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Use of Dromedary in climate change adaptation in Mali

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Declaration

I, Mian Shakib Murshed, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been added. This work has not been previously submitted to any other university for the award of any type of academic degree.

Signature.....

Date.....

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Abstract:

Dromedary (Camelus dromedarius) is commonly known for its climate robustness. This study was undertaken in Mali, a country characterized by a poverty rate of 41.9%. Two-thirds of Mali is made up of arid and semi-arid areas. This country has faced several droughts during the last five decades and is a country very much exposed to climate change. The objective was to assess dromedary as a climate change adaptation tool and to study services by dromedary that can be used in times of stress to improve food security.

This research has three major approaches, a bio-physical study of dromedaries, a socio-economic study, and a key informant interview among the dromedary herders' community. The study found that the principal dromedary activities are grazing, walking, resting, watering, and rutting. The research station of Niono is in the Sahelian zone (400-500 mm/year of rain), and the research station of Sotuba is in the sub-humid zone (800-1000 mm/year of rain). Despite location and season, Grazing remains the main activity (61.7% in Niono and 53.2% in Sotuba). Dromedary adjusts the actions to have access to sufficient fodder and water. Grazing time was higher during the rainy season (80.0% in Niono and 65.0% in Sotuba) than in the cold dry season (62.0% in Niono and 58.0% in Sotuba) and the hot dry season (60.0% in Niono and 59.0% in Sotuba). Dromedary tends to move faster and longer to collect required fodder in areas where fodder is scarce. Sotuba (25.5%) has a higher resting time than Niono (8.8%). When dromedary grazes, they do not eat everything from a plant but eat the most palatable part and keep the rest for the future. The study found that dromedary's reproductive capability did not change much between locations. The fertility rate was about 90% at both sites. Dromedaries provide several services important for food security, such as milk and meat production. Dromedary milk is also essential for nomadic people to meet their protein and food demand. 88.0% of respondents answered that the milk is intended for self-consumption or given to neighbors or relatives who do not have the means. Also, in 98% of cases, it is being managed and preserved by the females of the household. Though camel milk has a market value, most (87.6% of herders) don't want to sell due to cultural reasons. The survey showed that the season impacts camel milk production; production was 2.6 l/day during the rainy season and 1.3 l/day during the dry season. It was also observed that in southern areas of Mali milk production per dromedary was lower than in areas further to the north with less rainfall.

Sotuba has 1.35 kg per day while Niono produces 4.2 kg per day. The average lactation duration was 278 ± 79 days in Sotuba and 332.3 ± 39.0 days in Niono. By physical condition, the dromedary is a tall, strong animal and can provide traction services to aid agriculture, transporting goods or humans, pulling water from sources, etc. The study shows that dromedary can undertake traction work faster than cattle. During the research, camels took 5:35 hours for plowing and 4:08 hours for ridging, while cattle took 7:11 hours and 6:21 hours, respectively. Dromedary traction service has financial value in Mali; it costs 7500 CFA per dromedary per day in the agricultural field and transporting goods can cost up to 20000 CFA depending on products and distance. Dromedary traction is an environmentally friendly alternative to motor vehicles transporting agricultural goods. The study found that dromedary was not much affected by common animal diseases, and their average mortality rate was 8.4%. The average vaccination cost of dromedary in both sites was 320 CFA, equivalent 0.49 EURO only. The average health cost per dromedary per year is 1536 CFA in Sotuba and 1132 CFA in Niono. From interviews, key informants said that the average health cost per dromedary per year is 5000-6000 CFA which is higher than what was found in the bio-physical research, but still, it is low compared to their size and market value. Interview with key informants suggested that dromedaries are well adaptive animals that can provide versatile services to humans and the environment. They believe that the perception of dromedary rearing in Mali has changed from the past. In 59% of cases, one or more household members were responsible for the herd management; the labour is mostly unpaid. Lack of awareness remains a problem for dromedary rearing and herd management. The survey showed 94.8% of dromedaries were unvaccinated in Kidal, and in 84% of cases deworming was not carried out. Lack of access to veterinary services (45.4%), lack of vaccines (24.0%), and ignorance (11.7%) were the major causes behind this. At both research sites, parasitosis was the main cause of dromedary sickness, followed by injuries.

The study showed dromedary's adaptability to different environments. The study results support the hypothesis of dromedary adaptation in the stress condition but adapting to a more humid climate is not proven, and further study is needed.

Keywords: Dromedary, climate change, adaptation, Niono, Sotuba, Kidal, survey etc.

Abbreviation

BBC: British Broadcasting Corporation

CFA: Communauté Financière Africaine

CEDEAO : Communauté Economique des États de l'Afrique de l'Ouest

DNPIA : Direction Nationale Des Productions Et Des Industries Animale

FAO: The Food and Agriculture Organization of the United Nations

IER : Institut d'Économie Rurale

IPCC : The Intergovernmental Panel on Climate Change

NUPI: The Norwegian Institute of International Affairs

PANA : Programme d'Action National d'Adaptation aux Changements Climatiques

PIDRK : le Programme Intégré de Développement de la Région de Kidal

UNFCCC: The United Nations Framework Convention on Climate Change

UN : United Nations

WB: World Bank

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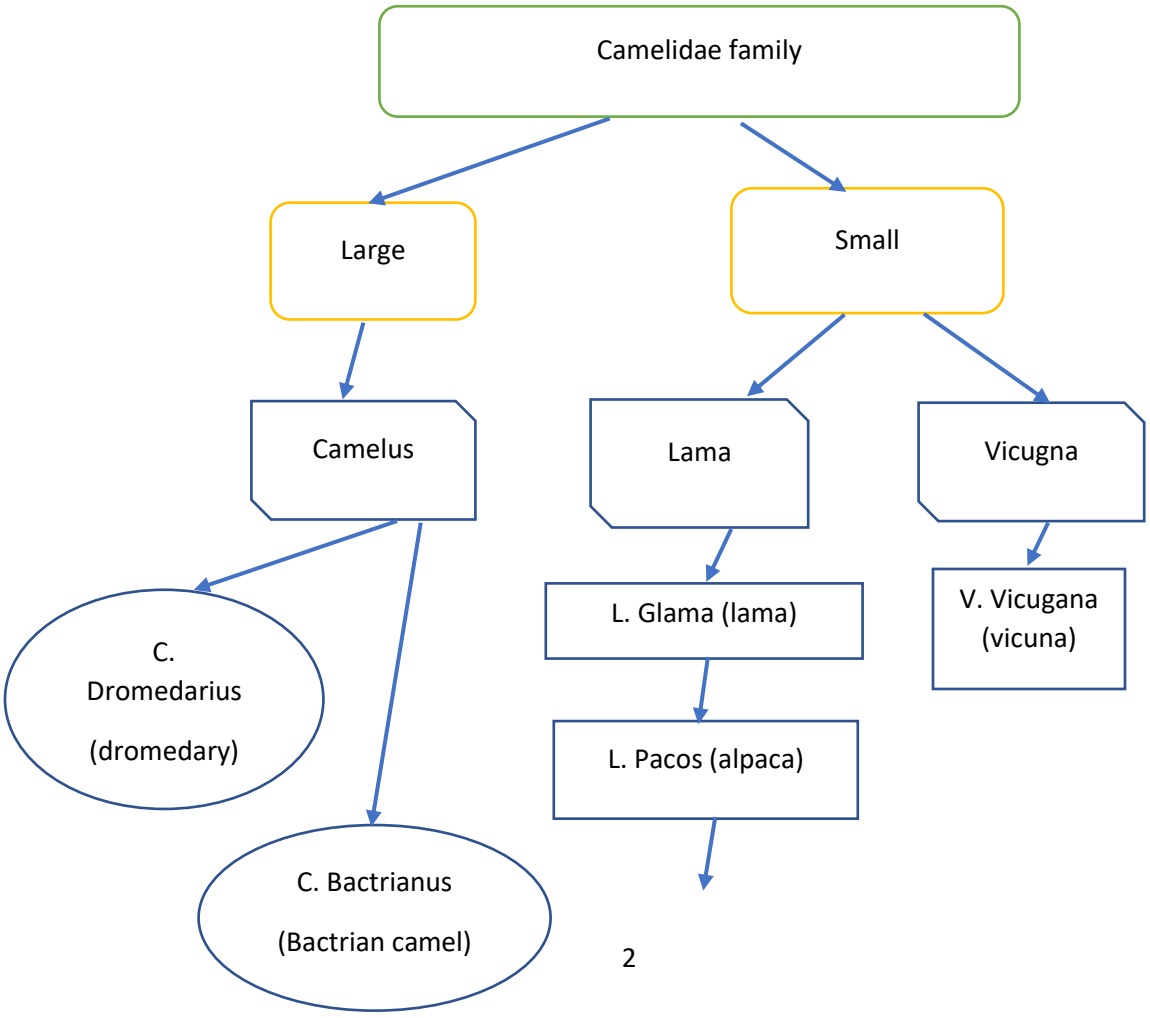
Chapter 1:

Introduction to dromedary and climate change:

Dromedary (Camelus dromedarius) is amongst the most important domesticated animals in human history. It is domesticated about 3000–2000 B.C. in Arabia (Herbison & Frame 2022). Though camel was domesticated early it still represents 1% of the world population of domestic ruminants. They are found in all drylands of the world and also in the relatively high rainfall areas in Russia, Iran, Pakistan, India and northern Africa. Camels are not found in southern Africa (Traoré et al. 2019). The name camel is derived from the Latin (Camelus) and Greek (Kamélos) languages (Fasseha and Desta 2020). They are members of Camelidae family and Camelidae probably appeared in North America 35 million years ago during the Ecocene period. Camelidae family of mammals belong to the order of Artiodactyles and to the sub-order of tylopoda (padded feet animals). Despite camel is a ruminat they are different from the other ruminants of the other rumintia, mainly from bovinae family. The family of camelidae divided into three genus: Camelus, Lama and Vicugna (Figure 1). (Faye 2015).



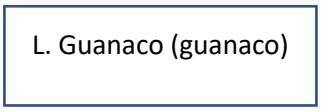


Figure 1: Classification of the Camelidae family (Edited from Faye 2015).

There is no universal classification but generally camels are differentiated based on size, color, function and habitat. There are two major types of camels: large and small. The small camelids originate from Andin Mountains of South America include two domestic species (lama and alpaca) and two wild species (guanaco in genus lama, and vicuna in genus vicugna). The large camelids include two domestic species: Camelus dromedarius, the single-humped camel and Camelus bactrianus, the two-humped camel. Dromedaries are popularly known as Arabian camels and was first domesticated around five to six thousand years ago in the Arabian Peninsula (Fasseha and Desta 2020). Arabian camels mainly exist in the Middle East and parts of tropical and subtropical regions. They are, most prevalent in the hot and arid region from eastern Asia to the northern part of Africa. Dromedary populations are mainly concentrated in the Horn of Africa and in Sahelian countries, arid areas of Africa, particularly in the arid lowlands of Eastern Africa namely, Somalia, Sudan, Ethiopia, Kenya and Djibouti. (Faye et. al. 2012, Fasseha & Desta 2020, Hoter et. al. 2019 and Gebreyohanes & Assen, 2017). Thus, the Camelidae family have unique characteristics of living in remote areas, arid lands or high mountains. This suggests high ability to adopt to different ecosystem and this also explain how this family can do work in the harshest places of the world (Faye 2015).

Dromedary production may have become more important as a result of climate change as camels have the extraordinary power to withstand thirst and hunger for long time in the most difficult ecological conditions (Fasseha & Desta 2020).

Dromedary can become an important animal in relation to climate change. Climate change is one the most important issues of 21st century and also pose threat to human, animal, ecosystem and biodiversity. UN Secretary General António Guterres made a comment on the recent sixth assessment report of Intergovernmental Panel on climate change (IPCC) and calls it “Code Red for Humanity”. Average surface temperature has already risen 1.2 degrees Celsius (UN 2021). The Earth has observed the hottest five years the past five years since 1850 and sea level rise at great pace. This is already causing many extreme weather events across the globe. Since 1950s hot and

extreme weather events such as heatwaves have become more frequent, severe, and cold waves are less intense and frequent.

The drylands of Africa are also facing global warming. The climatic condition of Mali is showing that regular decrease of rainfall with spatiotemporal variation. Droughts, temperature fluctuations, frequent floods and strong winds have become persistence since 1970s (Wako et al. 2017). Arid and semi-arid landscapes of Africa have observed a substantial increase in temperature and decrease in rainfall since 1990s (Wako et al. 2017).

In Mali, agro-pastoralists are facing the compound challenges related to climate shocks and climate change, thus traditional pastoral system has become vulnerable to climate stresses. Africa's economy is highly depending on agriculture and agriculture is an economic activity very much exposed to climate change. Therefore, Africa has become "hot spot" for climate variability and change impacts. IPCC projections suggest that warming scenarios risk having devastating effects on crop production and food security. There are key risks include reduced crop productivity linked with heat and drought stress, disease damage, increased pest damage and flood impacts on food system etc. resulting serious adverse effects on food security and on livelihoods at the household to regional levels. (UNFCCC, 2020). Despite, the attention to the importance of drought-resistant crops, the use of drought resistance livestock has received limited attention as a climate adaptation strategy (Watson et. al. 2016). Camel has a natural adaptation ability to water deprivation, high heat load and food scarcity. They are well suited to the harsh desert environments as well as high ambient temperatures and other environmental stresses (Gebreyohanes & Assen, 2017).

There is a clear relation between climate variability on cattle survival because cattle are less adaptive to climate shocks than camel and can loss their production or even life due to environmental shocks like drought, heat wave or water deprivation. In recent decades, the pastoralists in southern Ethiopia have shifted their livestock herds composition as an adaptation against climate change. These adaptive strategies include livestock diversification and camel management. (Wako et al. 2017).

Objective of the study:

Mali is the eighth largest African country by size with approximate total area (1,240,192 square kilometers). Mali is one of the largest landlocked countries in west Africa and this Sahelian country

is surrounded by seven countries. Algeria in the north, Niger in the east, Burkina Faso and Cote d'Ivoire in the south, Guinea in the south-west, and Senegal and Mauritania in the west. Its population is about 20,250,834 (World Bank) and the majority of the population live in the southern parts. Bamako is the capital and largest city. Spoken languages are French and Bambara (Bamanankan), and many more. About 90% of its population are Muslims. Mali gained independence from France in 1960, Mali has since independence suffered droughts, rebellions, and a military dictatorship until democratic elections in 1992. Then again after 2012 they are facing unrest and insurgency. (BBC, 2021).
The population has doubled in 20 years and life expectancy at birth is 59 years (WB 2020). Mali is one of the poorest countries of the World with 41.9 percent living below poverty line. Malian populations are mostly rural as about 75% live in rural areas. Mali was exposed to severe drought in the periods 1972-73, 1985 and 2002. These droughts caused the drying of the Lake Faguibine in the Northern Mali.

Agriculture, nomadic and agro-pastoralism are cornerstones of the economy of Mali. The effects of climate change create seasonal irregularity and droughts and floods are risks to livelihood security. There are severe political tensions and violent conflicts in Mali. Some of these conflicts are also related to access to natural resources. Small-holder farmers and herders are largely dependent on seasonal rainfall and annual flooding of the rivers. The effects of climate change on natural resource availability may increase the risk of conflicts when alternative livelihood strategies are limited. Mali is physically exposed to adverse effect of climate change and has become vulnerable to climate change. As a result, malians are facing the negative effect of climate change and pastoralists are among the most vulnerable people. Pastoralist must therefore adopt to a new climatic condition (NUPI, 2021)

The planning and implementation of useful and successful adaptation strategies are critical in order to cope with adverse situation, enhance livelihoods, achieve food security and agriculture growth. The long-term coping strategy to vulnerability is called adaptation. The main objective is to study how dromedary production can be important as climate change adaptation measure and to assess how dromedary can provide diversified services to the local community in time of stress.

Chapter 2:

Background Information

Environment and geography of Mali:

Mali is located between 10 degree and 25-degree North latitude and 4 degrees east to 12-degree west longitude. The climate can be divided into four climate zones (World bank, 2011):

The Sahara climate- (rainfall below 200 mm) (1), **the Sahelian climate**- rainfall between 200-600 mm (2), **the Sudanese climate** with rainfall from 600 mm to 1000 mm (3), **the Sudano-Guinean climate** above 1000 mm in the extreme south of the country (4).

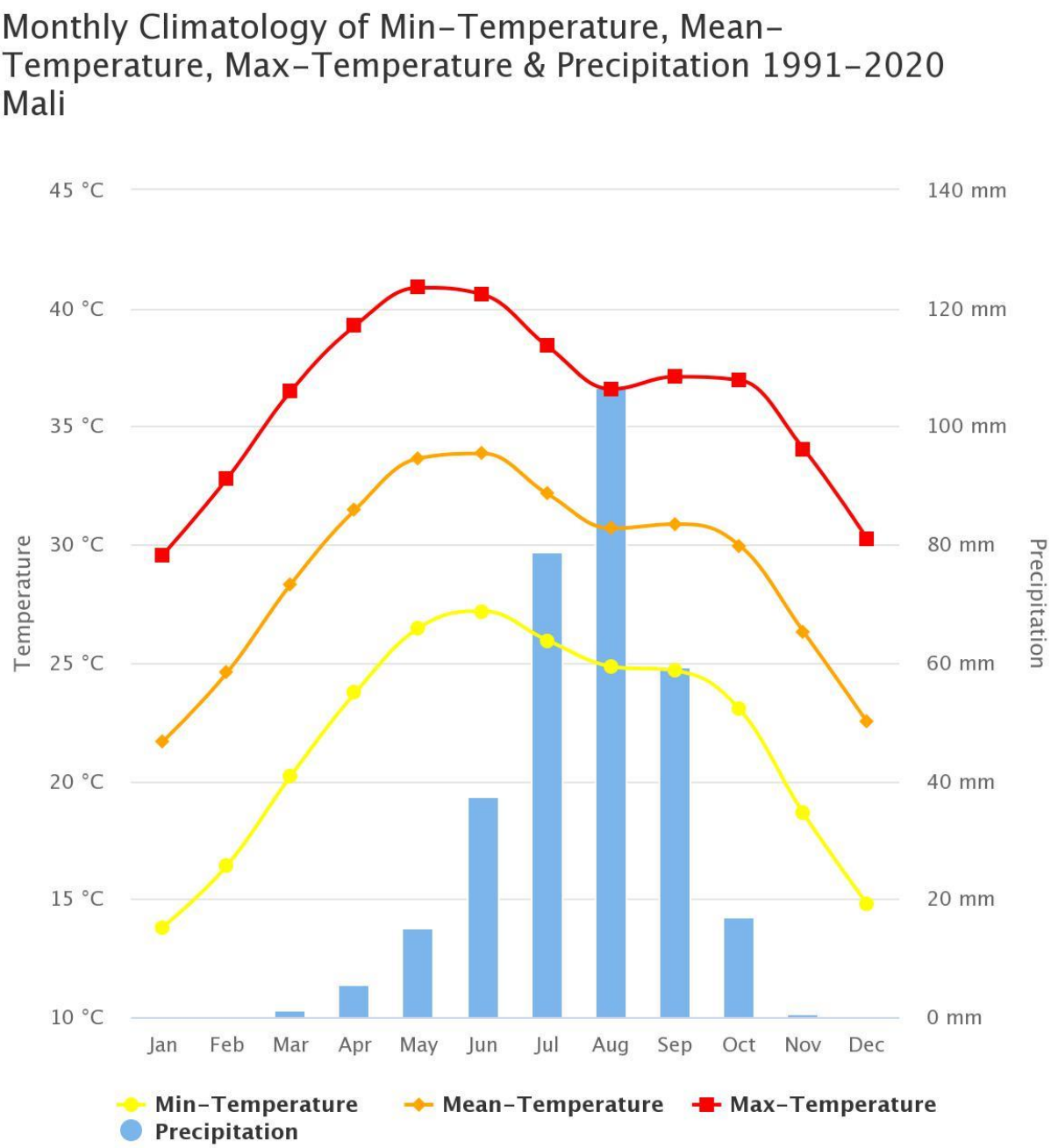


Figure 2: Monthly climatology of Min, Mean and Max temperature and precipitation 1991-2020, Mali. (World Bank).

