

Characterization of transhumant camel herding systems in the wadi-Fira province of eastern Chad

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Abstract

The dromedary, *Camelus dromedaria*, is a symbol of human survival in arid regions. It is vital for herders and the Chadian population. The dromedary is used for multiple purposes. In addition to meat and milk production, it plays an important role in transporting goods and people, providing traction, and facilitating trade. The dromedary is highly valued in Chad; it symbolizes traditions and Muslim culture. For its owner, it represents the embodiment of social success. The objective of this study is to characterize dromedary herding in the Wadi-Fira province. Surveys were conducted over four months in the departments of Guéreda, Amzoer, Iriba, and Tiné, with 25 herders interviewed per department. Data analysis identified three breeds of dromedary camels (Arabian 54.90%, Tibesti 33.16%, and Manga 11.94%) raised in the Wadi-Fira province. The main causes of conflict cited by herders are: fields (26%), transhumance corridors (45%), water (18%), and pastures (11%). A dromedary herd consists on average of 1.68 ± 0.10 adult mâles, 33.59 ± 2.23 adult females, 5.10 ± 0.24 young males, and 6 ± 0.26 young females (minimum 7 head and maximum 108 head). Our surveys indicate that dromedary herding plays a significant role in the economic and social lives of herders in the Wadi-Fira province.

Keywords: Characterization; Typology; Dromedary; Wadi-Fira; Chad; Transhumance

1. Introduction

The Wadi Fira Province is one of Chad's most important pastoral areas, due to the extent and quality of its natural pastures, which support transhumant livestock systems [1]. In this Sahelian region, transhumance serves as an ecological adaptation mechanism that enables the rational use of pastoral resources in response to seasonal variations. The mobility of camels helps avoid overgrazed areas and facilitates access to pastures that meet the animals' nutritional needs [1]. However, despite this ecological adaptation, this livestock system continues to face significant socioeconomic and environmental constraints. Transhumance is associated with a demanding lifestyle, particularly for women and children, due to isolation, long distances traveled, precarious living conditions, and inadequate sanitation [2]. Furthermore, the effects of climate change, increasing human and livestock population pressure, and the growing scarcity of natural resources are further undermining this pastoral system [3]. These constraints manifest themselves notably through increased degradation of natural resources linked to repeated droughts [4] competition for access to water and pastures, a source of conflict between farmers and herders [5] longer transhumance routes, leading to increased energy expenditure and reduced livestock performance [6]; crossing waterways during the rainy season, increasing the risk of animal mortality, and epidemiological risks linked to mobility and inter-herd contact [7]. In this

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context marked by profound ecological and socioeconomic transformations, a central question arises: How is the transhumant camel herding system in Wadi Fira Province adapting to current environmental and socioeconomic constraints, and what are the implications for zotechnical performance and the living conditions of herders?

General Objective

The general objective of this study is to contribute to the understanding of the transhumant camel herding system in the Wadi Fira Province (Chad) and to analyze its characteristics, constraints, and adaptation strategies.

