Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 116 No. 1 (2015) 37–47

urn:nbn:de:hebis:34-2015011347137 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

Dairy farms typology and management of animal genetic resources in the peri-urban zone of Bamako (Mali)

Abdoulaye Toure [a,b], Nassim Moula [a,c], Ali Kouriba [b], Bakary Traore [a,b], Kisito Tindano [a], Pascal Leroy [a,c], Nicolas Antoine-Moussiaux [a,c,*]

[a] *Fundamental and Applied Research for Animals & Health (FARAH), Sustainable Animal Production, Faculty of Veterinary Medicine, University of Liege, Belgium*

[b] *Institut d'Economie Rurale (IER), Bamako, Mali*

[c] *Tropical Veterinary Institute, Faculty of Veterinary Medicine, University of Liege, Belgium*

Abstract

Facing growth in demand, dairy production in peri-urban areas of developing countries is changing rapidly. To characterise this development around Bamako (Mali), this study establishes a typology of dairy production systems with a special focus on animal genetic resources. The survey included 52 dairy cattle farms from six peri-urban sites. It was conducted in 2011 through two visits, in the dry and harvest seasons. The median cattle number per farm was 17 (range 5–118) and 42 % of farmers owned cropland (8.3 ± 7.3 ha, minimum 1 ha, maximum 25 ha). Feeding strategy was a crucial variable in farm characterisation, accounting for about 85 % of total expenses. The use of artificial insemination and a regular veterinary follow-up were other important parameters. According to breeders' answers, thirty genetic profiles were identified, from local purebreds to different levels of crossbreds. Purebred animals raised were Fulani Zebu (45.8 %), Maure Zebu (9.2 %), Holstein (3.0 %), Azawak Zebu (1.3 %), Mere Zebu (0.5 %) and Kuri taurine (0.1 %). Holstein crossbred represented 30.5 % of the total number of animals (19.0 % Fulani-Holstein, 11.2 % Maure-Holstein and 0.3 % Kuri-Holstein). Montbéliarde, Normande and Limousin crossbreds were also found (6.6 %, 0.7 % and 0.3 %, respectively). A multivariate analysis helped disaggregate the diversity of management practices. The high diversity of situations shows the need for consideration of typological characteristics for an appropriate intervention. Although strongly anchored on local breeds, the peri-urban dairy systems included a diversity of exotic cattle, showing an uncoordinated quest of breeders for innovation. Without a public intervention, this dynamic will result in an irremediable erosion of indigenous animal genetic resources.

Keywords: dairy cattle, genetic resources, multivariate analysis, Mali, zebu, crossbreeding

1 Introduction

In Mali, with a gross national income of around 660 USD per inhabitant (about 336,000 FCFA) and a Gini index of 33 (UNDP, 2012), milk consumption is unequally distributed across the country. It has been estimated at 30 litres/person/year for nomadic populations, between 5 and 6 litres in the southern part of the country and at 10 litres for the rest of the country (Bonfoh *et al.*, 2006). This demand drives changes in the livestock sector aiming at an increase in production, through an increased use of inputs and/or a better exploitation of the local forage resources.

* Corresponding author
Dr. Nicolas Antoine-Moussiaux
Email: nantoine@ulg.ac.be; Phone: +32(0)43664142

Published online: May 21, 2015

Mali is a Sahelian country, with two thirds of the territory being arid or semi-arid. This region is traditionally devoted to mobile livestock keeping. The variety of livestock systems gave birth to a wide genetic diversity of cattle, represented by two sub-species: zebus (*Bos indicus*) and taurines (*Bos taurus*). As in most sub-Saharan countries, dairy production is based on natural pastures. Thus, it is subject to the high seasonal variability of fodder availability and quality (Bosma *et al.*, 1996). To increase dairy production, public authorities initiated a crossbreeding program using exotic breeds, mainly from Europe in the late 1980s. Hence, three development projects on peri-urban livestock, financed by the French Cooperation Agency, took place successively between 1989 and 1999. These projects could achieve about 7,000 artificial inseminations across the country (Kouamo *et al.*, 2009). As a result, Mali owns an important number of crossbred cattle (Holstein and Montbéliarde), mainly around the cities of Bamako, Segou and Sikasso, located in the southern region, under Sahelo-Sudanian climate. The country also imported the Charolais beef breed, which is an isolated case among the member states of the Economic Community of West-African States (ECOWAS). Other member states, as Senegal or Burkina Faso, mainly imported the dairy Holstein breed (Valle Zárate *et al.*, 2006).

The current development of dairy production around Bamako is mostly driven by private investors of various sizes. In support of these private operators, public investment is still active in the building of semen collection centres. Ten years ago, the livestock keepers supplying milk to Bamako were located within a radius of 100 km around the city (Bonfoh, 2002). Due to urbanisation, herds are progressively forced to move away from the urban centre and thus from markets and consumption (Molina d'Aranda de Darrax, 2009). Nevertheless, a significant production still takes place in the direct vicinity of the city. Several studies emphasise the poor adaptation of European cattle breeds to less-favoured husbandry conditions, in terms of health, feeding and housing, which are prevailing in developing countries (Madalena *et al.*, 1990; Syrstad & Ruane, 1998). This study proposes a typology of peri-urban dairy production around Bamako. It aims at a better understanding of the different production types and management practices as well as the exploited animal genetic resources (AnGR) in the peri-urban zone of Bamako.