The Malian climate is characterized by three main seasons: a hot and dry season in March to June, a rainy season from June to October when humid winds (monsoon)

blowing from the southwest (Gulf of Guinea) to the northeast, and a cold season from October to February characterized by a drying Saharan wind called the harmattan. The average temperature varies between 24°C in January and 35°C in May.

North always experience higher temperature than south during summer months, but the opposite is the case during winter months. The maximum temperature varies between 34 and 37°C and the minimum between 21 and 23°C. The maximum temperatures of the year sometimes exceed 45°C and minimum temperatures are often below 10°C in the north.

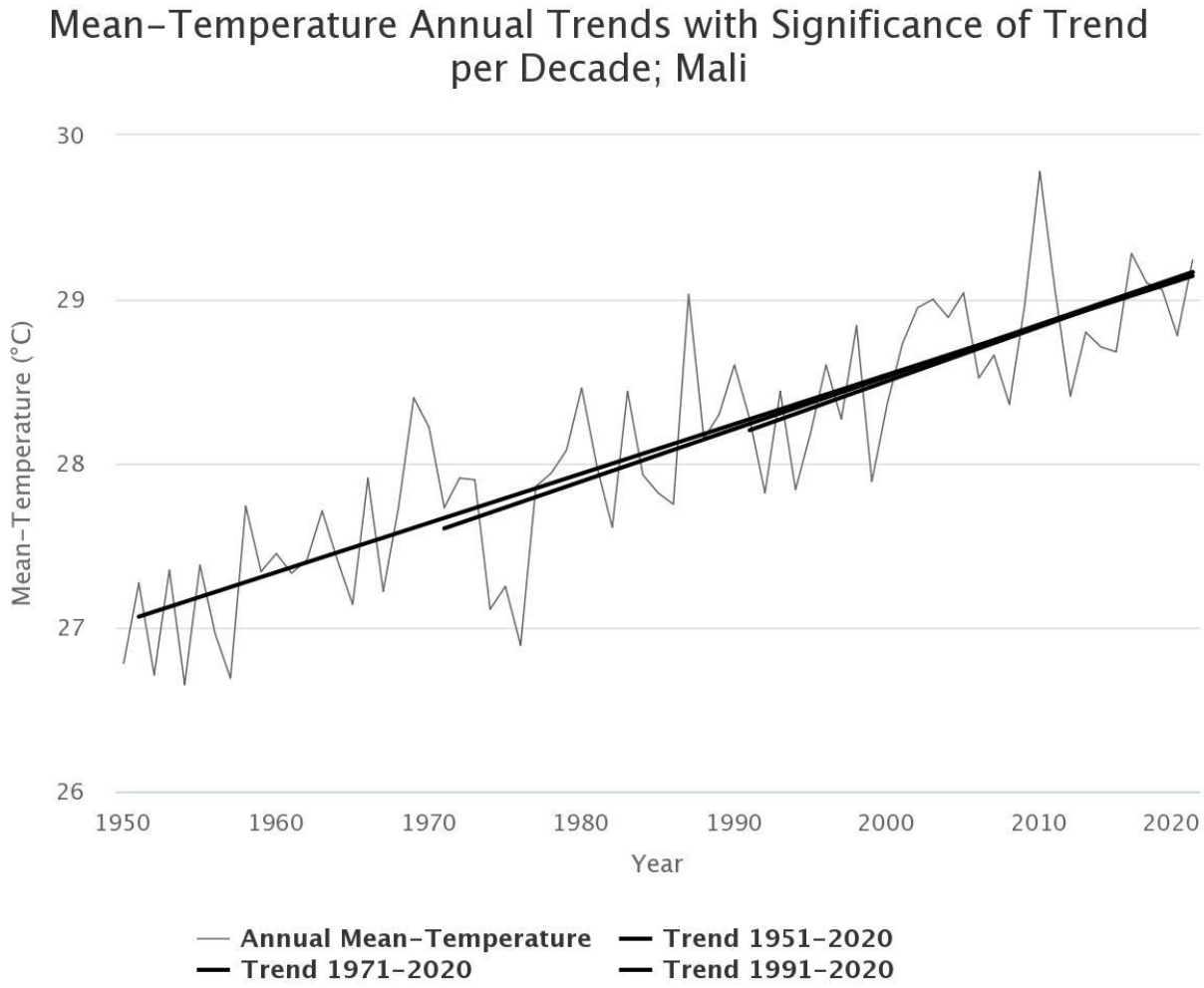


Figure 3: Annual mean temperature trends with significance of trend per decade. (World Bank)

Evidence of climate change in Mali:

Persistence of drought:
Two thirds of the territory of Mali are made up of desert areas (arid and semi-arid) in the North. In 30 years (1980-2010), Mali has experienced five major drought episodes including those of the 1980s and 2005 (Birama, 2020)

Intensification of flood events:
Mali has suffered 15 floods in less than forty years (1980-2014) (Richard, 2007). The main areas at risk of flooding are in the Inner Delta of the Niger River (64,000 km²), which is a particular hydrological ecosystem. Besides Bamako the capital, the regions of Timbuktu, Gao, Mopti, Ségou, Kayes, Koulikoro and Sikasso are among the most exposed.

Decline in rainfall
Over the last 70 years (1941-2010), the rainfall pattern is severely affected by climate change. At the national level, rainfall has decreased throughout the country compared to the reference period of 1941-1970. These changes are not same all over the country because places like Bamako, Bougouni, Kayes, Mopti, Nioro and Ségou, has observed a slightly increase rainfall over the past 30 years (1981-2010 compared to 1971-2000). But at the country level rainfall remain lower since 1970 and the overall deficit varies between 10 and 28% (PIDRK, 2011).

The study of climate risks conducted analyzed the data available since 1951 at the level of the country's meteorological stations on rainfall and temperature. The results showed that, from 1921 to 1940, average rainfall was close to 700 mm/year. From 1941 to 1971, there was an average annual rainfall lower than the previous two decades. From 1971 to 2000s downward trend continued and observed with a minimum of 400 mm /year during 1980s. The isohyets (a line on a map or chart connecting areas of equal rainfall) have moved from north to south between the reference the period of 1951-1970 and the period 1971-2000. (Birama 2020). Since 2000, there has been as alteration of wet periods and dry periods and the level of precipitation remains low to the years before 1960. There is also great intra-seasonal variability in rainfall within each of the four climatic zones. All these variations clearly indicate a reduction in average annual rainfall and a persistent alternation between dry years and wet years at all stations.

Increase in average temperature
Mali have experienced great spatial variability in temperature. Generally, the temperature increases from the southwest to the northeast. The maximum temperature recorded during the summer exceeding 45°C (a common event) while the minimum temperature rarely go below 10°C.

Since the late 1970s, average temperature has increased from 0.2°C to 0.8°C throughout the Mali (CEDEAO, 2009a).

Dromedary statistics in Mali:

The camel pastoralists are usually nomadic people who are moving frequently and thus camels are not usually subjected to obligatory vaccination (Faye, 2014). According to (FAOstat 2020), the total number of camel heads is almost 38.5 million and this numbers is probably underestimated especially in the Sahelian countries like Mali, Sudan, Niger, Chad, Mauritania, Ethiopia. However, this population is still only 1% of total domestic animal population. More than 80% of the camel population lives in Africa with 60% in the horn of Africa. The world camel population is increasing regularly with a yearly growth of 2.1%. Since 1961 (date of the first FAO statistics) but the trend is not same for all the countries. Mali is a country with high recent growths.

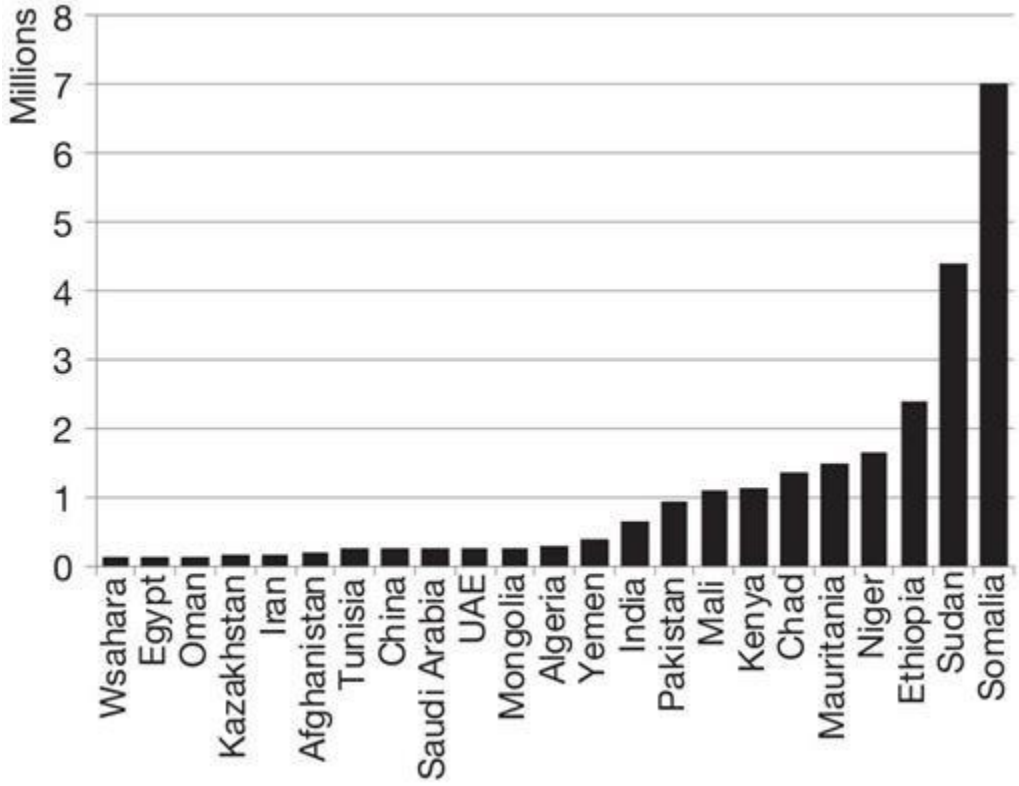


Figure 4: Number of camels around the world (Faye 2015).

The countries with a camel population over 1 million are Somalia, Sudan, Ethiopia, Niger, Chad, Mauritania, Kenya, Mali, Pakistan (Figure 4).

The DNPIA, (2015) report suggest that Mali had 1008,540 heads of camel and in 2020 this number has increased to 1265915 (FAOstat 2020).

Table 1: Number of camel heads and percentage in total camel heads in Mali. (DNPIA, 2015)

Regions	Camel heads (Number)	Camel heads (percentage of total camel population in Mali)
Kayes	2800	0.28
Koulikoro	10500	1.04
Sikasso	0	0
Ségou	800	0.08
Mopti	16510	1.64
Tombouctou	210080	20.84
Gao	234220	23.22
Kidal	533530	52.90
Bamako	0	0
Total in 2015	1008540	100

Kidal has the highest number of camels in Mali (52.9%) of the total national dromedary herd is found here. The next two highest camel herding regions are Gao and Tombouctou respectively.

The trend in milk production in Mali does not show any consistent trend. From 2013 camel milk production placed among within top two in Mali.

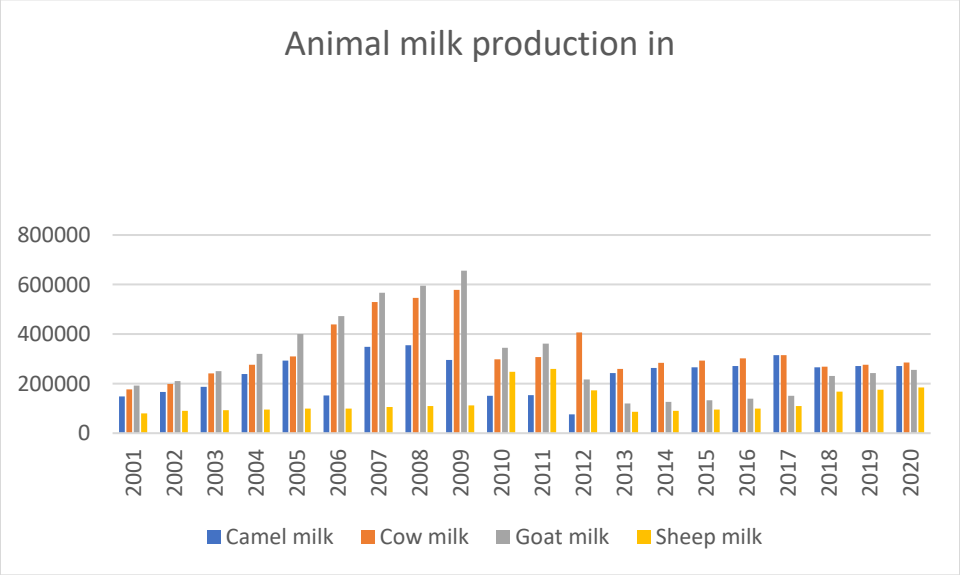


Figure 5: Animal milk production in Mali (2001-2020) (FAOstat)

Mali saw a reduction in milk production since the year 2009. From 2013 to 2020, camel milk reaches the second position in terms of production per year due not only to increased production of camel milk but also due to less production from other sources. In the last 8 years camel milk production sees a steady and slightly increasing trend and now at the same level of cow milk production (FAOstat and DNIPA 2015).

Table 2: Regional information about number of camels slaughtered and total meat weight in 2015 (DNPIA 2015).

Region	Number of camels slaughtered	Total meat (Weight in kg)
Kayes	18	5180
Koulikoro	0	0
Sikasso	0	0
Ségou	572	31049
Mopti	27	3780
Tombouctou	101	17000
Gao	363	59040
Kidal	-	-
Bamako	0	0
Total in 2015	1081	116049
Total in 2014	564	96116
Variation (%)	91.67	20.74

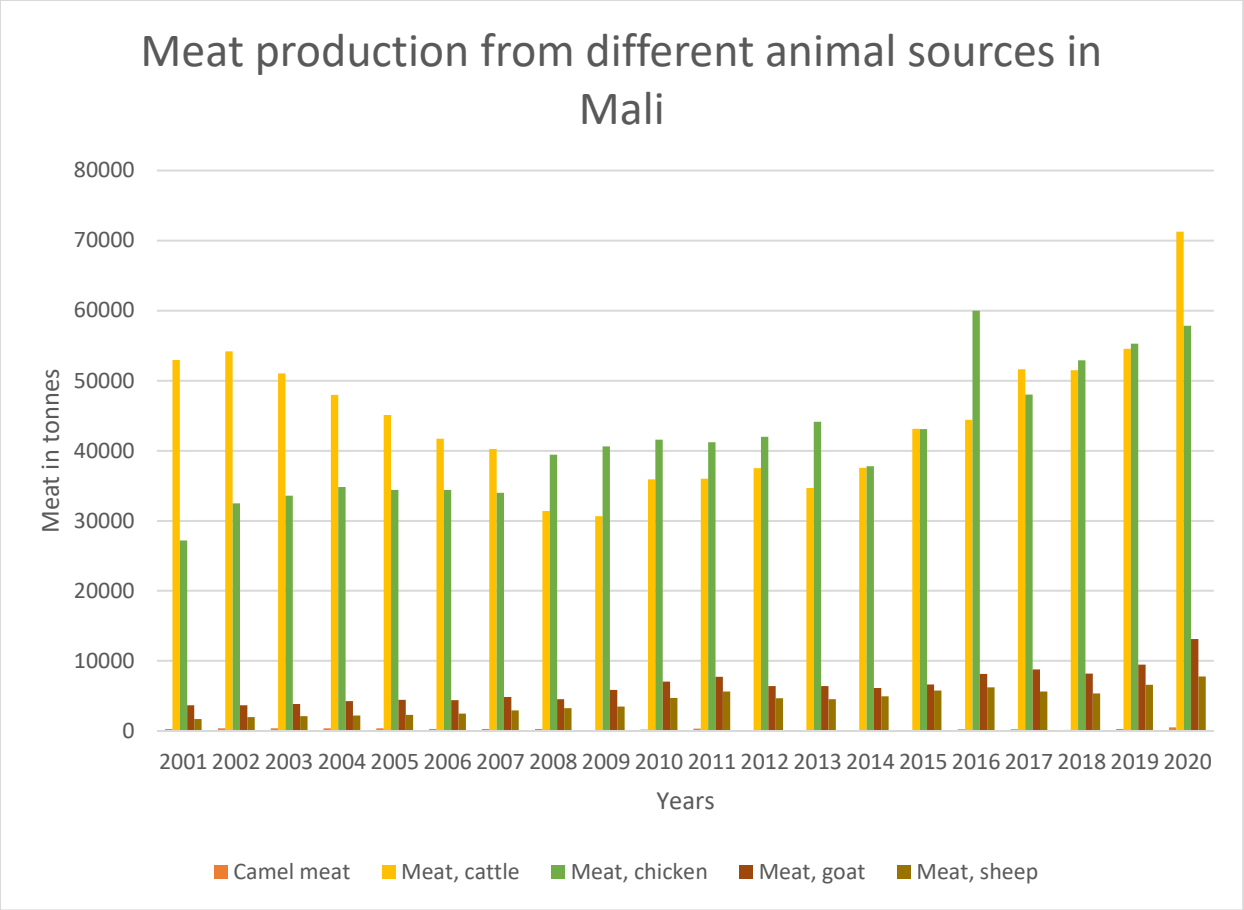


Figure 6: Meat production in tonnes from different animal sources from 2001 to 2020 (FAOstat)

Camel meat production is low compared to other forms of meat production. Highest meat production is obtained from cattle followed by chicken (Figure 5). From the graph it is hard to find a place for camel meat in the country's meat production.

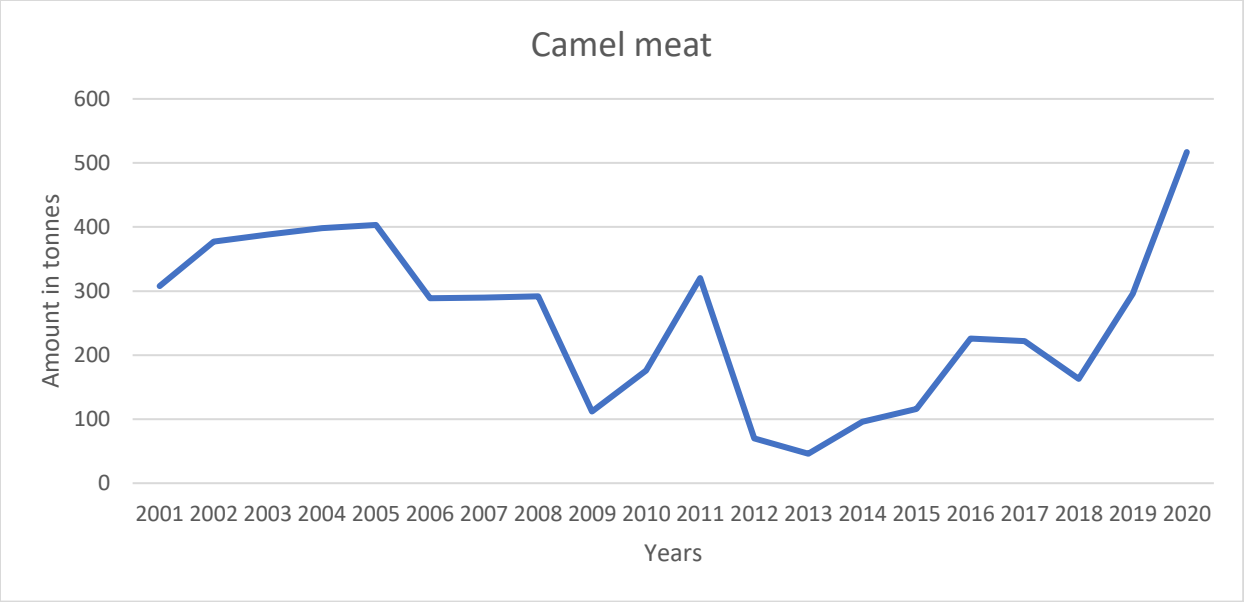


Figure 7: Camel meat production in Mali from 2001-2020 (FAOstat 2022)

In 2001 meat from dromedary was only 308 tonnes and in 2020 it has increased to 517 tonnes in Mali. There was increasing trend from 2001 to 2005 and then decreasing trend till 2009. Production increased again from 2009 to 2011 and then a sudden fall and reached the lowest production in 2013. After 2013 again it has shown a clear growth and in 2020 it reached the 500 tonnes mark (Figure 6). At the same time number of slaughtered camels also increased which is related to meat production. In 2015 number of slaughtered camels were 1081 which was almost double from 2014 with 564 camels (DNPIA 2015).

