LIVESTOCK MARKETS IN THE SAHEL:
MARKET INTEGRATION AND THE ROLE OF CLIMATE AND CONFLICT IN PRICE FORMATION

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BRACED KNOWLEDGE MANAGER

Working paper

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Stéphanie Brunelin is a development economist with seven years of work experience in international organisations and development agencies including 5 years at the World Bank where she works primarily on social safety nets and employment programs among the poor in West Africa. She holds a PhD in Economics from the Center for Studies and Research on International Development (CERDI) and has published in a number of economics and development journals. Her research interests include regional trade integration, agricultural value chains, food price dynamics and climate shocks.

Lucie Royer works as a consultant on climate change adaptation. She conducts climate risks and vulnerability assessments, supports adaptation planning and implementation of policies and strategies. She holds an engineering degree in agronomy and environment from AgroSup Dijon, with a specialisation in natural resources management (AgroParisTech Nancy).

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Acronyms

ACLED	Armed Conflict Location & Event Data Project
AFD	Agence Française de Développement (French Development Agency)
AMIS	Agricultural Market Information System
AQIM	al Qaeda in the Islamic Maghreb
BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters
CFAF	Communauté Financière Africaine Franc (African Financial Community Franc)
CILSS	Comité permanent Inter-États de Lutte Contre la Sécheresse dans le Sahel (Inter-State Committee for Drought Control in the Sahel)
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (French Agricultural Research Center for Development)
CRU	Climate Research Unit
DfID	The UK Department for International Development
DNPIA	Direction Nationale des Productions et Industries Animales (National Directorate for Animal Production and Industry)
ECOWAS	Economic Community of West African States
EWS	Early Warning System(s)
FAO	Food and Agriculture Organization
FAOSTAT	FAO statistical database
FCFA	Franc CFA (financial community in Africa)
GDP	Gross Domestic Prodcut
GMM	Generalised Method of Moments
IRAM	Institute of Research and Application of development Methods
ISPS	Information System on Pastoralism in the Sahel
MIS	Market Information System(s)
OECD	Organisation for Economic Co-operation and Development
NGO	Non-Governmental Organisation
OLS	Ordinary Least Systems

OMA	Observatoire du Marché Agricole (Agricultural Market Observatory)
OPAM	Office des produits céréaliers du Mali (Mali office of cereal products)
PRAPS	Projet Régional d'Appui au Pastoralisme au Sahel (Regional Sahel Pastoralism Support Project)
PREGEC	Charter for Food Crisis Prevention and Management
RCP	Representative Concentration Pathway
RPCA	Réseau de Prévention des Crises Alimentaires (Food Crisis Prevention Network)
SIPSA	Système d'Information sur le Pastoralisme au Sahel (Information System on Pastoralism in the Sahel)
SWAC	Sahel and West Africa Club
UBT	Unités de Bétail Tropical (Tropical livestock unit)
UN COMTRADE	United Nations International Trade Statistics Database
VAR	Vector Autoregression
WAEMU	West African Economic and Monetary Union
WFP	World Food Programme

Executive summary

West Africa is receiving renewed attention from the international community. At the heart of climatic, migratory and security issues with international consequences, the region is the source of many resilience, humanitarian aid and security programmes as well as development projects.

This report aims to inform governments, regional institutions and technical and financial partners about current livestock market dynamics in the Sahelian zone.

Over the last 10 years, national spatial price dispersion in all three countries has declined. Therefore, markets are becoming increasingly integrated on a national level. Mali has the strongest price dispersion between markets, which has been considerably reduced over the 2014-2016 period. Between Burkina Faso and Niger, price dispersion is not much higher than the price variation within each country, which shows good integration on a regional level. Regional-level analyses highlight the critical leading role Malian markets play in influencing price in Burkinabé markets. However, Malian markets only have a moderate influence on price in Niger. National-level leading Nigerien markets do not appear to be leaders on a regional level.

The estimation of the fundamental price, made on the basis of a panel of 45 markets using monthly data over the 2008-2018 period, confirms that climate and conflict variables play a predominant role in the explanation of price dynamics. Thus, the year's cumulated rainfall has a negative and significant impact on prices. Conflicts on the market peripheries significantly influence price formation; distance between conflicts and markets plays a particularly significant role.

Despite the limitations of the analysis, mainly due to inconsistencies in national data collection systems and the irregularity of data collection for certain markets, it has been possible to highlight current livestock market dynamics in the region.

The results of the statistical analyses lead to the conclusion that markets are well integrated at the national and regional levels. This integration is most certainly supported by transhumance movements favouring the circulation of goods, people and information. Production areas in Mali and Niger play a key role in the zone's market dynamics. The lack of information on coastal terminal markets limits the analysis, and therefore does not allow for an evaluation of the role these markets play. Lastly, climate conditions and conflicts play a key role in the formation of livestock prices. In particular, rainfall and conflicts of terrorist origin have a significant and negative impact on livestock prices.

1. INTRODUCTION

IMAGE: CATTLE A HERD OF CATTLE OUTSIDE THE ZORRO VILLAGE, BURKINA FASO. PICTURE TAKEN BY: ©OLLIVIER GIRARD/CIFOR

1.1 Context

West Africa is receiving renewed attention from the international community. At the heart of climatic, migratory and security issues with international consequences, the region is the source of many resilience, humanitarian aid and security programmes as well as development projects. Under the context of fragile countries exposed to multiple risks, innovative cooperation initiatives seeking to combine socioeconomic development, defence and humanitarian measures are multiplying, especially in the Sahel. Thus, the area is a flagship region of the Agence Française de Développement (AFD) and its 3D strategy (Defence, Diplomacy, Development). The UK government has recently formed a multidisciplinary Sahel team to address challenges in the region. It gathers experts from the

Ministries of Defence and Foreign Affairs and DfID. Many donors seek to better coordinate their activities around initiatives such as the Sahel Alliance (an international cooperation platform).

Therefore, pastoral issues are the focus of attention and debate: What solutions are there for the challenges that Sahelian and west African pastoralists face? What is the role of pastoral populations in the zone's security and stability? At the heart of each of these issues is livestock farming. As the main source of income and business activity for these populations, it plays a central role and is the target of development activities and programmes aimed at maintaining income. Therefore, a better understanding of the sector through an analysis of the zone's markets is crucial. Extensive livestock farming, particularly transhumance, constitutes the driving force of economic integration in the region, however it is still poorly understood and scarcely studied from an economic point of view. Many recent studies have contributed to a better understanding of the sector's dynamics, but livestock markets have not yet received the same attention as grain markets, the dynamics of which are seen as key indicators of food security.

1.2 Objectives and hypotheses

This report aims to produce an initial analysis of livestock market dynamics in West Africa over the last 10 years, in order to inform governments, regional institutions and technical and financial partners about current livestock market dynamics in the Sahelian zone.

This regional analysis of livestock markets in West Africa has several objectives:

- **Data valuation and collection carried out by national and regional institutes on livestock prices.** This information has never been published. A fruitful and long-term collaboration with Inter-State Committee for Drought Control in the Sahel (CILSS) made the compilation, cleaning and analysis of this database possible.

- **Contribution to gaps analysis in terms of early warning systems (EWS) and crisis management adapted to pastoral areas.** During the last meeting of the Food Crisis Prevention Network (Réseau de Prévention des Crises Alimentaires, RPCA) in Brussels in April 2019, the Restricted Group of Network members emphasised the 'urgent need to strengthen the integration of the dimensions [...] of pastoral vulnerability in data collection tools required for the Harmonised Framework analysis. The study aims to contribute in fulfilling the current need for a better understanding of pastoral contexts and the implementation of appropriate indicators for the livestock sector and pastoral context' (RPCA, 2019).

- **Highlight the benefits and obstacles to the regional integration of livestock markets in price crisis management.** Assuming that market integration is a resilience factor against climate and price shocks, a good physical and informational connection between markets helps mitigate price and supply shocks. This report aims to study the level of regional integration of livestock markets. The Economic Community of West African States (ECOWAS) and the extensive livestock farming system based on livestock mobility are key factors in regional integration.

It therefore seems relevant to gain a better understanding of how livestock markets are connected to each other and the evolution of livestock prices in recent years. Finally, this analysis, which is similar to studies that have already been implemented in grain markets, aims to promote reflection on the role of indicators calculated on the basis of monitored livestock markets within an effective EWS for pastoral populations.

1.3 Method and limits

The analysis presented is based on a statistical and econometric analysis of price series available on a monthly basis for several markets within the zone over a span of 10 years. The data collected by national market information systems (MIS) was centralised by CILSS and made available to the authors for analysis. The authors recognise the limits of this database, which is so far composed of heterogeneous indices. National MIS do not currently have a harmonised data collection system on a regional level. However, systematic differences between the three national databases can be controlled. The purpose of this report is, rather, to underline the existence and value of these databases in order to support a more frequent, rigorous and harmonised collection of data that can provide a better understanding of livestock markets and pastoral dynamics on a regional level.

2. PASTORALISM, CLIMATE AND FOOD CRISES IN THE SAHEL

IMAGE: A WOMAN DRIVES A DONKEY CART LOADED WITH FIREWOOD BACK TO ZORRO VILLAGE, BURKINA FASO. PICTURE TAKEN BY: ©OLLIVIER GIRARD/CIFOR

2.1 Pastoralism, transhumance and trade flows in the Sahel

2.1.1 Pastoralism in various forms

West Africa is a region in which pastoralism and agropastoralism are very important activities, with an estimated stock of more than 60 million cattle and 160 million small ruminants (ECOWAS and SWAC/OECD, 2008). In Africa, approximately 40% of the land is reportedly exploited by pastoralists, and about 268 million people depend directly on pastoralism for subsistence (FAO, 2018).

Traditionally, pastoralism refers to extensive livestock production, mainly in arid and semi-arid zones, using pastures and a route-based mobility strategy, allowing for dynamic and flexible herd management based on climate variability and the availability of natural resources (mainly water and biomass).

Pastoralism adopts various forms based on different strategies for managing livestock and natural resources in pastoral or agropastoral zones.[1]

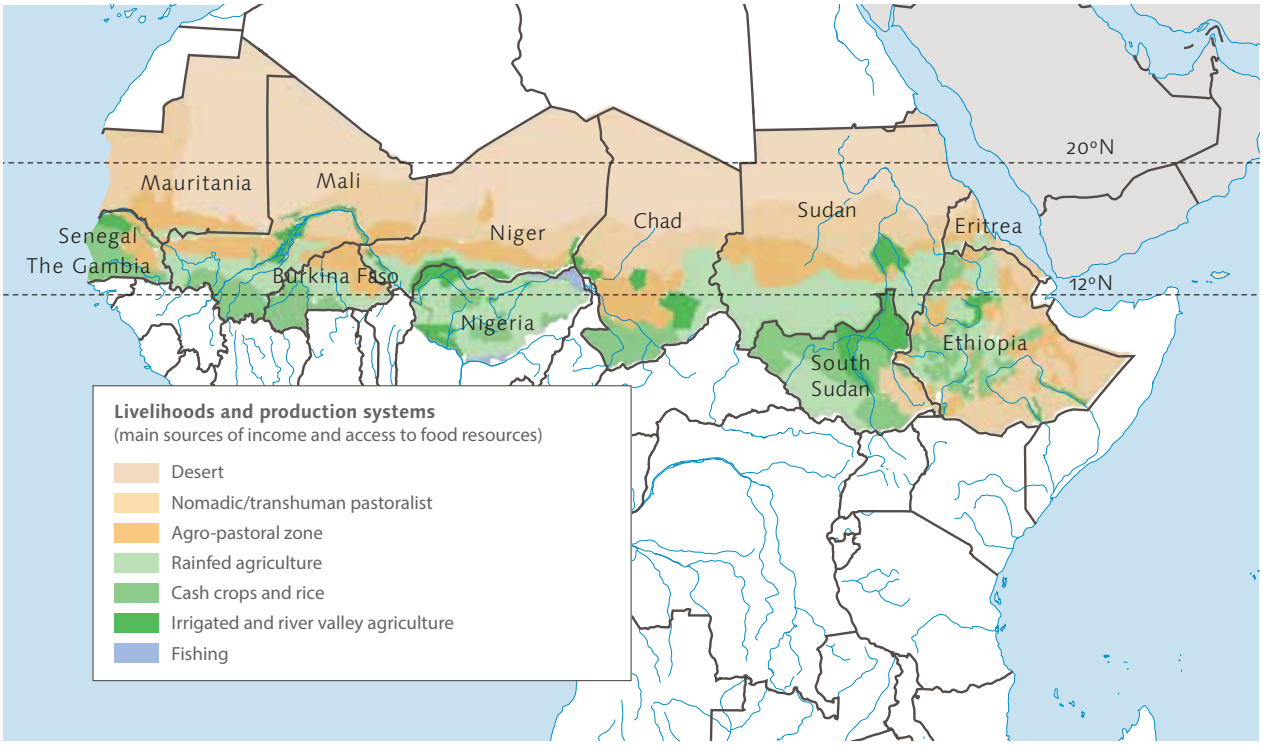
Nomadism refers to the movement of non-agricultural livestock producers who rely solely on the sale or exchange of their animals, and secondary products, for food. They follow pastures and water resources in a pattern that varies from year to year depending on the availability of these resources.

Transhumance represents the regular movement of herds between fixed points and more or less established routes in order to exploit the seasonal availability of pastures. A characteristic of transhumance is herd splitting. Pastoralists take most animals with them, while leaving lactating animals (cows or camels) at the resident community (Liniger et al., 2011).

Agropastoralism is a strategy combining agriculture and livestock farming. It thus makes it possible to increase the economic resilience of livestock farmers in the event of climate hazards.

1 The definitions below refer to the Pastoralists' Network of the Sahel: http://pasteursdusahel.org/index.php/systemes-pastoraux

Figure 1: Subsistence systems in the Sahel and the location of pastoral and agropastoral zones

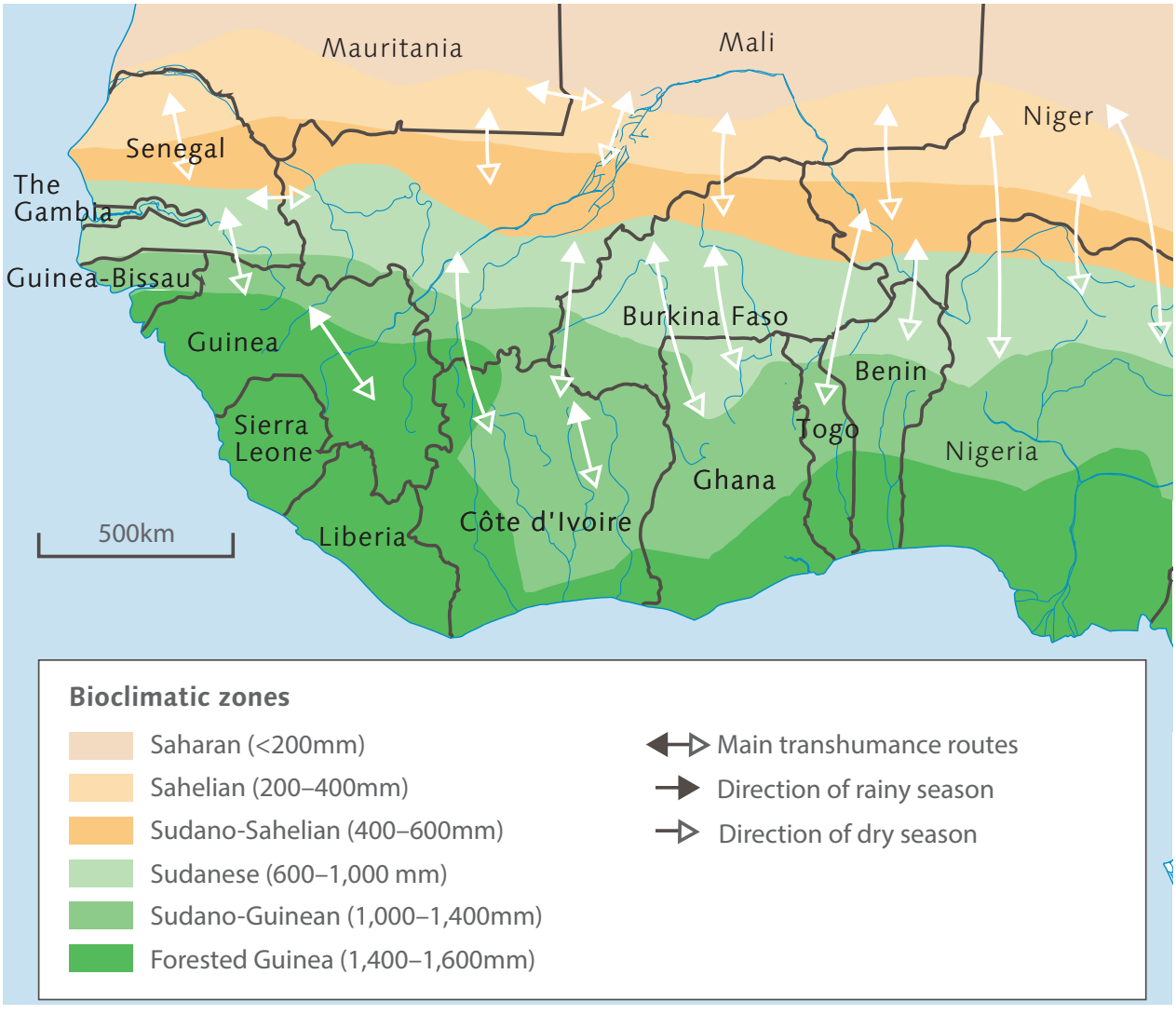


Source: Salliot (2010)

2.1.2 Climate, agroecological zones and mobility strategies

Our study – covering Mali, Burkina Faso and Niger – targets a complex pastoral context, where high mobility is observed between different agroecological zones. From a climatic point of view, West African livestock farmers are in a very contrasting environment indeed, with strong annual variations. From the Sahara to the shores of the Gulf of Guinea, average annual rainfall increases along a north-south gradient (Gonin, 2017). Transhumance allows an itinerant adaptation to this rainfall gradient; herds head south in the dry season, in search of the first rains, and move back up north during the rainy season, thereby benefiting from the start of the monsoon (Ibid.)