2. Materials and Methods

2.1. Presentation of the study area:

2.1.1. Wadi-Fira Province

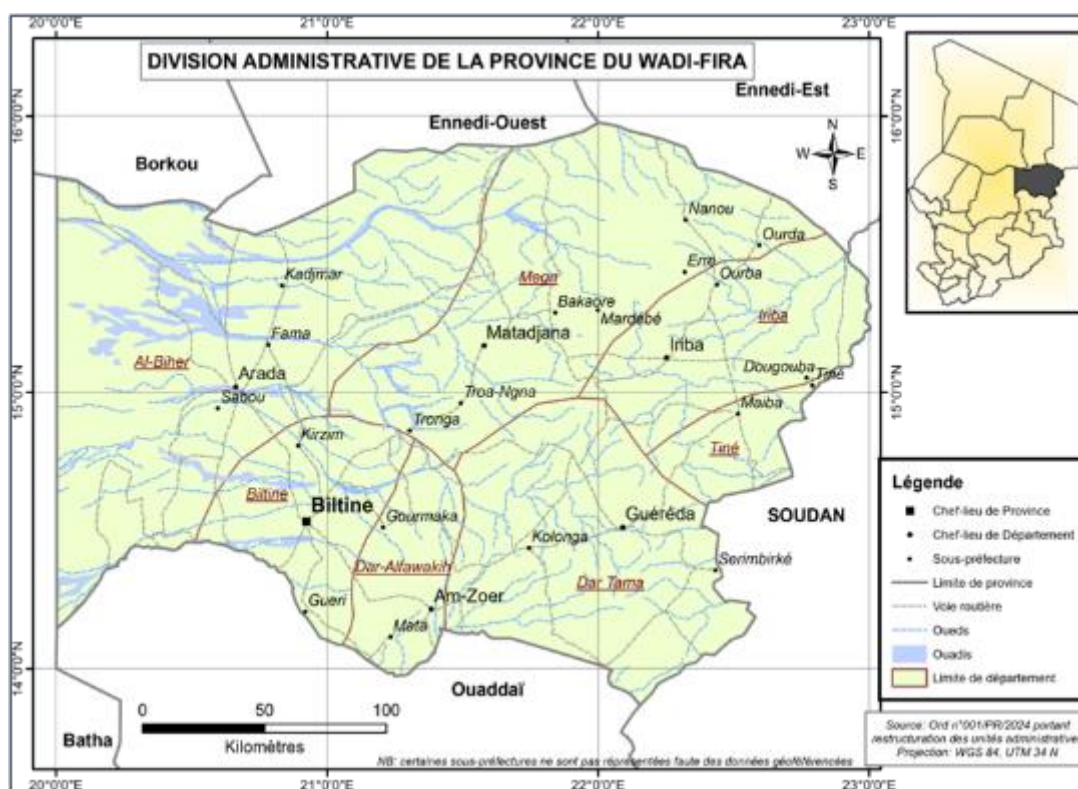


Figure 1 Map of the Study Area (CNRD 2024)

Wadi-Fira Province is located in eastern Chad, between the 11th and 16th parallels of north latitude and the 20th and 23rd meridians of east longitude. It is bordered to the east by the Republic of Sudan, to the north by the Borkou-Ennedi-Tibesti region, to the west by the Batha province, and to the south by the Ouaddaï province [8]. Its geographical location gives it a strategic role in cross-border trade and Sahelian pastoral dynamics. The province of Wadi-Fira is part of the Sahelian zone of Central Africa, characterized by a hot, dry Sahelo-Saharan climate marked by a long dry season and a short rainy season [9]. Rainfall is low and irregular. The average annual rainfall recorded in the city of Biltine, the province's main urban center, varies between 300 and 500 mm depending on the year [10]. This interannual variability in rainfall is a determining factor for agro-pastoral activities and the availability of natural resources. Ecologically, the vegetation is dominated by a steppe-like formation with Sahelian characteristics, consisting mainly of annual herbaceous species and drought-resistant shrubs [11]. Vegetation cover density gradually decreases from south to north, reflecting an ecological transition toward desert-like areas. This dynamic strongly influences the extensive livestock systems practiced in the region, particularly in terms of pastoral mobility and pasture management. Thus, the geographical, climatic, and ecological characteristics of Wadi-Fira shape the local populations' land-use patterns and production strategies. They justify the selection of this province as a relevant setting for the study of agro-pastoral systems in the Sahelian environment.