Dromedaries adaptation techniques in the Dessert environment :

Dromedaries have several adaptation strategies that are important in relation to survival and adaption to dryland conditions. Survival in desert or arid environment is difficult and dromedaries have physiological, anatomical, and behavioral adaptation mechanisms that make them resistant to harsh climatic conditions.

Physiological adaptation:

Water conservation: Adapted camels have evolved physiological adaptations that are able to reduce the water loss or are able to tolerate significant water loss. In mild climates where green forage is available then they may survive several months without drinking. Usually during winter or cold season they can go without water for months even if you offer water to them, still they do not drink. In hot conditions they drink only in every eight to ten days. During this process, they loss

up to 30 percent of its body weight through dehydration. Under the mean temperature of 30-35 degree Celsius they can go without water for 10-15 days but the survival period without water shortens when temperature exceeds 40 degrees Celsius (Gebreyohanes & Assen 2017).

The digestive and urinary tracts are better specialized in water conservation than cattle. Cattle lose 20 to 40 litres of fluid daily through feces, but camels lose only 1.3 litters. This is one of the primary methods for resisting water deprivation in the desert. Fluid is absorbed in the end part of the intestines, where the small fecal balls are produced (Fesseha & Wondwossen 2020).

The body of camels can tolerate over 30% of water loss over body weight whereas other mammals can die if they loss half of this value (Gebreyohanes & Assen, 2017).

A camel may drink more than one third of its body weight and rehydration is important for animal survival in water scare situation. A camel can drink 110 liters in 10 minutes (Gebreyohanes & Assen, 2017). In other animals' rehydration at these levels would lead to over hydration and possibly death. The reason why the dromedary can have such a high intake of water is because large amounts of water can be stored for up to 24 hours in the gut to avoid a rapid dilution of the blood.

Unique features of blood:

The camel can dehydrate without compromising blood viscosity. The camel's blood plays a principal role in adaptive mechanisms to high heat load and dehydration. Blood composition and volume remain relatively constant and haemoglobin function remains normal. Red blood cells in dromedary can easily flow quicker in a dehydrated state of the animal as compared to the round-shaped red blood cells in other mammals (Fesseha & Wondwossen 2020).

Thermoregulation:

Body temperature regulation: A fully hydrated camel has a daily body temperature range of 36 to 38°C. However, when dehydrated and exposed to high environmental heat load body temperature may fluctuate by 6 to 7°C, from approximately 34 to 41°C. Other animals also allow body temperature to increase but not to the same extent. It allows a considerable amount of heat to be stored during the day and dissipated at night (by radiation) without the expenditure of water. It is not uncommon that in the middle of the day, rectal temperatures in camels may reach 43 C. These variations could induce death in other mammalian species. Camels are able to maintain high body temperature without compromising vital organ and cellular functions through special anatomical

and physiological mechanism. Furthermore, under euhydration state, camels seem to display more stable thermal homeostasis compared to other domestic animals that are reared under the same desert biotope (Fesseha & Wondwossen 2020).

Selective brain cooling: Selective brain cooling has been assumed as a mechanism for animals to maintain brain temperature below thermal critical values when body temperature increases the camel can resist intensely high body temperatures without damaging its brain. A study in Saudi Arabia showed that during the summer months, sheep registered an increase in rectal and skin temperatures that are respectively twice and four times higher than what camels experience. Camels are able to survive these extreme hot temperatures using a selective brain cooling mechanism and oxidation of fat to obtain water. (Tibary & El Allali, 2020).

Digestion and metabolism:

Gastric digestion: The great digestive capacity of cellulose by camels is due to a specific and differentiated motility, a very active microflora and better microbial digestion and more significant food mixing in pre-stomachs. Water is absorbed very slowly from the stomach and intestines allowing time for equilibration without severe osmotic problems (Fesseha & Wondwossen 2020).

Lipid metabolism: The well-known capacity of the dromedary to resist thirst and lack of food is related to remarkable adaptive mechanisms, including the mobilization of the body reserves of lipids (fatty tissue) during malnutrition and the storage of fat during favourable periods.

Glaycidic metabolism: The camel's energy metabolism differs in particular from that of ruminants. After a 10 days water deprivation, the glycemia increases from 20 to 80% without glucosuria. A dehydrated camel reduces moisture losses by maintaining a high glycemic and practically null glucosuria. The hypo-insulinemia would allow the camel to maintain a low basal metabolism by decreasing glucose use (Ouajd & Kamel. 2009).

*Nitrogen metabolism***:** The nitrogen recycling in Camelids increases in the case of lower proteins in the diet and/or dehydration. This great aptitude of urea recycling is due to very powerful mechanisms whose effectiveness does not deteriorate in the case of dehydration.

Anatomical adaptation of camels:

Skin and coat: The camels' thick coats insulate them from the intense heat radiated from desert sand and during the summer the coat becomes lighter in color, reflecting light as well as helping to

avoid sunburn. Dromedaries have a pad of thick tissue over the sternum called the pedestal. When the animal lies down, the pedestal and other small areas of padded contact points raise the body from the hot surface and allow cooling air to pass under the body (Fesseha & Wondwossen 2020).

Eye, nostril and lips: The slit-like closable nostril protects against blowing sand and moistens air on its way to the lungs. When camel exhales, water vapor become trapped in their nostrils and is reabsorbed into the body to conserve water. The small wound ears covered with tufts of hair is protected from entering of the blowing sand. Camels have long eyelashes that help protect the eyes from the sun and the blowing sand. They have also a third, clear eyelid that protects their eyes from blowing sand (Gebreyohanes & Assen 2017).

Large body size and height: The large size and height of the camel can be of some advantage in heat regulation. A large body mass heats up much more slowly than a smaller mass exposed to the sun. The comparatively small surface-area-to-volume ratio of large animals reduces the proportion of the animal exposed to solar radiation, reducing potential environmental heat load.

Large foot pads: Their large broad 'elastic' pads with two fingers, nail-like toenails on front are also important structures to easily walk on the desert sand which is not possible for other ungulates to walk on tips of hoof covered toes. The advantage of this broad leathery pad in camels is to disperse their weight in a wider surface area and their feet don't sink in the loose sandy soil. (Gebreyohanes & Assen 2017).

Chapter 3:

Materials and method:

Study design:

A research design is essential to carry out flawless research and provides a framework for collecting and analyzing data. It reflects the priority given to a range of dimensions of the research process. (Bryman, 2008, p 46). Before designing this research, it is considered that due to the current political situation and global pandemic it is not possible to go to Mali physically. This study is designed as a mixed method of study, hence there are two parts - quantitative and qualitative. This term stands for integrative research and includes both quantitative and qualitative research within a single project (Bryman, 2008). A combination of these two methods will give us an in-depth view of what this study is looking for. The quantitative study focused to research on

the bio-physical study of dromedaries in two research stations the Niono agricultural research station, the Sotutba agricultural research station, and in Kidal.

The survey among dromedary herders in Kidal will carry both quantitative and qualitative data to analysis. Finally, key informant's interview with key informants will uncover the qualitative perspective of this research.

Study Area:

This study has been conducted in the agricultural research station of Niono and Sotuba and in Kidal region.

***Five blue dots in the map represent all study area.**

Figure 8: Mali administrative map. (collected from www.mapsofworld.com).

Maps legend given here in French. Frontiere Internationale : International Borders, Limite de la province : Provincial borders, Capitale nationale : National capital, Capitale de la province : Provincial capital, D'autres villes : Cities.

Mali is divided into eight regions and one capital district, and those regions are subdivided into 49 cercles and a cercle is the second level of administrative unit. These subdivisions bear the name of their principal city. The regions are named after their region capitals: Gao, Kayes, Kidal, Koulikoro, Mopti, Ségou, Sikasso, Tomboctou (Timbuktu), and Bamako the capital district.

Niono agricultural research station:

Niono agricultural research station covers a total area of 12,000 ha. It is located in the Sahelian zone with a dry tropical climate characterized by a single rainy season which lasts four months, from June to September. It is in the town of Niono at an altitude of 277 m. Located between 13°30' and 15°45' north latitude and between 50°5' and 6°35' west longitude. The Niono cercle (a second level of administrative unit) has a Sahelian-type climate with rainfall randomly distributed over the entire cercle. Rainfall in Niono is characterized by a short rainy season (from June to September), followed by a dry season which lasts 8 months (October to May). Rainfall is between 500 and 600 mm/year and the average rainfall is 425 mm per year. The ranch is a plant species conservation area for research activities. The average temperature is 29.2°C and temperatures have been stable over the period from 1966 to 2003. The pasture is characterized by the dominance of woody species. (Moussa et al. 2020).

The Sotuba Agricultural Research Station (SRA):

Sotuba Agronomic Research Station covers an area of 268 hectares with an altitude of 322 m. It is located between 12° 39' 07.3" north latitude and 007° 55' 34.0" longitude west. The climate is of the Sudano-Sahelian tropical type with a regular succession of a well-marked rainy season, of short duration, from June to September and a long dry season from October to May. The rainfall varies between 800 and 1,000 mm/year. The average annual temperature varies between 25.7 and 39°C, with a strong amplitude. The maximum temperature in April can reach 42°C while in January, the mercury level drops to 18°C.

Overall, three types of soil are encountered in the natural pastures of Sotuba:

a) The clayey soils with temporary hydromorphy located on the Niger Riverbank to the south and south-west of the stables. The pastures there are exploited in the dry season. The dense woody vegetation is dominated by various thorny species such as Acacia spp and Dichrostachys glomerata.

b) The loamy to loamy-sandy soils to the south of the experimental plots are occupied by rainy season pastures which make up the majority of the station's routes. These include fields and fallows. The woody vegetation is composed of thorny shrubs.

c) The sandy soils to the east (Serotherapy area). This part of the Sotuba estate is the subject of intense cultivation by the people of Sotuba. (Moussa et al. 2020)

The Kidal region:

The Kidal region is located in the Saharan zone of North-East Mali between 18° and 21° North latitude, 43° East longitude and 19° West longitude. It covers an area of 260,000 km², or 21% of the national territory. It is bounded to the north by the Republic of Algeria, to the south by the region of Gao, to the east by the Republic of Niger and to the west by the region of Timbuktu. Rainfall is very low and decreases from the South (121 mm per year) to the North (75 mm per year). Administratively, the region includes four circles, those are Kidal, Tessalit, Tina-Sako and Abéibara. Four major ecological zones characterize the region: 1) the Adagh, a zone of more or less high but still massive mountains, located in the central part of the region. It is dotted from east to west by valleys that drain rainwater; 2) the Telemsi valley which occupies the south-west of the region constitutes a fossil valley, a real receptacle for the waters drained by the great valleys which descend from the Adagh and the best salty land for livestock such as Aslagh, Eghabab, Takabart; 3) the Tamesna, located on the eastern edge of the Adagh, is a vast series of plains, plateaus, dunes, ergs and arid regs. Despite low rainfall (about 100 mm/year), this area has excellent herbaceous and woody pastures, especially in the cold dry season; 4) finally, the Timtaghene is an area dominated by a mountain range located in the far west of the region, separated from the Adagh by the Telemsi valley (PIDRK, 2011) (Ouologuem et al., 2020).

Gao:

Gao is a city in Mali and the capital of Gao region. It is situated on the Niger River at the southern edge of the Sahara, about 200 miles (320 km) east-southeast of Timbuktu. The coordinate of Gao is 16°16′N and 0°03′W. The population consists chiefly of Songhai people. Gao, founded by fishermen in the 7th century, is one of the oldest trading centers in western Africa. Gao became the capital of the Songhai Empire in the early 11th century. Under Songhai rule, the town thrived as a significant trans-Saharan trading center for gold, copper, enslaved people, and salt.

Gao's climate is hot and dry, with the only rainfall occurring between June and September. August is usually the wettest month. The average annual rainfall is only 220 mm, but significant year-to-year variations exist. May is the hottest month, with an average daily high temperature of 43 °C. December and January are the coolest months, with daily low temperatures of 15 °C. From October to March, the north-easterly Harmattan wind blows from the Sahara during the dry period.

Mopti:

Mopti is a town in eastern Mali, located at the confluence of the Niger and Bani rivers. This is the capital of the Mopti Cercle and the Mopti Region. Situated 630 km northeast of Bamako, the town lies at the confluence of the Niger and the Bani Rivers. It is linked by an elevated causeway to the city of Sévaré and situated between 14°29′45″North and 4°11′55″West. Mopti is an important commercial town and the center of Mali's fishing and livestock industries. The city is located on three islands and is one of Mali's most densely populated areas. Major crops grown in the surrounding area are rice, millet, onions, cassava, and peanuts (groundnuts). Livestock raising and fishing are also significant.

Mopti has a hot semi-arid climate near the Sahel region's southern boundary. Rainfall occurs between June to September. Average daily maximum temperatures in April and May exceed 40 °C. December to January have average daily maximum temperatures below 32.2 °C

Segou:

Segou is a town and an urban commune in south-central Mali that lies 235 kilometers northeast of Bamako on the right bank of the Niger river. The coordinates are between 13°27′N and 6°16′W. The town is the capital of the Ségou Cercle and the Ségou Region and was the first capital of the Bambara kingdom. The region in which Ségou is situated is essential agriculturally because of an extensive irrigation system that began in 1932. Irrigated rice cultivation in the area has been expanded, and other crops include cotton, sugar, millet, peanuts (groundnuts), cassava, and beans. Livestock raising is also important.

Ségou has a hot semi-arid climate. Ségou has two seasons: a rainy season and a dry season. The rainy season starts in May and lasts about five months until September. The dry season includes a relatively mild period followed by sweltering heat. The average yearly rainfall is about 640 mm. The harmattan is the dominant wind in the dry season and blows from north to south. The monsoon blowing from south to north-west is frequent during the rainy season.

Chapter 4:

Data collection:

Primary data has been collected through the Adapting Agriculture and Livestock project to climate change (ACC I) phase I (PANA). This project is carried out by Institut d'Économie Rurale (IER) in Mali and is funded by the Kingdom of Norway and the Republic of Mali. This project (phase I) ran from 2011 to 2016. As part of this project and aim to publish this work, I am allowed to use the data collected through this project. For this research, both qualitative and quantitative data have been accumulated. Most of the quantitative data were from the bio-physical study on dromedaries in Sotuba and Niono research station. On the other hand, the project has done a household survey among dromedary herders in the Kidal region. Finally, the key informant's interview conducted by me provided quantitative and qualitative data.

Physical study on dromedaries in Mali:

Grazing behavior of adult dromedaries:

This research was conducted in Sotuba and Niono. There was total 24 camels, 12 in Sotuba and 12 in Niono and the average age was 5 years. Three experiments were done on each two sites at the rate of 4 camels per experiment. The behavior of the dromedaries on pasture was monitored every month for 12 months. On both sites 4 camels were selected taken at randomly. The camels were observed basis from herd were followed individually for 7 days by 4 observers. (Moussa et al., 2020).

Reproductive behavior:

Research was conducted at in the Agronomic research station of Niono and Sotuba to assess the reproductive behavior of females since their arrival in February 2013 (Ouologuem et al., 2020).

The study has been done on a total 29 female camels, of which 17 were reared in Niono and 12 in Sotuba. The animals in Niono were 2 to 3 years old when they arrived, while in Sotuba their age was between 3 to 6 years old. After grazing, the animals received an average of 3 kg of concentrated feed based on wheat bran, grain maize and cottonseed meal. The data was collected related to matings, abortions, farrowings, postpartum duration and the weight of calves at birth. All data was collected from February 2013 to June 2016 through direct observation of the animals in the morning and in the evening and by the intermediary of the shepherd for events that occur at grazing time. To diagnosis pregnancy of dromedary traditional "raised tail" was used. The

descriptive statistics method and analysis of variance were used to analyze data and the site, and the sex of the fetus were taking as factors.

Forage intake behaviour:
The study was conducted in Niono and Sotuba agronomic research station.

Every month 4 observers monitored 4 dromedaries in each site on pastures for 12 months. The study began in September 2014 in Sotuba and in December 2014 in Niono. The four 7-year-old male dromedaries of the Tabayaten breed were used. This is the intermediate breed between Air and Sahel breeds, originating from Ansongo, Mali. All study animals were treated for external, gastrointestinal and blood parasites. Cases of injuries and other specific conditions were treated with appropriate products such as antibiotics, anti-inflammatories, etc.

Four tests were conducted on each site during the following three seasons (Moussa et al., 2020)

Rainy season- June-September

Cold dry season: December-January

Hot dry season: March-May

The method used that of (Chaibou, 2005) which consists of carrying out total collection of feces using bags which attached with camels. The bags are collected twice a day: between 9 a.m. and 10 a.m. and between 4 p.m. and 4:30 p.m. After each detachment, the weight of feces is determined by weighing. Then, 10% sample is taken from each animal, weighed and stored in the freezer until the end of experiment. For each animal, the feces of the evening and those of the following morning constituted the quantity of feces of a day of grazing.

The plant species browsed by the camel have been identified and collected the sample by using "shepherd's collection" method (Chaïbou, 2005). This method is a simple method of simulating the bite of an animal by hand and collecting the same species of same amount. But, in the case of thorns, it is difficult to imitate by hand and in these cases, sample were taken without simulating the bite. All these sampled were put together in the same cretonne bag which represents the diversity of the daily menu and then bag is weighed. Finally, a label bearing each animal, the weight of the sample and the list of species is put each bag (Moussa et al., 2020).

The digestibility of dry matter was calculated by the in vitro method of Telley and Terry (1963).

The dry matter ingested was calculated by the formula given by Chaïbou (2005):

MSI=MSF * 100/ (100-DMS in p.100)

MSI: Amount of dry matter ingested

MSF: Amount of dry fecal matter

DMS: Dry matter digestibility coefficient

Statistical analyzes of the data on the amount of dry matter ingested were made by the method of analysis of variance, considering the main factors of the season and the site.

Milk production experiment:

Two herds of dromedaries were introduced in the study area to study milk production in different climatic condition. The Agronomic research station of Niono and Sotuba were the two testing sites. Seven lactating camels were in Sotuba and eight in the Niono. Milk was collected in the morning and in the evening. It was done to find the milk production of camels in their new breeding areas. Those camels were gazed between 8 a.m. to 4 p.m. Every herd received 4 kgs of commercial concentrated feed containing wheat bran, corn and cottonseed cake consisting of 16% raw protein. The given amount provided the herd with 3.24 UF of net energy and 484 g of digestible nitrogenous matter. Salt was given once a week.

After giving birth, the young calf was allowed to suck mother's milk for the first 15 days, then the partial milking started to make the camel accustomed with the milking process during the next 15 days. In Niono adaptation time was longer because the camels were primiparous and the herders responsible for milking were inexperienced. As a result, monitoring of milk production could not be started before the 3rd month.

On both sites, the quantity of milk was collected until drying off camels by monitoring daily milkings, twice a day, in the morning and in the evening after the camel has stimulated the descent of milk into the udders.

The data were collected as the quantity of milk production per day, the duration of lactation and production per lactation. The data were processed by the method of analysis of variance and camel and the date of parturition as main factors (Ouologuem et al., 2020).