Figure 2: Transhumance, an adaptation to the rainfall gradient



Source: Gonin (2017)

Different bioclimatic zones are encountered along the rainfall gradient, with repercussions on the behaviour of pastoral activity (Touré et al., 2012):

The **Saharo-Sahelian zone** is characterised by large pastoral areas and generally devoid of agriculture. These are very sparsely populated areas where pastoralism is the dominant production system. These are very arid areas, where nomadic and transhumant pastoralists travel with their herds according to the availability of resources (fodder and water) (Touré et al., 2012).

The **Sahelo-Sudanian zone** is characterised by a high variability of rainfall over time and space, leading to a variety of agroclimatic scenarios (Vall et al., 2008). Agropastoral production systems are more frequent. The alternation between densely populated and sparsely populated regions within this zone leads to strong competition for space and resources, in a region where pastoral farming has an important role. Land reserves in sparsely populated areas are becoming increasingly scarce and livestock mobility is under increasing pressure.

In the **Sudanian zone**, mixed production systems predominate, alternating between cash crops (cotton, peanuts, cashew), grain production (including corn) and livestock farming (Nugteren and Le Côme, 2016). Relations between agriculture and livestock farming are both complementary (manure, residues, herd sharing, animal traction, land security) and competitive (exploitation of the same areas and resources). In these regions, population density is relatively high and land pressure is quite significant, including in silvopastoral areas, transhumance routes and livestock trading routes (Gonin, 2017).

The **Sudano-Guinean zone** is a region of strong agricultural and livestock farming expansion, with mixed production systems. Population density is increasing, but many resource areas still exist and play a major role in the resilience of the pastoral system. Pastoral reserves and the availability of fodder resources provide transhumant herds with strategic retreat areas, especially during crises in the Saharo-Sahelian (or Sudanian) zone, generating large movements of livestock.

2.1.3 Trade flows and the contribution of pastoralism to the agricultural economy

Burkina Faso, Mali and Niger are three exporters of live animals (cattle, sheep, poultry and horses), while coastal countries are net importers. However, as coastal countries gradually become large livestock-farming countries, the meat consumed there no longer comes solely from Sahelian countries (PRAPS, 2019).

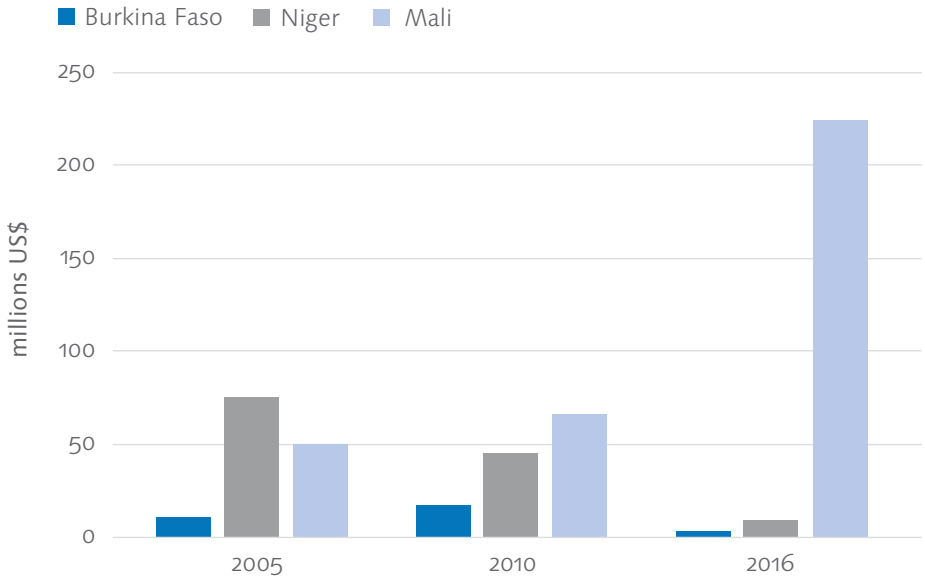
Although Burkina Faso is a net exporter of live animals, its export numbers are lower than those of Niger and Mali (Figure 3). Among coastal countries, Togo, Benin, Ghana and Côte d'Ivoire are net importers. Nigeria was also a net importer of live animals over the 2006-2016 period with the exception of two years – 2012 and 2013 – where Nigerian live animal exports surpassed imports (UN COMTRADE).

Trade circuits, traditionally linking production areas to consumer centres, such as large cities and coastal countries, can be a few dozen to hundreds or even thousands of kilometres long. These long distances mean livestock farmers frequently cross borders between various communes and states in the region.

The single survey carried out by the NGO (non-governmental organisation) Acting for Life in the context of the BRACED-Livestock Mobility project (Thébaud, 2017; Thébaud et al., 2018) – covering 386 households in northern Senegal, southern Mauritania, northern and eastern Burkina Faso, western Niger and northern and western Mali – made it possible, for the first time, to evaluate the costs of this transhumance for livestock farmers (Thébaud, 2017). The survey shows that the total amount of expenditure declared in 2014-2015 by the 386 families surveyed reached 475 million CFAF. This amount represents an average annual budget of 1,230,000 CFAF per family. The largest expenditures are made on livestock feed (44%) and food (22%). In this analysis, the amount of taxes reported is low (1.6%) but does not include taxes paid in livestock markets. This ratio

should be considered with caution. First of all, there are many levies (fines, tourist or transit tax, local royalties or taxes) and transhumant peoples often have difficulty specifying what they pay and to whom they pay these taxes and levies.

Figure 3: Net exports of live animals (USD millions)



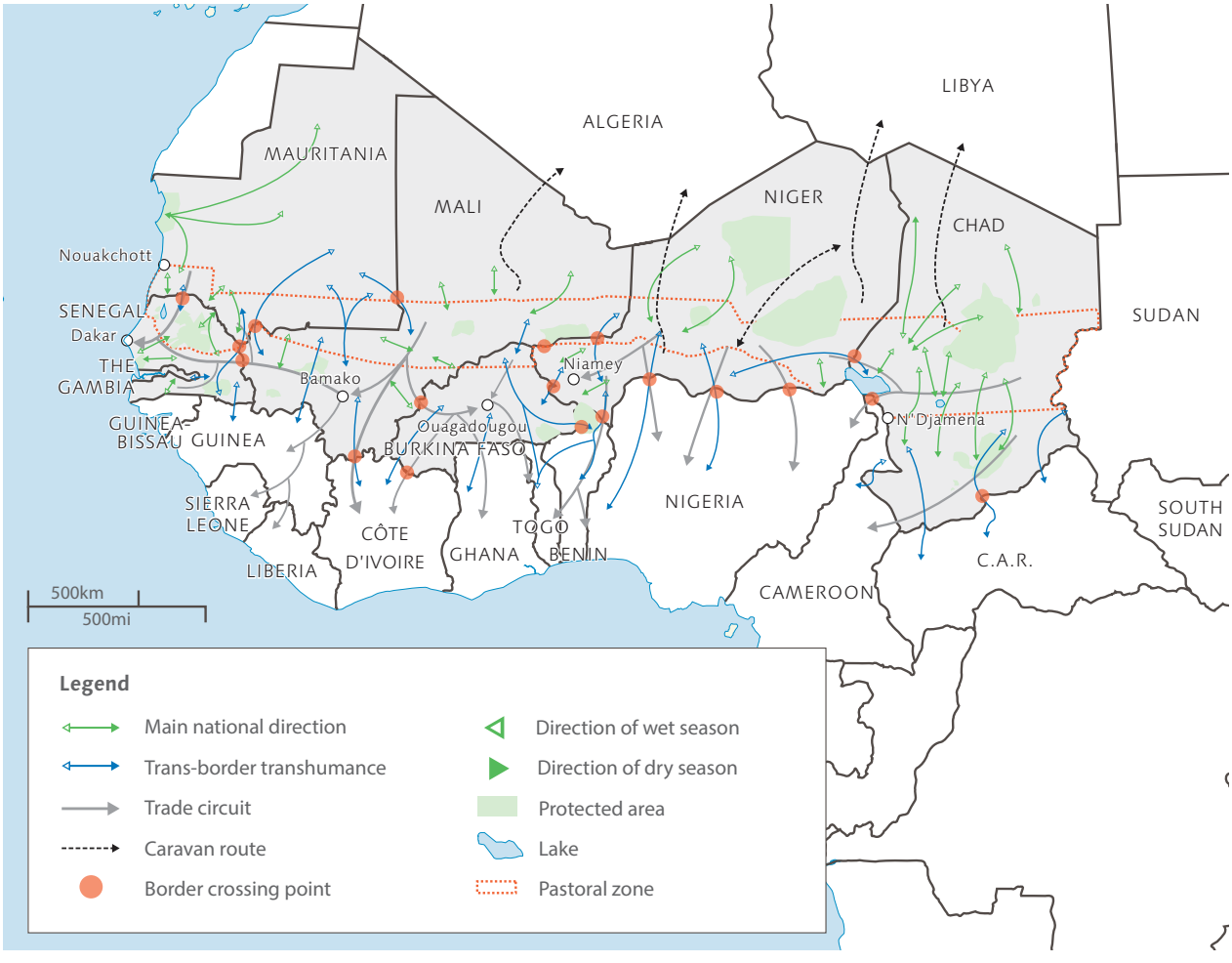
Source: Authors' own, based on UN COMTRADE data (consulted in June 2019)

In addition, interviews with families showed that transhumance-related costs are difficult to quantify: 'Harassment at border crossings, restrictions to water or pasture access, field invasions, cattle theft, armed robberies and corridor blockades are all difficulties which can cause conflicts, their resolution often generating costs (money, animals)' (Thébaud et al., 2018).

Evaluating these is more complex. During the 2014-2015 transhumance, the survey shows that the most significant payments were firstly due to field conflicts (6 million CFAF), and secondly to harassment during border crossings.

Figure 4 shows the main transhumance routes in the Sahelian and Sahelo-Sudanese zones, and highlights livestock trading circuits between Sahelian countries, producers and exporters, and coastal importing and consumer countries. Burkina Faso, Mali and Niger are the main exporting countries in West Africa (Cisse et al, 2014). The coastal countries' terminal markets (Ivory Coast, Ghana, Togo, Benin, Nigeria and Senegal) are in fact largely supplied by Sahelian livestock from Burkina Faso, Mali and Niger (Corniaux, 2014).

Figure 4: Summary of recent national and trans-border movements and livestock trading circuits



Source: Ibra et al. (2012) as seen in Nugteren and Le Côme (2016)

In **Mali**, livestock trading circuits are complex. In this sense, the origins of trade circuits (i.e. supply routes) involve several regions. From Dembele (2017), we can distinguish:

- Circuits originating in the Western Sahel which cross the northern parts of the Kayes, Koulikoro and Ségou regions, to serve Côte d'Ivoire, Liberia and Senegal;

- Circuits originating in the Central Delta which cross the Ségou and Sikasso regions to serve Bamako, Côte d'Ivoire, Liberia and Ghana;
- Circuits originating in Upper Central Gourma which cross Gourma and Haoussa to serve Bamako, Côte d'Ivoire, Niger, Burkina Faso, Ghana, Nigeria and the southern Algerian markets.

Dembele (2017) further states that the main routes served are:

- The routes serving the Bamako refrigerated slaughterhouse and regional slaughterhouses (Kayes, Sikasso, Ségou and Mopti);
- The routes serving coastal markets (Côte d'Ivoire, Liberia, Ghana, Guinea-Conakry, Nigeria, Senegal);
- The routes serving southern Algerian markets.

In **Burkina Faso**, Guibert et al. (2009) note several horizontal and vertical livestock trade flows:

- The western central circuit (Mali and Burkina Faso to Mauritania, Senegal, Gambia, Guinea-Bissau and Guinea-Conakry, Sierra Leone and Liberia);
- The central corridor circuit (Mali and Burkina Faso to Côte d'Ivoire, Ghana, Togo, Benin and Nigeria);
- The eastern central circuit (Niger to Nigeria); and
- The eastern circuit (from Chad, Central African Republic and Cameroon to the consumer areas of Central Africa).

Aboubacar (2017) identifies two main trade routes in **Niger**:

- The north-south route (this route also stipulates a westward

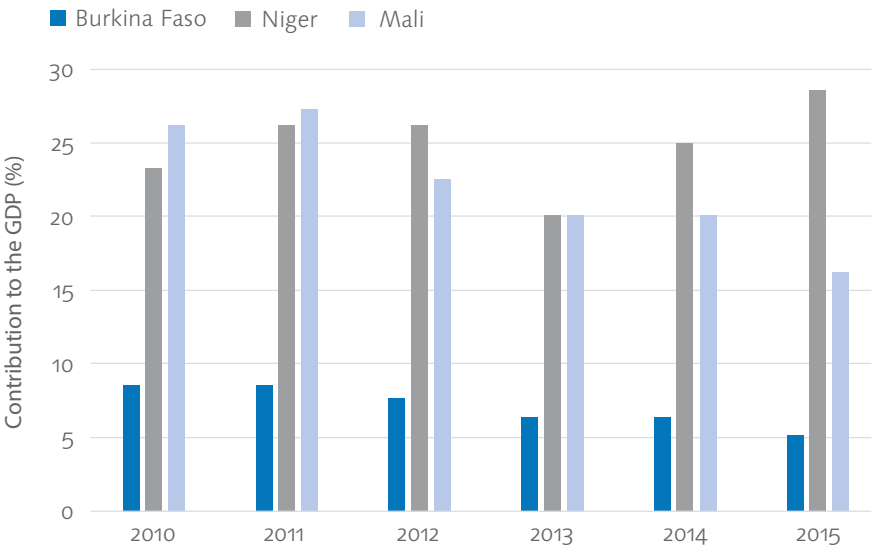
direction): cattle and small ruminants trade runs from north to south (with flows to the west) and use about 10 corridors that converge at the terminal markets of Nigeria (Maiduguri, Kano, Lagos), Benin (Cotonou), Ghana (Accra) and Côte d'Ivoire (Abidjan). The westward direction heads to Burkina Faso and Mali. Burkina Faso is the country from which Nigerien livestock is re-exported to Côte d'Ivoire and Togo.

