose the animals to diseases, thereby increasing the risk to human health in terms of general hygienic problems, zoonotic disease transmission (Ameni et al., 2006) and use of broad spectrum antibiotics to counteract these, either in treatments or prophylactically (Katakweba et al., 2012; Abrahmsén et al., 2014).

Considerable contamination of the urban environment due to poor disposal of animal wastes has been reported in earlier studies (Curtis et al., 2000; Burkholder et al., 2007; Thorne, 2007; Alirol et al., 2010; Awomeso et al., 2010). We thus agree with Fernández-Rivera et al. (2004) that opportunities for exploiting the full potential of this system lie in sustaining the feed availability (both in quantity and quality), feed and manure markets, but also in improving its nutrient use efficiency. In the study area, organic (manure-based) fertilization of vegetables produced for the market is a common practice (Sangare et al., 2012). The market price of manure has been officially set by the municipal authorities to 1000 FCFA per cart of 125 kg, thus, 8 FCFA per kg (Commune de Bobo Dioulasso, 2006), although it actually varies from 500 to 3500 FCFA per cart (4–28 FCFA per kg). However, the high proportion of farmers dumping animal manure in the intra-urban ILBF, SICF and EXCF clusters and the peri-urban SIP cluster suggests their poor connection to the manure marketing system. We therefore argue that enhancing urban manure market development and investing in ways to better link the landless livestock farmers to this market will promote better manure management practices (including its collection, conservation and use) more rapidly and effectively than regulation by laws, and will moreover increase resources use efficiency at the accumulation hotspots that a city always represents (Buerkert and Hiernaux, 1998).

The existence and relative importance of SIMBF and IMBF farm types in the intra-urban area as well as MAMD and SAPDM systems in the peri-urban area indicate a trend towards intensification and integration of livestock and crop production. Crop farmers who represent 85% and 41% of farmers operating in the MAMD and SAPDM systems, respectively, have realized the advantages of keeping animals and integrating them into their farming systems. Likewise, more livestock-oriented farms reap benefits of growing crops by using animal wastes as organic fertilizer. Yet, the degree of crop and livestock integration varies between farm types. SIMBF and MAMD farm types are more similar to the fully integrated crop-livestock system described by Jagtap and Amissah-Arthur (1999) than IMBF and SAPDM systems. However, in contrast to the two peri-urban farm types MAMD and SAPDM, crop fields and livestock are spatially separated in the two intra-urban farm types SIMBF and IMBF, where cropping activities takes mainly place at the outskirts of the city and livestock activities in the intra-urban area. According to Fernández-Rivera et al. (2004), this spatial separation of cropping and livestock keeping limits the full exploitation of the benefits that could result from their interaction.

Our results also confirm the existence, in the peri-urban area, of a semi-sedentary pastoral system similar to the semi-settled and transhumant farm types previously described by Hamadou et al. (2003) and Sidibe et al. (2004) for Bobo Dioulasso, and by Chaibou et al. (2011) for Niamey. This system significantly differs from all other peri-urban cattle farm types by the large herd size and practice of seasonal transhumance. While this finding agrees with the notion that keeping large herds is not (easily) adapted to the rapidly changing peri-urban conditions (Bebe et al., 2002; Hamadou et al., 2003), we argue that the practice of transhumance is a transient response to the increasingly difficult access of cattle to grazing areas around the city and a transitory step towards a sedentary production system.

Finally, compared to the intra-urban ILBF and IMCF systems, all other farm types, regardless of their intra-urban or peri-urban location, might have difficulties in adapting to the rapidly ongoing urbanization and will likely disappear in the longer term, mainly because of their large dependency on continuously shrinking peri-urban grazing areas (Brinkmann et al., 2012). If farmers operating these production systems are determined to cope with the foreseeable challenges, they will very likely have to intensify their cattle operation in the medium term and develop towards intensive stall-feeding operations, depending on their ownership of cropland and overall financial means as well as farm labor.

4.2. Implications for policy development and planning

The principal opportunities for urban and periurban livestock development in Bobo Dioulasso and in other West African cities include the growing urban market for animal products and the complexity of urban life combined with high unemployment and poverty levels. Cattle keeping in cities and their surroundings, because of its high initial costs, is mainly practiced by wealthier urban individuals (Dossa et al., 2011a; de Haan 2013) usually with strong political influence. As a consequence, although bylaws prohibiting or regulating this land use practice exist in almost all cities in Sub-Saharan Africa they are usually poorly implemented and enforced by municipal authorities for fear of political repercussions (Msangi 2014; Mlozi et al., 2015). Further reasons explaining the bylaws' weak enforcement might include their inappropriateness and limited awareness among the local community. We therefore argue that, despite its environmental and public health risks, the simple prohibition of this activity through bylaws would be impossible. Instead, existing bylaws should be revisited to enable the better integration of this activity into urban planning and awareness created among its practitioners about their existence.

Furthermore, the diversity of production systems and differences between urban and peri-urban zones observed in our study suggest that livestock farmers may respond differently to alternative policies depending on their location (urban or periurban). City planners and policy-makers should therefore treat urban and periurban livestock production systems differently when designing adequate policy measures and supportive programmes. "Good practice" policy measures and zoning regulations implemented elsewhere to formalize these production systems (Kitilla and Mlambo 2001; Butler 2012; McClintock et al., 2014) might potentially be transferred to the West African policy context.

Finally, livestock extension services should be made more available to urban and peri-urban producers. At present, government policies towards livestock development in almost all West African countries are much more focused on improving rural production.

5. Conclusions

Grazing-based cattle production systems comprised 85% of the surveyed cattle operations in intra-urban and peri-urban areas of

Bobo Dioulasso. However, given the continuous shrinkage of grazing lands around the city, these enterprises will likely intensify towards stall-feeding systems operating on the basis of (purchased) crop residues, crop by-products and concentrate feeds. The intensive landless cattle fattening operation, the second most important intra-urban system in terms of proportion of involved farms, seems to be the most promising farm type for the future development of urban beef production – partly also due to the young age and entrepreneurial approach of its practitioners. However, sustaining year-round qualitative and quantitative feed supply and ensuring a rewarding manure marketing system along with efficient and environmentally-friendly manure management practices are crucial for the future sustainability of this farming system. Presently studies are conducted that analyze the current feeding and manure management practices in this system and to identify locally adoptable options to increase its overall efficiency.

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