Disease and pathology study of dromedary:

Research has been done with herd of 35 camels in the ranch located 20 km from the Agronomic Research Station of Niono and another composed of 15 heads in the Agronomic Research Station of Sotuba. Health monitoring was carried out from 2013 to 2015 by daily animal visits in Sotuba and every 2 or 3 days in Niono, during which all pathological cases are identified and recorded. Blood and faeces samples are often taken depending on the subject for confirmation of the various suspicions. Then the necessary corrective measures were taken. In addition to treating pathological cases, the animals were dewormed twice a year, at the beginning and end of wintering against gastrointestinal and blood parasites. Against external parasites, the animals were treated monthly during the wintering but during the dry season, as needed when ticks were observed under the tail, around the rectum and vulva, between the legs, and on the teats. The products used were ivermectin, flumetrine, or sipronil. Gastrointestinal parasites were treated with almetic (albendazole), while diminazene diaceturate and dimivet were used against blood parasites. Against bacterial infections, oxytetracycline or its equivalents have been used.

In 2015, a protocol for assessing the seasonal dynamics of camel pathology vectors was implemented by dividing the year into three seasons: rainy season (June - September), cold dry season (October - February), and hot dry season (March - June).

During these outings, vectors (flies and ticks) were captured. At the same time, blood and feces samples were taken from the animals. In blood samples, hematocrit (PCV) levels were determined and plasmosomal parasites were identified, while in fecal samples, parasite eggs were identified. Finally, the financial cost of animal health maintenance was calculated from the purchase prices of the various products used for treatment, parasite prophylaxis and vaccines. The data were analyzed by descriptive statistics (frequency, mean, standard deviation) (Baradji et al., 2020)

Dromedary traction experiment:

The comparative study has been done in Sotuba research station to improve the use of dromedaries in agricultural work. Experiment has been conducted in an experimental plot area of 3920 m^2. Area of elementary plots: 49m x 20m = 980 m2, Number of lines: 20, and a Line length: 20 m.

Four types of experiments done using the same area and same techniques with both cattle and dromedaries.

Those are T1 Direct seeding without tillage, T2 Multicultivator ridging + sowing with seeder, T3 Scraping the soil with a multicultivator + sowing with a seeder, T4 Plowing the soil with a multi-cultivator + sowing with a seeder

Interview and survey:

Key informant's interview:

In addition to the field experiments interviews were conducted with pastoralists in northern Mali. Interviews were done with five key informant persons from a group named platform. Platform is a social group of dromedary herders in Mali. Interviews were conducted by myself with the help of my supervisor. A set of questionnaires was prepared. Zoom and Skype credit has been used to perform these interviews. WhatsApp was used to communicate with the respondents initially. Due to a poor mobile network and a rare internet connection, it was a considerable effort to communicate and set time for the interviews. Even after setting an appointment, I had to change it several times because of unexpected issues. With their consent, the session has been audio recorded to facilitate transcription. These interviews were done in French. Every session took almost an hour. The interview focused on 20 open-ended questions related to dromedary and climate change adaptation.

Platform of innovation: Platform is a social group of dromedary herders, owners, managers, researcher. The platforms created provide a framework for exchanges, information and learning between actors, facilitating the generation and dissemination of research results and their adoption at cost. It is in fact a space for learning and exchanges, constituted by a coalition of actors who interact in a spirit of synergy and complementarity, while sharing their experiences, knowledge, skills, resources, and ideas in order to seize opportunities and solve problems of common interest. These actors initiate and implement activities together to meet a challenge.it appears that the innovation platforms have contributed significantly to the appropriation and large-scale dissemination of climate change resilient technologies through the various links in the value chains and through the areas of intervention.

Household survey

A survey was conducted among camel herders to collect data. Before starting the survey, initial meetings were held between the research team, communication service managers and local community leaders to establish the best way to reach camel herders. It has been decided to take 50 breeders from each cercle of the Kidal, thus 200 breeders were targeted as a sample. The survey

was conducted between July to November 2011 among 194 breeders using a questionnaire. Before the questionnaire administration, an information meeting was held under the chairmanship of the local mayors or deputies at the level of municipalities and at the level of local fraction, village chief or their advisors used to do the same. Then, the questionnaire was administered individually to the head of the household or the most active person in the breeding activity. The data were analyzed using descriptive analysis methods (frequency, mean, median, standard deviation). However, milk production data analysis was done using the General Linear Model (GLM) of the software SPSS and calculated analysis of variance by considering the category and the cercles of the region as factors.

Limitation of the study:

It isn't easy to conduct any research ideally. Every work has some flaws and identifying and addressing those flaws are essential to make the study reliable and valid. In quantitative research, reliability is an issue likely to be concerned with the question of whether a measure is stable or not (Bryman, 2012, p 46).

Like every work, my research also has some limitations. To conduct this research, I faced several difficulties. Initially, it was planned to visit pastoralists in Mali, but it did not come true because of covid restrictions and fragile internal security in the country. Then I tried to communicate with local pastoralists. It also failed because they often live far from their home in transhumance. Finally, I got in contact with several key informants, mainly regional leaders of the group "Platform of innovation" from different parts of the country. Still, a few challenges left. At first, I tried "zoom" software to establish video meetings but later found this impractical because of low internet speed. Later I tried "WhatsApp," but the same problem occurred; only voice clips, photos, and written messages could be passed. Finally, the solution came with "Skype out calls," where we can directly call those leaders and talk with them over the phone. All the interviews have been done over the phone except for one where I used zoom meetings. Only five complete interviews were undertaken; we tried with a few more pastoralists but failed. Although all these interviewees were friendly, I still sensed they were not quite open to me. Especially when they had to provide internal financial data or something related to their culture or community, they did not answer with specific data. Instead, they used a range. They are leaders and do not know all the issues with dromedaries, such as they could not provide the amount of daily milk production, average daily meat production, or exact figure of the medical cost per animal per year.

Secondary data was the only option in some cases, like meat production. But those data were collected from Mali's national database, which is not entirely reliable. The least developed countries sometimes manipulate their data according to their need. We could not find any other research project or reliable sources to cross-check those data.

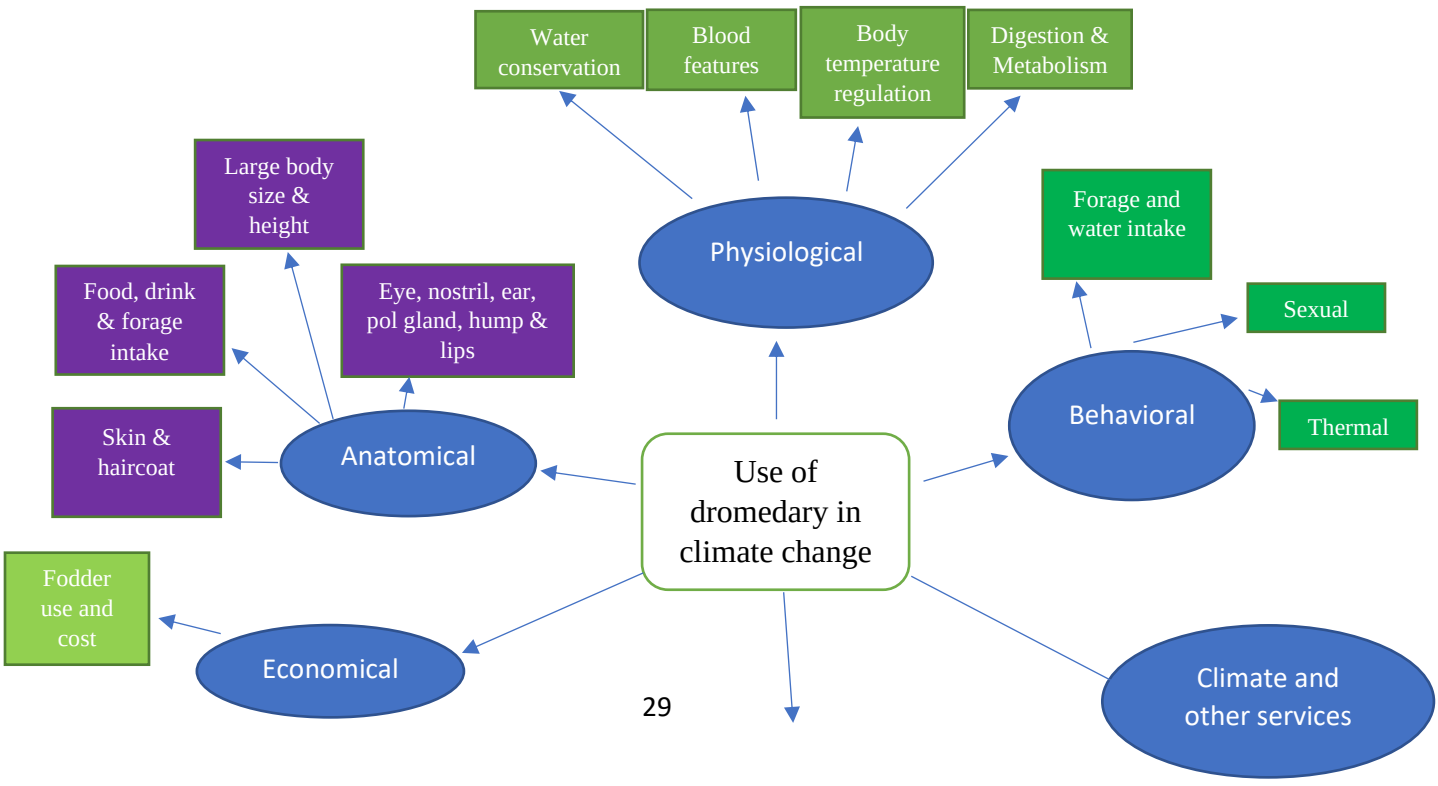
Only two agricultural research stations were used to conduct biophysical research, but more research stations in different locations could have given more diversified data. Thus, better information can be produced. Also, no research station was selected from Kidal, where more than half of the dromedaries in Mali were found.

Chapter 5:

Results and discussion:

Dromedary in climate change adaptation:

Combining different research methods gives insight into key challenges and opportunities for dromedary production in Mali. The study gives an overview of how dromedary can contribute to adaptation to climate change and create resilience against climate change. The figure below shows why dromedary is well adapted to climate change and how dromedary can be used as a tool in climate change adaptation.



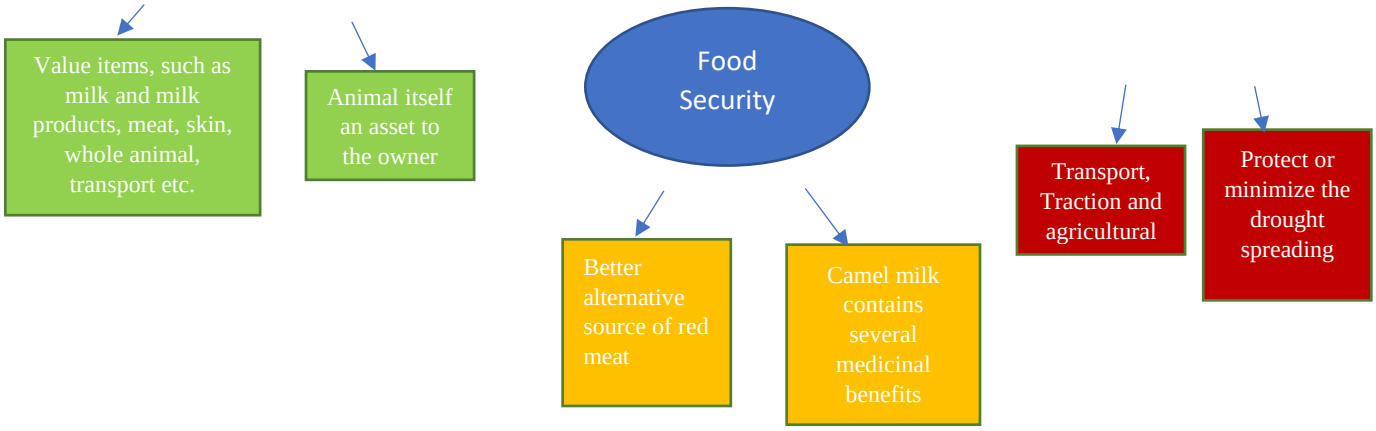


Figure 9: Dromedary in climate change adaptation.

Not every part of the diagram was included in my study: Physiology, and anatomy of camels was not studied in this research. For those parts, only results from other studies will be present.

There are three major approaches in this research, the Bio-physical study of dromedaries and the socio-economic study and the key informant interview among dromedary herders' community. The physical study was done in Sotuba and Niono research station and the socioeconomic study has been done in the form of survey and key informants' interview with representatives from Kidal, Gao, Segou, Mopti and Bamako regions.

This study has five parts concerning 1. Behavioral study to understand adaptation, 2. Role of dromedaries in economy and food security, 3. Services provided to economy and environment, 4. Contribution to the national economy, 5. Health and diseases of dromedary

Behavioral study to understand adaptation:

Behavior (grazing) of adult dromedaries in Mali:

No camel behavior study has been done in Mali before the present study. Dromedary has a behavior that makes it an animal well adapted to climate change. It can move more over long distances at high speed and its behavior on the pasture is primarily determined by the climatic conditions. It is sexual behavior also very much dependent on the seasons. In this study we did not study all the behavioral aspects of dromedary, but we show that the dromedary moves faster in the dry season when fodder is scarce compared to other seasons. Dromedaries resting time more in Sotuba than in Niono because of better fodder availability.

The main activities of dromedaries found in the study were grazing, resting, walking, watering, and rutting. At both sites, grazing remains as principal activity. Rest and walking were the following two activities in Sotuba, while in Niono, walking was the first, followed by rest (Table 1). Watering and breeding took little time, and a few cases of bubbling were observed; however, taken time was negligible. In Niono dromedaries took longer to walk and browse compared to Sotuba, indicating less fodder availability, while resting was more frequent in Sotuba (Moussa et al., 2020).

Table 3: Main resting activities of camels on pasture and percentage of time spent

Type of activities	Niono	Sotuba
	%	%
Bubbling	0.4	0.59
Grazing	61.7	53.2
Walk	25.5	19
Rest	8.9	25.4
Watering	2.7	1.8
Rut/Mating	0.8	0.1
Total	100	100

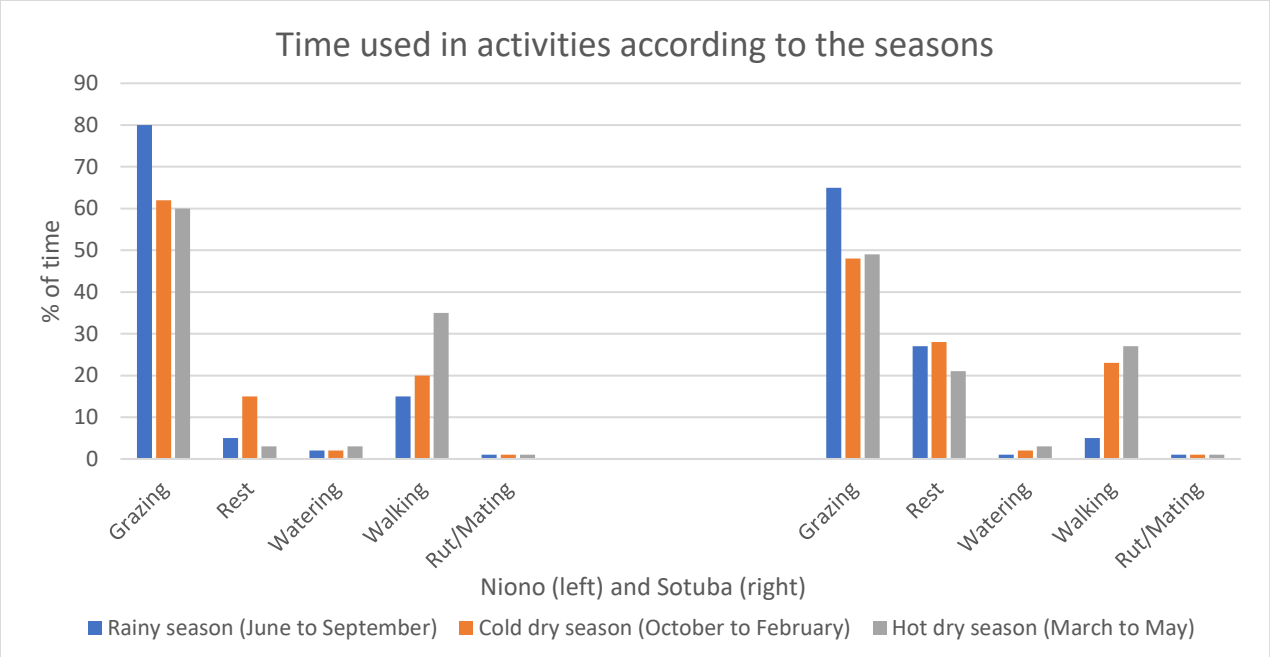


Figure 10: Main activities of dromedaries according to the seasons in Niono and Sotuba

The activities of dromedary change with the seasons. However, whatever the season, grazing remains as the main activity, followed by resting, walking, and watering. Whatever the site, the percentage of the time devoted to grazing was higher in the rainy season than of the other two seasons. This is because the availability of plants during rainy season and in the two dry seasons walking percentages were higher because they need to walk more to get the required amount of food. In every season Sotuba camels can take more rest time than Niono site because it falls under the Sahelian zone with less rainfall and Sotuba is under the subhumid zone with more rainfall and green vegetation so dromedaries can use less time in grazing to fulfill their food demand. This shows the adaptive nature of dromedary according to the climate and season and how they can change their activities according to the requirements. On the other hand, in other two seasons the situation was similar (Figure 10).

Table 4: Different resting attitudes of dromedaries

Rest position	Niono	Sotuba
	%	%
Standing/Stationary	56.5	40.1
Laying	21.9	51.8
Rumination	21.6	6.6
Bubbling/paddling	0	1.5
Total	100	100

The camels adopted a standing position and laying position for resting (Table 4). Standing position was more dominant in Niono but a laying position was more frequent in Sotuba site. One reason for this is that the dromedary can get rid of more heat in a standing position than in a laying position. Laying position means more contact with the soil and hot soil prevents them to lay down. In Niono the temperature is generally higher than in Sotuba. In Niono time used for rumination was similar to laying. On the other hand, in Sotuba, stationary rest was 2nd most by frequency and similar to time used in the laying position but rumination was very short in comparison to the standing and laying position. Bubbling or paddling in the water or on the ground is a resting position was only found in Sotuba, although the frequency was very low.

Resting attitudes differed according to the seasons. Thus, in Niono, no rest in the lying position found during the rainy season and few times during hot dry season. No concrete reason found why time use in laying rest position was low during wet season, but it can be assumed that it may be

due to possibilities of getting dirty and chances of skin infection. During hot dry season also not suitable for lying because the sand or soil become too hot to tolerate. Also, during the cold dry season, standing position was more frequent than of lying down. Rumination was not seen on the pasture during the rainy season, while during the cold dry season its frequency was close to the lying position, but in the hot dry season it down to half than of lying position.

Table 5: Different positions of dromedary at rest according to the seasons in Niono and Sotuba

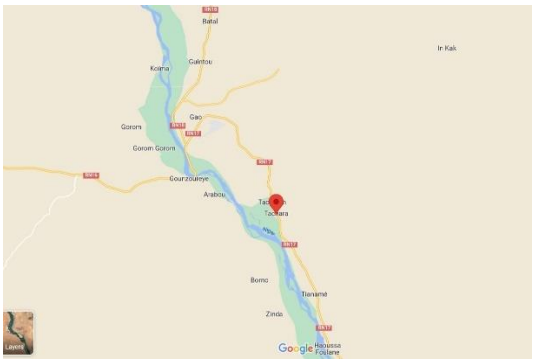
Season	Rest types	Niono	Sotuba
		%	%
Rainy season (June-September)	Standing/Stationary	100	21.7
	Lying	0	70.7
	Rumination	0	3.9
	Bubbling	0	3.7
	Total	100	100
Cold dry season (October-February)	Standing/Stationary	43.8	51
	Lying	30.1	44.2
	Rumination	26.1	4.8
	Bubbling	0	0
	Total	100	100
Hot dry season (March-May)	Standing/Stationary	82.7	55.9
	Lying	1.9	24.6
	Rumination	15.4	19.5
	Bubbling	0	0
	Total	100	100

In Sotuba, as a rest type laying position was more frequent during rainy season, while during other two dry seasons, standing position was dominant. Rumination was more frequent in the hot dry season than other two seasons. Bubbling has only been observed during the rainy season.