- The northern Niger-Maghreb route: this has two main destinations:
    - Algeria, which is characterised by a non-monetary exchange system (the practice of bartering dates for livestock is quite developed), and
    - Libya, which is an importer of live animals, especially camels.

'In the Sahel and West Africa, transhumant pastoralism plays an important role in the livestock farming sector. In Sahelian countries, it accounts for 70-90% of cattle farming, and 30-40% of sheep and goat farming', (Traoré, 2011). Practiced mainly in arid zones, this type of farming is the only productive activity that adds value to these areas.

In the non-coastal countries of the Sahel, Mali, Burkina Faso and Niger, which are net exporters of the central corridor of the west African region, the contribution of the livestock farming sector to GDP varies between 10% and 15% (ECOWAS and SWAC/OECD, 2008). Livestock production contributes an average of 40% to agricultural GDP in the Sahel region (Ibid.), 84% in Niger, 33% in Mali (44% in 2011) and 24% in Burkina Faso (Liniger et al., 2011).

Figure 5: Contribution of pastoralism to GDP (%)



Source: Authors' own, based on FAOSTAT data (consulted in June 2019)

The case of Niger illustrates the economic importance of ruminant livestock farming in the Sahel. In 2005, the Nigerien livestock population, all species combined, had a total value of 706 billion CFAF and an annual production of 191.5 billion CFAF (FAOSTAT).[2] Livestock farming thus makes a strong contribution to the economy of the country and the region, and more specifically to the rural poor, who either totally or partially depend on livestock for food or income.

2 The Nigerien livestock population at that time, according to ECOWAS and SWAC/OECD (2008), was estimated at nearly 7.5 million tropical livestock units (TLU).

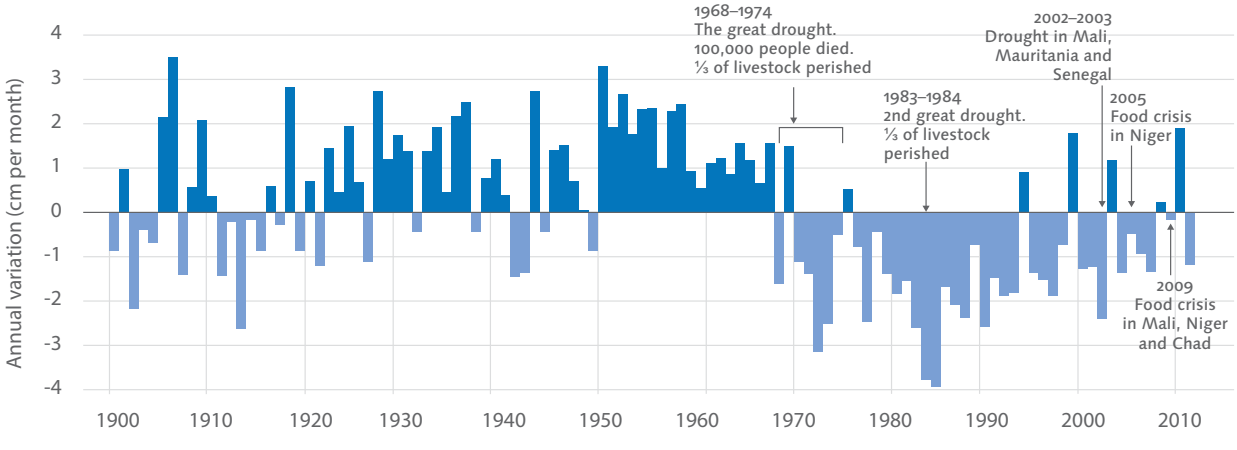
2.2 Droughts and pastoral crises in a context of climate change

Livestock farming and transhumance activities face many challenges, including various forms of insecurity (conflict, robbery, bribe, etc.) in a global context of climatic, demographic, socioeconomic and political changes.

2.2.1 The recurrence of extreme events

Since the end of the 1960s, due to a global decrease in rainfall, the Sahelian ecosystem has suffered a succession of major periods of water stress, which has created a state of generalised water stress (Véron, 2014). The main challenge currently facing pastoralism lies in the recurrence of extreme climate hazards. But under climate change forecasting such hazards remains uncertain.

Figure 6: Annual rainfall variation index for the Sahel between 1900 and 2010



Source: Touré et al. (2012)

The analysis of rainfall data from 1900 to 2010, provided by the Information System on Pastoralism in the Sahel (ISPS), shows a change that began in the 1970s, with a succession of drought years until 1993. From 1994 to 2010, wet years occur only every four years.

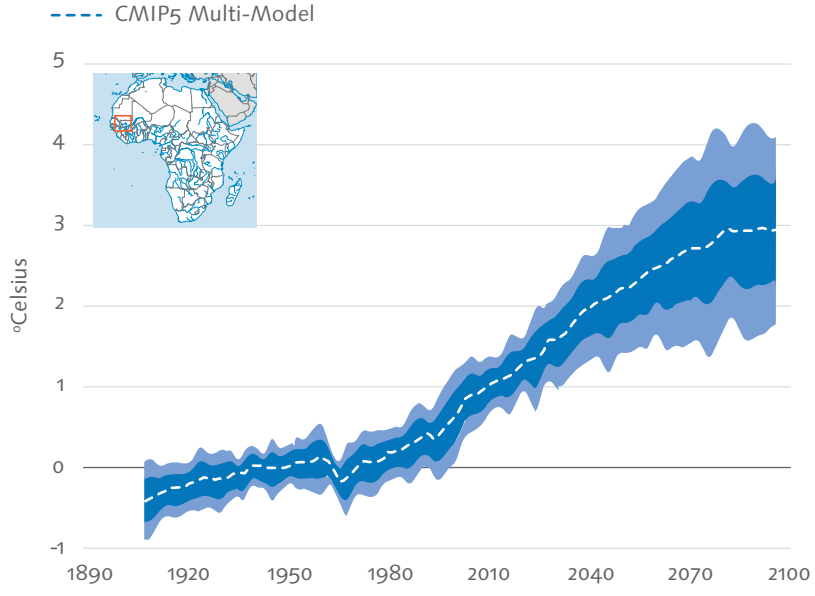
Box 1: Climate change in the Sahel: what do the forecasts say?

Climate forecasts for the Sahel are particularly uncertain for two reasons: 1) the great climatic variability observed during the 20th century makes it difficult to identify a sign that can be attributed to climate change; and 2) climate forecasts based on various models remain uncertain and are sometimes contradictory with regard to the region. This is especially true of rainfall-based models that can differ even on the direction of change; some suggest a tendency toward aridification while, on the contrary, others suggest more rain (Heinrigs, 2010).

Temperature forecasts tend to be more consistent across climate models. The trend toward regional warming, which has already been confirmed, by 1.1°C since 1950 (Taylor, 2018), should continue in the future with a notable increase, especially in the summer months of June, July, August and September (Heinrigs, 2010). In comparison with the last 20 years of the 20th century, this regional warming is likely to be higher than the global average, with temperatures increasing by 3 to 4°C by the end of the 21st century (Ibid.). The greatest degree of regional warming (≈4°C) would occur especially in the western region of the Sahel. On the coast and near the southern limits of the region, temperature increases are expected to be lower, though still significant (≈3°C) (Ibid.). The frequency of heat waves is also expected to increase (i.e. temperatures reaching 41°C for more than three consecutive days) (Taylor, 2018).

Summary on the evolution of temperatures in West Africa:

Figure 7: Temperature anomalies in West Africa (RCP 4.5)



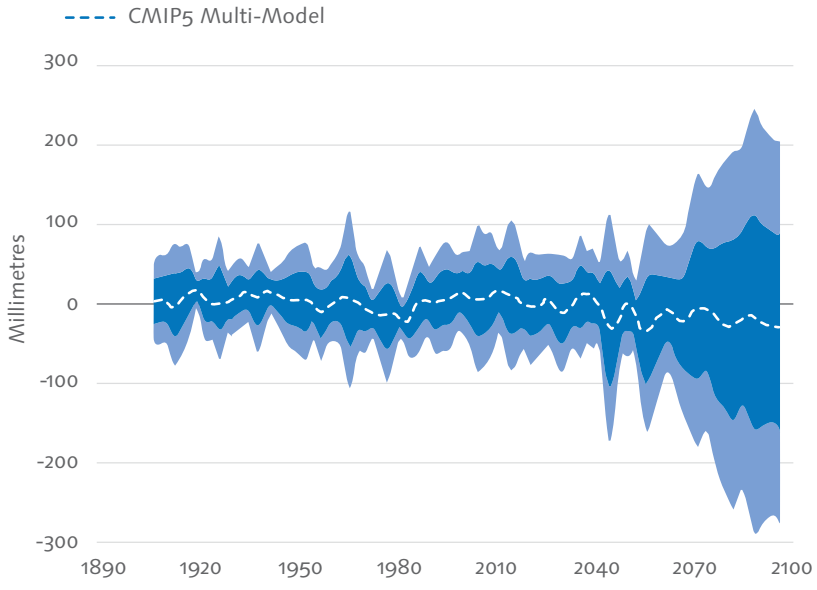
Source: Gaye (n.d.)

Average warming by +1°C in 2010, +2°C in 2040 and +3°C in 2100;

- Relatively low uncertainty until 2040, but quite high beyond that point;
- As from 2070: uncertainty regarding temperature trends varying between +1.8 to +4°C (Gaye, n.d.).

Summary of rainfall trends in West Africa:

Figure 8: Rainfall anomalies in West Africa (RCP 8.5)



Source: Gaye (n.d.)

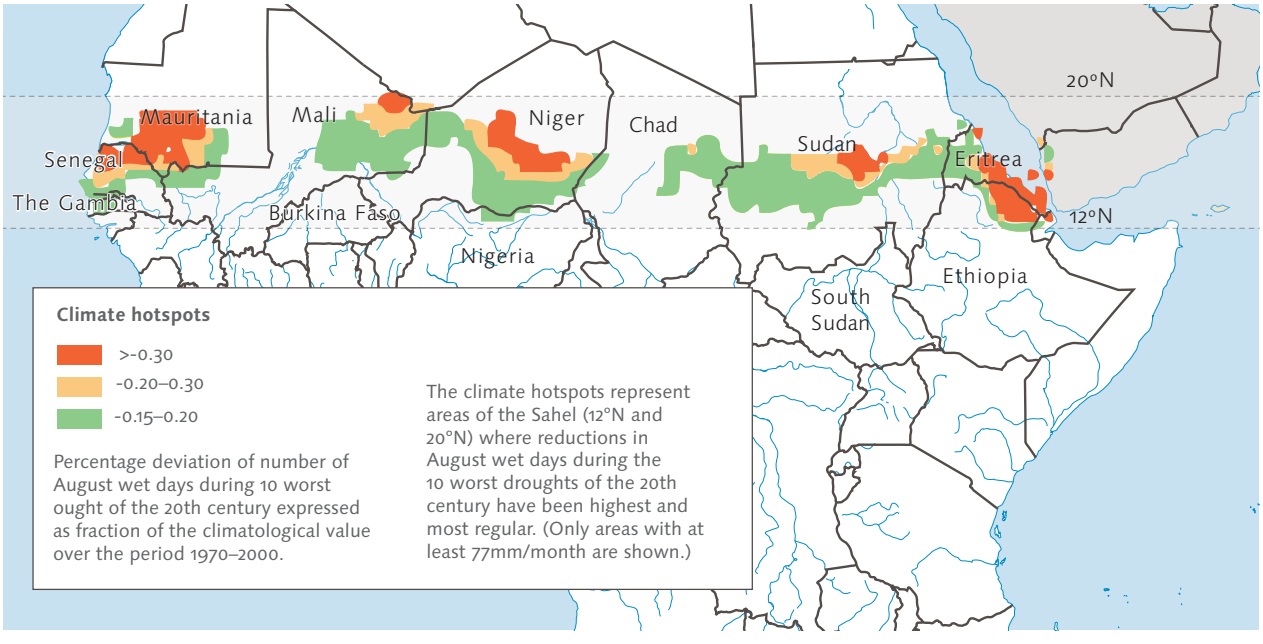
- Great rainfall variability from one season to the next;
- Very high uncertainty across models regarding precipitation trends ±250 mm;
- Tendency toward decreased precipitation as from 2040

Consequence: **alternation of rainfall surplus/deficit** (Gaye, n.d.).

2.2.2 Natural resource depletion and modified migrations

Historical observations over the 1901-2000 period identified vulnerable zones in which droughts caused the greatest difference in rainfall between dry and normal years. The results of this analysis suggest that there are at least two particularly sensitive regions in West Africa: one is located in the westernmost region of the Sahel (Senegal and Mauritania), and the other is between Mali and Niger.

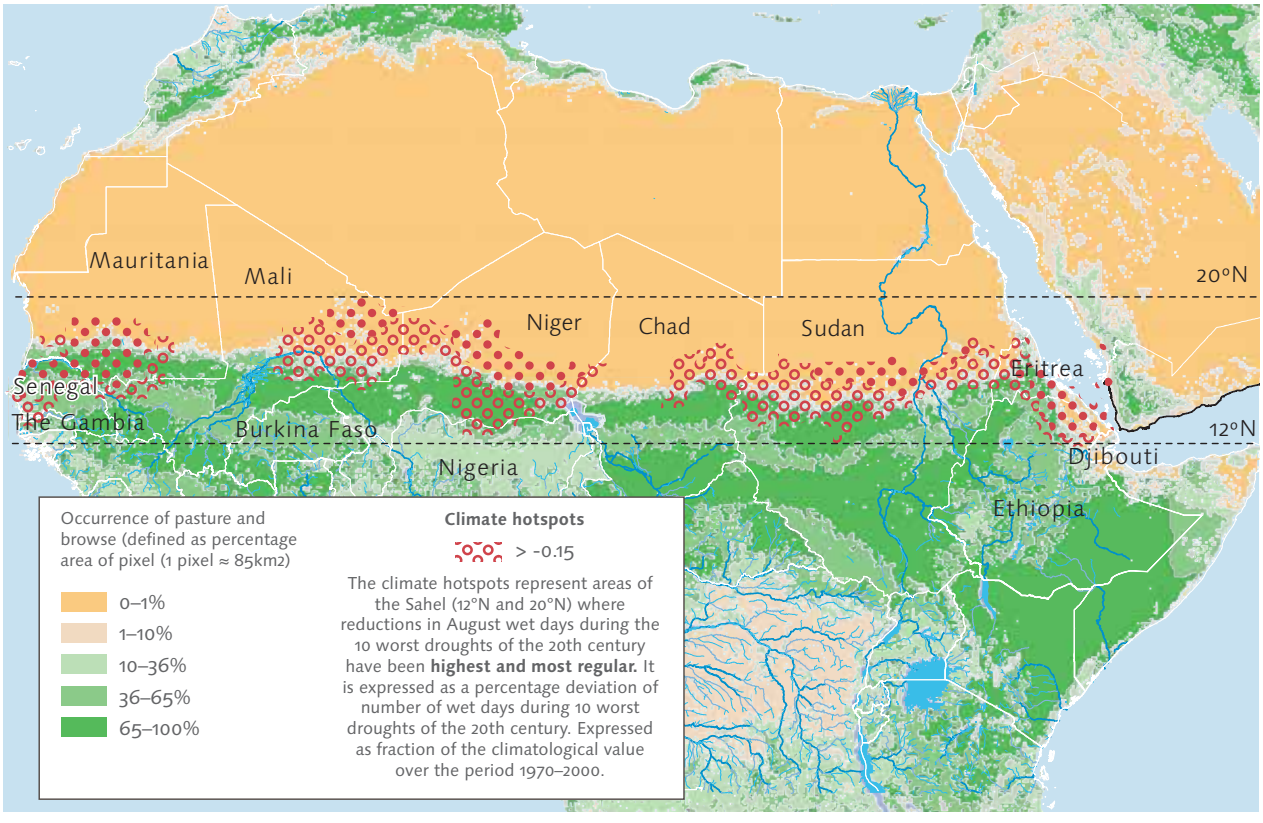
Figure 9: Areas historically most exposed to drought



Source: Salliot (2010)

Associated with the location of agroecological areas, the pastoral and agropastoral areas most vulnerable to drought are shown in Figure 10.