3. Survey Methodology

The sampling method used in this study is based on a purposive approach (or non-probabilistic sampling), which allows for the selection of observation units deemed relevant to the research objectives [12]. This method is particularly suitable when the target population has specific characteristics requiring selection based on predefined criteria. Survey sites were selected to ensure a balanced geographic distribution of pastoralist holdings. The study covered four departments: Guéréda, Amzoer, Iriba, and Tiné. In each of these departments, a sample of twenty-five (25) herders was selected, bringing the total sample size to one hundred (100) respondents. The selection of respondents was based on clearly defined inclusion criteria, notably their active involvement in camel farming and their availability to participate in the survey. According to [13], determining sample size must balance statistical representativeness with logistical constraints. To this end, the sample size used in this study is considered sufficient to allow for reliable statistical analyses and comparisons between departments. Thus, the methodological approach adopted aims to guarantee the scientific relevance of the data collected while respecting the rigorous standards inherent in academic work.

3.1. Data Collection Tools and Techniques

The field study was conducted over a four-month period from October 28, 2024, to February 27, 2025. Data collection was carried out using a survey form administered through semi-structured interviews, allowing for both standardization of the information gathered and a degree of flexibility in interactions with the herders. The questionnaire, initially developed in French, was translated into local Arabic by a bilingual speaker to ensure better comprehension of the questions by the respondents and to guarantee the reliability of the answers. The information sought covered the socio-professional identification of the herder, herding practices and herd structure, transhumance practices, camel feed, types or breeds of camels raised, health aspects, and the main diseases encountered.

3.2. Data Analysis

Data Analysis The collected data were coded and entered into an Excel spreadsheet. Then, they were imported into the Statistical Package for the Social Sciences (SPSS), version 27.0.1, to perform descriptive analyses (frequency, mean, and standard deviation calculations). The significance level was 5%.

4. Results

4.1. Characteristics of livestock farmers

The camel herders surveyed belonged to five distinct ethnic groups: the Zakhawa, Tama, Abcharib, Arabs, and Mimi. The distribution of respondents by ethnicity showed a predominance of the Zakhawa (40%), followed by the Tama (22%), Abcharib (18%), Arabs (17%), and Mimi (3%). The Zakhawa were thus the most represented group in the province during the survey. Regarding gender, almost all of the herders surveyed were male, reflecting the traditionally male nature of pastoralism in the region. In terms of marital status, the majority of respondents were married. Concerning education level, the results indicated that 60% of the herders had completed primary school, making them the most represented group. In contrast, the number of farmers with a higher education level was very low. Statistical analysis revealed a significant difference between the observed education levels ($P \leq 0.05$) (Table 1).

Table 1 Socio-professional characteristics of livestock farmers

Variables	Guéréda	Amzoer	Iriba	Tiné	Effectif	P. 100 (%)
Linguistic distribution of livestock farmers						
Tama	12	4	3	3	22	22%
Arabe	6	5	4	2	17	17%
Zakhawa	4	1	18	17	40	40%
Mimi	-	2	-	1	3	3%
Abcharib	3	13	-	2	18	18%
Total	25	25	25	25	100	100%
Gender						

Male	21	20	23	18	82	82%
Female	4	5	2	7	18	18%
Total	25	25	25	25	100	100%
Marital Status						
Married	16	14	10	20	60	60%
Single	5	6	8	3	22	22%
Divorced	2	1	-	2	5	5%
Widowed	2	4	7	-	13	13%
Total	25	25	25	25	100	100%
Level of Education						
Primary	15	17	10	18	60	60%
Secondary	10	8	8	7	33	33%
Higher	-	-	7	-	7	7%
Total	25	25	25	25	100	100%

4.2. Activities of the respondents

The objective of camel breeding in the Wadi Fira Province was multifaceted (Figure 2). These results revealed that more than half of the breeders raised their camels primarily for production, followed by trade, agriculture, and other activities ($P \leq 0.05$).

