

The importance of camel (*Camelus dromedaries*) in the livelihoods of herders: the case of camel herders' households in peri-urban N'Djamena and pastoral Fitri, Chad

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ABSTRACT

The objective of this study was to analyse the contribution of camel farming to pastoral household livelihood. A survey was conducted among 200 households, 108 in peri-urban N'Djamena and 102 in pastoral Fitri in central Chad. Two types (one per zone) of household livelihood strategies were used to analyse the data. Camel herders' households are largely specialised, with camels comprising at least 80% of herds (in terms of tropical livestock units, TLU). Such households are livestock farming specialists, with 60% of households not undertaking any cultivation. Camel farming in peri-urban N'Djamena differed from that in pastoral Fitri because of the importance of milk sales that contribute to the monetary income of families. Milk self-consumption as part of the gross product of camel farming represented 45% for pastoral Fitri and 21% for peri-urban N'Djamena. Households also exploited live animals for meat, mainly for sale, and a little for self-consumption in Fitri. The added value of live animals represented 55% (3.6 animals/year) of camel gross product in pastoral Fitri, because of the volume of milk self-consumption, and only 10% (1.6 animals/year) in peri-urban N'Djamena, because of milk sales. The livestock per adult equivalent (AE) was, on average, double for households in Fitri compared to those in peri-urban N'Djamena (14 vs 7 TLU/AE). Livestock composition was more diversified in Fitri, with camels (80% of TLUs), small ruminants and cattle, whereas households in peri-urban N'Djamena were even more specialised towards camels (90% of TLUs), besides keeping small ruminants. At Fitri, 40% of households grew crops, compared with only 24% around N'Djamena. The size of livestock holdings ranged from 7.8 TLU/AE for small-size households (4.8 AE) to 8.2 TLU/AE for very large-sized households (9.3 AE) in peri-urban N'Djamena, whereas at Fitri small households had a very high capital endowment (24.4 TLU/AE), medium-sized households were moderately endowed, with 13.9 TLU/AE, and large households were poorly endowed, with 10.8 TLU/AE. In both areas, camel farming provided a daily gross margin per AE over 663 CFA francs/day for three quarters of households, which corresponds to the national poverty threshold. However, only 16% of households generated a gross margin higher than the guaranteed interprofessional minimum wage, estimated at 2000 CFA francs/day. This specialisation of moving to camel herding allowed herders to get well adapted to arid environments. Additional research work is needed to provide a global vision of the potential of camels as a basis for livelihood strategies.

Keywords: camel, chad, contribution, households, livelihood, livestock, pastoral, peri-urban, resilience.

Introduction

Pastoral livestock farming is one of the main income-generating activities in the economy of Sahel countries, with a contribution generally exceeding a third of agricultural gross domestic product (GDP) (Amole *et al.* 2022). The production system is characterised by

its mobility, which allows planned exploitation of available pastoral resources in a highly variable and unpredictable environment, while taking advantage of the ecological diversity and the relationships among the different agro-ecological zones throughout the year (Krätli *et al.* 2018). To best utilise the extensive rangelands, pastoral livestock farming relies in particular on the knowledge, practices and know-how of pastoral herders, on domestic animal genetic resources particularly well adapted to this mobility (herds of cattle, small ruminants, camels, or horses), and on a social organisation allowing the best management of the movements of families and animals (Marty *et al.* 2009; Manoli *et al.* 2014; Thebaud 2017). However, in recent decades, climate change has resulted in increased temperature, more abundant rains (particularly in the form of violent episodes), and more frequent droughts (Wako *et al.* 2017; Chagnaud *et al.* 2022). These ecological tensions, coupled with other tensions in markets or in the area of security and access to rangelands, have led to the deterioration of the resilience capacity of ecosystems and of the livelihoods of pastoral societies (Yosef *et al.* 2013). Several studies conducted in East Africa in particular indicate that cattle herds have suffered significant losses caused by drought (Yosef *et al.* 2013; Wako *et al.* 2017), and that herders have developed various adaptive strategies over the years so as to minimise their vulnerability (Elhadi *et al.* 2015; Watson *et al.* 2016; Turner and Schlecht 2019).

Nori (2021) and Scoones (2023) distinguished the following five strategies and principles of management of pastoral systems: (i) adaptive management of the herd, (ii) diversification of livelihoods; (iii) mobility; (iv) complementarity among different activities conducted within agropastoral territories; and (v) inclusion in social networks, allowing herders to negotiate access to resources. An example of adaptive herd management is the substitution of cattle by camels and goats among some herders in arid zones, as evidenced by the 10% increase in the camel numbers in several Sahel countries over the past 20 years (Rahimi *et al.* 2022). Camels present many advantages because of their remarkable adaptive ability, allowing survival in severe droughts because of biological and physiological characteristics (Yosef *et al.* 2013). Camels are capable of utilising woody and thorny plants not consumed by most other herbivores, with a greater capacity to digest poor fodder (Dereje and Uden 2005). Camels can survive several days without drinking, a consequence of their greater tolerance to dehydration than in other species (Kagunyu and Wanjohi 2014). This allows access to more distant pastures, with less risk of crop damage (Marty *et al.* 2009). Camels provide a range of foodstuffs (milk and meat) as well as essential services such as transport, water extraction, etc. (Faye 2016).

Chad has a large camel herd, and is ranked number one in the world. In 2021, camel numbers were estimated at 9.4 million head by Food and Agriculture Organization of the United Nations (FAO). This nomadic livestock farming is

traditionally concentrated in the central and northern regions of the country. However, with drought episodes experienced in recent decades, it is increasingly common in more southerly regions (MEPA 2016). Many herders have invested in camels not only because of climate change, but also the growing demand for camel products favoured by urbanisation and changes in dietary behaviour. However, despite its socio-economic and demographic importance, the potential for camel farming remains underestimated. This study aimed to analyse the contribution of camel farming to the household economy outside the Saharan zones, where it is still at the heart of activities.

Following a series of shocks and stresses (droughts of the 1970s and 1980s, rinderpest epidemic and political unrest), nomadic pastoral populations in the Batha region left their home territory in the 1980s. They migrated further south, while specialising mainly in the herding of camels (Mahamat Ahmat *et al.* 2022). Camel herders' households have settled in different situations, either in pastoral areas or in peri-urban areas around the capital N'Djamena. We hypothesised that specialisation in camel breeding is an effective strategy to strengthen families' livelihoods through sale and self-consumption of milk and meat. We also assumed that being located close to the N'Djamena, urban market helps improve household incomes. Depending on the context, how are the products of camel farming exploited and adding value? This study examined whether this subsistence strategy based on camel farming allows these households to escape poverty?