Figure 10: Location of pastoral and agropastoral zones most vulnerable to drought



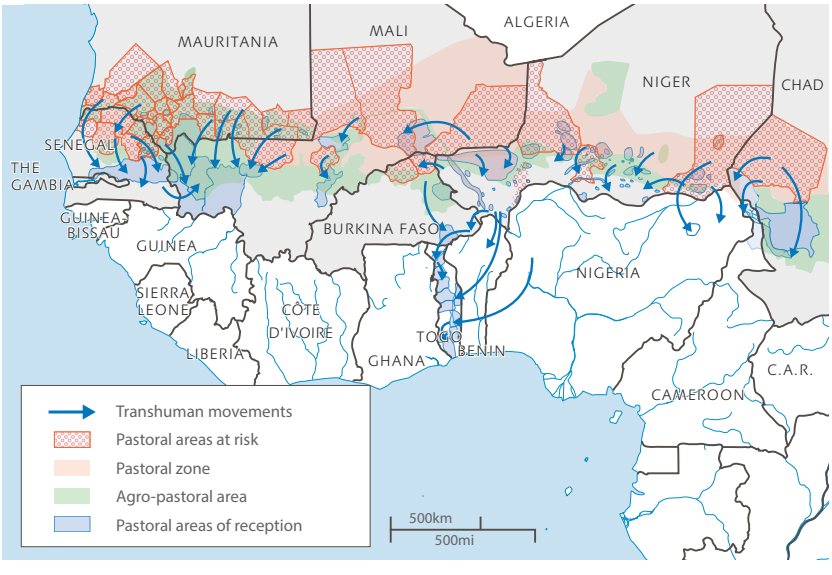
Source: Salliot (2010)

It is particularly in these areas that, during consecutive droughts, the availability of water resources and biomass for grazing is strongly threatened, with serious consequences for the mobility of pastoralists.

Box 2: Natural resources under stress: the example of 2017

The year 2017 was characterised by a high deficit of surface water in many Sahelian states (Soumaré, 2018). Significant water deficits were particularly observed in northern Niger and Mali. As a result, biomass production in Mauritania, Senegal and Chad was close to, if not below, that of 2011-2012, a year of severe drought. Large pockets of biomass deficiency were also observed in Mali, Niger and Burkina Faso. Many areas at risk of pastoral crisis have been defined due to a lack of fodder, lack of water resources and an already precarious food security situation (see Figure 11).

Figure 11: Pastoral areas at risk and transhumant movements, 2017-2018



Source: Soumaré (2018)

In these areas, fodder availability only made it possible to feed herds until the end of March, marking the lean season in pastoral areas, when important early transhumance movements, both national and trans-border in nature, began to take place.

Thus, since the end of the 1960s, pastoralists have been pushing the southern limits of dry season pastures because of recurring episodes of extreme drought and the depletion of natural resources (Véron, 2014). The low availability of pastoral resources during times of drought further aggravates the situation by leading to early migrations, which are becoming more frequent and worrying. All this pushes pastoral communities into crisis situations.

2.2.3 Endangered pastoral resilience and areas under increasing tensions

By definition, pastoralism is based on a permanent adaptation to environmental and climatic factors (Liniger et al., 2011), which are nevertheless increasingly varying and uncertain. Currently, pastoral activity is gradually losing its flexibility, limiting the ability of livestock farmers to cope with or adapt to droughts. In addition to these climate risks, pastoralists are losing mobility due to several factors: reduced availability of pastures; transhumance routes that are increasingly blocked, particularly at the borders; land-use changes due to the encroachment of crops; population growth and expanding urbanisation; worsening of security conditions, etc.

For example, in 2017, despite the presence of biomass surplus areas for cattle grazing (Soumaré, 2018), some areas remained inaccessible to pastoralists. In fact, the resources around Lake Chad and in one part of northern Mali were particularly difficult to access because of the armed conflict and insecurity that prevailed there. Additionally, areas where the transhumants stop (called reception areas), which are agricultural and agropastoral regions, end up with an overconcentration of animals that gradually exacerbates tensions surrounding land management.

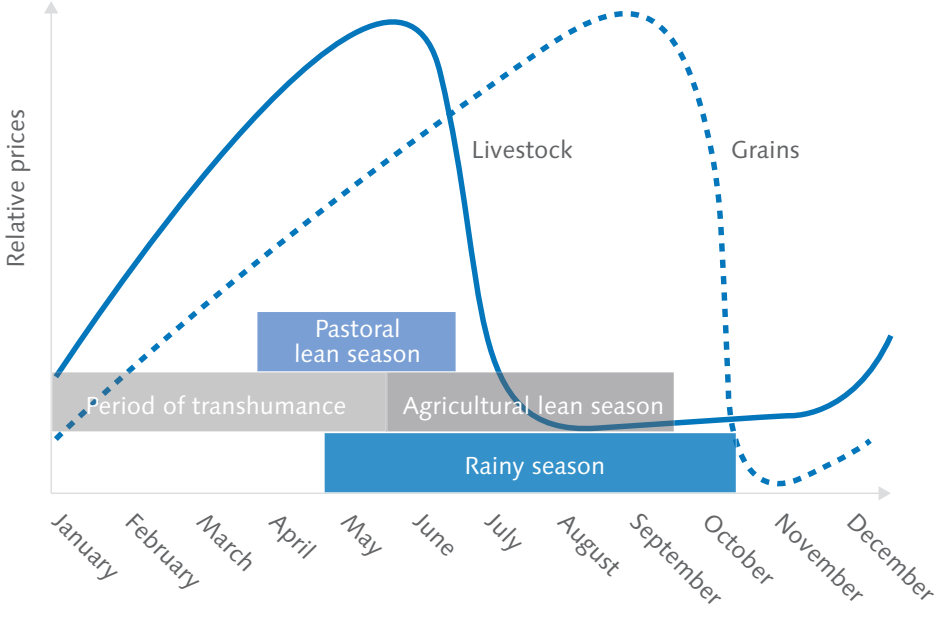
2.2.4 Causes of economic, food and security crises

Pastoral herders are vulnerable populations that are marginalised politically and economically, with limited access to resources (land, water, pasture) and basic services (health, education). The consequences of drought on the pastoral economy can therefore be dramatic.

In fact, during such periods of drought, the destocking of livestock results in lower animal prices due to a market flooded by poor quality animals (amount of meat per animal) (Liniger et al., 2011). This trend is inversely related to the prices of agricultural crops, which rise during bad harvests due to drought. For example, following the drought recorded in 2017, there was a clear downward trend in livestock prices in 2018 compared to 2017. Prices fell by 20-30%, and even reached -50% in some places (Soumaré, 2018). The purchasing power of livestock farmers was therefore strongly affected, considering food prices are at best stable and, in most cases, rise at the end of the agricultural season.

In addition to the impact of drought, other factors can affect livestock price formation (Jenet et al., 2016). Livestock routes stretch over hundreds of kilometres, leaving pastoralists with no real influence over unstable prices in intermediate and terminal markets (despite an almost constant demand in major coastal capitals). In addition, border harassment, conflict and insecurity undermine regional integration and interrupt livestock flows between countries. Information on prices and levels of supply and demand that pastoralists need in order to make sales decisions and develop marketing strategies are rare, and not harmonised. Such information is mainly obtained from informal

Figure 12: Livestock/grain price behaviour in Burkina Faso's Sahelian markets



Source: Author's own (based on Guibert et al., 2009)

sharing between livestock farmers. Finally, the negotiation of sales prices is often limited by asymmetric information between market players.

Lastly localised conflicts regarding access to resources, plus the economic precariousness of the players involved (which is heightened in times of drought), can contribute to more generalised regional conflict (Salliot, 2010). For example, the Tuareg rebellions in Niger (1990-1995); the self-defence movement of Ganda Koy in Mali (1990-1996); the food crises in Niger (2004-2006); the war in Darfur (2003-2006); and, more recently, the crisis in Mali (see Box 3).

Box 3: Droughts, pastoral and security crises: the example of Mali

Since the great drought of 1970-1990, the Sahel has been increasingly subjected to extreme climate episodes of strong and unpredictable intensity and frequency. This is especially the case in Mali, which has been struck by a series of drought periods in 2010, 2011 and 2012 (Wilkinson and Peters, 2015).

Two years of low and erratic rainfall in 2008 and 2009 caused a major crisis in 2010 among Malian pastoral communities (Wilkinson and Peters, 2015). The inadequate regeneration of northern pastures and the resulting biomass deficit have pushed pastoralists to begin their seasonal migration prematurely and to travel exceptionally long distances. Many animals died, and a massive destocking to limit losses led to an excess of animals on the market, resulting in a decline of livestock prices by about one-third (Réseau Billatal Maroobé, 2010). This crisis reduced the income of pastoralists and sedentary small farmers.

A year later, in 2011, irregular rainfall in West Africa strongly impacted agricultural crops. In Mali, the entire territory was affected, causing a decrease in harvests of about 10% compared to the previous year (CILSS, 2012). The drop in production led to a spike in prices, thus depriving the most vulnerable sectors of access to food products (landless farmers, pastoralists without livestock, nomads engaged in agricultural activities, etc.). In Mali agriculture accounts for 40% of GDP (Wilkinson and Peters, 2015), of which a significant part is produced by pastoralism (Liniger et al., 2011). Thus, this crisis had a significant impact, plunging the country into a food shortage situation.

The impact of this food crisis was further compounded by political instability – marked by a military coup in 2012 – conflict and weak governance. In particular, the rebellion of the Tuaregs and Islamist groups in the north of the country, where agropastoral activities are

mainly located, led to the creation of an area 'beyond the control of the national government'. In April 2012, at least 270,000 people took their livestock with them as they fled the conflict zone. That number includes more than 161,000 people from neighbouring countries. It is estimated that around 100,000 cattle crossed the border into Burkina Faso (Wilkinson and Peters, 2015). As of March 2014, 1.5 million people in Mali were still considered to be affected by food insecurity. In 2015, 660,000 children were estimated to be at risk of acute malnutrition. One quarter of Malian households were affected by food insecurity, 40% of which were in the north. These migratory movements, linked to the recurrence of droughts and unstable security, still tend to aggravate conflicts over access to natural resources, such as pastures and water, which are becoming increasingly rare (CILSS, 2012).

Source: Based on the study conducted by Simonet, Mendier de Suarez and Harvey, as seen in Wilkinson and Peters (2015).

Mali's experience shows that the intensity and recurrence of droughts, combined with the resulting economic shocks, within an unstable sociopolitical and security context, can create a complex multi-hazard dynamic that entrenches poverty and hampers the resilience of pastoral communities and the country as a whole (Wilkinson and Peters, 2015).

Also, it is crucial to gain a more specific understanding of how markets and livestock prices are affected by economic, climate and security shocks within the context of climate change. Some studies highlight the complexity of livestock farmers' economic strategies arising from complicated trade-offs and permanent 'adjustments' to prices (Duteurtre, 2009). However, the current state of knowledge does not yet clearly understand these price dynamics.

Still, price indicators calculated on the basis of grain price series are at the heart of MIS and EWS implemented at the national level (Niger, Burkina Faso, Mali), regional level (PREGEC Charter indicators) and by donors and UN organisations (Food and Agriculture Organization (FAO), World Food Programme (WFP), etc.). While these indicators and analyses provide a better understanding of food security situations in West Africa, particularly for rural agricultural populations and vulnerable urban populations, an analysis of livestock prices would contribute to a reflection on pastoral crisis dynamics and determinants.

Our study thus analyses the temporal and spatial dynamics of livestock prices using original data collected by national MIS, made available by CILSS, covering the main livestock markets over the 2008-2016 period in Mali, Burkina Faso and Niger.

3. CHARACTERISTICS OF THE MIS AND LIVESTOCK MARKETS STUDIED

IMAGE: MARKET DAY IN FERLO, SENEGAL. PICTURE TAKEN BY: ©ASSANE BEYE

3.1 MIS in national programmes for the prevention of pastoral and food crises

During a study conducted by the authors in 2010 (Araujo Bonjean et al., 2010), MIS in Sahelian countries were studied in depth.

MIS were set up in Sahelian countries in the late 1980s, along with measures to liberalise the production and trade of agricultural products (Ibid.).

The primary mission of MIS was to collect market prices of main agricultural (and livestock) products and disseminate them as widely as possible among various actors: producers, consumers and traders (Ibid.). Under the context of abandoning agricultural trade

regulations and prices, the creation of MIS was aimed at improving the sharing of and the access to information on the markets, thus increasing transparency in the exchanges. MIS would therefore contribute to the development of competition and better stock management. Beyond this initial mission, the MIS also aim 'to provide public authorities with useful information to guide their decisions on food security, which are integrated into national food crisis prevention programmes,' (Ibid.).

Agricultural MIS and EWS have been the subject of numerous studies, but this analysis focuses on specific livestock issues: the prevention of pastoral crises and the collection of livestock price information.

MIS and the livestock crisis prevention system in Burkina Faso

The creation of the Permanent Diagnosis project (funded by CILSS) (Araujo Bonjean et al., 2010) in the early 1980s marked the beginning of a national MIS in Burkina Faso. Until 2009, the data collection network on livestock MIS included 14 livestock markets across the country (Traoré, 2011). As from May 2009, the network was expanded with the introduction of eight new markets. Monitored livestock markets were selected on the basis of their importance in the livestock trading system and their geographical position.

Diagnostic monitoring of food security mobilises different sources of information (consumption, nutritional situation, production, prices). Price information is based on data from the EWS, crop MIS and livestock MIS. Poor geographical coverage and a lack in regular data collection are the main weaknesses of this particular collection system. The analytical capabilities of the MIS in terms of understanding and monitoring the food situation also need to be strengthened.

The MIS and the livestock crisis prevention system in Mali

The Malian grain MIS coincided with the liberalisation of the cereals market in 1989 and was hosted by the Office des produits céréaliers du Mali (OPAM), mainly focusing on cereal. Almost ten years later, in 1998, the MIS was restructured and became the Agricultural Market Observatory, which monitored grain as well as livestock markets (in conjunction with the National Directorate for Animal Production and Industry (DNPIA) (Araujo Bonjean et al., 2010). In 2008, it went from monitoring 22 to 98 cattle markets.

The MIS and the livestock crisis prevention system in Niger

In Niger, the Agricultural Market Information System (AMIS) was also created in 1989. As from 2000, it was placed under the supervision of the Ministry of Trade, Industry, Crafts and Private Sector Promotion (Araujo Bonjean et al., 2010). AMIS monitors 78 cattle markets. There is one surveyor affiliated to each market, and one inspector for each of the nine regions. These regional representatives are responsible for controlling and centralising data collected by surveyors each week on all monitored markets.

AMIS provides data and information to the coordination cell of Niger's EWS. Nine monitored indicators compose this EWS. One refers to deficient fodder balance and another refers to the terms of livestock/basic grain exchanges. However, there is no indicator based on livestock market prices as such (Araujo Bonjean et al., 2010).