Forage intake of dromedaries:

Key informant interview gives us information that dromedary herders use natural grazing ground to feed their animals. But sometimes they need to buy forage from the market to meet the demand. A dromedary needs a minimum 2.5 kilo of dry matter per day. One kilo forage cost in Mali is 40 Fcfa. So, for one dromedary one need to spend only 2.5*40=100 FCFA per day. Based on 3 August 2022 google showing exchange rate 1 West African CFA franc is equivalent to 0.0015 US Dollars. So, 100 CFA is equivalent to only 0.15 $.

One interviewee suggests location is important in relation to grazing pattern and forage intake. He explained that area like Tachara is suitable for grazing. Tachara is in the Gao region south to Gao city, on the bank of river Niger and contains the best pasture for dromedary in the region.



Map of Tachara, Gao, Mali (screenshot from Google maps).

Tachara is well known among dromedary herders in Gao for good quality forage. Kidal region is another source of good quality forage for dromedary (Interview).

According to them dromedary can survive without water for long time but still availability of good quality forage can make them stay within the area. Dromedary can easily eat thorny bushes and herders also use plants from thorny bushes as a medicine for dromedary without any additional cost (Interview). The dromedary selects only a few leaves from each plant and ingests the foliage parts. It prefers halophytes plants. they consume a varied range of fodder including legumes, fodder, grasses, herbaceous plants, woody plants etc.

Chemical composition of fodder on the pastures of Sotuba and those by Niono

In Sotuba, crude protein levels were higher during the rainy season (11.2%) than during the cold (6%) and hot (7.3%) dry seasons (Table 6). Hot dry season forages had a higher rate than cold season forages (Table 6). The same was valid for cellulose (35.1% versus 33.7%). The cellulose rate was lower during the rainy season. However, these rates do not seem to have influenced the digestibility of the dry matter, which was overall low. The digestibility rate was higher during the cold dry season, followed by the rainy season. In contrast, hot dry season forages had the lowest digestibility rate (35.6%).

Table 6: Chemical composition and digestibility of fodder on the pastures of Sotuba and Niono, during different seasons of the year (%)

Site	Season	Dry matter	Organic material	Ashes	Crude protein	Cellulose	Digestibility
	Cold dry	32.7	90.0	10.0	6.0	33.7	45.2
Sotuba	Hot dry	37.59	94.4	7.7	7.3	35.1	36.6
	Rainy	34.30	89.9	10.1	11.2	32.4	42.0
	Cold dry	55.84	90.8	9.2	14.2	26.7	47.6
Niono	Hot dry	55.24	91.2	8.8	11.4	28.8	48.9
	Rainy	44.27	91.5	8.5	12.5	33.9	47.1

In Niono, the highest crude protein content was observed in samples taken during the cold dry season (14.2%), followed by those from the rainy season (12.5%). That of the rainy season was the lowest (11.4%). On the other hand, crude fiber was higher in the forages of the rainy season (33.9%) and lower in those of the cold season (26.7%). The digestibility rate was almost similar between seasons, although the hot dry season was slightly higher.

Overall, protein and digestibility rates were higher in Niono than Sotuba, while cellulose has an opposite trend.

The high rate of cellulose during the rainy season in Niono can be explained on the one hand by the late start of the rainy season during the year of study and on the other hand by the presence of several fruits rich in fibers on certain shrubs such as ***Acacia ehrenbergiana*** and ***Sclerocarya birrea***.

There is no explanation for the low rate of digestibility of fodder from these pastures. But the fact that the analysis focused on the hand samples can have an effect because the quality of this type of sample might differ from that the animals consume.

The migration of dromedaries towards the more humid areas is important as this also indicates that dromedaries can be adapted to the more humid environment (Moussa et al., 2020). One key informant explains the movement of dromedaries depends on the food and water availability. When water and fodder are scarce, they move towards areas where food and water is available. Because herders have to move with dromedary and they also have to survive, so they always prefer a place where man and dromedary both can survive better (Interview).

It usually can graze 4 to 8 hours a day, or more, depending on available resources. In general, it grazes in the morning and evening as long as the weather remain cool (Faye & Tisserand, 1989 and Richard et al. 1985). Seasonal variations have a significant effect on camel's diet. Camels are

important for humans to strengthen resilience against climate change effect (Longo et al., 2007). Also, it can contribute to slowing down the process of desertification or can maintain the current situation without deteriorating for several decades because dromedary hooves are less destructive than other animals (Fayed, 2001).

It was found that, rest was taken mostly between 2 p.m. and 3 p.m., which is the hottest hour of the day. The daily rhythm of activities, observed in the current study was different from (Chaïbou 2005). In the previous study, the author studied herds of dromedaries under traditional grazing mode with a duration from 8 a.m. to 8 p.m. However, in the current study, the driving schedule was set from 9 a.m.-5 p.m., regardless of the season because the animals were in research station. During the rainy season, camels went out from 10 a.m. after the morning and in the cold dry season they came out earlier at 9 a.m. The animals thus had less grazing time, which probably resulted in an accelerated of the grazing rate. However, camel's grazing time can vary from 4 to 8 hours or even more depending on the density of available resources (Faye et al. 1997). The percentage of grazing time is higher during the rainy season due to the availability of the fodder in this season. Indeed, camels need less movement to have access the fodder. On the other hand, in the dry season, fodder becomes scares as the season progresses. Therefore, walking and grazing of animal were more frequent and rest rarer. This observation is confirmed by other study where it indicated that the speed of the dromedary movement is higher in the dry season (4.85 km/h) than during the rainy season (2.81 km/h), however the speed of grazing has evolved in the opposite direction: 0.32 km/h during the rainy season, against 1.027 km/h in the dry season (Hoshino et al. 2017). All these findings indicates that during the dry season availability of fodder resources are more limited than in the rainy season and consequently the dromedary must move faster to get access it (Moussa et al., 2020).

Reproductive behavior of female dromedaries in Mali:

It is important to study reproduction to understand their capacity of surviving in harsh conditions. The study showed no apparent difference between Niono and Sotuba, which indicates that the dromedary is well adapted to different parts of Mali regarding reproduction.

Table 1 represents the reproductive status of females as of June 30, 2016. The fertility rate is high in both Sotuba and Niono, while the birth rate was higher in Sotuba than in Niono. The birth rate of Niono is lower, due to the fact that there were still pregnant females left.

Table 7: Main reproductive parameters of females from February 2013 to June 30, 2016

Parameters	Sotuba	Niono	Sum
Number of dromedaries	12	17	29
Number of pregnant dromedaries	11	15	26
Number of dromedaries given birth as of June 30, 2016	10	9	19
Number of abortions	1	1	2
Number of premature births	2	0	2
Number of pregnant dromedaries as of June 30, 2016	1	6	7
Fertility rate	91.7	88.2	90.0 (average)
Birth rate	90.9	64.0	77.5 (average)
Abortion rate	9.1	6.7	7.9 (average)

The pregnancy period of the camels was the same in Sotuba and in Niono. On the other hand, postpartum duration was significantly longer in Niono than in Sotuba. However, it was not possible to explain this difference because the herd management techniques were same on the two sites. Indeed, the parent was permanently in the herd with the females.

Table 8: Duration of pregnancy and postpartum in camel herds in Sotuba and Niono as of June 30, 2016

Parameters	Sotuba			Niono			Total	Probability
	Mean	Minimum	Maximum	Mean	Minimum	Maximum		
Pregnancy duration (Days)	369.5 (20.1)	278.0*	417.0	362.2 (13.1)	334.0	404.0	362.2 (11.9)	0.778
Postpartum duration (Days)	100.4 (27.8)	29.0	279.0	234.5 (50.1)	81.0	366.0	154.1 (30.5)	0.025

* The camel was born premature and died 3 days after birth; the numbers in parentheses indicate the standard error

The average duration of pregnancy for camels that gave birth to females was 375.3 ± 10.6 (ES) days against 342.0 ± 34.0 days for those that gave birth to males. The minimum and maximum values were 334 days and 417 days in females and 278 days and 394 days in males. The sex of the calf did not have a statistically significant effect on the duration of pregnancy (P = 0.233).

The fertility rate does not differ between Sotuba and Niono. The study showed that geographical and climate difference did not affect on the fertility rate which is a good sign of adaptability. In the stress condition it can maintain the reproduction capacity without needing extra effort.

The birth weight of the calves is presented in Table 3. No significant difference was observed between the two sites. However, the coefficient of variation was higher in Sotuba than in Niono.

Table 9: Birth weight of calves in Sotuba and Niono

Sites	Number	Weight (KG)	Standard error	Coefficient of variation	Minumum	Maximum
Sotuba	9	29.8	2.1	21.2	21.5	38.5
Niono	9	28.3	0.9	9.7	26.5	35.0
Mean	18	29.1	1.3	16.5	21.5	38.5
Probability		0.517				
Significance		NS				
NS: Non-Significant						

Similarly, no significant difference was observed between the weight of males (30.2 ± 1.9 kg) and that of females (27.7 ± 0.6 kg) even if the former is slightly heavier. (P = 0.277) with a coefficient of variation three times higher (20.1%) than in females (6.6%). Increasing the sample size would better elucidate this issue.

No correlation was detected either between the duration of gestation and the weight at birth of the calf (r = 0.079; P = 0.85) or between the weight and the duration of postpartum (r = 0.188; P = 0.65). On the other hand, there is a negative but non-significant correlation between the duration of gestation and the duration of postpartum (r = - 0.66; P = 0.08). However, these results should be taken with caution due to the low amount of data.

Birth weight also correspondence the fertility rate, no significant difference found due to change of location and climate. These parameters suggest healthy calf irrespective of any location which can ensure stability and give confidence to dromedary herders.

Corresponding results from the survey in Kidal:

Survey data showed the most breeders (74.2%) manage reproduction by removing the sire from the herd, while 24.0% keep it throughout the year. Weaning age is set at 12 months by 77% of breeders, while 9.4% extend it to 18 months. The age at the first mating was three years for 65.3% of breeders and four years. for 19.6%. For the rest, it varied between 2.5 and 3.5 years. Males not retained for breeding are either castrated (24% of breeders), taken out of the herd to serve as transporter (35.1%) or used in various works (23.5%). The interval between giving birth was two years for 65.5% of the breeders, while 19.4% used a three-year interval or more.

Importance of reproductive behavior in adaptation:

The sexual or reproductive behavior of an animal is important to know that how it can cope with the situation to reproduce. The reproductive physiology of camelids is not same as other livestock as it differs in many aspects. Female camels do not have any regular oestrous cycles that are typical to spontaneous ovulators. Hence, like other farm animals such as sheep and cattle they do not exhibit distinct periods of overt oestrus. (Mahla et. al. 2015).

Species that inhabit arid and semi-arid areas with unpredictable environmental conditions display more opportunistic breeding patterns, with young born over a more extended time. The camel's reproduction is characterized by a seasonal activity which is typically timed to ensure that parturition occurs at a favorable time of the year to maximize offspring survival. (Gebreyohanes & Assen 2017).

The reduction in postpartum duration is a sign of improvement in reproduction compared to traditional breeding where duration is at least 12 months. The seasonality of reproduction deserves is critical as a female can come into heat a few days after giving birth and be mated when nutritional conditions are good (Faye et al. 1995 and Zarrouk et al. 2003). The postpartum duration found in this study was longer than Hammadi (sd) who found a calving-mating interval of 17.92± 9.11 days by early weaning the calves at 15 days after birth. This reduction will help to reduce the interval between two successive calvings. Hammadi (sd) found an interval of 403.5± 8.2 days against 714.6 days under traditional condition in southern Tunisia (Ouologuem et al. 2020).

(Nagy et al. 2015) reported that fertilizing protrusion causes milk production to drop sharply. The shortening of lactation varies from 220 to 249 days (34.2% to 37.6%), which caused the drop in total milk production between 1532 and 2151 liters. All these authors recommended breeding at mid-lactation, but milk production will drop four months after conception. The Niono results about postpartum duration seems to correspond the recommendation of (Nagy et al. 2015).

The method used in this study to diagnosis of pregnancy is "raised tail" method, which is quite simple and practical, but it is 80-90% accurate. Mistakes are therefore possible. The average duration of pregnancy here is 362 days which is shorter than 376 days found in southern Algeria. The duration is influenced by several factors such as race, sex of the fetus, season and nutritional level etc. (Aichouany, 2011 and Zarrouk et al. 2003).

Role of dromedaries in economy and food security:

Income generating source:

To get an idea about ins and out of dromedary farming it is important understand the herder's lifestyle. Our survey in Kidal showed that, 74.2% of those surveyed gained their income from livestock farming only, 21.1% practice dromedary production in association with other business, 2.1 % have job or is employed: only 2.5% had a third activity such as craftmanship in addition to livestock and trade. The objectives of breeders are diversified. 39.7% declared milk as the sole objective of breeding, 30.9% breeders said the objective is not only for milk but also for meat and monetary income, 20.6% practice this breeding for meat in addition to milk, 6.2% for milk, meat, hides and monetary benefits, 1% of respondents doing this for financial benefits and 1.5% for meat and others. Among respondents 56.2 % raised dromedary only. However, keeping dromedary in association with goat, sheep and cattle in different combination is a common practice in the region.

For a quarter of the surveyed population, the dromedary was the only source of household income, while it contributes 90% of income for 23.0% of households, 80% for 30.8% households and 60% for 21.6% of households.

Structure of surveyed camel herds:

The number of animals surveyed was composed of total 14,618 camels. The number of dromedaries reared by one herder, or a family of herder is termed as "herd". The herd size differs from small to very large. The mean herd size was 75.7 ± 3.4 dromedaries. The smallest herd consisted of 10 dromedaries, while the largest included 266 dromedaries. For this study herd size

categorizes in four groups, “small” contains 1-50 dromedaries, “medium” contains 51-100, “large” consists of 101-150 dromedaries and “very large” means more than 150 dromedaries. However, ranking these herds by size showed that the “medium” and “small” are the most numerous. They are followed far behind by the category “large” and “very large” (Table 10).

Table 10: Distribution of dromedary herds according to their number in the Kidal region.

Classification of herd composition	Number of herds	Average number of dromedaries in a herd	Standard deviation
Small (1-50)	71	35	8
Medium (51-100)	73	70	14
Large (100-150)	35	127	14
Very large (150+)	13	192	31
	192 (Sum)	75.7 (Mean)	3.4

The distribution of herds by circle shows Abéibara had only small herds, while in the other three cercles, all categories were present. Medium-sized herds were more numerous in the circle of Kidal, followed by Tessalit and Tina-sako. On the other hand, Tessalit had more large and very large herds than the other three circles (Figure 11).

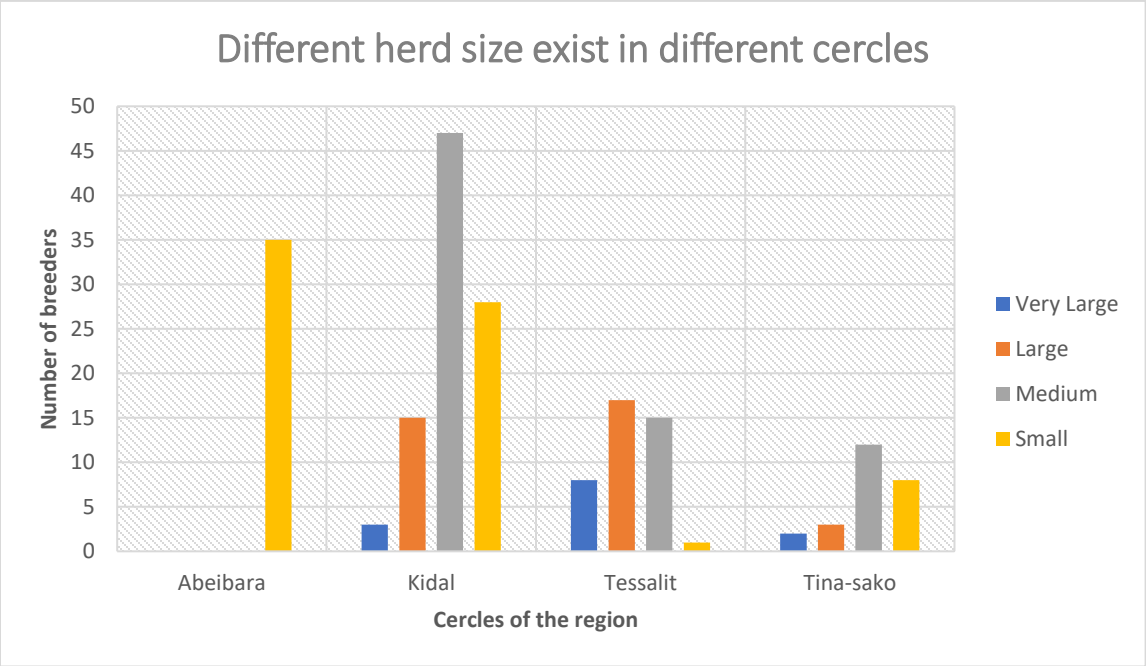


Figure 11: Different herd size exist in different cercles

Non lactating adult females were dominant in the herd, followed by non-breeding adult males and castrated males. The trend was the same in all four herd classes.

Herd management:

59% of respondents said a family member carries out herd management. In 75.4% of the cases, this labour was unpaid, while in only 24.6% of the cases, shepherds got paid. Breeders were reluctant to give a vaccine or internal or external deworming. About 94.8% of the dromedaries were not vaccinated, and in 84.0 % of the cases deworming was not carried out. The dromedary owners explained this reluctance as the inaccessibility to veterinary services (45.4%), lack of vaccine (24.0%), and ignorance of the benefits of these practices (11.7%). Anthrax is the disease against which vaccination was most frequent (75%). The average mortality rate was less than 10% (Table below). The mortality rate was lower among small and medium-sized herds than in the large and very large-sized herds. The mortality rate was highest in young suckling males, followed by females, especially in large and very large herd groups. However, young, weaned males' mortality rate is high in small-sized herds.

Table 11: Mortality rate of dromedaries according to herd classes

Classification of herds	Male adult	Female adult	Young male (Weaned)	Young female (Weaned)	Young male (Unweaned)	Young female (Unweaned)	**Mean**
Small	8.3	8.2	13.7	8	12.9	11.5	**6.2**
Medium	3.8	6.5	6.4	2.5	10.8	7.2	**6.2**
Large	6.2	7.5	5.8	2.9	17.7	14.2	**9.1**
Very large	4.3	6.5	9.8	11.2	26.1	14.5	**12.1**
Mean	**5.7**	**7.2**	**8.9**	**6.2**	**16.9**	**11.9**	**8.4**

Feeding and watering:

Camel farming is extensive, and the animals are fed almost exclusively on pasture (94.4%); Only 5.6% give oilseed by-products such as cottonseed meal as a supplement. Transhumance (moving livestock from one grazing ground to another in a seasonal cycle) was practiced by 76.3% of herders. For 85% of the breeders, the movement accounts for all categories of dromedaries except for a few dairy and weak animals. The average distance of the transhumance was 76 km, but it varied from 10 to 400 km. The average duration of transhumance was 3.4 months, ranging from 2.7 months in Tin-Essako to 4.1 months in Tessalit. In Kidal and Abeibara, the time was 3.3

months. A few breeders (12.5%) still practice nomadism. In addition to transhumance, herders have adopted different grazing methods, such as grazing at other times of the day and night. Depending on the season and weather, grazing can only be done during the day. The watering point for the animals was, on average, 20 km from the grazing ground, but the distance varied from 2 to 100 km depending on the breeders and the seasons. However, animals can access runoff water and nearby temporary ponds during the rainy season.