Materials and methods

Description of study areas

The study was conducted in peri-urban N'Djamena and in pastoral area of Fitri in central Chad (Fig. 1). Both are agricultural areas, but also very rich in pastoral resources. Many herders have taken refuge in these two areas because of the wealth of water resources and pastures, particularly woody pastures, despite the presence of biting insects that are disease vectors.

Peri-urban N'Djamena is located between 11°N and 12°N and 14°E and 15°E. The climate is Sahelo-Sudanian, with a short rainy season from July to September, and a long dry season from October to June. Average annual precipitation ranges from 500 to 700 mm. Vegetation is mainly steppe shrubs and/or thorny trees (*Acacia senegal*, *Acacia nilotica* and *Balanites aegyptiaca*), frequently juxtaposed with the non-thorny steppe shrubs of Combretaceae and Anacardiaceae (Worgue 2012). The hydrographic network comprises the Chari and Logone rivers and their tributaries, the Ngourkoula and the Linia.

Pastoral Fitri is located between 12°N and 13°N and 17°E and 18°E, 300 km east of N'Djamena. It has substantial ecological diversity, characterised by a Sahelian-type

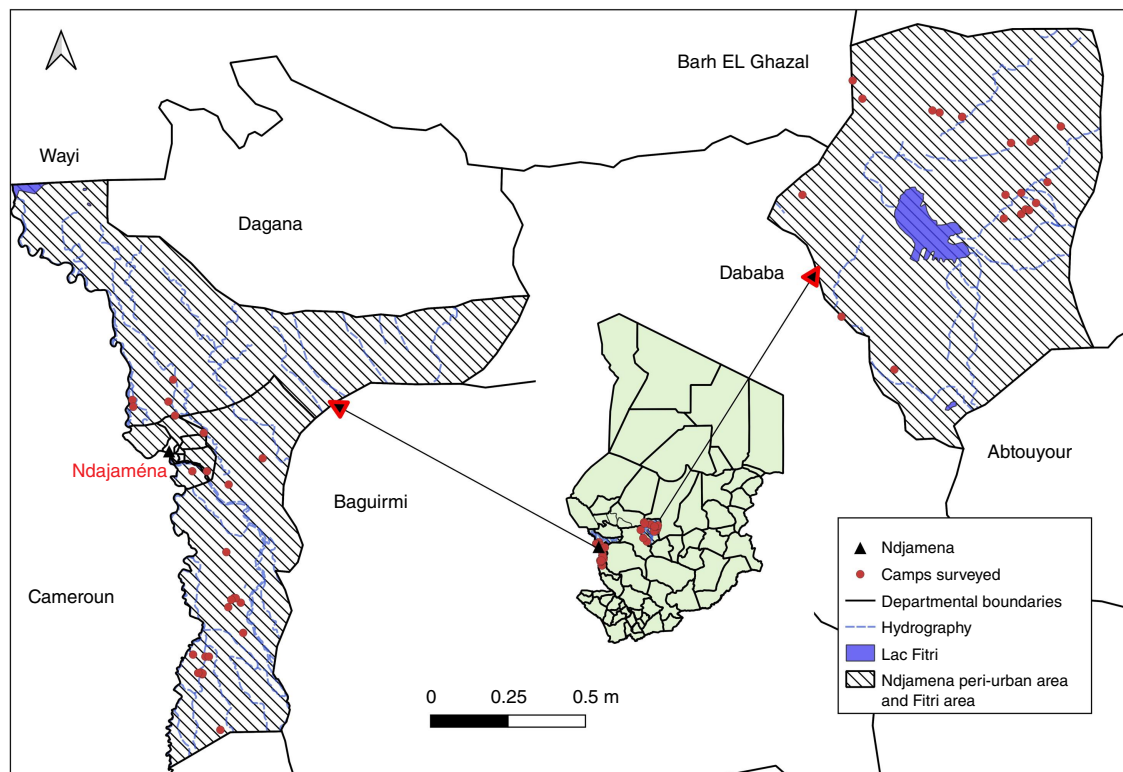


Fig. 1. Location map of study areas.

climate with two contrasting seasons, a long dry season (October to May) and a rainy season (June to September). Precipitation is strongly irregular both spatially and temporally (Niel *et al.* 2005) and averages 450 mm annually. Vegetation consists mainly of herbaceous and woody plants, but also aquatic plants. The area is crossed by mostly temporary watercourses and a shallow endorheic lake the surface area of which can increase three-fold between the dry and rainy seasons (Courel *et al.* 1995).

Camel herders' households in the Fitri area are of the Arab and Gorane Kreda ethnic groups and those in peri-urban N'Djaména are generally members of the Arab ethnic group. The Arabs all come from Batha province and the Goranes Kreda from the Bahr El Gazel province, which they left in the 1980s. They reorganised their nomadic activities from their new installation area. Households in the N'Djaména area are nomadic around three agro-ecological zones. During the dry season, the herds are divided into two groups. Lactating females are kept around N'Djaména for milk sales, in the Sahelian zone, and the remainder is sent to pastoral Sudanian zone in southern Chad with a young herder. During the rainy season, the entire herd along with the household moves to Kanem, northern Chad, in Sahelo-Saharan zone, with the entire household. Households in the Lake Fitri area are nomadic around two agro-ecological zones. During the dry season, herds and families camp in the sahelian pastoral Fitri, and

during the rainy season herders head north in the Saharan zone. A first group of herders go to the north of the Batha province, a second to the north of the Bahr El-Gazel province, and a third north to camp in the south of the Borkou province.

Sampling

Co-operation with producer organisation made it possible to determine the number of camel herders' camps in the two selected areas, including 27 camps in peri-urban N'Djaména and 23 in pastoral Fitri. The survey unit was the household. A household was defined as all the people living under the same roof (or in the same place if it is a camp or a concession) and subject to the decisions taken by the head of the household. The household comprises a variable number of domestic units, which are defined as subsets made up of a wife, her children and the people for whom she is responsible for providing subsistence (Beaman and Dillon 2012). A household head is defined as one who owns and controls major resources, makes essential decisions, and meets the basic needs of household members (Elhadi *et al.* 2012). An initial survey with herders' representatives identified 27 camps in peri-urban N'Djaména and 23 in pastoral Fitri, with a number of households varying from 6 to 12. To best consider the diversity of situations encountered while maintaining a reasonable sample size, we surveyed four

household heads in each camp. In total, 200 household heads were surveyed, 108 in peri-urban N'Djamena and 92 in pastoral Fitri. The survey was conducted in each camp by taking into account the very first household head encountered in the camp according to their availability and their willingness to participate in the survey, then by interviewing their direct neighbours.