In general, it is important to note that at the regional level, livestock MIS do not yet have a harmonised and common collection method. Together with other approaches supporting the definition of specific pastoral indicators, this work, which was

initiated by the *Projet Régional d'Appui au Pastoralisme au Sahel* (Regional Sahel Pastoralism Support Project, PRAPS), should allow for a coherent analysis of the pastoral situation at the regional level. This harmonised approach would allow for both a regional understanding of pastoral crises and coordinated crisis management. Promoted by CILSS and the Harmonized Framework, the regional approach is relevant because the West African Economic and Monetary Union (WAEMU) allows for the free circulation of goods and people within the sub-region. Droughts have an ambiguous and indirect impact on malnutrition, especially across markets. The regional approach captures the movement of goods and people that can impact nutritional situations. In addition, states retain a sovereign control of crisis management, but the harmonised regional approach allows for a better allocation of funds and a better understanding of the issues influencing the national situation.

Finally, it is important to emphasise that the west African region serves as a reference in terms of systematic market data collection. However, this data collection and analysis implies a significant cost. The sustainability of these systems requires budget support and capacity-building for the national agencies which are primarily responsible for producing, analysing and sharing this information.

Box 4: Review of the food and nutrition situation based on the results of the agropastoral season of 2017-2018

The Food Crisis Prevention Network (Réseau de Prévention des Crises Alimentaires, RPCA) confirmed the critical state of the pastoral situation in April 2018, in light of significant fodder deficits, particularly in Senegal and Mauritania, where deficits exist in 80% and 95% of pastoral zones respectively (RPCA, 2018). This situation led to an early departure of transhumance animals within a complicated security context, raising fears of numerous conflicts between pastoralists and farmers in transit and reception areas.

The food and nutrition situation has been severely deteriorating in several areas of the Sahelian belt (Burkina Faso, Mali, Mauritania, Niger, Senegal and Chad). About 7.1 million people are in need of food assistance, including 3.7 million in north-eastern Nigeria (Ibid.). Among the most affected populations, pastoralist and agropastoralist households, and especially women and their children, are facing a crisis situation. This situation is doubly aggravated, firstly by persistent insecurity in the Lake Chad area and Liptako-Gourma, and secondly by the economic context marked by the depreciation of certain local currencies and the effects of inflation. In April 2018, the RPCA issued a warning on the urgency of the crisis: if vigorous measures were not implemented, the number of people affected could reach 10.6 million by the June-August lean season, and the number of malnourished children could increase from 1.1 to 1.6 million in six countries of the Sahel (Burkina Faso, Mali, Mauritania, Niger, Senegal and Chad) (Ibid.).

Access to livestock price data in the Sahel region is still rather limited. The role of livestock price-based indicators in national and regional food crisis prevention programmes appears to be insufficient – if not non-existent – with information collected by MIS that is not exploited in a way that can truly assist governments in their decisions. The numerous examples of food and security crises resulting from the fragility of pastoral systems demonstrate the importance of strengthening the monitoring and analysis of livestock market prices.

The study covers three Sahelian countries – Burkina Faso, Mali and Niger – and focuses on cattle used in national and trans-border trade. Thisstudy exploits newly acquired information on livestock prices during the 2008-2016 period (from bull price monitoring), collected by national MIS in Mali, Burkina Faso and Niger in order to understand their spatial evolution and the degree of market integration at the regional level, as well as to analyse temporal price dynamics in relation to climate and security shocks. The CILSS gathered national MIS data for a sample of markets in order to produce a consolidated regional picture on a regular basis. The data used in the following analysis are those gathered and consolidated by CILSS.

Our analysis aims at assessing price series, looking in particular on food crisis situations characterised by significantly lower prices, resulting in a massive destocking of livestock. Hypothetically, low livestock prices in the early lean season increase food insecurity for pastoral populations.

3.2 Typology, location and role of cattle markets studied in commercial circuits

Table 1: Number of cattle markets monitored in the study area

Country	Number of cattle markets
Burkina Faso	15
Mali	22
Niger	50

Source: Authors' own, based on CILSS data (consolidated in 2018)

Livestock markets are geographically dispersed and form a complex trade network. According to the typology proposed by the IRAM (Guibert et al., 2009) and later employed by Traoré (2011), there are four different types of markets that play distinct roles in the livestock trade:

Collection centres, also called production markets, are primary markets located in production areas or livestock farming areas. The animals come directly from livestock farms or small markets in the surrounding villages, and supply is often dependent on the season. It is the main point of entry for animals into the trade circuit.

Assembly centres are located in small urban centres. The animals in these markets come from collection centres. The livestock is then sold by batch (unlike the collection centre, where most transactions are by unit). These batches are then sent to export markets or terminal markets. These markets not only gather regional actors, but also actors from neighbouring countries. In addition to livestock farmers, exporters and buyers, butchers are also present in this market.

Export markets are considered to be intermediary markets. These are assembly points, the main function of which is to export livestock to trans-border and/or terminal markets in other countries.

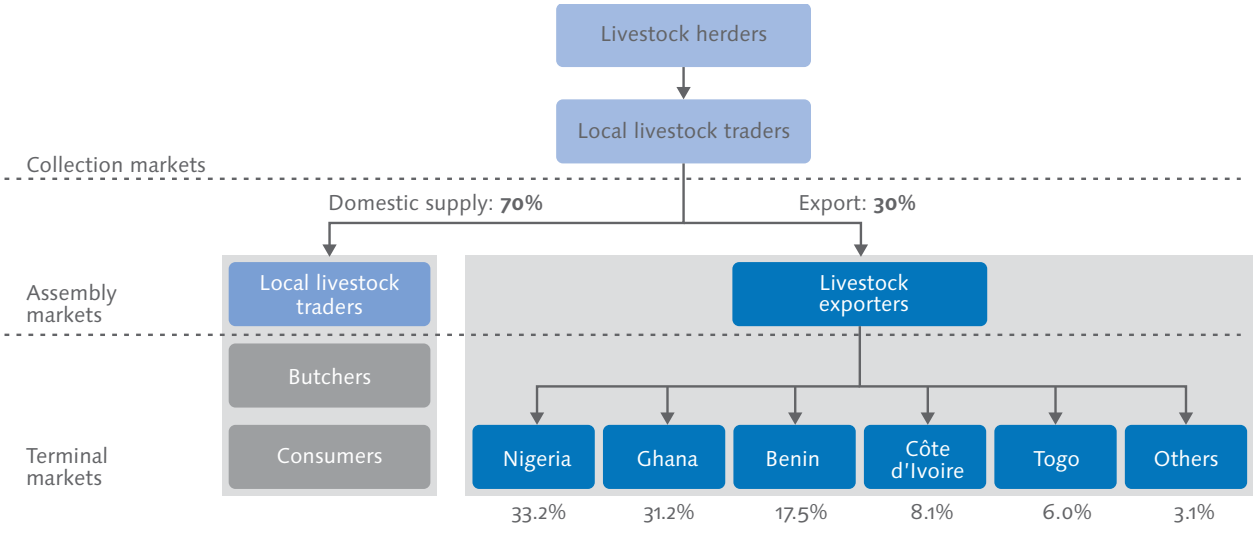
Terminal markets are consumer markets. They are located in major urban centres (often the capital cities of Sahelian and coastal countries). They are distinguished by an almost constant demand and very stable prices. These markets are very often adjacent to a slaughterhouse.

It should be noted that the typology of markets is not fixed. The classification of a market varies according to the state of the agricultural season.

BURKINA FASO

There are two types of livestock market in Burkina Faso: the domestic market and the sub-regional market. The relationship between these two types of markets helps regulate the demand for meat and the price of livestock in local markets (Traoré, 2011). In 2007, the foreign market share in controlled livestock trading was 66%, 23% and 53% for cattle, goats and sheep, respectively (Traoré, 2011) (this data differs from the graph in Figure 13, which only includes cattle market information). On this basis, more than half of the livestock subject to controlled trading is destined for export, mainly to Nigeria, Ghana and Benin, which reveals the importance of the sub-regional market in livestock trading.

Figure 13: Livestock trade flows in Burkina Faso (situation in 2007)

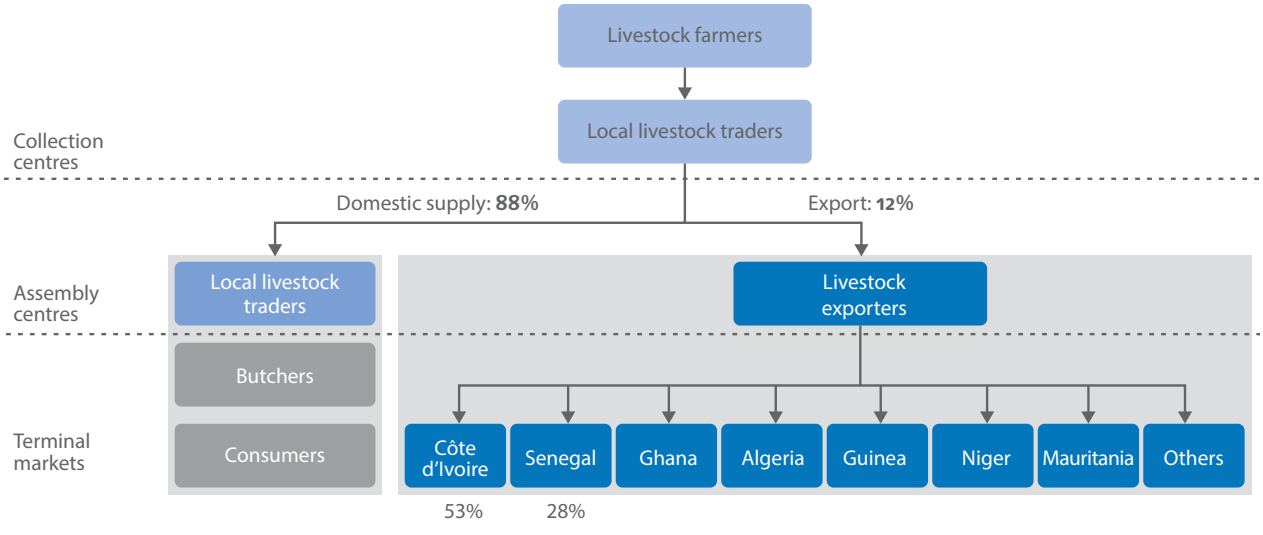


Source: adapted from Nugteren and Le Côme (2016)

MALI

The flow chart involving the different actors in the livestock meat sector is displayed in Figure 14. A majority of Mali's meat remains in Mali, 88%, while 12% supplies the markets of neighbouring countries including, quite notably, Ivory coast and Senegal.

Figure 14: Livestock trade flows in Mali

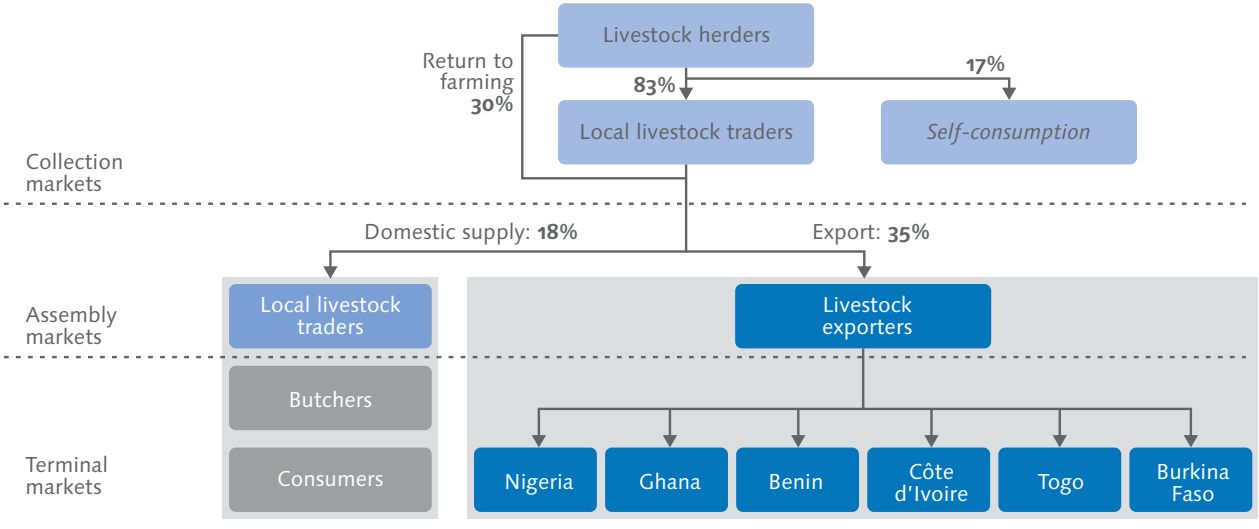


Source: adapted from Dembele (2017)

NIGER

As shown in Figure 15, 17% of the cattle stock in Niger is for self-consumption, 30% is intended for re-breeding (reproduction, fattening, animal traction), 18% supplies the domestic market and, lastly, the remaining 35% is exported.

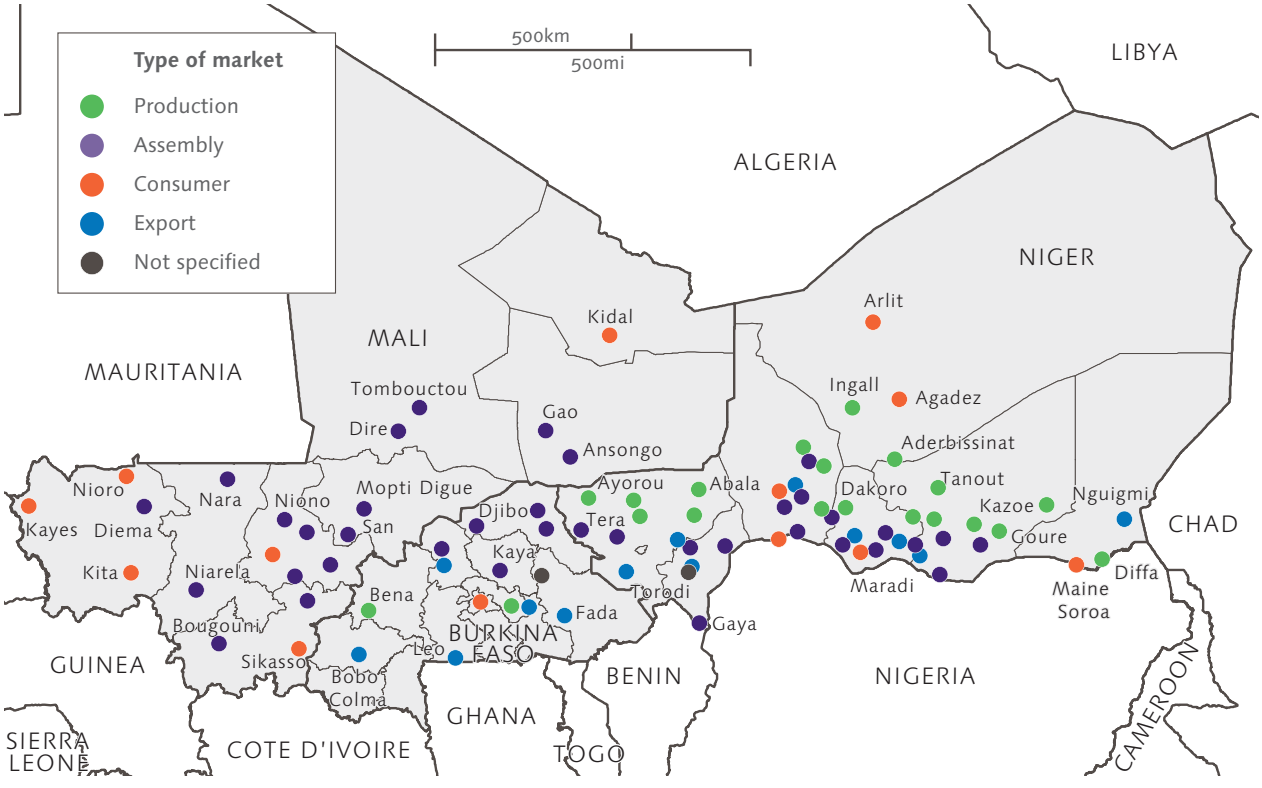
Figure 15: Livestock trade flows in Niger (situation in 2011)



Source: adapted from Aboubacar (2017)

Figure 16 shows the location of the markets covered by this study, for which livestock price data is available.