Constraints:

Food and diseases were the significant concerns of camel breeders. The food difficulties were due to the low productivity of the pastures, the disappearance of certain fodder species that are more palatable and richer in nutrition, and the lack of water, especially in the hot, dry season. They force many herders to travel long distances in search of food and water. The lack of health coverage has made pathologies such as anthrax, abortive diseases, camel diarrhea, and dermatoses a significant concern for breeders.

The average camel herd size observed in the present study was comparable to that observed by (Koussou 2009) in Chad, which was 66 ± 26 heads. In Niger, (Chaïbou & Faye 2005) found that 58% of herders owned between 50 and 100 camels, which is comparable to our results. However, in the Agadez dairy basin, (Chaïbou 2009) indicated that the camel herd has an average of 28 camels.

Ecotypes of dromedaries:

From the survey data five types of dromedaries found in the kidal region. Four of which are considered to be thoroughbreds (no crossbreed) and the fifth is a product of crossbreeding by breeders according to ecological zones. Thus, the Talamt-Nadagh or Tolmen-Nadagh type is encountered mainly in Adrar, the Talamt-tan Tamesna in Tamesna, the Talmarokit in Tessalit and in Tilemsi and finally the Tatawgite in the Timetrine in the west of the region on the border with the region of Timbuktu. However, these types have not yet been the subject of detailed phenotypic or genotypic characterization. These ecotypes are adaptive to the local environment and can provide services even in the difficult climatic condition.

According to key informants there are several types of dromedaries found in the country. Most of the times pastoralists use crossbreeding techniques to create a better type. There are several races

present like a type which is better for milk, a type better for meat and most of the types the cross to find a more adaptive and stronger race

Dromedary rearing:

Key informants suggest the place of the dromedary among livestock was better perceived after the droughts of the 1970s, 1985 and 2003 by its resistance compared to all the other animal species raised in the area. This assertion is confirmed by (Bourzat & Wilson 1987) and (Bourdanne 1998) who asserted that the camel population increased in the Sahel and North Africa after the great drought. The combination of camel breeding with other animal species seems to be a more resilient system against climatic hazards. This combination was also observed by (Traoré et al. 2014), (Chaïbou 2009) and (Faye et al. 2012).

The way of life of the camel herders is closely related to the management of camel breeding. Indeed, the method of driving, the mobility of the herd, the use of traditional plants are ways of managing the herd in terms of food, reproduction and animal health. The study by (Chaïbou & Faye 2005), (Chaïbou 2009) and (Mabrouk et al. 2010) indicated that herd mobility is an essential component of herd management. The ancestral knowledge of medicinal plants has enabled breeders to treat certain diseases where veterinarians are rarely accessible. These practices have been studied by (Diallo & Traoré 2009), (Antoine-Moussiaux et al. 2005). The breeding age of three to four years was comparable to data from Moslah et al. (2004), Zarrouk et al. (2003) and Titaouine (2006). The interval between two consecutive birth is two years was also comparable to the results of these authors. Mobility as a mode of feeding management is well known (Traoré et al., 2014; Chaïbou, 2009; Titaouine, 2006). Distances also depend on the availability of food and water. The ecotypes of dromedaries encountered in the region showed that the best dromedary for running in the country come from this region. Therefore, quite specific research must be carried out for their characterization.

Milk production:

The result from survey in the Kidal region:

Milking is done twice a day by 84.1% of farmers, while only 2.9% did it three times a day. 98.6% of the product was managed by the wife of the head of the household or under her responsibility. The quantity of milk taken by the shepherd for family consumption and estimated by the

respondent was statistically identical between the categories of herds (Table 12). The same observation was made between the four circles of the region.

Table 12: Quantity of milk in liters taken by the shepherd (for family consumption) according to the seasons

Classification of herds	Amount taken by the shepherd in the rainy season	Amount taken by the shepherd during the dry season
Small (1-50)	2.5 (0.7)	1.3 (0.5)
Medium (51-100)	2.7 (0.8)	1.4 (0.5)
Large (100-150)	2.6 (0.7)	1.4 (0.4)
Very large (150 +)	2.4 (0.5)	1.2 (0.5)
Mean	2.6 (0.7)	1.3 (0.5)
Significance	P = 0.282	P = 0.578
Numbers inside brackets indicate standard deviations.		

The above table from the survey report failed to show any valid data about milk production of Camel from that region. Instead, it gives an idea of what a shepherd is collecting only to meet up family needs. But a critical piece of information we are getting is that dromedary milk production is going down almost half during the dry season than the rainy season.

Results from Niono and Sotuba research station:

Results from two research station in Niono and Sotuba show differences in milk production. There was a significant difference between dromedaries (P = 0.001) in both Sotuba and Niono. The average daily production was 1.35 ± 0.78 kg in Sotuba, while it was 4.2 ± 1.53 kg in Niono (Table 13).

Table 13: Daily and monthly milk production (kg) in Sotuba and Niono

Daily milk production (kg)				
Site name	Average daily production (kg)	Standard Deviation	Minimum (kg)	Maximum (kg)
Sotuba	1.35	0.78	0.1	4.9
Niono	4.2	1.53	0.6	8.3

Monthly milk production (kg)				
Site name	Average monthly production (kg)	Standard Deviation	Lactation duration in days	Production par lactation (kg)

Sotuba	43.70	17.90	278.5±79.2	380.9±144.3
Niono	115.2	23.1	332.3 ± 39.0	1395 ± 306

The average production in the Sotuba, was less compared to Niono. The average lactation duration was 278 ± 79 days in Sotuba and 332.3 ± 39.0 days in Niono. But depending on females this duration varied from 101 days to 406 days. In Niono this duration varied from 291 to 405 days.

During this period, the average milk production per lactation was 1,395 ± 306 kg/dromedary in Niono, compared with 380.9 ± 144.3 kg in Sotuba.

The season significantly affected dromedary milk production ($p < 0.0001$). In Niono, winter season parturitions show increased production (1.5 ± 0.82 kg), followed by the rainy season (1.1 ± 0.56 kg). Camels that gave birth in the hot dry season produced the lowest daily production (0.88 ± 0.49 kg).

In Sotuba, daily milk production is also influenced by the season. Females calving during the dry season had significantly higher production (4.6 kg) than those calving during the cold season (4.1 kg) which is opposite of the Niono region. But this information must be interpreted with caution due to the very low number of animals monitored during the hot season.

Key informant observation on dromedary milk production:

Key informants explained that dromedary milk production is not well measured due to several causes. First, herders only take the amount of milk they need for themselves. Second, they are nomad people with a nomadic lifestyle, and they are always on move. They do not preserve the milk. Also, they don't have any fast transport with freezing capacity and, as a result they don't preserve milk. Thirdly, selling point of dromedary milk is far from its location when they are on the move. Finally, they don't have proper knowledge and technology to preserve milk or transform it into cheese or curd. According to them wastage of milk is very high, and it is, therefore, difficult to measure dromedary milk production.

Survey results from Kidal region indicating daily milk collection was of 2.6 l during the rainy season and 1.3 l during the dry season (mainly for family consumption). This was comparable to those found by (Traoré et al. 2014) in Ansongo, by (Titaouine 2006) in southeastern Algeria and (Chaïbou 2009) in Niger, but lower than those of (Kamoun 1995) in Tunisia. It does not reflect the

real potential of camels. However, it should also be noted that the rainfall in Kidal is extremely low and most of the dromedaries lack proper veterinary treatment (vaccination and deworming).

Though camel's adaptation against climate change is well known but no previous research found except for some occasional survey data. The level of camel milk production depends on several factors such as type of camel, milking method, breeding conditions, even the skill of the milker (Ouologuem et al. 2020). Seasonality, severe water deprivation also affecting milk quality and composition. Camel's milk composition strongly depends on season because quality of food, water availability, heat stress affecting the total solids of milk, and this has a direct impact on the camel milk components. Location is another factor affecting camel milk composition as food availability and quality varies with geographical location. (Al Jassim & Sejian, 2015).

Camels have the capacity to produce more milk for longer period during drought than any other domestic animals, which is of great value for pastoralists and agro-pastoralists (Al Jassim & Sejian, 2015).

Southern Sahel zone (Niono) and the sub-humid zone (Sotuba) were selected for the experiment. After grazing, animal from each area received same amount of feed with same energy contains. There are clear differences in milk production of dromedary in accordance with region.

The sub-humid zone Sotuba has a production rate of 1.35+-0.78 kg but in Niono it was 4.2+-1.53 kg which is significantly higher than Sotuba. The average milk production per lactation was 1395+-306 kg/dromedary in Niono where rainfall trend is 400-500 mm/year whereas the rainfall trend in Sotuba is 800-1000 mm/year but the milk production per dromedary per year is much less, 380.9+-144.3 kg.

The milk production obtained in Sotuba was low compared to Kidal. This may indicate that dromedary is better adopted to northern Mali. However, it is necessary to judge these productions in the context of the subhumid farming zone and other related factors. This is an area where it was not known if the dromedary could survive. Regular production of more than one liter per day cannot be considered good if considered what a goat can produce, but rather as a possible adaptation of animals to their new environment.

Management and benefits of camel milk:

The milk produced is managed in 98.4% of cases by the wife of the head of household. It is intended for self-consumption for 88.0% of respondents or given to neighbors or relatives. In 98.0% of cases, camel milk is not sold. The main reason is cultural (87.6%) and insufficient milk or inaccessibility of the market (12.4%). Curd is the main product processed from camel milk (73.9%), but 2.6% reported making butter in addition to curd and 1.7% cheese. For a quarter of the surveyed population, the dromedary was the only source of household income, while it contributes 90% of income for 23.0%, 80% income contribution for 30.8% and 60% contribution for 21.6% of households.

Camel has the unique ability to produce milk under more difficult weather conditions than other livestock. During dry season and in dry areas milk production may get lower than usual but still high enough to beat other domestic animals in milk production (Faye et al. 1997). Daily milk production varies between 2 to 15 liters under various conditions in different countries. According to (Bourdanne 1998) camels in Mali by Malian Hodh can produce 6-7 liters per day under the condition when fodder is adequate, and this production remains 7 liters average in winter and 6 liters in the dry season. Not only the production of milk but also composition of camel milk can contribute more to climate resilience than other types of livestock. For example, compared to the cow's milk it contains less fat, comparable rate of proteins and greater vitamin C contain (25-100 mg/ kg of milk) than cow's milk (50mg /kg). The characteristic like low amount of butyric acid facilitates good preservation under ambient temperature conditions.

Dromedary milk is also rich in the amino acids theromine, proline, thiamin, riboflavin, niacin, pantothenic acid and other vitamins (Pacholek et al., 2000). The average amount of components of dromedary milk is protein 3.1%, fat 3.5%, lactose 4.4%, ash 0.79% and total solids 11.9% (Zibaee et. al. 2015).

In terms of preservation under ambient temperature camel milk has other characteristics like smaller size fat globules (1.2μ to 2.4μ) improves storability under ambient environment than that of other species. Camel milk is also containing high antimicrobial factors, lactoferrin and lysozyme. Iron contains of dromedary milk (3.16 ± 0.03 mg/l) higher than cow (0.29 ± 0.02 mg/l) and Human (0.26 ± 0.05 mg/l). Dromedary milk also rich in minerals and manganese (7.96 ± 7.4 μg/l) which also higher than cow (2.78 ± 5.2 μg/l) and human (4.4 ± 04 μg/l) (Pacholek et al.,

2000). All those above characteristics indicate that camel milk can be kept longer in the ambient air than milk form other types of livestock. This is essential in relation to food security and adaptation to climate change. It can be conserved without use of refrigerators. It contributes to health and nutrition, such as helps to combat against certain infections and malnutrition, in particular anemia in children and the elderly, hence therapeutic properties attributed to it.

Meat production:

Camel meat production is increasing every year since 2013 except 2017 and 2018 shown below

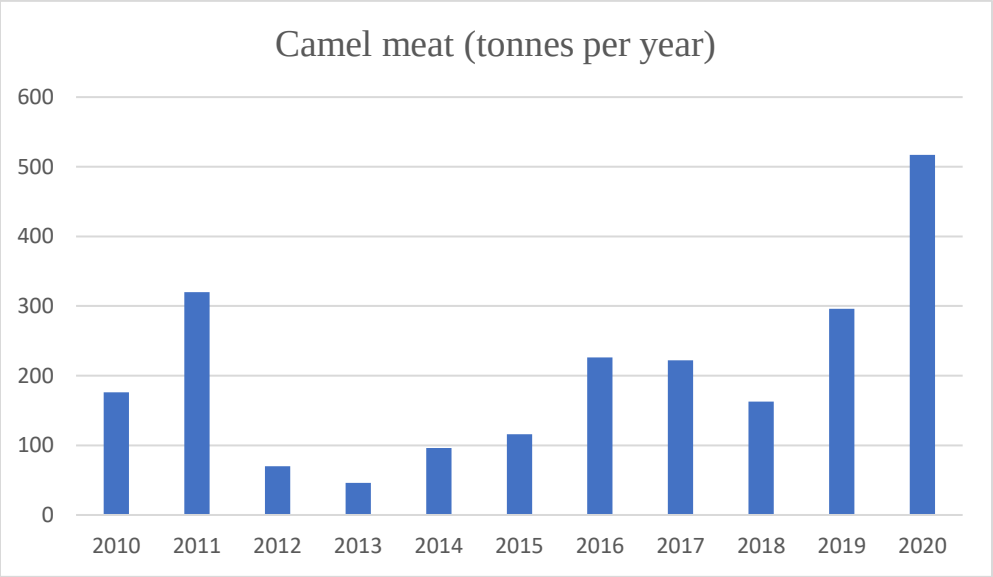


Figure 12: Camel meat production data (tonnes per year) (FAOstat 2020, DNPIA 2015, 2016, 2017)

Table 14: Number of dromedaries, slaughtered camels and meat production

Year	Number of slaughtered dromedaries	Number of dromedaries	Camel meat (kg)	Meat production per dromedary (Total meat/total slaughtered)	Percentage of slaughtered dromedaries (Total camel/total slaughtered)
2010	1146	904425	176000	153.577661	0.12671
2011	1817	922514	320000	176.114474	0.196962
2012	560	940964	70000	125	0.059513
2013	274	959783	46000	167.883212	0.028548
2014	564	978979	96000	170.212766	0.057611
2015	967	998558	116000	119.958635	0.09684
2016	1475	1028609	226000	153.220339	0.143398
2017	1404	1192900	222000	158.119658	0.117696

2018	1013	1216758	163000	160.908193	0.083254
2019	1642	1241093	296000	180.267966	0.132303
2020	2746	1265915	517000	188.273853	0.216918

Camel's contribution to the national meat production was estimated 0.12% only in 2012. It has increased to 0.19% in 2015 without counting the Kidal region (DNPIA, 2015). Mali is suffering severe climatic stress and has experienced several droughts in the last 60 years and water bodies and vegetation on the decline (https://reliefweb.int/report/mali/climate-change-and-violent-conflict-mali). As a consequence, food security is a major issue. Camel is a very good alternative in meat production because this animal is historically known for its adaptive capacity in the dry and harsh condition. Though camel slaughtering needs some technical and physical arrangement than of other animals but still this can be a good alternative to keep up the meat demand.

The growth of meat production is linked to the increase in the number of slaughtered animals and the increase in carcass weight following the increased demand of the populations. This demand is explained by the need to diversify animal protein sources, but above all the dietary quality of camel meat (Faye et al., 2013). Indeed, it contains less cholesterol than the meat of other domestic species, which is very important selling point and also a healthy diet alternative for people. Camel meat also contains vitamins such as thiamine (B1) 0.12 mg/100 g; Riboflavin (B2) 0.18 mg; pyridoxine (B6) 0.25 mg; and alpha-tocopherol (Vitamin E) 0.61 mg/100 g of meat. In harsh weather people have less choice for food and mainly depends on red meat as a meat source, so camel meat is more healthy or less harmful than other red meat and easily available in this climatic condition.

Table 15: Cholesterol content of the meat of some animal species by different authors reported by (Faye et al. 2013)

Species	Cholesterol mg/100g meat	Authors
Dromedary	50-61	El-Magoli et al., 1973 ; Sinclair et al., 1982 ; Holland et al., 1991 ; Abou-Tarbouch et Dawood, 1993 ; Sales, 1996 ; Kadim et al., 2008 ; Madruga et al., 2008 ; Yousefi et al., 2012, tous cités par Faye et al., 2013.
Cattle	59-73	
Sheep	53-78	
Goat	63-71	
Pork	60-80	
Chicken	57-76	
Ostrich	62	

Camel meat is very healthy diet but still posing only marginal contribution to the world production of red meat due to the low size of the camel population. The demand of camel meat is increasing outside typical camel areas. Since 1961, the world camel meat production has increased steadily with an annual rate 2.8%, and total production has increased from 123,000 to 381,000 tonnes (FAOStat, 2011) and in 2020 total production was 607,000 tonnes (FAOStat, 2020). Nevertheless, the contribution of the camel meat to the world red meat production represents 0.45% of red meat and only 0.13% of the meat produced in the world (Faye et al., 2013). But in the Sahelian countries and in the near east, it is found that camel's share in the red meat production is much higher with 4.1% in East Africa, 4.8% in North Africa and 2.9% in West Africa and 3.7% in the Middle East. Camel meat is not well accepted as a daily meal, but it is mostly consumed during festivals and certain festive events. But in several countries, such as Sudan, Ethiopia, Eritrea, Djibouti and in Somalia is found in the daily eating habits of the inhabitants. On the positive note, this habit is growing in the Maghreb, Gulf countries and in few Asian countries like Pakistan, Kazakhstan, Turkey etc.

Services provided to economy and environment:

Dromedary traction:

Dromedary traction is a useful service to pull cart, carrying goods, pulling water, transport man or machinery, use as an agricultural tool or replace working cattle etc. All these services can provide benefits to a community in relation to climate change adaptation. In an area like Kidal where roads of low quality, dromedary represent an excellent mean of transport.

From interview it is found that, camel is not only used in ploughing but also for transporting goods, pulling carts or transporting humans. In Gao they use camels' traction mainly for transporting millet and sorghum. In Bamako camel riding is to some extent used for recreational purposes. Pulling water from wells is a very common practice in the dry region like Gao, Tombouctou, Kidal etc. To pull water with camel traction is an important alternate of using motorbike or human energy, this is also environment friendly and priceworthy than using water pump or motorbike.

A study that was conducted showed the work speed of dromedary compared to cattle.

Table 16: Variability of camel and cattle working time

Activity	Working cattle (Time in hour: min)			Dromedary (Time in hour: min)		
	Start	End	Total hours	Start	End	Total hours
Plowing	9:19	16:08	7:11	8:10	13:45	5:35
Ridging	9:09	15:21	6:21	9:12	13:20	4:08

In working duration camels are using fewer working hours to give the same result as cattle. This is true for both plowing and ridging activities.

Table 17: Body temperature variability at work in camels and cattle

Activity	Working cattle (temperature in degree Celsius)			Dromedary (temperature in degree Celsius)		
	Start	End	Deviation	Start	End	Deviation
Plowing	38.4	39.5	1.1	37.32	38.30	0.98
Ridging	37.61	39+.61	2	37.5	39.2	1.8

Camel's body temperature is always one degree lower than cattle, and this is true for both start and in the end of work. This lower temperature help camels to keep their thrust in control.

Table 18: Variability of heart rate at work in dromedary and cattle

Activity	heartbeat per minute (bpm) (cattle)			heartbeat per minute (bpm) (dromedary)		
	Start	End	Deviation	Start	End	Deviation
Plowing	63	74	11	56	65	9
Ridging	60	68	8	56	60	4

Dromedary heartbeat and respiratory cycle both is lower than working cattle during start and in the end of work.

Table 19: Variability of respiratory rate at work in camels and cattle

Activity	Respiratory cycle per minute (cattle)			Respiratory cycle per minute (dromedary)		
	Start	End	Deviation	Start	End	Deviation
Plowing	18	26	8	12	16	4
Ridging	17	24	6	16	19	3

All those data help to explain dromedary's higher working capability. Ability to keep the temperature and heart rate lower than working cattle gives an advantage to dromedary to minimize the water need for them. Also, dromedary can plough and ridge a field faster than cattle.