Framework of analysis

We use the concept of livelihood strategy, defined by the portfolio of activities performed by household members and mobilising a set of capitals, in a given socio-economic and ecological context (Scoones 1998). This general framework of 'sustainable livelihoods' is widely used in work on pastoralist populations in sub-Saharan Africa, (Manoli *et al.* 2014; Dinku 2018; King *et al.* 2018; Gichure *et al.* 2020) and elsewhere, for example, Iran (Ghazali *et al.* 2022). Scoones (1998) distinguished the following four types of capital: 'natural capital, economic or financial capital, human capital and social capital'. For mobile herders' households, the economic or financial capital lies in livestock. We characterised livestock on the basis of the number of animals according to species (camels, cattle and small ruminants). To globally assess livestock capital, the numbers were transformed into TLUs (one camel = 1.2 TLU, one cattle = 0.8 TLU and one sheep or goat = 0.15 TLU). The second essential capital is labour and skill in terms of livestock management. We considered intergenerational farming skills within families were similar among families, and therefore assessed human capital based on the number of AEs, using a conversion rate of 0.75 for each child under 12 years old and one for each person over 12 years old (Thebaud 2017). We considered that access to natural and social capitals was similar among families within the same area, and therefore analysed livelihood strategies independently for each zone. The main activity practiced other than livestock farming was cereal cultivation for self-consumption. In the N'Djamena area, three other activities linked to camel farming were practiced, namely, transport, collection and resale of milk. These activities were recorded systematically, which was not the case for other activities identified, such as the livestock trade, which seemed more anecdotal.

Data collection

Interviews were conducted from 25 May to 20 June 2022 in peri-urban N'Djamena, and from 23 June to 7 July 2021 in pastoral Fitri, by using two directive questionnaires designed on the *Kobotoolbox* tool. All the data are based on farmers' declarations. The first questionnaire focused on available capital (human, livestock and financial), including age of the household head, marital status, number of wives, size of household, working people per household, age working people, and numbers of herds of camels, cattle, small

ruminants. Another set of questions concerned milking camels, including number of camels milked, quantity of milk milked per camel per day in litres, quantity of milk consumed by the household in litres, quantity of milk sold in litres, and price per litre of sold milk. Farmers declared the average milk quantities (milked per camel, self-consumed or sold) during the rainy and the dry seasons. Finally, the variables concerned the other activities, namely, crop farming, transportation and milk collection. The second questionnaire focused on demographic dynamics and off-take of camel herds by using the '12-month' retrospective survey method (Lesnoff *et al.* 2008). It consisted of a census of the herd and demographic events occurring in the past 12 months on the basis of the memory and declarations of herders. The events were birth, death, slaughter, loan, purchase and sale. Purchase and sale prices were collected.

Data processing

We initially considered two types (one per zone) of household livelihood strategy, based on a multiple correspondence analysis (MCA), followed by hierarchical clustering on principal components (HCPC) by using the method of Ward aggregation. We performed these multivariate analyses with the FactoMineR and ADE4 packages of the R software ver. 4.2.1 (R Core Team 2022). From the 32 variables, we chose or calculated eight active variables for these analyses: (i) family size, number of AEs, to characterise human capital; (ii) number of head of each type of livestock present (camels, small ruminants and cattle) divided by the number of AEs, so as to assess the livestock capital endowment; (iii) the practice of other activities (agriculture, transport and milk collection), coded as yes or no. For each zone, continuous variables were grouped according to the distribution of the variable in the sample. For each zone, only non-zero variables were included (for example, cattle capital, a species absent in the N'Djamena zone, was not considered for this zone). Then we characterised the identified types by a set of additional variables, such as the age of the household head, the number of wives, the total size of the herds by species, the total TLU, the proportion of camel TLU, the total TLU per AE. We used the Kruskal-Wallis test and the Wilcoxon test to compare means among groups, both being non-parametric tests, because the variables did not follow a normal distribution.

We focused the remainder of the analyses on camel farming, the main activity of these households, in order to assess its economic contribution to household subsistence. Thus, we used eight other variables (quantity of self-consumed milk/year, quantity of milk sold/year, quantity of milk drunk per AE per year, number of self-consumed animals/year, number of sold animals/year, gross product milk sold, gross product self-consumed milk, gross product sold and self-consumed animals). We initially analysed the production practices (milk yield per year per household; number of

live animals off-take), and any added-value activities (self-consumption, sale) of the camel herd. From the prices recorded (producer prices for the products sold, consumer prices observed in each area for self-consumed products) and the quantities of products, we calculated the total gross product, and evaluated the share of the different products in the total gross product of camel farming. Finally, we calculated the gross margin of camel products per AE by subtracting the operational costs from the gross product, at household level, divided by the number of AEs. For operational costs, we considered only the cost of purchasing livestock feed, the only significant expense. Given that there is almost no equipment for camel-farming management, no payment of land rent, no employees, and no repayment of credit, this gross margin is very close to the household income before tax. To assess the level of income generated, we compared this margin with the national poverty threshold, which is estimated at 663 CFA francs/day (World Bank 2021) and the guaranteed interprofessional minimum wage (GIMW) of Chad estimated at 2000 CFA francs/day according to Decree Number 55 of 21 January 2011 (République du Tchad 2011).

We calculated all of these variables for each household, then compared the averages for each type of household identified previously, so as to assess the results of camel farming according to the different distinguished livelihood strategies.

Results

Comparison of the contribution of camels to the livelihoods of households in the two areas

The average composition of camel herders' households was similar in both areas, with seven or eight people per household and an average household-head age of 45 years (Table 1). Specialisation in camel farming was marked in both areas; on average, household TLUs were at least 80% camels. Households specialised in livestock farming, with 60% or more not growing crops. Therefore, both areas consisted of mobile pastoral households (see above), highly specialised in camel farming.

However, the off-take of the camel herd varied. Camels were milked in both areas, but only for self-consumption in

Table 1. Comparison of camel herders' households in peri-urban N'Djamena and pastoral Fitri.