2 Materials and methods

2.1 Study area

Bamako is the capital of Mali. It is located on the Niger River (12°39' N, 8°0' W) and belongs to the Sahelo-Sudanian climatic zone, with a dry season from November to April and a wet season from May to October. Rain patterns present a high inter-annual variability (McSweeney *et al.*, 2010). Bamako has more than two million inhabitants and it is expected to increase further due to an annual urban population growth of 4.8 % (UN, 2014). The cattle number in the district is estimated as 44,000 heads (DNPIA, 2010).

2.2 Data collection

A survey was conducted with a sample of 52 smallholder dairy producers with a stated, although not exclusive, milk-marketing objective. The producers were identified through administrative services, collection centres and snowball sampling. They were selected inside a 70 km radius around Bamako, the selection being constrained by their accessibility. Each producer was visited twice in 2011. The first visit occurred in March-April, during the dry season (March–June), when pastures are poor. The second visit was in October-November, at the beginning of the harvest season, when fodder is abundant. The survey consisted of face-to-face interviews, with a close-ended questionnaire. Questions tackled the following topics: herd structure and management, feeding and health practices, milk production and genetic make-up of the animal (breed, parents, pedigree). Four of the 52 farms were followed by a veterinary agent and had accurate on-farm records of dairy production, feed costs and veterinary treatments. Based on these on-farm records as well as on the input structure of each producer, real costs (for fodder, feed and veterinary medicines) were estimated for each producer, disregarding opportunity costs (land, labour). In addition to the questionnaire, open discussions were led with all interviewed producers in order to collect discursive data about the farmer's perception of constraints and motives.

2.3 Statistical analysis

Both quantitative and qualitative variables were derived from the questionnaire. They can be grouped as follows:

– Identification of production units: location, environment, and personal information about the manager;

- Farm structure: labour, equipment and breeding infrastructure, calendar of agricultural operations, and available cropland;
- Livestock: herd composition, feeding, housing and breeding systems, (cross-) breds owned;
- Milk production per year and cow (quantity).

All statistical analyses were performed with the R software (version 3.0.0). Descriptive statistics were calculated for both quantitative (mean or median, standard deviation, ranges) and qualitative variables (percentages, ranges). A Principal Component Analysis (PCA) was performed including eight quantitative variables (herd size, milk production, fodder costs, fodder crops surface, feed costs, veterinary costs, relative variation of inventory, age of the herder) and one qualitative variable (use of artificial insemination, binary). The variables were selected according to the *a priori* knowledge of the production system and the variability observed through descriptive statistics. PCA analyses the relation between variables without any *a priori* structure, neither of variables, nor of individuals (Palm, 1998). A Hierarchical Classification Analysis (package FactoMineR, function HCPC) was then used for the initial variables and supplementary categorical variables (breed, mobility, main activity of the owner, herd ownership, housing) to categorise the farms and establish a local typology based on the three first principal components. This measure is called v.test, *i.e.* a normally distributed parameter, indicating the “standardised” deviation between the mean of individuals belonging to certain category and the general mean (Lebart *et al.*, 1997). The squared cosine ($\cos^2$) of each supplementary variable with the axes was also calculated, reflecting the actual correlation (r). Main and supplementary variables selected for PCA are presented in Table 1.

3 Results

3.1 Farm and livestock keeper characteristics

The median number of cattle per farm was 17 with an inter-quartile range of 12, the minimum and maximum being 5 and 118 heads, respectively. The herds were mainly constituted of females (0.77 ± 0.10). Adults represented 0.44 ± 0.08 of the herds, i.e. dairy cows (0.39 ± 0.09) and bulls (0.05 ± 0.02). Young bulls represented 0.12 ± 0.10 of the herds, and heifers 0.15 ± 0.01. Calves, males and females, amounted to 0.29 ± 0.07 of the herds (Table 2).

The median of milk production per cow and lactation period was 900 kg with an inter-quartile range of 650 kg, the minimum and maximum being 180 kg and 3800 kg, respectively. The length of the lactation period was between 210 and 330 days. The average age of the sampled interviewees was 40 ± 12 (minimum 18, maximum 55). Livestock husbandry was the main activity of about 44 % of them (pastoral herders). Other actors involved were civil servants (20 %) and liberal professionals (36 %). 42 % of the livestock keepers also owned some cropland ranging from 1 to 25 ha.

3.2 AnGR management: general overview

In the 52 surveyed farms, a total of 1428 animals were recorded and 30 genetic profiles were identified (Table 2). The majority of herds (68 %) were composed of different breed types, including indigenous purebreds and crossbreds. 32 % of the herds were composed of only one indigenous purebred. The Fulani Zebu was the most predominant breed, representing 46 % of the total animals. Crossbreds were mainly Holstein × Fulani Zebu crosses, amounting to 31 % of the total animals. Other crossbreds were present in smaller numbers, including Normande and Limousin crossbreds (0.7 % and 0.3 % of total animals, respectively).

Among the 29 livestock keepers exploiting exotic germplasm, 17 (59 %) stated their preference for the use of crossbred bulls which are shared between several farms. Nine respondents (30 %) preferred the use of artificial insemination (AI) with exotic germplasm (and sometimes also local germplasm) and expressed their satisfaction regarding the quality of the service as it is now organised. AI was, according to the breeders’ own terms, « a warrant of the transmission of good production ability ». The three remaining respondents (10 %) preferred their own bull to be used for mating because they judged the success rate of AI discouraging and showed distrust for shared bulls.

Two of the respondents (4 %) stated their willingness to progress towards an exclusive use of exotic breeds for outcrossing. These livestock keepers owned Holstein and Montbéliarde crossbreds at the time of the surveys.