Figure 16: Location and typology of cattle markets in the study area



Source: Authors' own, based on CILSS data (consolidated in 2018)

4. PRICE ANALYSIS

IMAGE: ONE OF THE LARGEST CATTLE MARKETS IN MALI OCCURS EVERY SATURDAY AT A MARKET THAT IS ABOUT ONE HOUR AWAY FROM BAMAKO ©ROMEL JACINTO

Cattle price series have a lot of missing data, making a large number of series non-exploitable. The monthly collection of data on the basis of information collected on a 10-day or weekly basis is very demanding. The absence of a data collection agent for one week, or a poor relay of information, can lead to missing data on the collected series. Thus, for data series with one or two missing data points, an interpolation was performed (the missing figure was replaced by the price average of the previous and next period) to ensure a better series continuity. In order to ensure the quality of the statistical analysis, only series with less than 10% of missing data were included. As shown in Table 2, this reduces the number of markets included in the analysis to 28: 11 in Niger, 10 in Mali and 7 in Burkina Faso.

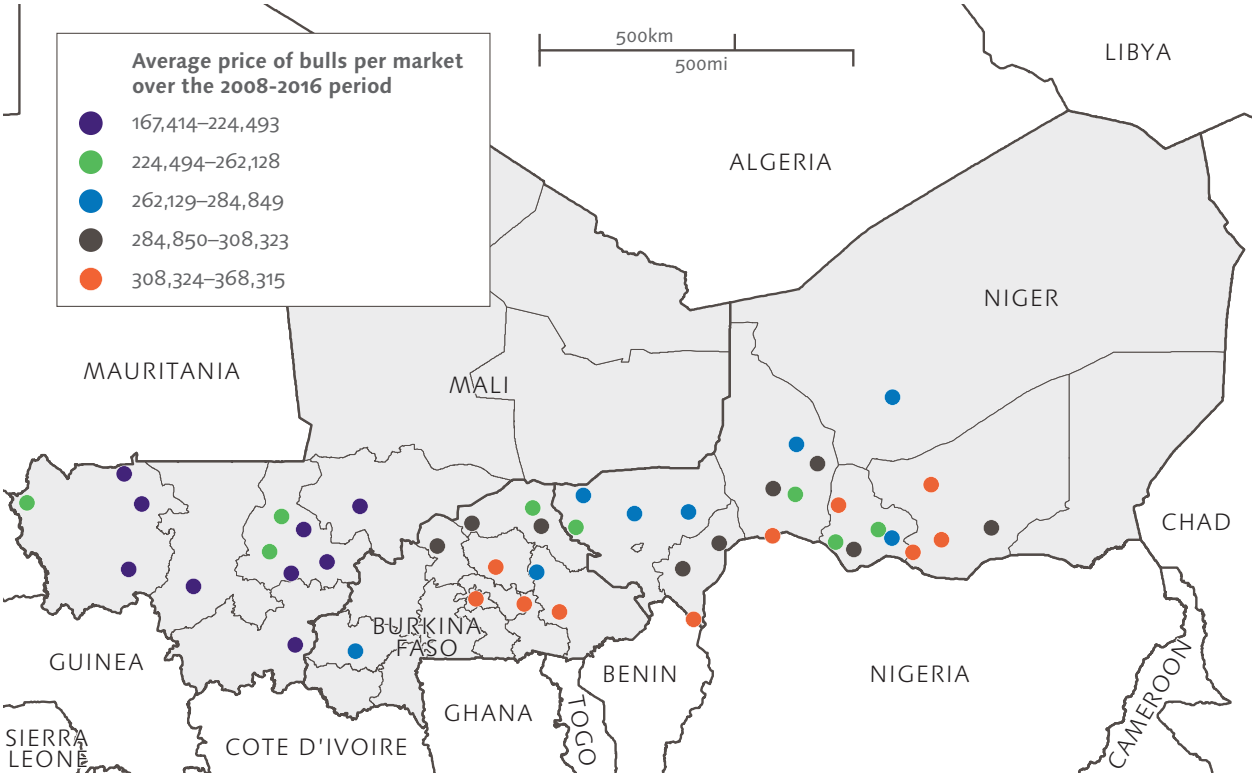
Table 2: Selection of cattle markets based on the ensured coverage rate of data collection for the 2008-2016 period (out of a total of 108 surveys)

	Selection criteria	Burkina Faso	Mali	Niger	Total by selection criteria
Number of markets	≥75%	11	15	24	50
	≥80%	11	12	22	45
	≥90%	7	10	11	31
Total markets per country:		15	22	50	

Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 17 shows the average level of cattle prices over the 2008-2016 period for the 45 markets with less than 20% of missing data, while Figure 18 is restricted to the 28 markets used in the rest of the analysis.

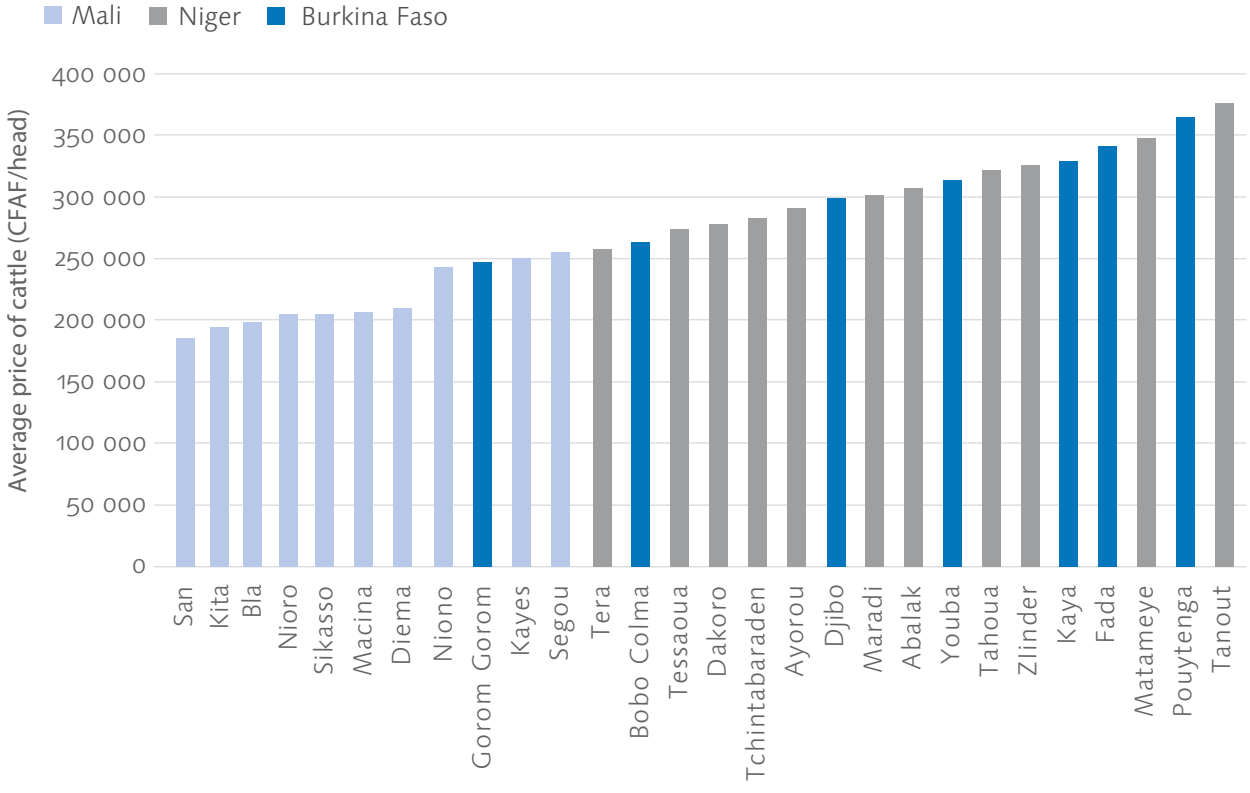
Figure 17: Average price of cattle in the study area, 2008-2016



Source: Authors' own, based on CILSS data (consolidated in 2018)

Cattle price disparities are high within the sub-region. Although all three countries are net exporting countries of cattle, cattle prices vary by as much as 100%, depending on the market. Malian markets have the cheapest cattle prices, as compared to Burkina Faso or Niger, where cattle are, on average, in the same price range. Since data collection systems are not yet harmonised across countries, price differences can also be explained by differences in data collection method (surveyors not surveying the same types or breeds of cattle), or by a cattle breed/quality effect (this could perhaps explain the price differences between the Malian, Nigerien and Burkinabé markets; Malian cattle being considered of better quality, for example).

Figure 18: Average price of cattle in markets used for this analysis (January 2008-December 2016; CFAF/head)



Source: Authors' own, based on CILSS data (consolidated in 2018)

4.1 Spatial price dynamics

Livestock trade is hampered by the high cost of transport, the cost of official export documents and official veterinary certificates, as well as export taxes which are particularly high in Burkina Faso and Niger. Added to these costs are other costs related to illegal practices such as road taxation. Lastly, the lack of harmonisation of national livestock policies is an additional impediment to livestock and livestock product trading.

In the absence of data on these various barriers to trade, spatial price dispersion is calculated as an indication of spatial market integration. Under the law of one price, if the markets are 'spatially arbitrated'[3], and in the absence of trade restrictions and transportation costs, the prices of identical goods must be the same between markets once converted into the same currency at the current exchange rate.

The existence of transport costs and other transaction costs contribute to the non-application of the law of one price. Transaction costs include transport costs, loading and unloading costs, and profits made by traders (Baulch, 1997). When there are transaction costs, prices between markets are not equal and the spatial arbitration process must equalise the supply and demand between markets so that the price difference is reduced to transaction costs: $|P_{ik,t} - P_{jk,t}| \leq T_{ij,t}$, where T_{ijk} are the trade costs (transport, taxes, etc.) between market i and market j for product k, $P_{ik,t}$ is the price of product k on market i, at time t, $P_{jk,t}$ is the price of product k on market j at time t. The law of one price is therefore: $-T_{ijk} \leq P_{ik,t} - P_{jk,t} \leq T_{ijk}$. As long as the price difference between markets is between $[-T_{ijk}, T_{ijk}]$, there can be no spatial arbitration.[4] The spatial arbitration process only occurs when the price difference exceeds the costs of inter-market transfers.[5]

3 See Enke (1951) and Samuelson (1952) for more literature on the subject.

4 That is to say, a choice between one market or another for economic actors.

5 Integrated markets correspond to places where prices are correlated, in geographical locations which are often connected (one-to-one or in a network).

4.1.1 Spatial price dispersion in Burkina Faso

La dispersion spatiale des prix est forte au Burkina Faso ; le prix
Spatial price dispersion is high in Burkina Faso; cattle prices are, on average, 44% higher in the most expensive market – the Pouytenga export market – in comparison to the cheapest market, which is the Gorom-Gorom production market (see Table 3). It is not surprising that prices are higher in export markets than in production markets. On the other hand, there is a significant price difference between the two export markets Bobo Colma and Pouytenga. Prices in Bobo Colma are relatively low and well below the national average, while prices in Pouytenga are very high.

Table 3: Characteristics of markets selected in Burkina Faso (January 2008-December 2016)

	Average price	Maximum	Minimum	Volatility	Market typology
Gorom Gorom	249665	318333	184444	0.081	Production
Bobo Colma	269782	345250	194583	0.090	Export
Djibo	284971	363750	213667	0.055	Assembly
Youba	297751	442130	190396	0.091	Assembly
Kaya	320631	412833	236556	0.076	Assembly
Fada	326460	404583	197625	0.082	Export
Pouytenga	359495	478617	255800	0.060	Export
National average	301192				

Note: Prices are expressed in CFAF/head of cattle. Volatility is calculated as the standard deviation of the monthly difference in prices expressed in logarithms.

Source: Authors' own, based on CILSS data (consolidated in 2018)

In terms of volatility, the markets of Djibo and Pouytenga are distinguished by their low volatility, unlike Youba and Bobo Colma.

4.1.2 Spatial price dispersion in Mali

The average price difference between the cheapest and the most expensive markets is roughly the same as in Burkina Faso; on average, cattle prices are 40% higher in the Ségou consumer market than in the San assembly centre (see Table 4).

Price volatility is significantly higher in Mali than in Burkina Faso, with the markets of Sikasso, Kita and Diéma being the most volatile.

Table 4: Characteristics of markets selected in Mali (January 2008-December 2016)

	Average price	Maximum	Minimum	Volatility	Market typology
San	184828	282000	88750	0.114	Assembly
Kita	196065	307000	119000	0.148	Consumer
Bla	199172	290875	132000	0.086	Assembly
Nioro	210394	310000	131250	0.139	Consumer
Sikasso	213681	338250	125000	0.163	Consumer
Macina	218381	311250	115375	0.102	Assembly
Diema	219165	331250	125000	0.144	Assembly
Niono	234065	313333	157900	0.081	Assembly
Kayes	254152	424250	31968.8	0.124	Consumer
Segou	259044	387700	143000	0.111	Consumer
National average	219248				

Note: Prices are expressed in CFAF/head of cattle. Volatility is calculated as the standard deviation of the monthly difference in prices expressed in logarithms.

Source: Authors' own, based on CILSS data (consolidated in 2018)

4.1.3 Spatial price dispersion in Niger

As in Mali and Burkina Faso, the most expensive market in Niger – Tanout – is 40% more expensive on average than the cheapest market – Tera – sampled. The level of Nigerien cattle prices does not appear to be determined by market typology, as average prices vary widely within the collection centres and within the export markets.

There is a very strong heterogeneity between markets in terms of price volatility, with weak volatility markets, such as those of Tessaoua or Ayorou, and markets characterised by high volatility, such as Dakoro and Maradi.

Table 5: Characteristics of markets selected in Niger (January 2008-December 2016)

	Average price	Maximum	Minimum	Volatility	Market typology
Tera	264216	357000	201500	0.092	Export
Tessaoua	276208	372750	191250	0.059	Export
Dakoro	278263	508567	174356	0.151	Production
Tchintabaraden	279661	353125	180334	0.090	Production
Ayorou	280147	350700	192000	0.066	Production
Maradi	291087	412958	161250	0.157	Production
Abalak	292420	415000	179400	0.086	Collection
Tahoua	300976	382417	182250	0.123	Consumer
Zinder	316897	450600	229540	0.113	Consumer
Matameye	331646	410375	203320	0.092	Export
Tanout	371361	496340	238074	0.104	Production
National average	298444				

Note: Prices are expressed in CFAF/head of cattle. Volatility is calculated as the standard deviation of the monthly difference in prices expressed in logarithms.

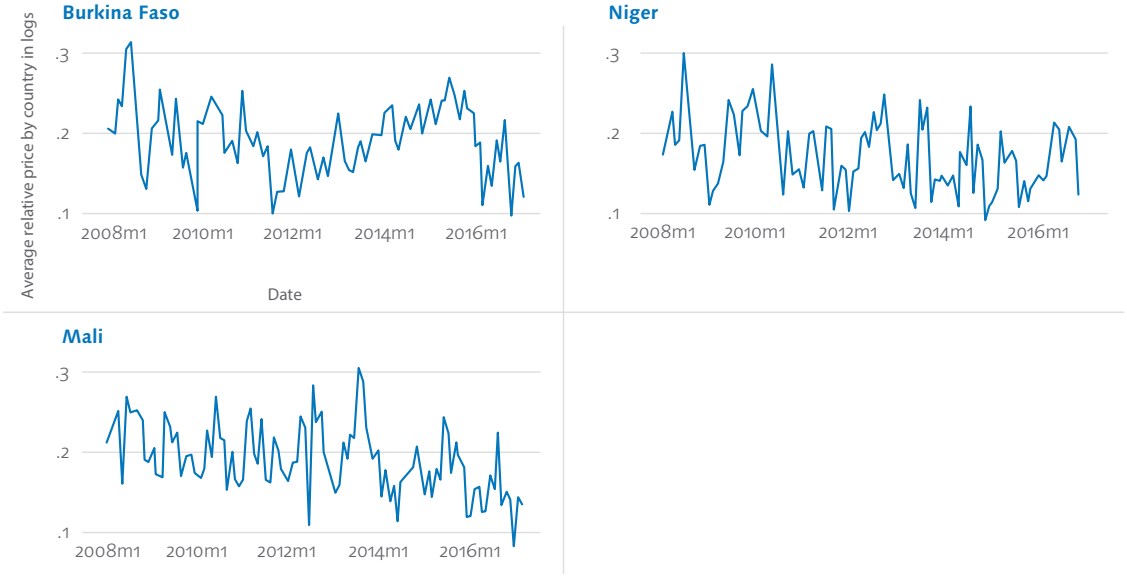
Source: Authors' own, based on CILSS data (consolidated in 2018)

4.1.4 Spatial price dispersion at the sub-regional level

Spatial price dispersion seems to be decreasing in the three countries, despite a period of higher dispersion in Burkina Faso between 2012 and 2015. Mali is the country in our sample with the strongest price dispersion between markets, though it has decreased over the 2014-2016 period.