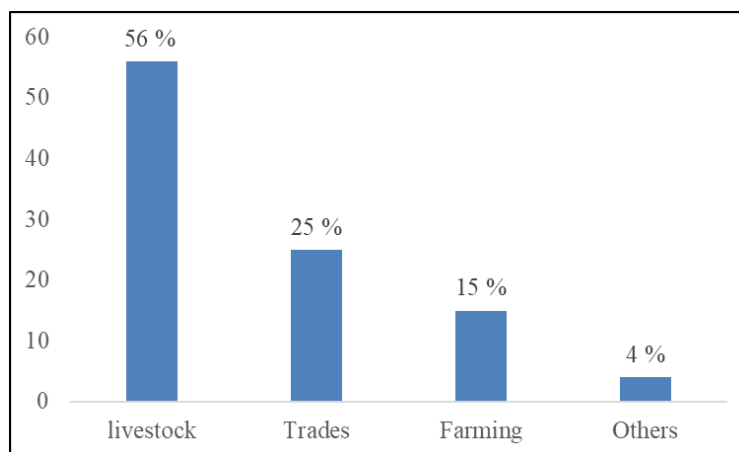


Figure 2 Activities of camel breeders

4.3. Camel Herd Structures

A total of 5045 camels were inventoried in the Wadi Fira Province, distributed among the departments of Amzoer (1002 head), Iriba (2000 head), Tiné (996 head), and Guéreda (1047 head). Analysis of the herds showed that the average herd size varied from 7 to 108 individuals, reflecting the heterogeneity of the herd sizes in the study area. The average number of herds per herder was 33.59 ± 2.23 adult females, 1.68 ± 0.98 adult males, 6.00 ± 0.26 young females, and 5.10 ± 0.24 young males.

Table 2 Structure of dromedary herds by department

Animaux	Resources by department				Ressources of the Province
	Guéreda	Amzoer	Iriba	Tiné	
Adult Males (AM)	1.48 ± 0.18 ^a	1.68±0.09	2,32 ± 0.18 ^b	1.28 ± 0.18 ^b	1.68±0.09
Adult Females (AF)	22.60 ±3.06 ^a	33.59±2.23	61,64 ± 3.06 ^a	22.64 ±3.06 ^a	33.59±2.23
Young Males	5.16 ± 0.47 ^a	5.10±0.24	5,76 ± 0.47 ^b	5.12 ± 0.47 ^{ab}	5.10±0.24
Young Females	5.20 ± 0.50 ^a	6±0.26	7,56 ±0.47 ^b	5.84 ±0.50 ^a	6±0.26
FA/MA Ratio	16.72±0.02 ^a	21.71±1.32	32,84±2.28 ^b	19.58±2.32 ^a	21.71±1.32
Juvenile/Adult Ratio	0.42±0.02 ^{ac}	0.37±0.01	0,23±0.02 ^b	0.45±0.02 ^c	0.37±0.01

4.4. Main breeds of dromedary encountered.

Information gathered from breeders showed that three main breeds of dromedary were identified in the study area: the Tibesti dromedary (33.16%), the Manga dromedary (11.94%), and the Arabian dromedary (54.90%).

Table 3 Main breeds of dromedary camels encountered

Dromedary Breeds	Départements				Total	Total Percentage (%)
	Iriba	Amzoer	Guéreda	Tiné		
Arab	1002	454	711	603	2770	54.90%
Manga	197	166	143	96	602	11.94%
Tibesti	801	382	193	297	1673	33.16%
TOTAL	2000	1002	1047	996	5045	100%

4.5. Herd Management and Practices

Camel feeding in the Wadi Fira Province was based exclusively on grazing in natural rangelands. Natron (sodium bicarbonate) was the main feed supplement used. Regarding crop residues, more than half of the herders used them in exchange for services rendered to farmers. Statistical analysis revealed a significant difference ($P < 0.01$) between the departments, reflecting varied feeding practices depending on the herding area.