The remaining 21 dairy producers exclusively use natural mating for their cows using the same breed as the cow (purebreeding).

3.3 Multivariate analysis and farm typology

3.3.1 Overall description of PCA results

The three first factorial components accounted for 74 % of total variability (i.e. 40.5 %, 20.6 % and 12.9 %, respectively) and were retained for analysis (Table 3). The main variables contributing to each of the three principal components are shown in Table 3, as well as their correlation with the considered principal components.

Table 1: *Variables used for functional typology of peri-urban dairy farms around Bamako (PCA, hierarchical clustering and further cluster description).*

Variables	*Description*
Quantitative variables	
Herd size	Number of heads (average of the two records)
Milk production	Quantity of milk (kg) per cow and year
Fodder crops surface	Agricultural surface allocated to fodder (ha)
Fodder costs	Cost per cow and year (quantity × market price, FCFA) of straw (millet, rice. . .) produced on-farm or collected/bought off-farm
Feed costs	Cost per cow and per year (quantity × market price, FCFA) of oil cakes (cotton and peanut) and cereal brans
Veterinary costs	Prophylaxis and curative treatments (FCFA) per cow and per year
Relative variation of inventory	Calculated, $= (\sum HS_{period2} - \sum HS_{period1})/HS_{period1}$ (HS: Herd size)
Age	Age of the interviewee (years)
Qualitative variables	
Artificial insemination	Practiced vs. not practiced
Breed *	Pure local breed vs. exotic/crossbred
Mobility *	Movement of animals within or beyond a 50 km radius
Activity *	Main activity of the owner of the herd (livestock keeper, civil servant, liberal profession)
Herd ownership *	Hired herder (absentee owner) vs. owner-herder
Housing *	Individual vs. Communal

* Variables included in the PCA as supplementary variables (not included in the calculation of principal component)

Table 2: *Genetic make-ups of cattle raised in dairy farms around Bamako.*

Genetic types	*Farms (N)*	*Female adults*	*Male adults*	*Young bulls*	*Heifers*	*Calves*	*Total*	*Share (%)*
Purebreds								
Fulani Zebu	29	255	18	81	99	201	654	45.8
Maure Zebu	11	43	10	12	17	49	131	9.2
Holstein	3	20	4	6	10	3	43	3.0
Azawak Zebu	1	5	2	2	2	7	18	1.3
Mere Zebu	1	2	1	1	2	1	7	0.5
Kuri	1	1	0	0	0	0	1	0.1
Crossbreds								
Holstein × Zebu	21	177	30	57	66	106	436	30.5
Montbéliarde × Zebu	7	33	8	5	10	38	94	6.6
Normande × Zebu	1	2	0	2	4	2	10	0.7
Limousin × Zebu	1	2	0	0	1	1	4	0.3
Azawak × Maure	1	1	1	0	0	0	2	0.1
Unknown	2	11	5	3	4	5	29	2.0
Total		552	79	169	215	413	1428	100

Table 3: *Principal components and their best-correlated variables.*

	Variables	*Correlation*			*Variance explained*	
		Principal component 1	*Principal component 2*	*Principal component 3*	*%*	*Cumulative %*
Axis 1	Herd size	0.88	–0.41	0.03	40.5	40.5
	Fodder crops surface	0.87	–0.27	0.10		
	Feed costs	0.84	–0.10	0.09		
	Veterinary costs	0.96	0.003	0.15		
Axis 2	Fodder cost	0.40	0.73	0.12	20.6	61.1
	Artificial Insemination	0.36	0.62	–0.03		
	Milk production	0.18	0.82	0.003		
Axis 3	Relative variation of inventory	–0.37	–0.018	0.62	12.9	74.0
	Age	–0.15	–0.02	0.84		

The first component accounted for 40.5 % of total variation. It is positively correlated to the herd size (r = 0.88), to the area allocated to fodder crops (r = 0.87), the feed costs per cow, composed by groundnut oilcake and cereal brans (r = 0.84) and veterinary care expense per cow (r = 0.96) (Table 3). The breed, as a supplementary variable, is also significantly (v.test, $p < 0.001$) linked to this axis ($\cos^2 = 0.84$), opposing "local breed" (coordinate –1.31) and "crossbred" (coordinate 1.04). Other qualitative categories with a positive coordinate on this axis and highly significant v.tests ($p < 0.001$) are mobility beyond a 50-km radius (coordinate 4.95; $\cos^2 = 0.83$), main activity as licensed professional (coordinate 2.98) and civil servant (coordinate 0.60). The coordinates of the categories "communal housing" and "individual housing" on this axis are negative (–1.11) and positive (1.40), respectively, with a significant v.test ($p < 0.001$) and a high correlation to the axis ($\cos^2 = 0.95$).

The second component is positively correlated to the fodder costs (r = 0.73), as well as with total milk production (r = 0.62). The use of artificial insemination (r = 0.62) accounted for 20.6 % of total variation (Table 3). The categories "crossbred" and "local breed" (coordinates 0.40 and –0.50, respectively) show a significant link with this axis ($p < 0.001$) and a low square cosine ($\cos^2 = 0.12$). Mobility beyond a 50-km radius has a significant v.test ($p < 0.001$) and a negative coordinate on this axis (–2.18).

The third component is positively correlated to the relative inventory variation (r = 0.62) and to the age of interviewee (r = 0.84). It represents 12.9 % of total variation (Table 3). No qualitative variable showed a statistically significant link to this axis.