Item	Variable	N'Djamena	Fitri	Wilcoxon test P-value
	Number of households (n)	108	92	
Human capital	Number of people	8.4 ± 2.6	7.2 ± 2.5	1.2e-03
	AEs	7.1 ± 2.1	5.9 ± 1.9	6.5e-05
Livestock capital	Camels/AE	5.6 ± 2.2	9.6 ± 6.6	1.2e-07
	Small ruminants/AE	5.2 ± 5.5	10.0 ± 7.4	5.9e-07
	Cattle/AE	–	1.4 ± 2.4	1.4e-11
Other activities	Agriculture (%)	24.1	39.1	–
	Transport (%)	12.0	0	–
	Milk collection (%)	14.8	0	–
Household and livestock structure (additional variables)	Age of household head	45.8 ± 12.9	43.2 ± 14.7	1.1e-01
	Number of wives	1.5 ± 0.6	1.2 ± 0.5	1.4e-03
	Number of camels	38.3 ± 16.3	50.4 ± 27.2	3.7e-03
	Number of small ruminants	35.6 ± 38.5	54.1 ± 39.0	1.8e-04
	Number of cattle	–	8.9 ± 15.4	1.4e-11
	Camel TLU (%)	89.6	79.8	3.7e-03
	Total number of TLU	51.3 ± 20.1	75.7 ± 37.8	2.0e-06
	TLU/AE	7.4 ± 2.6	14.2 ± 8.7	8.2e-13
Economic results (additional variables)	GP milk sold (%)	68.2	0	2.0e-16
	GP self-consumed milk (%)	21.8	45.4	2.6e-15
	GP exploited animals (%)	10.8	54.6	3.0e-12
	GM/AE per day (1000 CFA francs)	1.61 ± 0.68	0.76 ± 0.36	2.0e-16

Values are means ± s.d. AE, adult equivalent; TLU, tropical livestock unit; GP, gross product; GM, gross margin; CFA francs, francs of central Africa.

the Fitri area. Milk sales were very important in peri-urban N'Djamena, because of market demand of the urban population, and represented 68.2% of the gross product of camel farming. Self-consumption of milk represented a significant part of the gross product of camel farming in both areas. Households also exploited live animals for meat, mainly for sale, and a little for self-consumption in the Fitri area. The added value of live animals represented 55% of camel gross product in Fitri, from the volume of self-consumption of milk, but only 10% in N'Djamena.

Beyond the traits common to all camel households, differences were observed between the two areas (Table 1). The livestock per adult equivalent was on average double for households in Fitri compared with N'Djamena. Livestock composition was also more diversified in Fitri, with camels, small ruminants and cattle, whereas households in the N'Djamena area were even more specialised towards camels, with few small ruminants.

Despite a smaller camel herd size in peri-urban N'Djamena (Table 1), the contribution of camel farming to household income was higher. The average daily gross margin per AE was 1600 CFA francs. This was below the GIMW (80% of GIMW), but above the poverty line (240%). In the Fitri area, camel farming provided an income just above the poverty line (117%). This underlined the importance of self-consumption of milk in the Fitri area for the subsistence of camel-herder families; 45% of the gross product of camel farming came from milk self-consumption. This also explained the greater diversification of activities; in Fitri, 40% of households grew crops, compared with only 24% around N'Djamena. Finally, this indicated the important contribution of other species (such as cattle and small ruminants) to Fitri households, despite representing only 20% of the total TLU. The proximity of the urban market allowing the sale of milk to households in peri-urban N'Djamena explained the possibility of even greater specialisation in camel farming for households in this area.

Characterisation of the diversity of camel herders' households in the two areas

Within each area, there were differences among households according to their capital and activities. In the N'Djamena area, four types of household (N1–N2) stood out.

Type N1 households were small, with a young household head with one wife (Table 2). These young households had a small herd (26 camels and 30 small ruminants), but through the small size of the household, this represented a medium livestock capital per AE. Some households practiced agriculture and transport activities with their camels. Type N2 households were large, with the household head ~50 years old with two wives. These households had mixed camel and small ruminant herds. The larger household size compared with the younger N1 households was accompanied by an increase in the overall herd size, but the endowment in

livestock capital per AE decreased. The diversification of activities was more important than previously, with 30% of households growing crops (Table 2).

Type N3 households had, on average, a household head intermediate between those in Types N1 and N2 (Table 2). Household size was medium, and there was generally only one wife. The N3 households specialised in camel farming, with largest herd sizes. They had a strong endowment in livestock capital per AE. This allowed them not to cultivate crops. Some households (30%) used camels to sell transport services.

Finally, Type N4 households had an elderly household head and two wives (Table 2). Household size was medium, the oldest children having left the household (the son creating his own household and the daughter joining another household through marriage). These households had mixed herds of camels and small ruminants. These were the households with the lowest percentage of camel TLU in the area and low livestock capital per AE. These households greatly diversified their activities, with 60% of households growing crops and 50% collecting camel milk.

In the Fitri area, three types of household dominated, being based mainly on household size and livestock capital endowment per AE (Table 2). Type F1 households were small, with a young household head and high endowment of livestock capital per AE. Type F2 brought together medium-sized households, with an older household head and moderate endowment of livestock capital per adult equivalent. Type F3 households were large, with the eldest household head and poor endowment of livestock capital per adult equivalent. However, the average size and composition of the herd was similar regardless of the type of household (Table 2).

Contribution of camel-farming products to household livelihoods

In peri-urban N'Djamena (Table 3a), the four household types exploited their livestock in a similar way. During the 8 months of the dry season, when the family and the lactating camels were settled around N'Djamena, the camels were milked and the milk was shared between sale and self-consumption. During this season, the camel herders who went south with the remainder of the herd (males, young, dry camels) took a lactating camel for their own milk consumption. When households left peri-urban N'Djamena with all their livestock (migrating north in the rainy season), the milk was intended only for self-consumption. Over the year, self-consumed milk represented, on average, one-third of milk produced. Self-consumption of milk varied depending on the type of household, but remained within the same order of magnitude. Larger households (N4, and especially N2), with reduced camel capital per AE, consumed smaller quantities of milk, but still devoted a significant portion to self-consumption. Smaller households (N1 and N3), with

Table 2. Characterisation of the livelihood strategy of camel herders' households in (a) peri-urban N'Djamena and (b) pastoral Fitri.