Table 4 Herd practice and management (Feeding)

	Provincial Level					
		Guéreda	Amzoer	Iriba	Tiné	%
Use of crop residues	60	20	11	10	19	60%
Non-use of residues	40	5	14	15	6	40%
Total	100	25	25	25	25	100%

4.6. Camel Health

The survey showed that 55% of herders did not have regular access to veterinary services. Since these services were located in the departmental and sub-prefectural capitals, while herders were constantly moving through the bush, 25% of them resorted to self-medication. Statistical analysis revealed no significant difference ($P > 0.05$) between the four departments regarding the practice of self-medication.

Table 5 Animal health in the province

	Provincial Level	Départments				
		Guereda	Amzoer	Iriba	Tiné	Pourcentage
Lack of access to veterinary services	55	18	14	10	13	55%
Self-medication	25	4	8	6	7	25%
Access to veterinary services	20	6	5	3	6	20%

4.7. Animal Reproduction

As shown in Table 6, the selection of breeding stock was based on several criteria. Across the province, 28% of breeders selected their animals for the performance of their offspring, 24% for body size, 19% for coat color, 15% for endurance at work, and 14% for running speed.

Table 6 Selection criteria for the sire in percentage (%)

Criteria	Province	Guereda	Amzoer	Iriba	Tiné	Percentage%
Performance of offspring	28	6	6	8	8	28%
Portliness	24	7	5	7	6	24%
Dress color	19	4	5	4	6	19%
Work endurance	15	3	5	4	3	15%
Speed at the race	14	5	4	3	2	14%
TOTAL	100	25	25	25	25	100%

4.8. Causes of Conflicts Between Herders and Farmers

Conflicts between herders and farmers were linked to several factors. According to the respondents, 26% attributed the conflicts to the devastation of fields by transhumant animals, 45% cited transhumance corridors as a source of dispute, 18% mentioned water points, especially during the dry season, and 11% considered the scarcity of pastureland to be the cause of tensions between the different users. Statistical analysis did not reveal any significant difference ($P > 0.05$) between the four departments regarding these causes of conflict. The detailed results are presented in Table 7.

Table 7 Causes of conflicts between livestock farmers and crop farmers

Causes	Province	Départments				
		Guereda	Amzoer	Iriba	Tiné	Percentage %
Transhumance corridor	45	12	9	10	12	45%
Fields	26	5	8	7	6	26%
Water point	18	5	5	4	6	18%
Pastures	11	3	3	4	1	11%
Total	100	25	25	25	25	100%

5. Discussion

5.1. Socio-professional characteristics of camel herders

In the study area, camel herding was predominantly practiced by men (82%). This male predominance is mainly explained by economic constraints limiting women's access to initial livestock acquisition, a dynamic already observed in other Sahelian pastoral contexts [14]. In local socio-cultural practices, married women generally build their herds

from gifts or family inheritances, which restricts their ability to initiate or expand independent herding activities. Camel herding, strongly associated with pastoral mobility (transhumance) in search of pastures and water, was perceived as an essentially male activity, due to climatic hazards, long distances traveled, and difficult environmental conditions. Furthermore, herding and managing animals during transhumance were considered physically demanding tasks, difficult for women to perform, particularly in the region's desert context. Moreover, the analysis of the respondents' sociodemographic characteristics revealed that 60% were married and 60% had attained at least a primary education, reflecting a certain homogeneity in educational attainment among the pastoralist populations studied. These results corroborate observations from previous work on gender dynamics in pastoral livestock systems in the Sahel region of Africa, where access to productive resources and economic activities remains strongly influenced by social and cultural norms [14]. Transhumance and the Structure of Camel Herds Transhumance consists of the seasonal, cyclical movement of herds, following precise routes repeated each year [15]. In this context, the dromedary is particularly well-suited to the harsh climatic conditions of the Sahel, traveling long distances to access water and pasture [1]. It is also the primary means of transport for goods, luggage, natron, as well as for errands and long-distance travel [16]. Herds may consist of one or more breeds of dromedary, depending on the customs, traditions, and strategies of the transhumant communities. Dromedaries graze mainly on trees, shrubs, and herbaceous plants, while cattle feed primarily on herbaceous plants [17]. The dromedary's ability to go several days without drinking allows herders to exploit forage resources far from water sources. In this predominantly pastoral region, livestock farming is both an economic activity and a cultural tradition, representing the main source of household income. Herders assess pasture quality primarily based on the animals' body condition, rather than their carrying capacity or plant composition, reflecting an extensive farming approach [18]. In Chad, particularly in the departments of Iriba and Tiné, dromedary herding is characterized by a traditional nomadic system, where the livestock's nutritional needs depend almost exclusively on natural pastures. This location is favoured by the pedoclimatic conditions: the Province of Wadi Fira, located in the Sahel-Saharan zone, benefits from a dry climate, without floods or proliferation of biting insects, ideal conditions for camel breeding [19 ; 20].