3.3.2 Hierarchical classification and clusters' description

Classification analysis helped in defining three clusters of farmers. Figure 1 shows their distribution according to the two first principal components.

The means per cluster for the variables included in the hierarchical classification analysis are presented in Table 4.

Cluster 1 (n = 26; 50 % of total sample): small pastoral herds

The herds of cluster 1 count 14 heads on average, with a minimum of 5 and a maximum of 31. Costs for concentrate feeding (23.700 ± 21.000 FCFA per head and year; $p < 0.001$) as well as veterinary costs (4.000 ± 9000 FCFA per head and year; $p < 0.001$) are lowest among clusters (Table 4). Milk production is low, with 73 % of herds having an annual production below 1000 kg per cow (Table 4). 81 % include only local breeds. None of the breeders in cluster 1 use AI (Table 4). Half of the herds belong to the herder and only some herders are hired by civil servants (11 %) or licensed professionals (16 %). The average age in this cluster is 38 years (minimum 19, maximum 58). 85 % of these herds are kept in enclosures that communal authorities freely allocate to herders (Table 4).

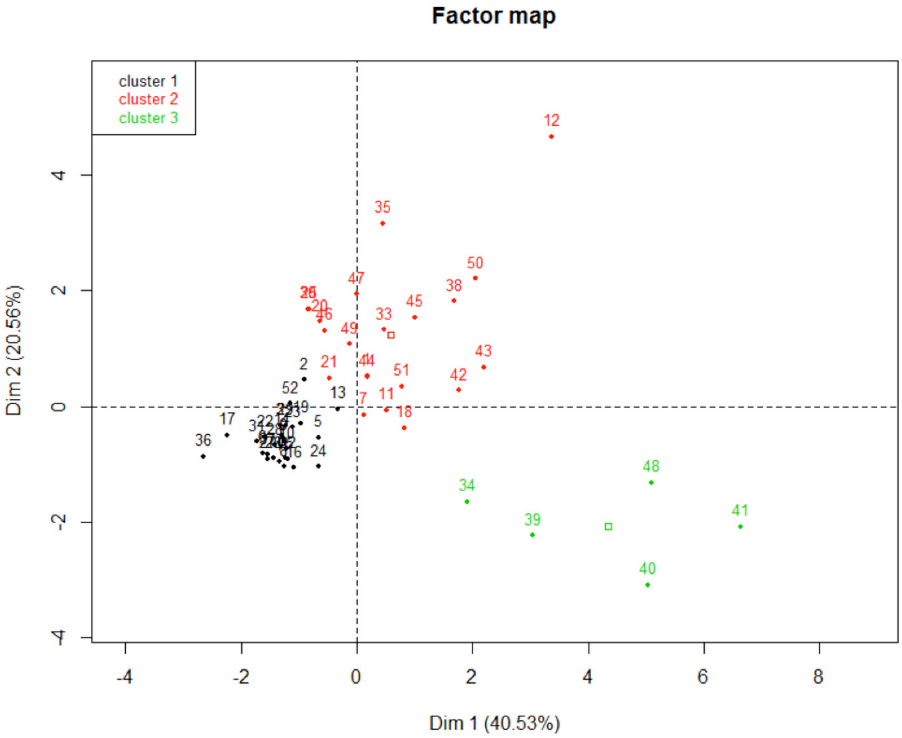

Fig. 1: *Distribution of farm clusters according to the two first principal components.*

Table 4: *General comparison of structural characteristics and performance of dairy farm clusters defined by hierarchical classification.*

	Cluster 1		*Cluster 2*		*Cluster 3*		*ANOVA*
Number of farms	26		21		5		
Quantitative variables	*mean*	sd	*mean*	sd	*mean*	sd	R^2
Herd size (number)	14.4 ^{a}	5.82	23.9 ^{a}	11.28	90.1 ^{b}	22.91	0.80
Fodder crop (ha)	0.2 ^{a}	0.59	3.7 ^{b}	4.33	19.0 ^{c}	5.81	0.73
Milk production (kg/cow/year)	726.3 ^{a}	297.91	1672.5 ^{b}	822.38	584.8 ^{a}	213.56	0.42
Veterinary costs (×10^3 FCFA/head/year)	4.0 ^{a}	9.03	17.5 ^{c}	10.87	12.3 ^{b}	3.12	0.72
Feed costs (×10^3 FCFA/head/year)	23.7 ^{a}	21.04	103.6 ^{c}	124.62	94.4 ^{b}	41.09	0.54
Fodder costs (×10^3 FCFA/head/year)	0.05 ^{a}	0.01	0.3 ^{b}	0.19	0.02 ^{a}	0.02	0.36
Relative inventory variation	0.20 ^{a}	0.43	0.21 ^{a}	0.32	–0.28 ^{b}	0.11	0.10
Age (years)	38.1 ^{a}	10.61	42.3 ^{a}	11.40	45.4 ^{a}	5.22	0.03
Adult cows† (% of total herd)	36.1 ^{a}	8.9	43.4 ^{b}	6.43	29.5 ^{a}	4.09	0.77
Adult bulls† (% of total herd)	3.9 ^{a}	1.6	4.6 ^{a}	1.64	12.8 ^{b}	6.33	0.70
Qualitative variables	*Share (% of breeders)*		*Share (% of breeders)*		*Share (% of breeders)*		χ^2 p-value
Exotic germplasm	19.2		100		100		**
Mobility over 50 km	0		0		100		**
Artificial insemination	0		66.7		20.0		***
Communal housing	84.6		0		0		***
Herder-owner	53.8		19.0		0		***

For quantitative variables, a different superscript letter (*a*, *b*, *c*) on a same line indicate statistically significant differences between cluster means. The ANOVA test considered a $p < 0.001$, except for Relative Inventory Variation ($p < 0.05$). For qualitative variables, the chi-square (χ^2) test was applied. ** indicate p-values under 0.01 and *** p-values under 0.001.