Item	Variable	N1	N2	N3	N4	N'Djamena
(a) Peri-urban N'Djamena						
	Number of households	31	39	23	15	108
	Percentage (%)	28.7	36.1	21.3	13.9	100
Human capital	Household size	5.5 ± 1.2a	11.1 ± 1.1b	7.6 ± 1.7c	8.8 ± 0.6d	8.4 ± 2.6
	AEs	4.8 ± 0.9a	9.3 ± 0.9b	6.4 ± 1.4c	7.5 ± 0.5d	7.1 ± 2.1
Livestock capital	Camels/AE	5.5 ± 1.3a	4.6 ± 1.3b	8.2 ± 2.6c	4.2 ± 1.2b	5.6 ± 2.2
	Small ruminants/AE	7.4 ± 6.2a	5.8 ± 5.2a	0.0 ± 0.0b	7.0 ± 3.9a	5.2 ± 5.5
	Cattle/AE	–	–	–	–	–
Other activites	Agriculture (%)	16.1	30.8	0.0	60.0	24.1
	Transport (%)	19.4	0.0	30.4	0.0	12.0
	Milk collection (%)	0.0	15.4	8.7	53.3	14.8
Additional variables	Age of household head	33.8 ± 7.8a	51.6 ± 10.4b	43.7 ± 9.0c	59.1 ± 10.3d	45.8 ± 12.9
	Number of wives	1.1 ± 0.2a	1.8 ± 0.6b	1.3 ± 0.5c	1.7 ± 0.5b	1.5 ± 0.6
	Number of camels	26.3 ± 7.8a	42.2 ± 12.8b	52.7 ± 19.7c	31.3 ± 9.5d	38.3 ± 16.3
	Number of small ruminants	32.0 ± 25.0a	53.0 ± 46.9a	0.0 ± 0.0c	52.2 ± 28.1a	35.6 ± 38.5
	Camel TLU (%)	86.8a	86.4b	100.0c	82.7d	89.6
	Total number of TLU	36.3 ± 10.7a	58.6 ± 18.8b	63.2 ± 23.6b	45.3 ± 9.8c	51.3 ± 20.1
	TLU/AE	7.8 ± 2.2a	6.3 ± 2.0b	9.8 ± 3.1c	6.0 ± 1.3b	7.4 ± 2.6
Item	Variable	F1	F2	F3	Fitri	
(b) Pastoral Fitri						
	Number of households	15	35	42	92	
	Percentage (%)	16.3	(38.0)	(45.7)	(100)	
Human capital	Household size	3.5 ± 0.9a	6.4 ± 1.5b	9.1 ± 1.6c	7.2 ± 2.5	
	AEs	3.1 ± 0.6a	5.1 ± 0.8b	7.5 ± 1.3c	5.9 ± 1.9	
Livestock capital	Camels/AE	17.0 ± 10.7a	9.6 ± 4.3b	7.1 ± 4.1c	9.6 ± 6.6	
	Small ruminants/AE	14.2 ± 8.7a,b	10.3 ± 8.3a	8.3 ± 5.4a,c	10.0 ± 7.4	
	Cattle/AE	2.4 ± 3.0a	1.1 ± 2.3a	1.3 ± 2.1a	1.4 ± 2.4	
Other activites	Agriculture (%)	46.7	42.9	33.3	39.1	
	Transport (%)	–	–	–	–	
	Milk collection (%)	–	–	–	–	
Additional variables	Age of household head	34.5 ± 14.3a	39.7 ± 14.2b	49.2 ± 12.9c	43.2 ± 14.7	
	Number of wives	0.9 ± 0.3a	1.1 ± 0.5b	1.4 ± 0.5c	1.2 ± 0.5	
	Number of camels	52.2 ± 33.6a	47.8 ± 21.7a	51.8 ± 29.2a	50.4 ± 27.2	
	NUmber of small ruminants	43.2 ± 28.7a	50.4 ± 39.7a	61.2 ± 41.0a	54.1 ± 39.0	
	Number of cattle	8.1 ± 10.4a	6.2 ± 13.0a	11.5 ± 18.3a	8.9 ± 15.4	
	Camel TLU (%)	82.8a	82.1a	77.2a	79.8	
	Total number of TLU	75.6 ± 46.6a	69.9 ± 31.2a	80.6 ± 39.6a	60.4 ± 37.8	
	TLU/AE	24.4 ± 13.6a	13.9 ± 5.9b	10.8 ± 5.1c	14.2 ± 8.7	

Values are means ± s.d. AE, adult equivalent; TLU, tropical livestock unit.

Within a row, values followed by the same letter are not significantly different between the household types (at 5% threshold; Wilcoxon test).

Table 3. Physical and economic contribution of different camel-farming products according to the livelihood strategy of camel herders' households in (a) peri-urban N'Djamena and (b) pastoral Fitri.

Item	N1	N2	N3	N4	N'Djamena
(a) Peri-urban N'Djamena					
Numer of households	31	39	23	15	108
Quantity of self-consumed milk (1000 L/year)	1.5 ± 0.2a	2.4 ± 0.3b	1.7 ± 0.3c	1.7 ± 0.3c	1.9 ± 0. 5
Quantity of milk sold (1000 L/year)	4.2 ± 1.1a	3.8 ± 1.7b	6.9 ± 1.3c	3.9 ± 3.9a,b	4.6 ± 2.0
Self-consumed milk (%)	26.2 ± 4.6a	41.0 ± 9.9b	20.0 ± 2.8c	39.1 ± 18.7b	32.0 ± 12.9
Quantity of milk drunk per AE per year (L)	315 ± 62a	263.7 ± 35.2b	273 ± 61c	232 ± 38d	276 ± 57
Number of self-consumed animals/year	0.0 ± 0.0a	0.0 ± 0.0a	0.1 ± 0.3a	0.0 ± 0.0a	0.0 ± 0.2
Number of sold animals/year	1.3 ± 0.9a	1.8 ± 0.9a	1.5 ± 0.8a	1.8 ± 1.1a	1.6 ± 0.9
GP milk sold (%)	72.2a	60.1a	77.3a	60.6a	68.2
GP self-consumed milk (%)	19.0a	28.5a	15.9a	25.3a	21.8
GP sold and self-consumed animals (%)	9.2a	12.7a	8.3a	15.4a	10.8
GM/AE per day (1000 CFA francs)	2.04 ± 0.49a	1.060 ± 0.28b	2.25 ± 0.50a	1.12 ± 0.43b	1.61 ± 0.67
Item	F1	F2	F3	Fitri	
(b) Pastoral Fitri					
Number of households	15	35	42	92	
Quantity of self-consumed milk (1000 L/year)	1.8 ± 0.2a,b	1.9 ± 0.3 ^A	2.0 ± 0.2a,c	1.9 ± 0.3	
Quntity milk sold (1000 L/year)	–	–	–	–	
Self-consumed milk (%)	100	100	100	100	
Quantity milk drunk per AE per year (L)	609 ± 157a	389 ± 98b	281 ± 61c	375 ± 149	
Number of self-consumed animals/year	0.8 ± 2.6a	0.9 ± 2.2a	0.9 ± 2.3a	0.9 ± 1.1	
Number of sold animals/year	3.2 ± 0.9a	3.8 ± 1.1a	3.6 ± 1.2a	3.6 ± 2.3	
GP milk sold (%)	–	–	–	–	
GP self-consumed milk (%)	44.4a	43.8a	47.2a	45.4	
GP sold and self-consumed animals (%)	55.6a	56.2a	52.8a	54.6	
GM/AE per day (1000 CFA francs)	1.23 ± 0.40a	0.81 ± 0.27b	0.548 ± 0.19c	0.76 ± 0.35	