5.2. Management Practices of Transhumant Herds in the Wadi-Fira Province

The organization of dromedary herds in the Wadi-Fira province is characterized by a structure typical of Sahelian transhumant systems. The adult male/female ratio is $1/21.71 \pm 1.32$, while the young/adult ratio is 0.37 ± 0.01 , results comparable to those reported in Tunisia by Ben [21] where the average herd composition varies from 60 to 150 head with one male for every 80 females. Production performance depends heavily on the herding systems and breeds, with herders traditionally distinguishing between animals intended for milk, meat, or racing [15]. The selection of breeding stock primarily concerns males aged 7 to 8 years and takes place within the herd, based on criteria such as coat color, size, speed, endurance, and morphology, similar to those observed by [22] in the Gao region of Mali. Males not selected are sold or used for transport and draft work. When the herd becomes large, it is divided to avoid conflicts between breeding males, which become aggressive in the presence of females [22]. Camels graze exclusively during the day, supervised by young family members or herders paid in cash or in kind, unlike in some regions of Mali where nighttime grazing is practiced [23]. The diet relies primarily on natural grazing, with supplementation essential during dry years to improve milk production and overall performance [24 ;25]. Dromedaries consume grasses, leaves, shrubs, straw, hay, silage, grains, and oilseed cakes, and can graze on thorny plants that other animals cannot eat, sometimes reaching heights of up to 3 meters [22]. Watering is seasonal: during the dry season, camels drink from wells, on average once a week, while during the cold season, a camel can go up to a month without water. During the rainy season, the animals drink from ponds and streams. Transhumance to the south of the country utilizes the Salamat, Chari, or Logone rivers, although access to water is sometimes a source of conflict among herders. Regarding supplementation, all livestock farmers in the province use natron, collected in the Faya-Largeau region during transhumance to the north, similar to practices observed in Gao, Mali [22]. Camp locations are chosen based on the availability of pasture, water, security, and the absence of fields to avoid conflicts with farmers. Animal health represents a major challenge: more than 97% of livestock farmers do not have regular access to veterinary services, which are located only in departmental capitals and sub-prefectures [22]. Medications pose problems of availability, cost, and quality. Among the feared diseases, camel trypanosomiasis (surra) is of particular concern to Chadian livestock farmers [26; 27]. Finally, farmer-herder conflicts are linked to field devastation, the obstruction of transhumance corridors, and the scarcity of water sources and pastures during droughts [28]. These tensions underscore the importance of establishing a concerted process for managing space and natural resources in order to preserve peaceful coexistence between herders and farmers.

5.3. Economic Exchanges Between Transhumant and Sedentary Herders

In the Wadi-Fira province, the sale of livestock is the main source of income for transhumant herders. During their northward migration, they supply the major markets in the areas they pass through, notably Biltine and Tiné, where camels destined for export to Libya, Egypt, and Sudan are collected. The economic importance of these markets is closely linked to the seasonal rhythms of the herds' ascent and descent. In addition to large animals, transhumant herders also