† The share of cows and bulls in the herds are calculated on basis of the mean of the two survey periods.

Cluster 2 (n = 21, 40 % of total sample): agro-pastoral systems

The mean herd size in cluster 2 is 24 (minimum 8 and maximum 48) not being statistically different from the average herd size in cluster 1 (Table 4). This cluster shows the highest milk production among clusters, with 1672.5 ± 822.4 kg per cow and year ($p < 0.001$), 71 % of the herds have a production above 1000 kg per cow and year. It also displays the highest costs among clusters, for feed, health care and fodder ($p < 0.001$; Table 4). 57 % of the farms own land, with a mean of 3.7 ha (minimum 2, maximum 15; Table 4). All farms from this cluster make use of exotic breeds. 58 % strictly rely on these breeds, while the remaining maintain some local purebreds in their herd. 67 % of these farms use artificial insemination. The owners are mainly urban dwellers from Bamako such as merchants (47 %) or civil servants (33 %). In half of the herds, the management is operated by livestock technicians who may live with the herd (Table 4).

Cluster 3 (n = 5; 10 % of total sample): large mobile herds

The cluster 3 includes the largest herds of the sample with a mean of 91 cattle (minimum 57, maximum 118; $p < 0.001$; Table 4). Veterinary and feed costs are higher than in cluster 1 but lower than in cluster 2 ($p < 0.001$; Table 4). Fodder crops surface is highest among clusters ($p < 0.001$) with a mean of 19.0 ± 5.8 ha per farm. None of the herds in cluster 3 exceeds 1000 kg milk per cow and year and the average milk production is the lowest of the three clusters, although no statistical difference with cluster 1 appears from analysis of variance. The management is handed over to one or several hired animal herders. These herders move more than 50 km away with the cattle herds. The relative variation of inventory is –0.28 ± 0.11, which distinguishes this cluster from the other clusters ($p < 0.05$). Finally, the herd structure also appears different in this cluster, with a higher share of bulls as compared to clusters 1 and 2 ($p < 0.001$).

4 Discussion

4.1 Production objectives and dairy production types in Bamako

This survey focused on smallholder dairy producers supplying milk to markets in Bamako. The average percentage of female breeding stock in the sample, which is close to 40 %, confirms the general orientation of the selected farms towards dairy production (Dehoux & Hounsou-Ve, 1993). The low individual yields and the lack of a tradition of milk marketing in this area show this orientation to be clearly the result of stimulation by demand, as theorised by the concept of Livestock Revolution (Delgado *et al.*, 1999). In the present case, this stimulation occurs through an active and direct approach of livestock keepers by urban dwellers to buy milk.

Cluster 1 is composed of sedentary pastoral breeders not involved in cropping activities. Although milk production in this cluster is relatively low, milk sales hold nevertheless a key-role in the food security strategy of the animal keeper. This key-role of milk production for sedentary pastoralist was found also by Thornton (2010). In this cluster, low feed costs result from the fact that these producers distribute very few concentrates to their animals, consisting of cereal brans bought in villages around Bamako. This bran is available all year long but these herders use it only during the dry season, with a priority to lactating cows (own data, not shown). Thus, while the low amount distributed is in accordance with the low priority given to milk production for marketing, the targeting of milking cows for supplementary feeding highlights their key-role in the livelihood strategy.

Cluster 2 is composed of sedentary livestock keepers cultivating crops and achieving higher milk production levels than the two other clusters. Discursive data from interviews tend to confirm that marketing represents a greater share of the farm objectives, being part of a profit-oriented milk production. The higher costs observed in this cluster fit in this production goal. Integration between livestock and crops also fits in this optimisation behaviour, by fodder cultivation (mainly *Vigna unguiculata* (L.), *Panicum maximum* Jacq., *Andropogon gayanus* Kunth) and conservation, use of animal draught power and manure for fertilisation, as also described by Tiffen (2006) for peri-urban regions in Senegal, Nigeria and Niger. This group corresponds to a first step towards intensive milk production. Fernández-Rivera *et al.* (2004) distinguished different sub-groups among such farms according to the specific roles ascribed to crops and livestock. The emergence of milk collection centres and mini-dairies, set up by livestock development projects, spurred a renewed interest in livestock activities. Hence, well-off urban newcomers are progressively investing their savings in livestock, benefitting from the social status derived from livestock ownership and for their leisure time (Bonfoh *et al.*, 2007). As a result, the management of livestock is most often entrusted to livestock technicians.

In cluster 3, the herds represent savings for their owners, who are high-ranking civil servants or well-off merchants. The symbolic value of the ownership of livestock may also be considered as part of the objective of the owner (Turner, 2009). Nevertheless, the orientation of the herd production is also driven by the objective of the herdsman to whom it is entrusted. Again, discursive data from interviews indicate that milk marketing is not central in the objectives of the cattle keepers of cluster 3, who give greater priority to the sale of live animal. This orientation is illustrated in the present results by the relative variation of inventory, which proved in this cluster negative and significantly different from other clusters. Indeed, the second period took place after the religious festivals Eid el Fitr, during which sales of bulls and young males occur. The variations in herd structure and performance between clusters are also in agreement with the different production objectives among the identified clusters (Millogo *et al.*, 2008). Also Dicko *et al.* (2006) reported of a varying relative importance of different categories of animals (age and sex) in a herd according to production objectives. The low proportion of males above 3 years-old (5 % in this study) is also a feature described for the periphery of Addis Ababa (Lemma & Kebede, 2011).