Key informants also suggests that use of camels can also be an alternative to use motorized traction. This may also save fuel.

Camel's traction services and its benefits to climate change adaptation:

Animal traction in agricultural is a very common practice in developing and less developing countries despite the technological boom in the 20th century. The principal use of animal traction is in agricultural operations like ploughing, weeding, sewing and ridging. Draft animals are also used for transportation of food, water, wood, harvests, manure and also people (La traction animal, 2010). The 21st century is observing the continuous technological advancement and developed countries have already almost abandoned the use of animal traction and in developing nations where production system is evolving is also experiencing more use of tractors and rototillers instead of draft animals. Currently, only least developed countries use animal traction in agriculture. According to FAO (Food and Agriculture Organization of the United Nations) it is estimated that around 400 million animals generate energy for agriculture through groundwork and transportation (La traction animal, 2010). Many countries in sub-Saharan Africa are seeing the growth in animal traction especially among drier rainfed farms of small-scale farmers.

An example of the growth of animal traction has been documented from Mali. In 2002, 35 percent of cropped area was cultivated using animal traction which was 4 times higher than that of 1964. There were 800000 work oxen, 170000 donkeys, 50000 horses and 1000 camels used to operate equipment like 350000 ploughs, 250000 cultivators, 100000 seeders and 230000 carts (FAO, 2010). In Mali, use of animal traction power in agriculture is a common practice. Animal traction technology is a significant component of agricultural mechanization especially where labor and technology are limited and difficult to obtain. Livestock industry in Mali plays an important role in the national economy and 30% of the primary sector and 9% to gross domestic product (GDP). Agriculture contributes 35 percent of its GDP and almost 80% people involved in agricultural activity (FAO, 2017).

Camels are physically tall, strong and can move fast. They have large feet and well adapted to long distance movement in harsh arid conditions. They can pull carts and plough fields, but they have high fodder requirements and are costly for smallholder farmers (Starkey, 2011).

Malians are looking for camels more and more due to their robustness. Previous drought (1972-73, 1985 and 2002) has made it necessary for farmers and pastoralist to develop adaptation measures to droughts. During droughts cattle or other animal cannot survive or work but dromedary can.

Contribution to the national economy:

Dromedary is a multiservice animal which can provide a wide range of services like transport, water pulling, agricultural tool etc. or can provide food like milk or meat, aesthetic value like creating tourist attraction with dromedary or organizing race, and finally dromedary itself as an asset which can be traded in a time of need.

Transportation and labour services by dromedaries are generating revenue these days. Those services and costs are given below-

- Labour and ploughing service per day cost 7500 Fcfa
- Goods transportation (agricultural goods, food products, millet, sorghum etc.) over 50 km costs 7500 Fcfa to 20000 Fcfa depending on distance and products.
- Transporting human from place to places or taking them to market and return, distance over 50 km costs 500 Fcfa /per person. They arrange seats and take up to 30 persons for one movement.

(Source: Interview).

From key informant interview it is found that, dromedary can provide food to the people who are leaving far from home. Tuareg population in Kidal or any other region use dromedary milk as a source of protein and vitamins. Also, the children and women, are benefiting from dromedary milk. Dromedary buying and selling is the main income source of many families in the Kidal region. From interview we got to know that, day by day dromedary is replacing slowly the position of cattle in Mali specially in the northern part where weather is hotter and drier than southern part. This statement is supported by data, because DNIPA (2015) report showed 52.9% of total

dromedaries (533530 heads) in Mali was found in Kidal whereas only 0.71% of total cattle (75420 heads) was present in Kidal at that time.

Dromedary price:

Dromedary price are highly variable in Mali. In most of the regions doesn't have any official data about market price. From interviews we also didn't get data for all the regions. During our interview sessions with key informants, we asked about the current market situation of dromedary and dromedary products in Mali. In response, we got to know that most of the time camel herders are preferring to sell outside Mali. Neighboring countries are the first choice due of easy access and good price. Senegal, Algeria, Mauritania and Burkina Faso are in their list. Pastures from Kidal like to cross the border and go to Algeria to sell and buy their dromedaries. Although there are several drawbacks like, they have to use Algerian dinar instead of CFA, security hazards from terrorists and bandits etc. Despite all those negatives, camel herders of Kidal like to move across border because traditionally this is a common trade route from the past. Key informants also describe that, distance between Kidal and the nearest market inside Mali, where camel can be sold is more distant than the Algerian market. Other reasons for selling abroad are, poor road communication, security hazard, less price is among the reason.

The price from the official record of (DNPIA 2015) shows that, market price of dromedary varies from region to region. Highest selling price was in Gao (285000 FCFA) and Tombouctou had the lowest (197000 FCFA). Average selling price is 244000 in 2015. In 2022 we came to know though key informants that the price has risen a lot. In Gao a good quality male adult camel price is 7,50,000 FCFA which is almost 3 times than 2015 price. Although young male camel can be bought between 3,00,000 to 4,00,000 FCFA. Most of the camels from Kidal still goes outside, as a result key informant couldn't provide any price data. In 2015 no data was available for Bamako because that time dromedary was not selling over there. Camel has already introduced in Mali, but it is growing slowly.

Meat and milk price:

In Gao, a camel milk transformation project is running. They sell the pasteurized camel milk for 2000 FCFA per liter, and after making Sour milk the price increase to 2500 FCFA per liter. Without pasteurization or any processing raw milk price is 1500 FCFA/Liter and the price remain same throughout the year irrespective of season.

Information from interview suggest that average milk price per liter is 2000 FCFA and average meat price per kilo is 3000 FCFA in Mali. No info found about whether it sells meat in different form like meat without bones, shredded meat etc.

Health and diseases of dromedary:

Camels can prevent most of the common diseases and adapt to nature easily. They are accustomed with arid and semi-arid harsh environment and are not affected by the common animal diseases like foot and mouth disease and rinderpest. (Abdurahman, O. Sh., & Bornstein, 1991). For the past several decades the scientific community have intensively studied the metabolic, pharmacological and immunological characteristic of dromedary and the focus has mainly been on blood and milk biochemistry. The research has been conducted on dromedary diseases and those are done mostly based on isolated observations at the abattoir or other findings by the Veterinary Services.

For Dromedary camels, the following diseases are significant:

-Viral diseases like camel pox, camel contagious ecthyma, rabies and papillomatosis.

-Bacterial disease such as brucellosis due to B. melitensis, caseous lymphadenitis, enterotoxemia, salmonellosis and colibacillosis.

-Parasitic and fungal diseases are trypanosomosis, mange, dermatophytosis, gastrointestinal parasites and tick infestation.

(Harrak, Faye & Bengoumi, 2011).

Findings after studying pathology:

In Sotuba it is found that parasites are the dominant cause of sickness followed by injuries, dermatoses and conjunctivitis (Figure 13).

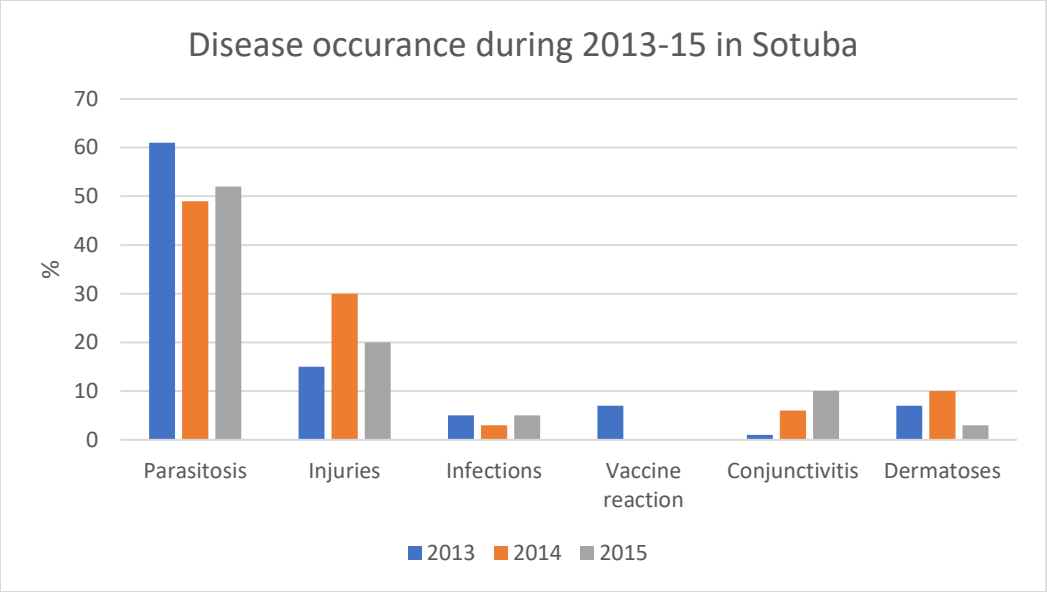


Figure 13: Percentage of diseases occurred during study in Sotuba

Other less important factors are microbial infections and post-vaccination reactions. This order remains same for the time of the study. However, in 2014 the rate of parasitosis had slightly decreased than the previous year before increasing in 2015 but couldn't reach the level of 2013. The increase in 2015 is explained by the heavy rainfall observed that year which meant the deworming was less effective. Injuries increased markedly in 2014 before decreasing in 2015. The post-vaccination reaction was no longer observed after 2013 due to the mastery of vaccine administration techniques. Dermatosis, which was significant in 2013 and 2014, decreased significantly in 2015 (Figure 13 & 14).

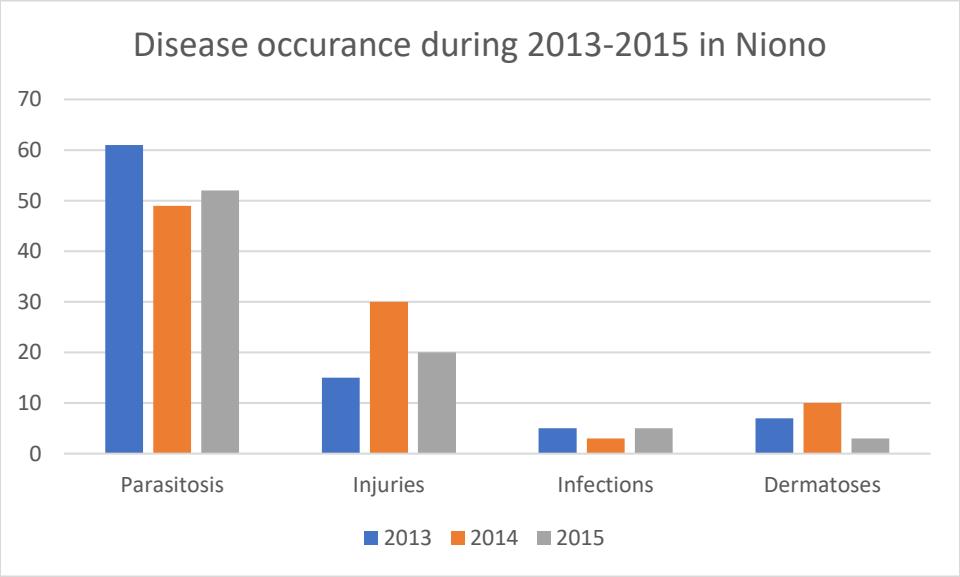


Figure 14: Percentage of diseases occurred during study in Niono

In Niono, main factors observed over the three years are parasitosis, dermatoses and injuries. Unlike in Sotuba, here parasitosis found higher in 2014 and 2015 than in 2013 while dermatoses, decrease in the last two years. Injuries were observed from 2014 and increased in 2015. This increase is explained by the multiplicity of quarrels between male dromedaries.

In both the sites, external parasitosis infection were most severe in 2013 and 2014 but in 2015 internal parasitosis infection became dominant. ticks were the dominant among external diseases.

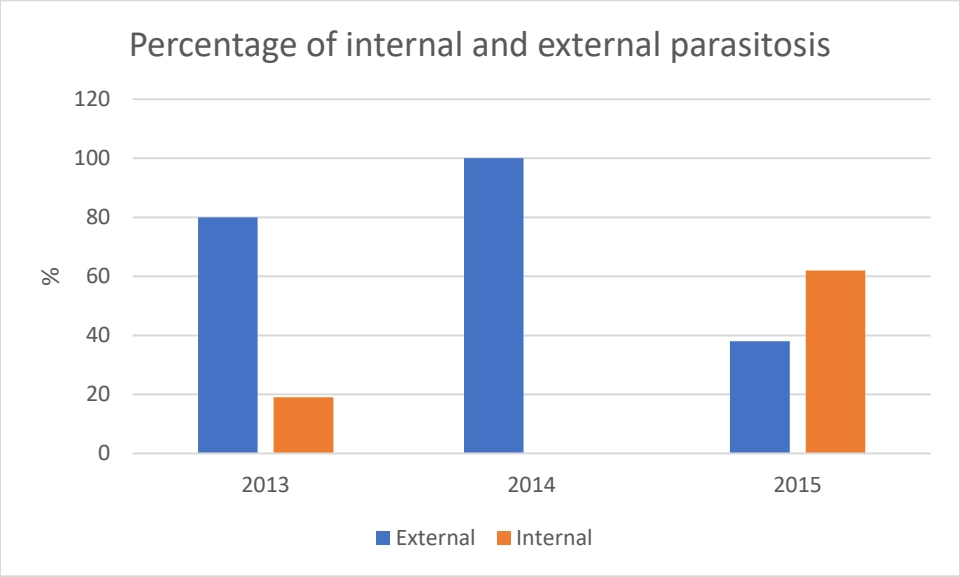


Figure 15: Percentage of internal and external parasitosis in Niono and Sotuba together.

Among ticks, the species Hyalomma spp is the most frequent (92.3%), followed by the species Amblyomma sp (3.8%) and Boophilus spp (3.8%) whatever the season of the year.

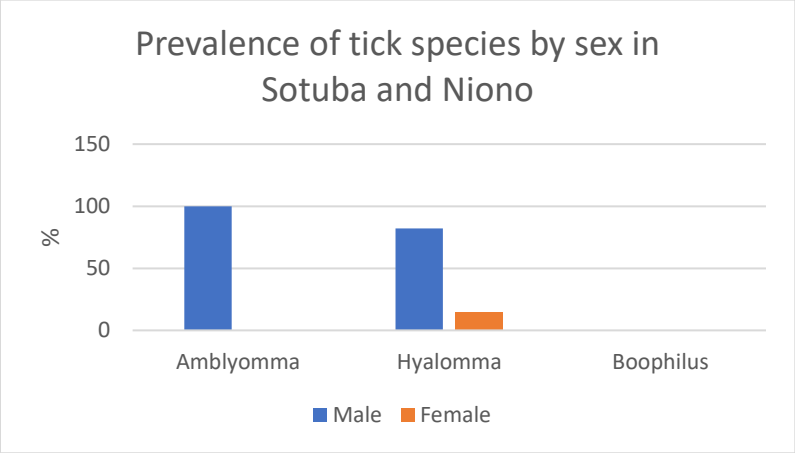


Figure 16: Prevalence of tick species (Amblyomma, Hyalomma and Boophilus) by sex in Sotuba and Niono together.

By sex, male was more frequently encountered on animals than females for Amblyomma and Hyalomma species; on the other hand, in the Boophilus type, no predominance was observed (Figure 16).

In case of gastrointestinal parasitosis, confirmation came through laboratory analysis in Sotuba and Niono. These parasitosis are evident during all seasons of the year. However, their frequency at the end of rainy season is higher than the hot dry season in Sotuba, while in Niono, no significant differences identified between seasons.

Despite the frequency of parasitism, parasite egg weight per gram (EPG) of feces was average in Sotuba. EPG of feces determine the presence of certain parasites. 50% of the samples had a low egg per gram (EPG), while 25% had the average count and 25% had high EPG. The heaviest EPG of feces observed in the end of the rainy season. In Niono, EPG varied from moderate to heavy in the cold dry season and heavy to moderate in May and weak in september. This situation could be explained by the lower frequency of treatments in the dry season and almost similar in the rainy season. Several parasite species were identified in the faeces, of which Trichostrongylus group were dominated. At Niono, the Trichostrongylus group, alone or in association with other parasite species, was the most frequent. The percentage of this group increases from January to September. Trichostrongylus sp was frequent from 41% to 100% in Sotuba and 41% to 98% in Niono. In both sites Trichostrongylus sp were increased till eptember which means rainy season observed highest presence of this parasites.

During the time of the study, the morbidity rate dropped from 40% to 13% in Niono and 17% to 13% in Sotuba. Niono showed the better result than Sotuba in reducing morbidity rate. The main pathologies were external and internal parasitosis, dermatitis and injuries in both Niono and Sotuba (Baradji et al. 2020).

Other than the study in Niono and Sotuba, our key informant's interview showed some fact about camel diseases such as one key informant said that dromedaries do not suffer from common animal diseases. Veterinary doctor who has experienced to treat dromedaries can do better in treating dromedaries – said by one key informant. As pastoralists stay in remote areas, they do not have easy access to veterinary services. According to one informant for the region of Kidal which

consists almost 60% of total dromedary population in Mali have only one veterinary medical facility. While another informant said 3 medical facilities are present in Koro. Consequently, there is a high demand for veterinary services. As a result, they try to use traditional knowledge to treat their dromedaries but not everybody has this competence.

Health cost of dromedary:

The health cost of dromedaries consists of several medical needs such as vaccination, deworming, and treatments of injuries, wounds etc.

Table 20: Costs of the various interventions on camels on average per animal and per year in Sotuba in CFA

	Average cost per animal	Standard error	Minimum cost	Maximum cost
Treatment (Wounds, injuries etc.)	767	35	7	7200
Deworming	2487	161	125	13320
Vaccination	320	0	320	320
Average cost per animal per year	1536	80	7	13320

Table 21: Costs of the various interventions on camels on average per animal and per year in Niono in CFA

	Average cost	Standard error	Minimum cost	Maximum cost
Treatment (Wounds, injuries etc.)	646	21	47	2310
Deworming	1436	103	50	4620
Vaccination	320	0	320	320
Average cost per animal per year	1132	61	47	14400

Table 22: Average number of veterinary interventions per animal in Sotuba and Niono

Year	Number of interventions in Sotuba	Number of interventions in Niono
2013	19	12
2014	21	18
2015	21	6

Results showed that the medical cost of dromedaries are different between the regions. Niono have lower cost than Sotuba. This can be explained by the location. There is less need for treatments in Niono compared to Sotuba as conditions are drier ion Niono. Deworming cost in Sotuba was almost double than Niono. Humid condition in Sotuba was reason for more deworming cost than Niono. This shows that the dromedary struggle to adapt with moist and humid condition due to more parasite infections.

The average cost per animal was lower in 2013; then, it increased in 2014 and again decrease slightly in 2015 (Baradji et al. 2020). On the other hand, in Niono, the cost increased from 2013 to 2015. Table 22, indicates that camels required fewer interventions in Niono than in Sotuba. This might be due to the adaptive techniques of dromedary which is more suitable to dry conditions. They prefer sand instead of moist soil under their feet.

Deworming was the most expensive one in both sites and vaccination cost was the same for both sites as vaccine price was fixed. Only treatment of wounds, injuries etc. cost were higher in Sotruba than Niono.

From the interview we got the information that the medical costing per animal per year varied from 5000 to 6000 CFA. One respondent said that the cost can be as high as 10000 CFA. This cost is quite higher than the physical study. This cost can be zero as well because some herders do not use the medical facility and use ancestral knowledge and local herds to treat their camels.

The costs differ from the key informant interview because the research has been done from 2013 to 2015 and the interview took place in 2022. Differences in the sites are clear, drier sites Niono has a lower cost in every sector except vaccination than more humid site Sotuba. Number of veterinary interventions per year per camel was also higher in Sotuba than Niono (Table 22).

Chapter 6:

Conclusion:

This study examines the potential of dromedaries against climate change in Mali. It has five parts: behavioral analysis to understand adaptation, role in the economy and food security, services to economy and environment, contribution to the national economy, and health and diseases of the dromedary.