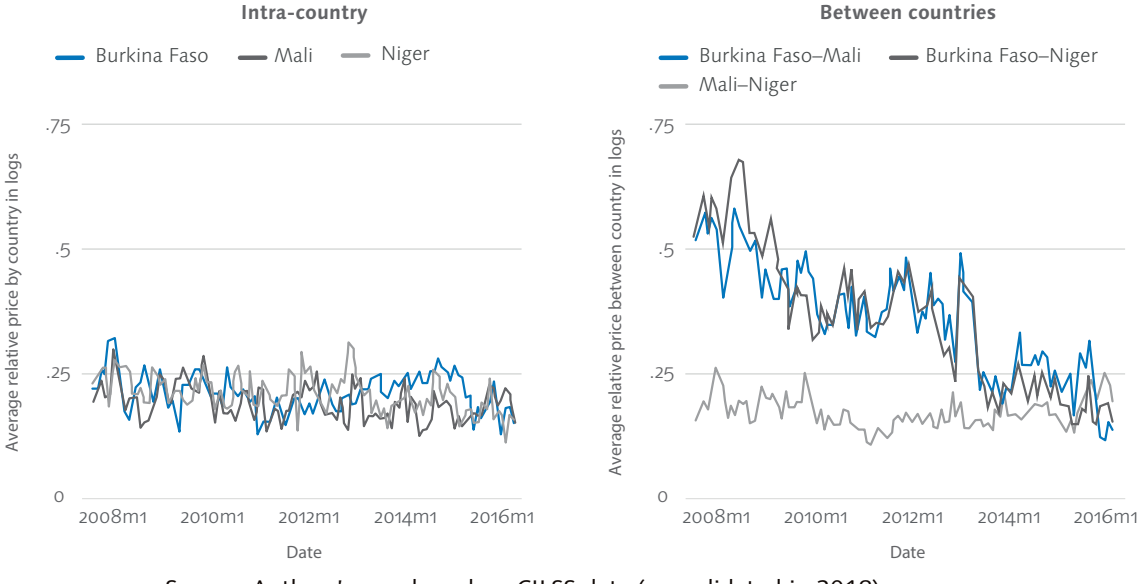
Inter-country price dispersion is, as expected, higher than intra-country dispersion, with one notable exception: market pairs between Burkina Faso and Niger, which are in fact not much higher than their own relative intra-country dispersions. On the other hand, price dispersion between Mali and its two neighbours was very strong between 2008 and 2010 and has since declined sharply, as shown in Figure 19. The 2008-2016 period is indeed a period of price convergence; since 2014, relative price dispersion between countries has been similar for each pair of countries.

Figure 19: Average relative price by country in logs (absolute value)



Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 20: Average relative price within and between countries in logs (absolute value)



Source: Authors' own, based on CILSS data (consolidated in 2018)

4.2 Identification of leading markets

Leading markets are markets that play a role in influencing prices in other markets at the national or regional level. Thus, lagging prices in leading markets can significantly explain current prices in other markets. Within the context of this study, the goal of identifying leading markets is to improve our understanding of livestock price dynamics.

The identification of these markets is done in the context of Vector Autoregression (VAR) modelling, which considers (i) that prices are determined simultaneously on a series of markets and (ii) a dynamic nature of price adjustments. Granger causality tests were performed. They indicate whether there is a statistically significant relationship between contemporaneous prices (those that were taken in real-time) and delayed prices (those that were delayed by one or more periods/months). Market leaders are considered to be markets that 'Granger-cause' a large number of markets, but are only 'Granger-caused' by a small number of markets.[6] Here, leading markets are considered to be those that cause at least 50% of other markets and are caused by less than one third of other markets.

Granger causality tests were first performed country by country before being conducted on a regional VAR model.

6 More simply, market A causes market B if the variations of market B at time t are explained by price variations of market A in the previous periods.

4.2.1 Burkina Faso

Granger causality tests do not highlight leading markets in Burkina Faso, although Pouytenga and Bobo Colma respectively cause three markets out of the seven sampled. These two markets are the only ones that seem to have an influence on national prices. The lack of leading markets in Burkina Faso may be due to the fact that this country is essentially a transit country for animals from north to south. Burkina Faso is also a smaller exporter of cattle than Mali or Niger. Lastly, the lack of price data in coastal countries does not make it possible to test the impact of Burkinabé export markets on the Beninese or Ivorian consumer markets.

Table 6: Granger causality tests for cattle markets in Burkina Faso (real prices, January 2008-December 2016)

Burkinabé markets	Cause		Number of times a market causes another	Number of times a market is caused by another
Bobo Colm	→	Djibo, Fada, Kaya	3	1
Djibo	→	Youba	1	2
Fada	→	/	0	2
Gorom Gorom	→	Kaya	1	0
Kaya	→	/	0	2
Pouytenga	→	Bobo Colma, Djibo, Fada	3	0
Youba	→	/	0	1

Note: Market typologies have been defined as follows:

Production | Assembly | Consumer | Export

Source: Authors' own, based on CILSS data (consolidated in 2018)

4.2.2 Mali

Two Malian markets stand out and can be considered leading markets at the national level: Kayes and Kita, which cause five and six markets at the national level respectively and are caused only by a small number of other markets. Kayes and Kita are both considered consumer markets. Kayes is located in Mali's border area with Mauritania and Senegal and can therefore partially reflect price variations in these two countries.

The markets of Niono and Nioro, on the other hand, seem isolated insofar as they do not cause any other market and are caused by only two domestic markets.

Table 7: Granger causality tests for cattle markets in Mali (real prices, January 2008-December 2016)

Malian markets	Cause		Number of times a market causes another	Number of times a market is caused by another
Bla	→	Niono, Sikasso, Ségou	3	0
Diema	→	Sikasso	1	2
Kayes	→	Diéma, Macina, San, Sikasso, Ségou	5	1
Kita	→	Diéma, Kayes, Macina, Nioro, Sikasso, Ségou	6	1
Macina	→	Kita	1	3
Niono	→	/	0	2
San	→	Sikasso	1	2
Nioro	→	/	0	2
Sikasso	→	Nioro	1	6
Segou	→	Macina, Niono, San, Sikasso	4	3

Note: Market typologies have been defined as follows:

Production | Assembly | Consumer | Export

Source: Authors' own, based on CILSS data (consolidated in 2018)

4.2.3 Niger

Granger causality test results indicate that four markets play a decisive role in price formation in Niger: Tessaoua, Dakoro, Abalak and Maradi. Prices in these markets cause the prices of five out of the other 10 markets considered. Tessaoua, Dakoro and Abalak appear to be leading markets, insofar as prices in these markets cause prices in a large number of other markets, while they are only caused by a small number of other Nigerien markets. Tessaoua, Dakoro and Maradi are all located in the Maradi region, which borders Nigeria and is an intense trans-border trade zone (Nigeria is the main destination Niger's livestock). Abalak, located in the Tahoua region, is an area where livestock is the main source of household income.

Table 8: Granger causality tests for cattle markets in Niger (real prices, January 2008-December 2016)

Nigerian markets	Cause		Number of times a market causes another	Number of times a market is caused by another
Tera	→		0	3
Tessaoua	→	Tera, Tchintabaraden, Ayorou, Maradi, Matemeye	5	2
Dakoro	→	Tchintabaraden, Abalak, Tahoua, Metemeye, Tanout	5	1
Tchintabaraden	→	Ayorou, Maradi, Zinder, Tanout	4	5
Ayorou	→	Dakoro, Tchintabaraden, Zinder	3	5
Abalak	→	Tera, Tessaoua, Ayorou, Maradi, Zinder	5	1
Maradi	→	Tchintabaraden, Ayorou, Tahoua, Metemeye, Tanout	5	4
Tahoua	→	Maradi	1	4
Zinder	→	Tera, Tessaoua, Ayorou	3	5
Matameye	→	Tchintabaraden, Tahoua, Zinder	3	3
Tanout		Tahoua, Zinder	2	3

Note: Market typologies have been defined as follows:

Production | Assembly | Consumer | Export

Source: Authors' own, based on CILSS data (consolidated in 2018)

4.2.4 Sub-regional level

In total, 22 markets were selected for the analysis of cattle market integration at the regional level. They include 10 Nigerien markets, four Burkinabé markets and eight Malian markets. The markets that were excluded from the sample are isolated markets that have no impact on other markets, namely the Tera market in Niger, the Niono and Nioro markets in Mali, and the Fada, Kaya and Youba markets in Burkina Faso.

The tests conducted at the regional level confirm the weak integration of Burkinabé markets and their lack of impact on Nigerien and Malian markets.

The regional analysis highlights the role of the Malian markets Bla and Kayes in Burkinabé markets. Bla and Kayes cause 50% and 75% of the Burkinabé markets in our sample respectively. On the other hand, Malian markets have only a moderate influence on prices in Niger.

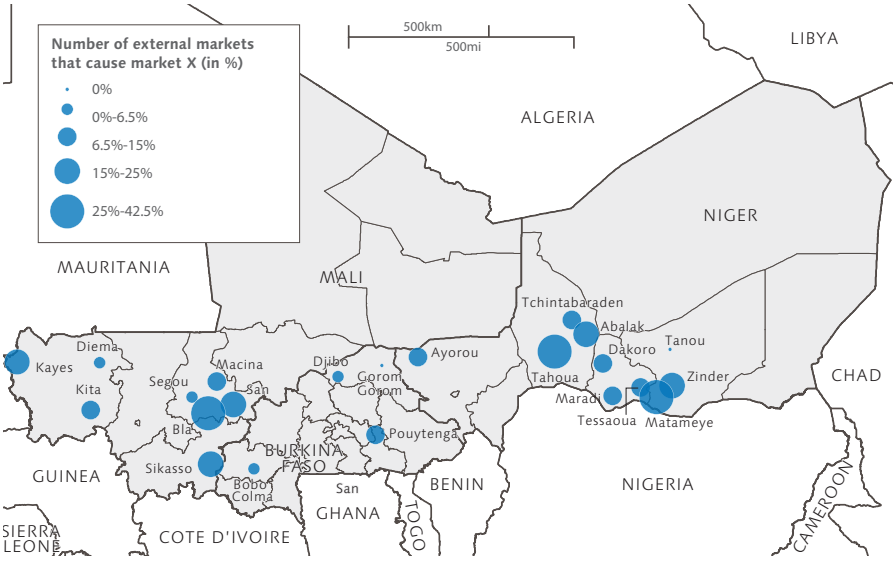
Leading Nigerien markets on a national level do not appear to be leaders on a regional level. Abalak causes only 25% of the Malian and Burkinabé markets, while Dakoro only influences 25% of Malian markets and zero Burkinabé markets.

Table 9: Granger causality tests for regional cattle markets (real prices)

Country	These markets cause...	The following Burkina Faso markets	The following Nigerien markets	The following Malian markets	Number of times a market causes another (%)			Number of times a market is caused by another (%)		
					In Burkina Faso	In Niger	In Mali	In Burkina Faso	In Niger	In Mali
Burkina Faso	Bobo Colma	/	/	San	0	0	13	0	20	13
	Djibo	/	Tessaoua	/	0	10	0	0	0	25
	Gorom Gorom	/	/	/	0	0	0	0	40	13
	Pouytenga	/	Ayorou	Kayes	0	10	13	0	10	50
Mali	Bla	Bobo Colma, Djibo, Pouytenga	Maradi	Ségou	75	10	14	0	10	14
	Diéma	/	Zinder	Sikasso	0	10	14	0	20	0
	Kayes	Gorom Gorom, Pouytenga	/	Diéma, San, Ségou	50	0	43	25	10	14
	Kita	Pouytenga	/	Diéma, Kayes, Macina, Sikasso	25	0	40	0	30	0
	Macina	/	Tchinta-baraden, Tahoua, Tanout	/	0	30	0	0	30	29
	San	Pouytenga	Abalak, Tahoua	Bla	25	20	14	25	30	29
	Sikasso	Djibo	Maradi, Tahoua	/	25	20	0	0	0	29
	Segou	/	Tessaoua	Macina, San	0	10	29	0	0	29

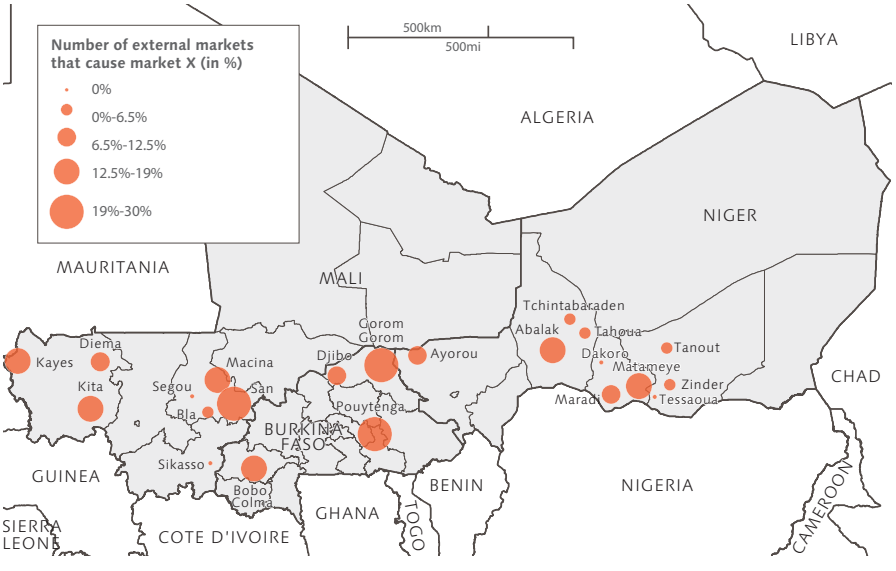
Country	These markets cause...	The following Burkina Faso markets	The following Nigerien markets	The following Malian markets	Number of times a market causes another (%)			Number of times a market is caused by another (%)		
					In Burkina Faso	In Niger	In Mali	In Burkina Faso	In Niger	In Mali
Niger	Tessaoua	Bobo Colma	Tchinta-baraden, Maradi	/	25	22	0	25	33	13
	Dakoro	/	Tchinta-baraden, Maradi, Tahoua, Matemeye and Tanout	Kita, San	0	56	25	0	0	0
	Tchinta-baraden	/	Ayorou, Maradi, Zinder, Tanout	Kayes, Kita	0	44	25	0	56	13
	Ayorou	Gorom Gorom	Tanout	/	25	11	0	25	22	0
	Abalak	Gorom Gorom	Tessaoua, Tanout	Diéma, Macina	25	22	25	0	22	13
	Maradi	Gorom Gorom	Tchinta-baraden, Ayorou, Abalak, Matemeye, Tanout	/	25	56	0	0	44	25
	Tahoua	Bobo Colma, Pouytenga	Maradi	San	50	11	13	0	22	38
	Zinder	/	Tessaoua, Tchinta-baraden, Matemeye	Diéma, Macina, San	0	33	38	0	33	13
	Matam-eye	Gorom Gorom	Tchinta-baraden, Abalak, Zinder	Bla, Kita, Macina	25	33	38	0	33	0
	Tanout	/	Tessaoua, Tahoua, Zinder	/	0	33	0	0	56	13