Values are means ± s.d. GP, gross product; AE, adult equivalent; CFA francs, francs of central Africa.

Within a row, values followed by the same letter are not significantly different between the household types (at 5% threshold; Wilcoxon test).

higher camel capital, could combine the highest levels of self-consumption and the lowest share of self-consumed milk, which allowed them to market significant quantities. With regard to live animal off-tak, households almost never slaughtered animals for self-consumption, except in cases of emergency, requiring the killing of the animal (accidents, etc.) without having marketed the animal. Households sold, on average, 1.6 camels annually, mainly males aged 3–5 years, the average price of which varied from 160,000 to 245,000 CFA francs, regardless of the household type. The share of the different products in the gross product of camel farming was similar; milk represented the largest share and meat represented only 10% of the gross product.

In the Fitri area (Table 3b), milk was consumed only by the family, although the quantity consumed was on, average, higher than in the N'Djamena area. This quantity varied

greatly depending on the household type. The total quantities of milk produced were identical, depending on the type of household (1900 L per household on average). The intensity of milking on the camel herd was therefore similar depending on the type of household, corresponding to a quantity of milk collected from the herd of 4–6 L per day, whatever the size of the herd and the size of the family, corresponding to the milking of one to three camels per day. Household size, therefore, explained differences in individual consumption levels. In the Fitri area, the off-take of live animals was more significant than in the N'Djamena area. In fact, households slaughtered 0.9 camels per year, on average, for self-consumption. In most cases (74%), animals were slaughtered only in the case of emergency from poor health or an accident. Camels sold per year were mainly males aged 3–5 years, the average price of which varied

from 143,000 to 188,000 CFA francs. This represented a total off-take of 4.5 camels per household, i.e. a livestock gross off-take rate of 9%. This rate was only 4% in the N'Djamena area. These livestock off-take practices were similar among the three types of household. Self-consumed milk represented a significant part of the gross product of camel farming, demonstrating the importance of this milk product, even if not marketed.

Contribution of camel farming to livelihoods

For both areas overall, camel farming provided a daily gross margin per adult equivalent (DGM/AE) higher than the national poverty threshold for three quarters of households. Only 16% of households generated a gross margin higher than the GIMW.

In peri-urban N'Djamena, almost all households (94.4%) generated a gross margin greater the national poverty threshold from camel-farming products. Camel capital available per AE explained differences among household types (Fig. 2). For the wealthier households (N1 and N3), a portion of households (29%) had a gross margin greater than the minimum wage, and almost all the others had a margin

more than twice the poverty threshold. For these types, camel farming assured the livelihood of the household; other activities were very rare, only 16% of N1 households and none of the N3 households grew crops. On the contrary, for poorer households (N2, very large family, and N4, large family with an elderly household head), camel farming ensured a margin only between one and two times higher than the poverty threshold, sometimes less (Fig. 2). The strategy of diversifying sources of income was therefore widely practiced, especially by the N4 households, to ensure the family's livelihood.

In pastoral Fitri, camel farming provided a much lower income, because of the lower added-value of milk, which was only self-consumed, despite the greater liveanimal off-take. For large households with little livestock capital (Type F3 households), camel farming provided an income greater than the national poverty threshold for only 17% of households. There was little diversification of activities, with only 30% of households practicing agriculture (Table 2b), compared with more than 40% in other types of household. For these other types, camel farming ensured an income one to two times greater than the poverty threshold (Fig. 1), but always smaller than the minimum wage (except for a