supply urban and rural markets with secondary products such as milk, dried meat, poultry, and wild fruits harvested during the transhumance. The herders take advantage of their presence in the markets to purchase cereals, sugar, tea, clothing, shoes, and veterinary products. The consumption of natron is an essential practice for camel herders: young people collect this mineral in Faya-Largeau in the north, transporting it on the backs of their dromedaries. Natron is used as a supplement for dromedaries and small ruminants, and some is sold in markets, thus providing an additional source of income [22]. During the southward journey, selling animals remains the primary activity. Animals that have gained weight after the rainy season are sold at higher prices than during the northward migration, a period coinciding with food shortages and pastoral drought. On their southward journey, camel herders also transport agricultural products for settled populations, generally paid in kind, often in the form of harvests. Furthermore, harvesting gum arabic from acacia trees is a supplementary activity that requires little tapping of the tree. Camel calves are weaned naturally and are not generally weaned, according to observations by [29] in the Agadez region of Niger. By comparison, in Kenya, [30] reports that 74% of female camels are weaned at 12 months, an age close to 13 months observed by [22] in the Gao region of Mali.

Regarding milk, a significant portion is reserved for the calves, while the remainder is used for personal consumption, bartering, or given to guests and neighbors. These practices are similar to those reported by [31] and [22]. Milking is generally carried out in the morning and evening upon the animals' return from the pasture, but it may exceptionally take place during the day for personal consumption or to supply settled populations near the pastures in exchange for food or used clothing.

5.4. Typology of Transhumance

Surveys conducted among livestock farmers in the Wadi-Fira province identified three types of transhumance based on the extent of annual movements: long-distance transhumance (43%) involves movements exceeding 450 km, often beyond national borders, with the entire family accompanying the herds; medium-distance transhumance (32%) involves movements between 150 and 450 km, generally with some family members; and short-distance transhumance (25%) is limited to less than 200 km, within the national territory, and rarely involves the entire family. This classification, based on distance traveled, type of movement, and family participation, accurately reflects the transhumance practices observed in the field. These results are generally consistent with those reported in other Sahelian regions. For example, [22] in the Gao region of Mali identified long, medium, and short transhumance patterns with comparable distances, and [20] in Niger observed that some families traveled over 400 km to secure access to pasture and water. However, the relatively high proportion of long-distance transhumance in Wadi-Fira (43%) can be explained by the need to travel long distances to find available pasture and by the province's climatic and geographic characteristics, whereas in other regions, herd mobility may be limited by security factors or stricter border controls. Thus, these differences reflect the adaptation of pastoral systems to local conditions while confirming the similarity of transhumance strategies across the Sahel.

5.5. Genetic Resources and Camel Breeds

Our findings identified three main breeds of dromedaries in the Wadi-Fira province: the Tibesti dromedary, the Manga, and the Arabian. The Tibesti breed, native to the north of the country and now widespread throughout the Western Sahara [34], is distinguished by its adaptation to running and walking in mountainous terrain, which explains its appeal to transhumant herders. The Manga and Arabian breeds, adapted respectively to scattered pastures and to speed and endurance, complement the local genetic diversity [15 ; 29]. This diversity is a major asset for the resilience and sustainability of pastoral systems, enabling herders to adapt their practices to environmental and climatic constraints (Aubague et al., 2011). It also underscores the need to promote strategies for the management and conservation of local breeds in order to preserve their productive and reproductive potential [22].

5.6. Conclusion and Perspectives

Camels play a central role in the livestock systems of Wadi-Fira Province, both economically and socially, providing transportation, draft power, milk and meat production, and facilitating trade. Despite their importance, herders face numerous constraints, including theft, health issues, lack of pasture and water, conflicts with farmers, and poor genetic performance of the animals. These challenges underscore the need for in-depth research and sustainable management strategies. Optimizing the efficiency and profitability of transhumant livestock farming, supported by participatory selection, improved access to veterinary services, and the rational management of pastoral resources, could strengthen food security and contribute to Chad's economic and social development.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

"Informed consent was obtained from all individual participants included in the study."

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