4.2 Milk production performances and production management

Milk production performances and production management are important parameters in differentiating dairy production types around Bamako. The average milk yield in this study is close to that reported for Fulani-Montbéliarde crossbreds in experiments led in rural settings in Mali, i.e. around 1012 litres for an average lactation length of 243 days (Coulibaly *et al.*, 2005). Nevertheless, a wide variation of milk performances could be observed. While all (cluster 3) or most of the herds (cluster 1) are below the performance level of 1000 kg per cow and year, 71 % from cluster 2 are above that average. This is mainly due to the improved feeding practices based on the purchase of concentrate feed, as well as the use of fodder crops and crop residues. Moreover, livestock keepers from cluster 2 most often have personally invested in animal housing while cluster 1 herds are fed on common pastures and kept at night in common paddocks, as described by Debrah *et al.* (1995). These common paddocks are located in or at the immediate surroundings of the city. They are often allocated to several livestock keepers by the communal authority. Herders reported here that private agents also attribute paddocks to breeders on temporarily unexploited fields. Besides the environmental effects that were not studied in this survey, the wide variability of performances may thus result from the observed differences in herd management, mainly in the feeding management, as has been also described by Mouli (2001) and Ba Diao *et al.* (2006).

The genetic make-up also influences the herd performance. However, in developing countries, improved breeds often do not express their full genetic potential for high milk yields because of the harsh climatic and husbandry conditions, especially insufficient or unbalanced feeding (Tamboura *et al.*, 1982; Madalena *et al.*, 2002).

4.3 Urbanisation and pastoral management

While urbanisation is a driving factor for the rise of the dairy sector around Bamako, it also leads to a decrease in the available pastoral area. As a result, the herds are forced away from the urban centre, and thus, from the consumption centre (Molina d'Aranda de Darrax, 2009). Increasing distances are leading to higher transport costs and lower the competitiveness of local milk against imported milk powder at their usual retailing places (Ouologuem, 2007; Molina d'Aranda de Darrax, 2009). Moreover, in accordance with the classical theory of spatial organisation of agriculture by Schultz (1953), in the vicinity of urban markets for products and inputs, production systems that are more productive per surface unit are often preferred to the pastoral activity that is land consuming. Therefore, livestock is replaced in these peri-urban zones by market gardening or other crops (Graefe *et al.*, 2008).

Facing the diminishing land availability, the different groups of livestock keepers adopted unique strategies. Livestock keepers from cluster 1 and 2 opted for a restricted mobility. Livestock keepers of cluster 1 centre on communal pens where animals are kept at night. Livestock keepers from cluster 2 have a similar strategy, but with even more restricted movements, and keep their animals at night in their own pens or buildings. This sedentary strategy is allowed by and allows for cropping activities, benefitting from the crop-livestock integration. Livestock keepers from cluster 3 adopt wider movements, delocalising non-productive animals to less densely populated locations. This practice of herd division according to productive status is common across West Africa as in other parts of the world (Dongmo *et al.*, 2007).

As described by Turner (2009), the case of cluster 3 is a typical illustration of the growing involvement of well-off urban dwellers in livestock activities, for whom livestock represents an opportunity for investing their savings while gaining social status. Farms from cluster 2 also witness this process of urban investment. Therefore these clusters are the illustration of the fact that urban investments may feed in both mobile and sedentary breeding. In cluster 3, the hired herdsmen belong to the Fulani ethnic group. Therefore, the mobile herding described here above is part of a wider picture, involving the respect of a traditional way of life, and the maintaining of social networks (Lhoste, 1984).

4.4 Erosion of animal genetic resources

Across the world, the main causes for the erosion of animal genetic resources (AnGR) are the massive diffusion of a few highly-productive breeds, the evolution of production systems and of producers' and consumers' preferences, spurred by socio-economic factors, as well as disasters (drought, famine, epidemics, civil conflicts) (Rege & Gibson, 2003).

In this survey, the proportion of crossbreds is close to 40 %, which is far greater than the 9 % reported in 2004 for Bamako (Bonfoh *et al.*, 2006). Besides the possible sampling bias due to the focus on farms with a milk-marketing objective, this might point to a gradual absorption of native breeds by exotic ones. Only two breeders expressed here the intentional practice of outcrossing, but a larger number of breeders participate to this dynamic in a less conscious manner. This process, being in the hand of the commercial sector, is a threat to AnGR diversity. Without public measures aiming at a rational use of exotic germplasm, the impact on native breeds may be severe (FAO, 2008). Since 2000 and the Bovine Spongiform Encephalopathy crisis in Europe, public authorities of Mali forbade the import of animals from Europe. The animals presently observed in the suburbs of Bamako are, thus, probably descendants from animals imported before 2000 (Bonfoh *et al.*, 2006).

Despite this major trend to erosion of AnGR diversity through uncontrolled crossbreeding, the diversity of dairy production systems shown in this survey point to a distinct role in this process for each of the three systems described. Indeed, using artificial insemination and exotic crossbreeding, cluster 2 may be considered as a focal point of the erosion process, whereas the situation is clearly different in cluster 1. In cluster 3, although all of the five herds concerned use crossbred animals, their more traditional practice lead them to retain and keep for part of the herd a strong preference for resilience, conservation and mobility traits. Indeed, these herders practice a separate management of crossbreds and local breeds. Hence, they are also home to native breeds and biodiversity. In accordance with this observation, national strategies for AnGR conservation may gain from involving these livestock keepers and supporting their mode of production. The third cluster might be nevertheless promising for conservation goals, the involved actors being well-off urban dwellers, not needing public support, and still attached to traditional breeding practices and native breeds. Their integration to national conservation policies should be considered.