The study found that dromedary adapt their behaviour according to weather, climate, or season. There was no difference between the sites regarding reproductive behavior, which is a good sign of adaptation. Dry conditions are more suitable for dromedaries, while humid conditions may increase veterinary costs. There were more pest problems in southern Mali because of the humid climate with more rainfall.

Besides grazing and reproductive behavior, forage is another crucial factor for animal survival. Dromedary standout in this matter because they showed a high capacity to move long distance. The average medical cost for dromedary is 5000-6000 CFA per year which is low in comparison to price of the animal. People are now more aware of the need of vaccinating dromedaries as they observe that vaccination and using veterinary service reduce mortality rate. Also, dromedaries' medical costs are not as high as for other domestic animals. This is a factor that will encourage herders to rear more dromedaries.

Milk production was higher in Niono than in Sotuba, which is strange regarding adaptation and financial aspects. Future studies are needed to understand dromedary milk production under sub-humid climatic conditions. Dromedary milk production difficult to assess because herders tend to collect only a portion of milk for their daily consumption. When they are on transhumance, they lack technologies and transportation facilities for preserving and transporting dromedary milk. As a result, they waste most of the produced milk and only collect what they need for consumption and rest for the calf. One of the key informants said that herders have no idea what amount of milk is wasted every day, and if we can prevent this wasting and sell the milk or milk products, then it will be a substantial financial advantage. People are not collecting dromedary milk regularly for commercial use; they only use it for their families. More investigation needs to find the correct amount of milk from dromedaries under different environmental conditions.

Meat is also essential for food security and income generation. Key informants ensure that dromedary meat consumption is expanding day by day. Some areas like Bamako and Mopti where dromedary was not introduced even 10 years ago, are now selling dromedary meat in the market. The slaughterhouse was also renovated to support dromedary meat processing and preservation. These positively contribute to the national economy and strengthen food security.

Commercial use of traction service provided by dromedary from transporting goods and humans to pulling water from water sources create an environment-friendly transportation system. It helps to generate revenue and, at the same time, makes a low-cost option for people. As dromedary hooves are less destructive to the soil, they cause less soil compaction.

Dromedary has shown more durability and efficient compared with working cattle in agricultural work or other traction-related services. It has some unique physiological and biological features that helps to work hard with fewer negative affect on their body.

This experiment has shown that dromedary can adapt to problematic conditions while a few areas are still under shadow. Such as, milk production is not well measured in dessert conditions, there is less reliable data related to meat production, and people are still unaware of keeping the milk for selling. They also neglect veterinary services and are reluctant to use a vaccine or other medical services. The lack of veterinary cabins in the area like Kidal where most of the country's dromedary reared is a drawback for its expansion. Dromedary is generally well adopted to dry condition, but under proper management this study show that they can also survive a thrive under more humid conditions such as in Bamako. However, more studies are need to adaptation of dromedary under more humid conditions.

Reference :

Aichouany M., 2011. Etude du potentiel reproductif et exploration de certains paramètres hématologiques et histologiques chez le dromadaire (Camelus dromaderius) du Sud-ouest l'Algérie. Thèse, Université d'Oran, 201p

Abri, M. A. A., & Faye, B. (2019). Genetic improvement in dromedary camels: challenges and opportunities. *Frontiers in genetics*, *10*, 167. https://doi.org/10.3389/fgene.2019.00167

Al-Jassim, R., & Sejian, V. (2015). Climate change and camel production: impact and contribution. *J. Camelid Sci*, 8, 1-17.

Baradji, I., Ouologuem, B., Cissé, Y. G., Dolo, A. M., Moussa, M., Sidibé, S., ... & N'Diaye, M. (2020). Main Pathologies of Newly Introduced Dromedaries in Southern Sahel and in Subhumid Zones of Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 335-350.

Birama, D. (2020). Climate Change and Its Impacts in Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 15-36.

Bourdanne, 1998. *L'élevage du dromadaire au Mali : Aspects socio-économiques et culturels. Thèse de doctorat vétérinaire*, EMSMV, Dakar, 120p. http://www.beep.ird.fr/collect/eismv/ index/assoc/TD98-13.dir/TD98-13.pdf.

Bourzat, D., & Wilson, R. T. (1987). La recherche cameline en Afrique. *Revue scientifique et technique (International Office of Epizootics)*, 6(2), 375-382.

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford University Press.

CEDEAO, (2009) a. Programme d'Action Sous-Régional de Réduction de la Vulnérabilité aux Changements Climatiques en Afrique de l'Ouest. Partie I : Aperçu de la vulnérabilité de l'Afrique de l'Ouest face aux changements climatiques et stratégies d'intervention, Communauté Economique des États de l'Afrique de l'Ouest (CEDEAO).

Chaïbou, M., (2009). Le bassin laitier d'Agadez au Niger : Caractéristiques et potentiel de production en lait. *Annales de l'Université Abdou Moumouni, Niamey, Niger. Numéro Spécial* : 15- 26.

Chaïbou M., (2005). Productivité zootechnique du désert : Le cas du bassin laitier d'Agadez au Niger. Thèse de doctorat, *Université de Montpellier II, France*, 310p. camelides.cirad.fr/fr/science/these_chaibou.html

Csemely, P., Schnaider, T., Soti, C., Prohaszka, Z., & Nardai, G. (1998). The 90-kDa molecular chaperone family: structure, function, and clinical application. *Compr Rev Pharmacol Ther*, 79, 129-168. https://doi.org/10.1016/S0163-7258(98)00013-8

DNPIA (2015). *RAPPORT ANNUEL 2015*, DIRECTION NATIONALE DES PRODUCTIONS ET DES INDUSTRIES ANIMALE. Retrieved from http://www.ofarcy.net/elevage-mali/docs/84-RAPPORT_ANNUEL_DNPIA_2015_docx.pdf

Food and Agriculture Organization of the United Nations. (2020). *FAOSTAT statistical database*. [Rome]: FAO.

Faye, B., Chaibou, M., & Vias, G. (2012). Integrated impact of climate change and socioeconomic development on the evolution of camel farming systems. *British Journal of Environment and Climate Change*, 2(3), 227-244. https://doi.org/10.9734/BJECC/2012/1548

Faye, B. (2016). The camel, new challenges for a sustainable development. *Tropical Animal Health and Production*, 48(4), 689-692. https://doi.org/10.1007/s11250-016-0995-8

Faye, B., Saint-Martin, G., Bonnet, P., Bengoumi, M., & Dia, L. (1997). Guide de l'élevage du dromadaire. 1ère éd, CIRAD-IEMVT. *Montpellier. France*. 126p

Faye, B., Vias-Franck, G., & Chaibou, M. (2013). Le dromadaire profite-t-il du changement climatique ? *Courrier de l'Environnement de l'INRA*, 63 : 131-140.

Fayed, R. H. (2001). Adaptation of the camel to desert environment. In *Proceedings of the ESART 11th annual conference.*

Lhoste, P., Vall, É., & Havard, M. (2010). La traction animale. *La traction animale*, 1-240.

Faye B., Jouany J.P., Chacornac J.P. & Ratovonanahary M., (1995). L'élevage des grands camélidés. Analyse des initiatives réalisées en France. *INRA, Prod. Anim.* 8(1) : 3-17.

Faye B. & Tisserand J. L., (1989). Problème de la détermination de la valeur alimentaire des fourrages prélevés par le dromadaire. *Opt. médit.* Série séminaires. n°2, 61-65.

Faye, B. (2015). Role, distribution and perspective of camel breeding in the third millennium economies. *Emirates Journal of Food and Agriculture*, 318-327. https://doi.org/10.9755/ejfa.v27i4.19906

Faye, B. (2014). The camel today: assets and potentials. *Anthropozoologica*, 49(2), 167-176. https://doi.org/10.5252/az2014n2a01

Fesseha, H., & Desta, W. (2020). Dromedary camel and its adaptation mechanisms to desert environment: A review. *International Journal of Zoology Studies*, 5(2), 23-28.

Garbuz, D. G., Astakhova, L. N., Zatsepina, O. G., Arkhipova, I. R., Nudler, E., & Evgen'ev, M. B. (2011). Functional organization of hsp70 cluster in camel (Camelus dromedarius) and other mammals. *PLoS One*, 6(11), e27205. https://doi.org/10.1371/journal.pone.0027205

Gebreyohanes, M. G., & Assen, A. M. (2017). Adaptation Mechanisms of Camels (Camelus dromedarius) for Desert Environment: A Review. *Journal of Veterinary Science & Technology*, 8(6), 1-5. https://doi.org/10.4172/2157-7579.1000486

Hammadi, M. (1995). L'allaitement artificiel des chamelons : une technique pour améliorer la productivité de l'élevage camelin. Département Des Sciences Animales Institut Des Régions Arides Médenine Tunisie. *CIHAM, Options Méditerranéennes*, 13, 137-141.

Herbison L., & Frame G.W. Encyclopedia Britannica: Camel. [(accessed on 12 August 2022)]; Available online: https://www.britannica.com/animal/camel

HOSHINO, B., MORIOKA, S., HASEGAWA, N., SUGAWARA, M., IMAMURA, K., ISHII, S., ... & HASHIMOTO, K. (2017). A New Methodology for the Evaluation of Ecological Characteristic of the Camel-A case Study of Climate Change and Breeding of Camel. *Journal of Arid Land Studies*, 26(4), 213-217. https://doi.org/10.14976/jals.26.4_213

Koussou, M. O., (2009). Production and marketing of milk in Chad: the case of Oualad Rachid Arabes transhumants in Chad. *Abstracts of Second Conference of ISOCARD, Djerba (Tunisia)*: 78p.

Li, Z., & Srivastava, P. (2003), Heat-Shock Proteins. *Current Protocols in Immunology*, 58(1), A-1T. https://doi.org/10.1002/0471142735.ima01ts58

Longo-Hammouda, F. H., Siboukheur, O. E., & Chehma, A. (2007). Aspects nutritionnels des pâturages les plus appréciés par Camelus dromedarius en Algérie. *Cahiers Agricultures*, 16(6), 477-483.

Machan, S. N., Agwata, J. F., & Oguge, N. O. (2022). Environmental Factors Influencing the Sustenance of the Camel Milk Value Chain in Isiolo County, Northern Kenya. *Resources*, 11(3), 27. https://doi.org/10.3390/resources11030027

Mahla, A. S., Vyas, S., Kumar, H., Singh, G., Das, G. K., Kumar, A., & Narayanan, K. (2015). Studies on sexual behaviour in female dromedary camel (Camelus dromedarius). *Journal of Camel Practice and Research*, 22(1), 145-149. https://doi.org/10.5958/2277-8934.2015.00023.5

Moussa, M., Ouologuem, B., Baradji, I., Dao, S., Nialibouly, O., N'Diaye, M., & Kouriba, A. (2020). Assessment of Forage Intake by Dromedaries in the Sahelian and Sub-humid Pastures of Malib-humid Pastures of Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 293-306.

Moussa, M., Ouologuem, B., Coulibaly, L., Coulibaly, N., Nialibouly, O., Baradji, I., ... & Aune, J. B. (2020). Behavior of Adult Dromedaries in the Sahelian and Sub-humid Pastures of Mali: Description of Main Activities. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 361-374

NUPI, (2021). *Climate, Peace and Security Fact Sheet Mali*, Norwegian Institute of International Affairs. Retrieved from https://policycommons.net/artifacts/1780036/climate-peace-and-security-fact-sheet-mali/2511682/ on 15 Aug 2022. CID: 20.500.12592/2rwbts.

Ouologuem, B., Moussa, M., & Coulibaly, M. D. (2017). Les types de dromadaires Talabayatten et Talmarokitt au nord-est du Mali ont un potentiel laitier élevé. *Livestock Research for Rural Development*, 29(2), 2017. http://www.lrrd.org/lrrd29/2/ouol29033.html

Ouajd, S., & Kamel, B. (2009). Physiological particularities of dromedary (Camelus dromedarius) and experimental implications. *Scandinavian Journal of Laboratory Animal Sciences*, 36(1), 19-29.

Ouologuem, B., Mohomoudou, M., N'Diaye, M., Baradji, I., Sissoko, P., Boré, F. G., ... & Soumaré, A. (2020). Diagnosis of the Dromedary Farming System in the Region of Kidal in North-eastern Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 279-292.

Ouologuem, B. & Moussa, M. (2020). Le dromadaire peut contribuer à la résilience au changement climatique. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 307-321.

Ouologuem, B., Mohomoudou, M., Nialibouly, O., Traoré, M. D., & N'Diaye, M. (2020). Dromedary Milk Production under Sahelian and Sub-humid Conditions in Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to Climate Change in Mali: Results and lessons learned in the Sahel*. Bamako, Mali: Institut d'Economie Rurale. 323-334.

Ouologuem, B. et al. (2020). Comportement reproductif des dromadaires femelles dans les conditions d'élevage sahélien et subhumide du Mali. In: N'Diaye, I. et al. (eds.) *Agriculture and Livestock to*

Climate Change in Mali: Results and lessons learned in the Sahel. Bamako, Mali: Institut d'Economie Rurale. 351-360.

Diallo B. O., Traoré K., (2009). *Etude sur la médecine vétérinaire traditionnelle dans la région de Kidal*, PIDRK, 57p.

Pacholek, X., Vias, G., Faye, B., & Faugère, O. (2000). Elevage camelin au Niger: référentiel zootechnique et sanitaire, Ministère des Ressources Animales. *Publ. Coopération Française*, Niamey, Niger. Retrieved from http://camelides.cirad.fr/fr/publications/pdf/elevage_niger_fr.pdf

PIDRK, (2011). Etude sur les techniques et les pratiques traditionnelles de l'élevage camélin dans la région de Kidal. *GIE-3K, Mali*, 106p.

Richard, D., Hoste, C. H., & Peyre De Fabrègues, B. (1985). *Le dromadaire et son élevage.* Institut d'élevage et de médecine vétérinaire des pays tropicaux. CIRAD-Montpellier.

Saeed, H., Shalaby, M., Embaby, A., Ismael, M., Pathan, A., Ataya, F., ... & Bassiouny, K. (2015). The Arabian camel Camelus dromedarius heat shock protein 90α: cDNA cloning, characterization and expression. *International journal of biological macromolecules*, 81, 195-204. https://doi.org/10.1016/j.ijbiomac.2015.07.058

Starkey, P. (2011). Livestock for Traction and Transport: World Trends, Key Issues and Policy Implications. *Food and Agriculture Organization of the United Nations, Rome, Italy*, 60. https://doi.org/10.13140/RG.2.2.29674.34245

Taylor, R. P., & Benjamin, I. J. (2005). Small heat shock proteins: a new classification scheme in mammals. *Journal of molecular and cellular cardiology*, 38(3), 433-444. https://doi.org/10.1016/j.yjmcc.2004.12.014

Tibary, A., & El Allali, K. (2020). Dromedary camel: A model of heat resistant livestock animal. Theriogenology, 154, 203-211. https://doi.org/10.1016/j.theriogenology.2020.05.046

Traoré, B., Govoeyi, B., Hamadou, I., Geda, F., Touré, A., Ouologuem, B., ... & Moula, N. (2019). Analysis of preferences of agro-pastoralists for the attributes of traction dromedaries in harness cultivation: A case study of the Koro district of Mali. *Pastoralism*, 9(1), 1-9. https://doi.org/10.1186/s13570-019-0153-9

Titaouine, M. (2006). *Considération zootechniques de l'élevage du dromadaire dans le sud-est algérien: influence du sexe et de la saison sur certains paramètres sanguins* [Doctoral dissertation] Université El-Hadji Lakhdar, Batna, Algérie.

Traoré, B., Moula, N., Toure, A., Ouologuem, B., Leroy, P., & Antoine-Moussiaux, N. (2014). Characterisation of camel breeding practices in the Ansongo Region, Mali. *Tropical animal health and production*, 46(7), 1303-1312. https://doi.org/10.1007/s11250-014-0644-z

Wako, G., Tadesse, M., & Angassa, A. (2017). Camel management as an adaptive strategy to climate change by pastoralists in southern Ethiopia. *Ecological Processes*, 6(1), 1-12. https://doi.org/10.1186/s13717-017-0093-5

Watson, E. E., Kochore, H. H., & Dabasso, B. H. (2016). Camels and climate resilience: adaptation in northern Kenya. *Human Ecology*, 44(6), 701-713. https://doi.org/10.1007/s10745-016-9858-1

Warda, M., Prince, A., Kim, H. K., Khafaga, N., Scholkamy, T., Linhardt, R. J., & Jin, H. (2014). Proteomics of old world camelid (Camelus dromedarius): Better understanding the interplay between homeostasis and desert environment. *Journal of advanced research*, 5(2), 219-242. https://doi.org/10.1016/j.jare.2013.03.004

World Bank (n.d.) Mali: Climate Data, *Historical*. Climate Change Knowledge Portal. https://tinyurl.com/24kn66dp

World Bank (2011). *Climate Risk and Adaptation,* Country Profile: Mali. https://tinyurl.com/xrds53hf

Wu, H., Guang, X., Al-Fageeh, M. B., Cao, J., Pan, S., Zhou, H., ... & Wang, J. (2014). Camelid genomes reveal evolution and adaptation to desert environments. *Nature communications*, 5(1), 1-10. https://doi.org/10.1038/ncomms6188

Zarrouk, A., Souilem, O., & Beckers, J. F. (2003). Actualités sur la reproduction chez la femelle dromadaire (Camelus dromedarius). *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, 56(1-2), 95-102.

Zibaee, S., Yousefi, M., Taghipour, A., Kiani, M. A., & Noras, M. R. (2015). Nutritional and therapeutic characteristics of camel milk in children: a systematic review. *Electronic physician*, 7(7), 1523–1528. https://doi.org/10.19082/1523

Appendix:

Questionnaire

Region et période vécu /travaillé ici

Age :

Homme/Femme :

Groupe ethnique :

Nombre de chameaux :

Section dromadaires

1. Quels sont les 5 principaux avantages de la production de dromadaires et parlez-nous des principaux avantages que vous tirez des productions de dromadaires ?
2. Quels sont les produits de dromadaire le plus vendus commercialisé ?
3. Pouvez-vous énumérer les 5 principaux problèmes de la production de dromadaires (nord, centre sud) ?
4. Ces problèmes deviennent-ils plus importants maintenant qu'ils ne l'étaient il y a 20 ans ?
5. Quels ont été les changements majeurs (positives et négatives) dans la production de dromadaires au cours des 20 dernières années (centre, sud) ?
6. Avez-vous constaté des changements climatiques ?

Climat, pâturage et santé animal :

7. Avez-vous constaté des changements dans la qualité des pâturages (lesquels ?) au fil des ans ? Et quelle a été la raison de ces changements ?
8. Y a-t-il eu des changements dans le mouvement du dromadaire au cours des 20 dernières années ? Si oui, quelles sont les raisons de ces changements et si non, pourquoi aucun changement ? Thids is a good good questions
9. Quelles sont les principales raisons de la perte d'animaux ?
10. Quels types de soins aux animaux les éleveurs fournissent-ils ? médecine moderne et médecine traditionnelle ?

11. Estimer le coût moyen de traitement par animal et par an de médecine traditionnelle ? et moderne ?

Economie :

12. Existe-t-il différentes races de dromadaires et quelle est l'approche pour améliorer la qualité génétique de troupeau de dromadaires ? Si oui, lesquelles ?
13. Quelle est la situation du marché du dromadaire et des produits du dromadaire dans
14. Quelle est l'importance de la production de dromadaires pour l'alimentation familiale (lait, viande)?

platform et coopérative :

15. Les éleveurs sont-ils impliqués dans la transformation du lait de chamelle ?
16. La viande est-elle vendue ou consommée dans le ménage (fraiche / séchée) ?
17. Quel type de bénéfice un éleveur peut-il tirer de sa participation à des plateformes d'innovation ?
18. Quelles sont les difficultés pour rendre opérationnelle une plateforme d'innovation ?
19. Comment le gouvernement ou les organisations en développement peuvent-ils aider à promouvoir la production de chameaux ?
20. Expliquer comment les femmes sont engagées dans la production dromadaire comment peut-on les intégrer mieux ?

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