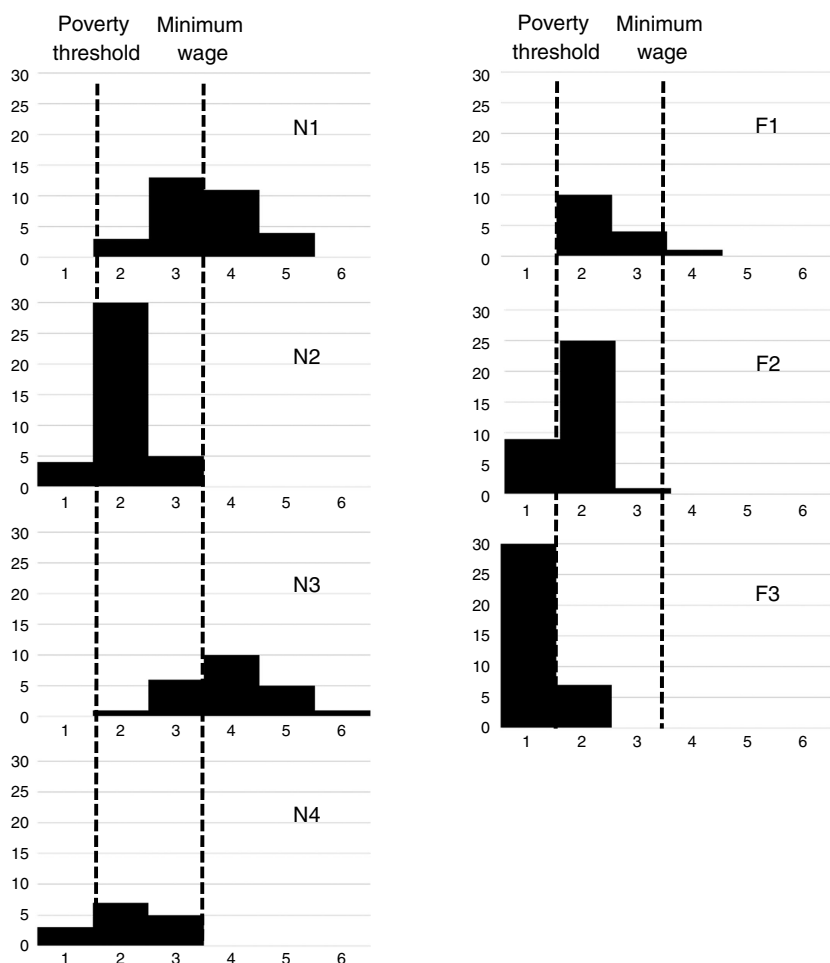


Fig. 2. Daily gross margin of camel-farming products per AE according to the livelihood strategy of camel herders' households, in peri-urban N'Djamena (N1–N4) and pastoral Fitri (F1–F3). See Table 2 for the characterisation of livelihood strategies.

household). Crops (for self-consumption) and other species (cattle and small ruminants, representing on average 20% of TLU) helped supplement household livelihoods in this pastoral area.

Discussion

Is specialisation in camel farming an effective livelihood strategy?

Specialisation in camel farming is very effective in peri-urban N'Djamena. Only 6.5% of households generated an income from camel farming smaller than the poverty threshold, and the income of 55% of households was greater than twice the poverty threshold. This was explained by herders having access to the capital's urban market for milk sales. Conversely, in pastoral Fitri, 48% of households generated income from camel farming smaller than the poverty threshold. Despite a greater camel capital endowment, and a greater herd off-take for sale, camel farming was insufficient to ensure the livelihoods of many households.

In both areas, livestock capital endowment, and in particular camels, is an essential resource to ensure the family livelihood. Households with large families (N2, N4 and F3) are poorly endowed with livestock capital compared with the family size and generated the lowest income per equivalent adult, being just above the poverty threshold for N2 and N4 households, and the vast majority being below the poverty threshold for Type F3 household. The availability of a workforce in these households could allow them to practice other activities, such as growing crops in particular. This is the case for Type N4 households, of which 60% grow crops or trade milk. The sale of camel milk to the urban market in the N'Djamena area obviously opens up this collection opportunity for them. This activity, practiced by women, requires a significant amount of working time, linked to the transport of milk to the city by public transport. Only women relieved of significant domestic responsibilities, particularly those without young children, can practice this activity. This is the case for women in Type N4 households, with an elderly head (average age 59 years). Some of these older households are beginning to settle around N'Djamena (certain family members remain in the area all year round), and are keeping the rights of access to land for cropping, whereas the larger households of Types N2 and F3 rarely implement other activities to supplement the low income from camel farming. In both cases, only 30% grow crops. The large family size and the availability of a workforce, generally considered advantageous for family livelihood (Mekuyie *et al.* 2018), appear unfavourable here. Access to land to grow crops could be a limiting factor in both zones.

These types of large households, with a head of household in the prime of life (51 years in Type N2, and 49 years in Type F3) and a higher number of wives than in other types, failed to capitalise enough livestock. Livestock growth

has not kept pace with the demographic growth of the family. The off-take of live livestock, to meet their increased needs, and the departure of young sons with the animals they inherited could explain this insufficient capitalisation. In comparison, younger households (N1 and F1, household head aged 34 years), and of smaller size, a young man and his wife, have become independent with sufficient livestock capital endowment to generate income greater than the poverty threshold. How will they be able to maintain sufficient endowment as the family grows? Type N3 households, with an older head (43 years), manage to maintain a balance between family size and herd size. The family is not much larger than that in Type N1 households (7.6 people compared with 5.5) and a large proportion of household heads stay with a single wife. However, they have a herd of 53 camels, which is double the size of the herd of Type N1 households. Total specialisation in camel farming could be one of the explanatory factors, but it is insufficient.

Given the very strong specialisation in camel farming (more than 80% of TLU and poor overall crop practices), the derived income, as shown in studies elsewhere, is a good proxy for evaluating the results of the livelihood strategy. Yosef *et al.* (2013) showed that the sale of livestock and livestock products is the main source of income and livelihood. Income from other sources contributes a small share to pastoral household income in almost all districts surveyed.

Are household livelihood strategies sufficiently resilient to cope with shocks and stresses?

Beyond results available from these livelihood strategies remains the question of household ability to cope with stresses or shocks (Scoones 1998).

First, we could identify several changes demonstrating how households transformed their livelihood strategies. A first change was specialisation in camel farming. Unlike some households, those from the provinces of Batha and Bahr El-Gazel already owned a few camels; they were mainly cattle and small-ruminant herders. Specialisation allowed them to base their farming activity on a species particularly well adapted to arid environments, but also to semiarid, Sahelian and even Sudano-Sahelian zones, to which these populations migrated since the 1980s. This change in favour of camels has already been described in other pastoral societies, for example, in Kenya (Volpato and King 2019), and more generally in a set of pastoral communities in sub-Saharan Africa. The 10% increase in camel numbers in several Sahel countries in recent years has confirmed this (Rahimi *et al.* 2022). Camel herders' households were also able to take advantage of the opportunity to access the urban market, particularly for milk produced by households who camp part of the year in peri-urban N'Djamena. Ensuring herd mobility is important in pastoral livestock farming because it safeguards herd nutrition by acknowledging the spatio-temporal variability of fodder and water

resources (Turner *et al.* 2014). During migration from areas of origin and their specialisation in camel farming, households reorganised the mobility of their herds, both to access the urban milk and meat market (in particular in the N'Djamena area), but also to best feed their animals. For this they (i) move towards the south in the dry season, (ii) avoid humid areas and pathologies linked to biting insects, and (iii) move north in the rainy season (Mahamat Ahmat *et al.* 2022). Camel-farming facilitates this new mobility, which can be extensive, from 400 to 800 km. In the Fitri area, households maintained a diversity of large ruminant species, i.e. cattle in addition to camels. The departure and return dates of the two species are not the same, and camels travel further than cattle. Within a camp, households help each other group livestock of the same species and share guarding duties by young people from different households. These arrangements constitute an example of social capital mobilised by households, allowing them to organise mobility by pooling work. These different elements show the adaptive capacities of these households, throughout their history since their migrations in the 1980s.