While an erosion of genetic diversity is seemingly at play, this does not give a full picture of the on-going dynamic. Indeed, some breeders are experimenting crossbreeding between different native breeds. Crossbreds between Fulani and Azawak zebu are more particularly tested in farms owned by merchants or civil servants with the stated aim of experimenting the adaptation of such animals to the evolving climatic conditions in the Sahel. This point confirms the potential role for such actors in a general policy aiming at the promotion of native breeds. This also opens a way for the evolution of breeds that would not entail the use of the globally dominant exotic germplasm that are Holstein and Jersey breeds.

5 Conclusion

This study highlights the diversity of dairy herds around Bamako. The discriminating variables refer to the level of intensification of production and the endowment of the livestock keepers: herd size, surface allocated to fodder crops, expenses for livestock care (feed, fodder, health). Also, the genetic types exploited, labour and mobility proved interesting variables. Whereas three clusters could be described, the variability within cluster remains significant, amounting to 26 % of total variability. The urban development has an important impact on livestock in the surrounding areas. This survey illustrates the multiple influences of urbanisation in the case of Bamako, namely through the growing demand for livestock products, through the competition for space, and through the investment of urban savings in more intensive crop-livestock integrated production systems or in highly mobile capital-driven herds. The diversity of farms involved in the supply of milk to Bamako results from that differentiated impact of urbanisation on livestock actors, according to their resource endowment (land, labour, links to urban investors). In turn, the evolution of AnGR is tied to this diversity of actors. Policies aiming at the development of the local dairy production should take this diversity of actors into account.

References

Ba Diao, M., Dieng, A., Seck, M. M. & Ngomibé, R. C. (2006). Pratiques alimentaires et productivité des femelles laitières en zone périurbaine de Dakar. *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, 59 (1-4), 43–49.

Bonfoh, B. (2002). Lait Sain pour le Sahel. Atelier de restitution des résultats "Hygiène et qualité du lait et des produits laitiers au Mali: Implications en production laitière et en santé publique", LCV/ INSAH – STI/ ETHZ, Bamako, Mali. URL `http://www.hubrural.org/IMG/pdf/laitsainsahel_rapport_seminaire_2002.pdf` (last accessed: 21.03.2013).

Bonfoh, B., Corniaux, C., Coulibaly, D., Diabaté, M., Diallo, A., Fané, A., Koné, Y., Napo, A., Poccard-chapuis, R. & Traoré, A. (2006). Synthèse bibliographique sur les filières laitières au Mali. Réseau de recherches et d'échanges sur les politiques laitières. Institut sénégalais de recherches agricoles Bureau d'Analyses Macro-Economiques (ISRA-BAME). URL `http://fsg.afre.msu.edu/promisam_2/references/Bonfo_et_al_2006_Synthese_Bibliographique_Lait_Mali.pdf` (last accessed: 10.12.2012).

Bonfoh, B., Fokou, G., Ould Taleb, M., Fané, A., Woirin, D., Laimaibao, N. & Zinsstag, J. (2007). Dynamiques des systèmes de production laitière, risques et transformations socio-économiques au Mali. *Revue de médecine vétérinaire*, 60 (1-4), 67–76.

Bosma, R., Bengaly, K., Traoré, M. & Roeleveld, A. (1996). *L'élevage en voie d'Intensification : Synthèse de la recherche sur les ruminants dans les exploitations agricoles mixte au Mali –Sud*. Amsterdam : (KIT) Royal Institute of the tropics, Pays-Bas ; Institut d'Economie Rurale, Bamako, Mali. Pp.202.

Coulibaly, M. D., Ouologem, B. & Togola, D. (2005). Recherche par voie de croisement de génotypes appropriés pour la production de lait. Rapport final de recherche, 11ème Session du comité de programme. Programme Bovin/IER, Bamako. Pp 32.

Debrah, S., Sissoko, K. & Soumaré, S. (1995). Etude économique de la production laitière dans la zone périurbaine de Bamako au Mali. *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, 48 (1), 101–109.

Dehoux, J. P. & Hounsou-Ve, G. (1993). Productivité de la race bovine Borgou selon les systèmes d'élevage traditionnels au Nord-Est du Bénin. *Revue mondiale de Zootechnie*, (74–75), 36–48.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. & Courbois, C. (1999). Livestock to 2020. The next food revolution. IFPRI, FAO paper.

Dicko, M. S., Djitèye, M. A. & Sangaré, M. (2006). Les systèmes de production animale au Sahel. *Sécheresse*, 17 (1-2), 83–97.

DNPIA (2010). *Rapport d'activités annuelles*. Direction Nationale des Productions et des Industries Animales (DNPIA) de Bamako, Mali. Pp.113.

Dongmo, A. L., Djamen, P., Vall, E., Koussou, M. O., Coulibaly, D. & Lossouarn, J. (2007). L'espace est fini ! Vive la sédentarisation ? Innovations et développement durable en question chez les pasteurs des zones cotonnières d'Afrique de l'ouest et du centre. *Rencontres Recherches Ruminants*, 13, 153–160.

FAO (2008). L'état des ressources zoogénétique pour l'alimentation et l'agriculture dans le monde. Commission des Ressources génétiques pour l'Alimentation et l'Agriculture. L'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome. URL `http://www.fao.org/docrep/011/a1250f/a1250f00.htm` (last accessed: 22.01.2013).

Fernández-Rivera, S., Okike, I., Manyong, V., Williams, T. O., Kruska, R. L. & Tarawali, S. A. (2004). Classification and description of the major farming systems incorporating ruminant livestock in West Africa. In T. O. Williams, S. A. Tarawali, P. Hiernaux, & S. Fernandez-Rivera (Eds.), *Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa. Proceedings of an international conference* (pp. 87–122). International Livestock Research Institute (ILRI).

Graefe, S., Schlecht, E. & Buerkert, A. (2008). Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. *Outlook on Agriculture*, 37 (1), 47–56.

Kouamo, J., Sow, A. A., Leye, A., Sawadogo, G. J. & Ouedraogo, G. A. (2009). Amélioration des performances de production et de reproduction des bovins par l'utilisation de l'insémination artificielle en Afrique Subsaharienne et au Sénégal en particulier : état des lieux et perspectives. *Revue africaine de santé et de productions animales*, 7 (3-4), 139–148.

Lebart, L., Morineau, A. & Piron, M. (1997). *Statistique Exploratoire Multidimensionnelle*. Dunod, Paris. Pp. 439.

Lemma, A. & Kebede, S. (2011). The effect of mating system and herd size on reproductive performance of dairy cows in market oriented urban dairy farms in and around Addis Ababa. *Revue de médecine vétérinaire*, 162 (11), 526–530.

Lhoste, P. (1984). Le diagnostic sur le système d'élevage. *Cahiers de la Recherche – Développement*, 3-4, 84–88.

Madalena, F., Agyemang, K., Cardellino, R. & Jain, G. (2002). Genetic improvement in medium to low-input systems of animal production. Experiences to date. In *7th World Congress on Genetics Applied to Livestock Production, August 19-23, 2002*. INRA, Cedex, France.

Madalena, F., Teodoro, R. L., Lemo, A. M., Monteiro, J. B. N. & Barbosa, R. T. (1990). Evaluation of Strategies for Crossbreeding of Dairy Cattle in Brazil. *Journal of Dairy Science*, 73 (7), 1887–1901.

McSweeney, C., New, M. & Lizcano, G. (2010). UNDPP climate change country profiles: Mali. United Nations Development Programme (UNDPP), University of Oxford. URL http://country-profiles.geog.ox.ac.uk/ (last accessed: 10.05.2013).

Millogo, V., Ouedraogo, G. A., Agenäs, S. & Svennersten-Sjaunja, K. (2008). Survey on dairy cattle milk production and milk quality problems in periurban areas in Burkina Faso. *African Journal of Agricultural Research*, 3, 215–224.

Molina d'Aranda de Darrax, S. (2009). Le lait local en périphérie de Bamako : une filière en sursis ? *EchoGéo*, 8. URL http://echogeo.revues.org/11012 (last accessed: 18.08.2013).

Mouli, C. L. (2001). Diversité des pratiques et variabilité des performances animales dans un système agropastoral sahélien. In *Pratique d'élevage extensif. Identifier, modeler, évaluer*. INRA Etude et Recherche sur les Systèmes Agraires et le Développement, 27. Pp.390.

Ouologuem, B. (2007). Recherche de mode de gestion du troupeau pour une exploitation économique durable des bovins laitiers dans les zones périurbaines du Mali : production, commercialisation et consommation de produits laitiers en zones périurbaines du Mali. Résultats de Recherche 2003–2007. Pp.48.

Palm, R. (1998). L'analyse en composantes principales : principes et applications. Notes de Statistique et d'Informatique. (Gembloux) 98/2, Belgique. Pp. 33.

Rege, J. E. O. & Gibson, J. P. (2003). Animal genetic resources and economic development: issues in relation to economic valuation. *Ecological Economics*, 45 (3), 319–330.

Schultz, T. (1953). *The economic organization of agriculture*. McGraw-Hill, New York. Pp. 374.

Syrstad, O. & Ruane, J. (1998). Prospects and strategies for genetic improvement of the dairy potential of tropical cattle by selection. *Tropical Animal Health and Production*, 30, 257–268.

Tamboura, T., Bibe, B., Rabile, R. & Petit, J. P. (1982). Résultats expérimentaux sur le croisement entre races locales et races améliorées au Mali. *Sommaire*, 4, 401–412.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365 (1554), 2853–2867. doi:10.1098/rstb.2010.0134.

Tiffen, M. (2006). Urbanization: impacts on the evolution of "Mixed farming" systems in Sub-Saharan Africa. *Experimental Agriculture*, 42, 259–287.

Turner, M. (2009). Capital on the move: The changing relation between livestock and labor in Mali, West Africa. *Geoforum*, 40, 746–755.

UN (2014). *World Statistics Pocketbook, 2014 edition*. United Nations Statistics Division. New York, US.

UNDP (2012). World DataBank. URL http://databank.worldbank.org/data/home.aspx (last accessed: 09.08.2013).

Valle Zárate, A., Musavaya, K. & Schäfer, C. (Eds.) (2006). *Gene flow in animal genetic resources: a study on status, impact and trends*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Germany. URL ftp.fao.org/docrep/fao/010/a1250e/annexes/Thematic%20Studies/Geneflow/GeneflowStudy.pdf (last accessed: 18.03.2012).