Diversity of livelihood sources is often highlighted as a favourable factor in the face of variations in climatic and market conditions (Watson and Binsbergen 2008). Overall, these camel households rely heavily on camel farming, unlike other pastoral communities, which have diversified their activities towards crops, particularly irrigated (Hemingway *et al.* 2022), or extra-agricultural activities (Headey *et al.* 2014). However, the households studied here often keep a diversity of animal species, particularly small ruminants. This association between species with a long breeding cycle (camels and cattle) and a short breeding cycle (small ruminants) is classic in pastoral communities such as in Mongolia (Sabatier *et al.* 2017) or, more recently, through diversification, such as in Ethiopia (Megersa *et al.* 2014). Camels are capable of coping with significant shocks and stresses, but have a slow growth rate. Their sale can cover significant expenses. Small ruminants are more fragile than camels, but breed more quickly, and their sale can cover smaller expenses. The hyper-specialisation of Type N3 households, raising only camels, could be explained by the fact that milk sale replaces small ruminants, providing a regular cash flow. Is this strategy of complete specialisation risky? The milk market in the city of N'Djamena is growing because of urban population increase and changes in dietary behaviour. Indeed, camel-milk consumption is appreciated by different groups of the population, no longer by only those from the north who accepted the product. Dry-season outlets for camel milk are well assured. Moreover, resumption of small-ruminant farming would be easy to organise for these households, which have a high income and could readily purchase small ruminants. Conversely, the workforce is limited in these households, which could constrain raising an additional herd, requiring significant supervision.

A second important dimension of the sustainability of livelihood strategies is their ability to sustain the maintenance or renewal of the natural capital on which they are based. This study did not allow assessment of this dimension, and additional work is necessary. In particular, one important issue is renewal of woody fodder resources, the basis of the dry-season camel diet around peri-urban N'Djamena. Another question concerns the extent of cultivated areas (for both zones), which limits pastoral resources for camel farming. The use of livestock feed for feeding camels, still little used but a common trend for camel farming in peri-urban areas in other countries (Noor *et al.* 2012, Mammeri *et al.* 2014), could reduce income from camel farming and weaken the livelihoods of these households.

Importance of milk among herders in terms of economic income and also nutritional benefits

Camel milk constituted an important source of food and income among camel herders in both study areas. In peri-urban N'Djamena, camel milk can contribute up to 90% of income from camel-farming products, including 21.8% for self-consumption and 68.2% for sale. This sale is favoured by the concentration of herders at the market in the city of N'Djamena. In pastoral Fitri, milk is reserved solely for home consumption and passing guests, a consequence of the distance of herders from urban centres. However, home consumed milk would provide nearly 50% of income from camel-farming products. In Ethiopia's Afar pastoral zone, camel milk is particularly important to some herders, because it provides the main food source, nutrition and income security throughout the year (Gebremichael *et al.* 2019). Camel milk has also been found suitable for feeding infants, because it is rich in proteins, fats, vitamins and minerals, with a composition similar to breast milk (Rai *et al.* 2022).

Faye *et al.* (2011) noted an increasing worldwide demand for camel milk because of its perceived health benefits and unique taste, allowing producers and distributors to expand their business and increase their income.

Changes in socio-economic and environmental conditions are currently leading to a change in pastoral production systems, which are moving from a subsistence to a market economy (Farah *et al.* 2004). In several sub-Saharan and northern African countries, the emergence of mini-dairies is occurring in peri-urban areas, particularly in Mauritania, Niger, Djibouti, Kenya, Morocco and Algeria (Noor *et al.* 2012; Mammeri *et al.* 2014), under the influence of public policies or the private sector. There are semi-industrial or even industrial dairies emerging in certain countries such as the United Arab Emirates, Saudi Arabia and Kazakhstan (Babiker 2014).

The off-take of animals in both areas

The off-take of live animals differed significantly between the two study areas. In peri-urban N'Djamena, it can

contribute up to 11% to income from camel-farming products (1.6 animals/year), compared with 55% in pastoral Fitri (3.6 animals/year). The low contribution of animal off-take in peri-urban N'Djamena results in milk sales playing a leading role that largely generates sufficient monetary income, unlike in pastoral Fitri, where of live-animal sales are main monetary income and livelihood source. Overall, the study showed that self-consumption of camel meat among herders in both areas is very low. In peri-urban N'Djamena, self-consumption of camel meat is low or nil, whereas in pastoral Fitri, it averages one animal annually. These results agree with those of Mirkena et al. (2018) who pointed out that in Ethiopia camels are not slaughtered by herders for domestic consumption except occasionally during festivities (weddings, funerals, etc.), or when camels are accidentally injured.

Furthermore, in Chad, the camel meat consumption is experiencing a remarkable development. Previously, having mainly been consumed by populations in the north and central area, in recent years, under urbanisation and changes in dietary habit, consumption has become popular among the entire Chadian population, where it is consumed as grilled meat in restaurants. This is probably linked to camel-meat health benefits. Meat production increased from 70 to 800 Mg per year between 2000 and 2010, whereas the share of camel meat in total production increased from 1% to 3% (Koussou and Mahamat Ahmat 2012).

Baba et al. (2021) claimed that camel meat is an excellent protein source, with many human health benefits. Faye et al. (2013) claimed that the potential for camel meat production for meeting animal protein needs of consumers in arid countries is favourable, all the more so because it is believed that camel meat has dietary benefits because of its low cholesterol content and high protein and mineral contents. Despite this, worldwide consumption is very low, being only 0.13% of the total meat produced in the world and 0.45% of the red meat obtained from herbivores (Bougherara et al. 2023).

Conclusions

This work has highlighted the strategic role of camel farming in pastoral and agropastoral household livelihoods in peri-urban and pastoral areas. In peri-urban N'Djamena, the commercialisation of milk is the main source of monetary income for households. This allows herders to have a gross margin well above the national poverty threshold. However, in pastoral Fitri, animal sale most effectively contributes to household monetary income. The gross margin per AE is slightly higher than the national poverty threshold. Camel farming is a promising option for food security in pastoral households exposed to uncertainties. To have a global vision of the potential of camel as a basis for the livelihood strategy of certain herders, additional work is necessary. Camel has often been neglected from a research point of view in the

Sahelian countries. However, its adaptability in the face of global changes means that this species can substantially contribute to food security in the Sahel.

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Data availability. The data used to generate the results in the paper are available and can be made available upon request.

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