Figure 21: Location of leading markets in the sub-region (Granger test)



Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 22: Location of markets caused by other markets in the sub-region (Granger test)

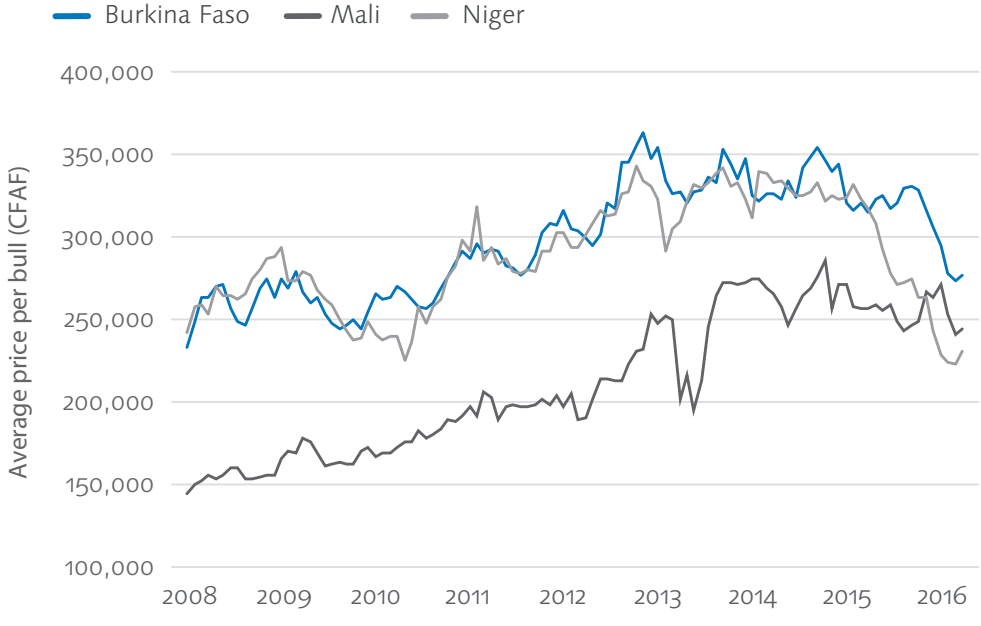


Source: Authors' own, based on CILSS data (consolidated in 2018)

4.3 Temporal price dynamics

On average, cattle prices in Niger and Burkina Faso are very similar and seem to be affected by the same fluctuations. Since the beginning of 2016, prices in Niger have dropped sharply. Prices in Burkina Faso have also followed a downward trend, but it is less prominent than Niger's. Prices in Mali do not seem to have been affected by the same determining factors as in Niger and Burkina Faso. Mali's prices, which are lower on average, have been steadily increasing since 2008, an increase that has been accentuated over the 2012-2014 period. Lower prices in Burkina Faso and Niger, combined with successive price increases in Mali, lead prices in our regional sample to converge in 2016. This trend could be explained by a decline in the price of the Naira with which it coincides.

Figure 23: Evolution of the average price of a bull per country, 2008-2016 (CFAF/head)

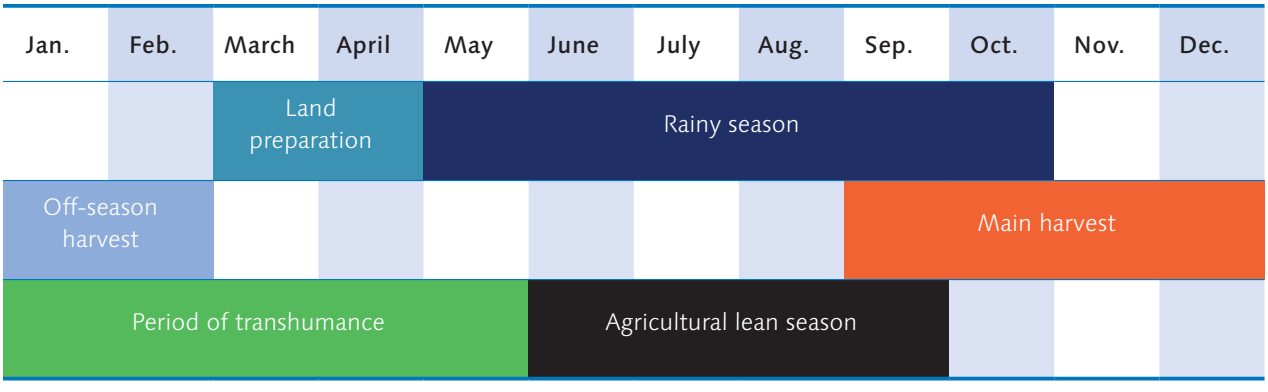


Source: Authors' own, based on CILSS data (consolidated in 2018)

4.3.1 Seasonality of prices in Burkina Faso

The calendar of agricultural and pastoral events in Burkina Faso, Mali and Niger are similar, though with some variations. The rainy season in Burkina Faso and Mali begins in May, which is a month earlier than Niger. The rainy season in Burkina Faso is long; it lasts almost six months in comparison to five months in Mali and four months in Niger. Thus, the grain harvesting period begins earlier in Burkina Faso than in Mali and Niger.

Figure 24: Cultivation and pastoral calendar in Burkina Faso, typical year



Source: FewsNet (2013) available on https://fews.net/fr/node/14748 (consulted in June 2019)

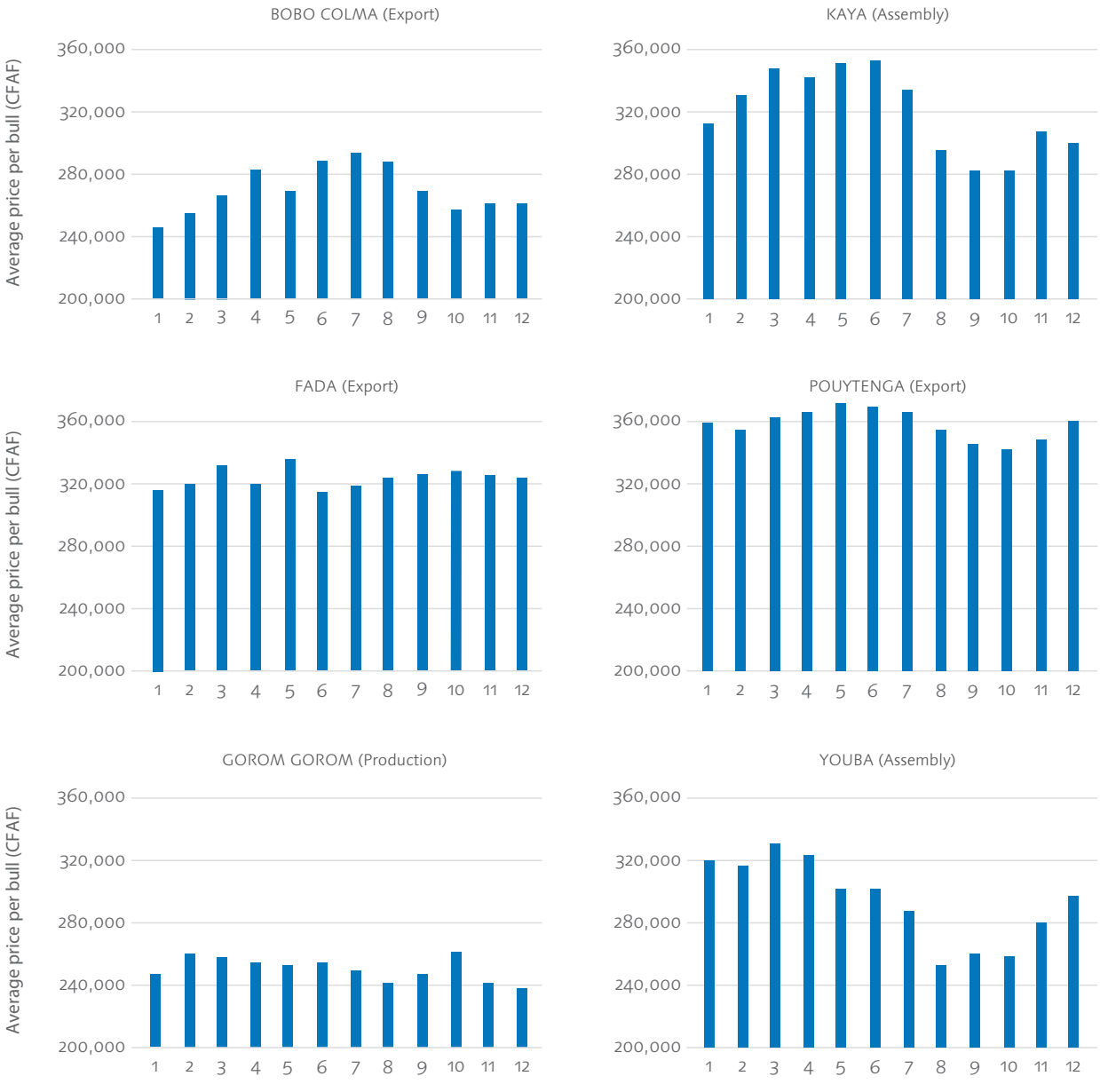
Cattle prices reach their peaks earlier in Burkina Faso and Niger than in Mali. Of the seven Burkinabé markets considered, five reach their highest price periods before June. After this peak period, prices begin to fall before reaching their lowest points between August and January. It should be noted that the seasonality of livestock prices is relatively consistent between Burkinabé markets, with the notable exception of Fada, which seems to follow another dynamic (see Figure 25). Prices in Fada over the period considered are, on average, at their lowest in June before trending upward until October.

Table 10: Average seasonal amplitude of livestock prices in Burkina Faso (CFAF/head)

Market	Maximum price		Minimum price		Average price	(Max-Min)/Average
Fada	337523	May	314745	June	326460	0.07
Youba	332488	March	260302	August	296579	0.24
Kaya	354659	June	283684	September	320915	0.22
Pouytenga	380896	April	341545	October	359495	0.11
Djibo	293570	April	277202	November	284971	0.06
Gorom Gorom	259895	February	240080	December	249665	0.08
Bobo Colma	298111	July	245381	Janvier	269782	0.20

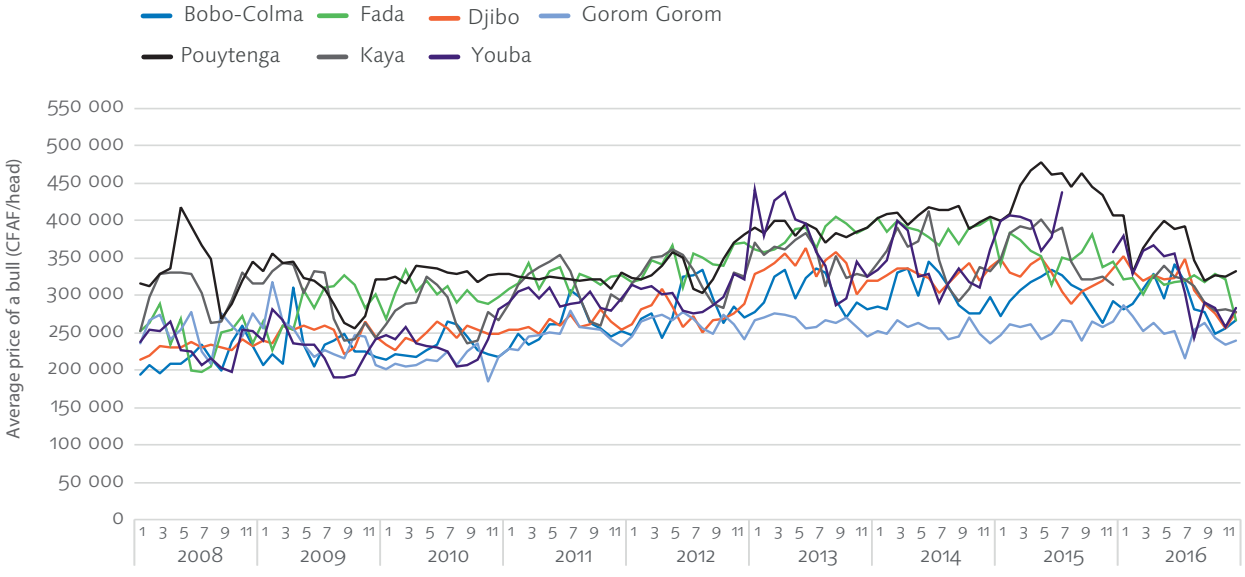
Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 25: Average monthly price in Burkina Faso markets (January 2008-December 2016; CFAF/head)



Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 26: Evolution of the average price of a bull per Burkinabé market, 2008-2016 (CFAF/head)

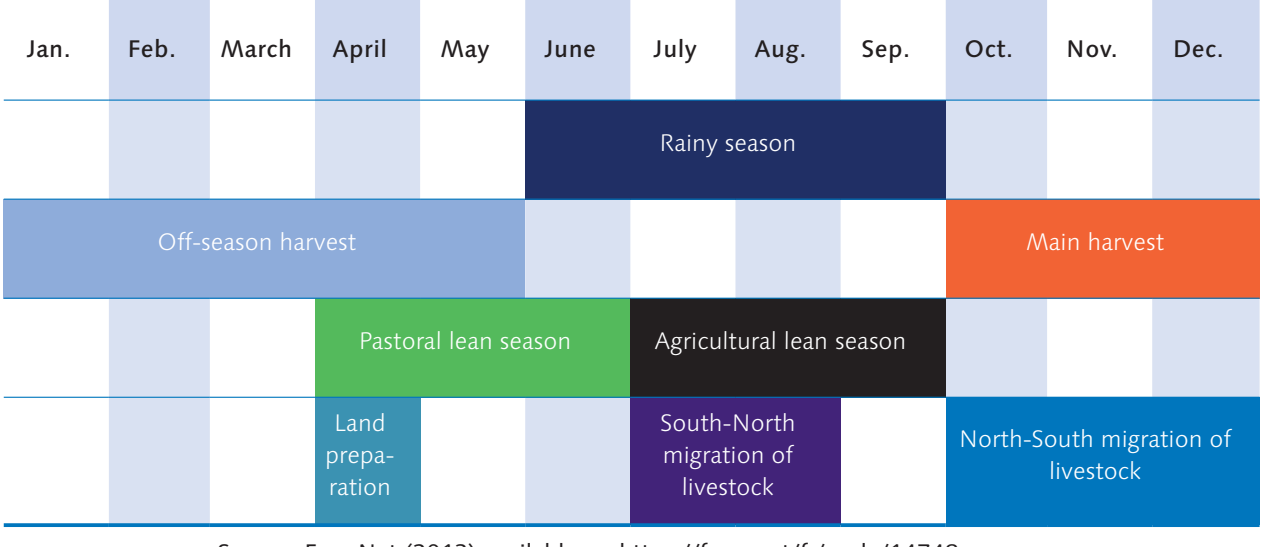


Source: Authors' own, based on CILSS data (consolidated in 2018)

4.3.2 Seasonality of prices in Mali

Despite a fairly similar agricultural calendar to Burkina Faso, the seasonal dynamics of cattle prices in Mali appear to be less clear. Of the 10 markets considered, six reach their highest prices in June and July. This period corresponds with livestock herds returning north. Prices then fall before reaching their lowest points between September and January, in eight of the ten markets considered. This period coincides with the transhumant departures of livestock herds towards the south. Figure 28 shows, however, that price seasonality in Mali is harder to read than in Burkina Faso. Indeed, the prices in Kita, Diéma and San do not follow a clear seasonal trend, unlike those in Niono.

Figure 27: Cultivation and pastoral calendar in Mali, typical year



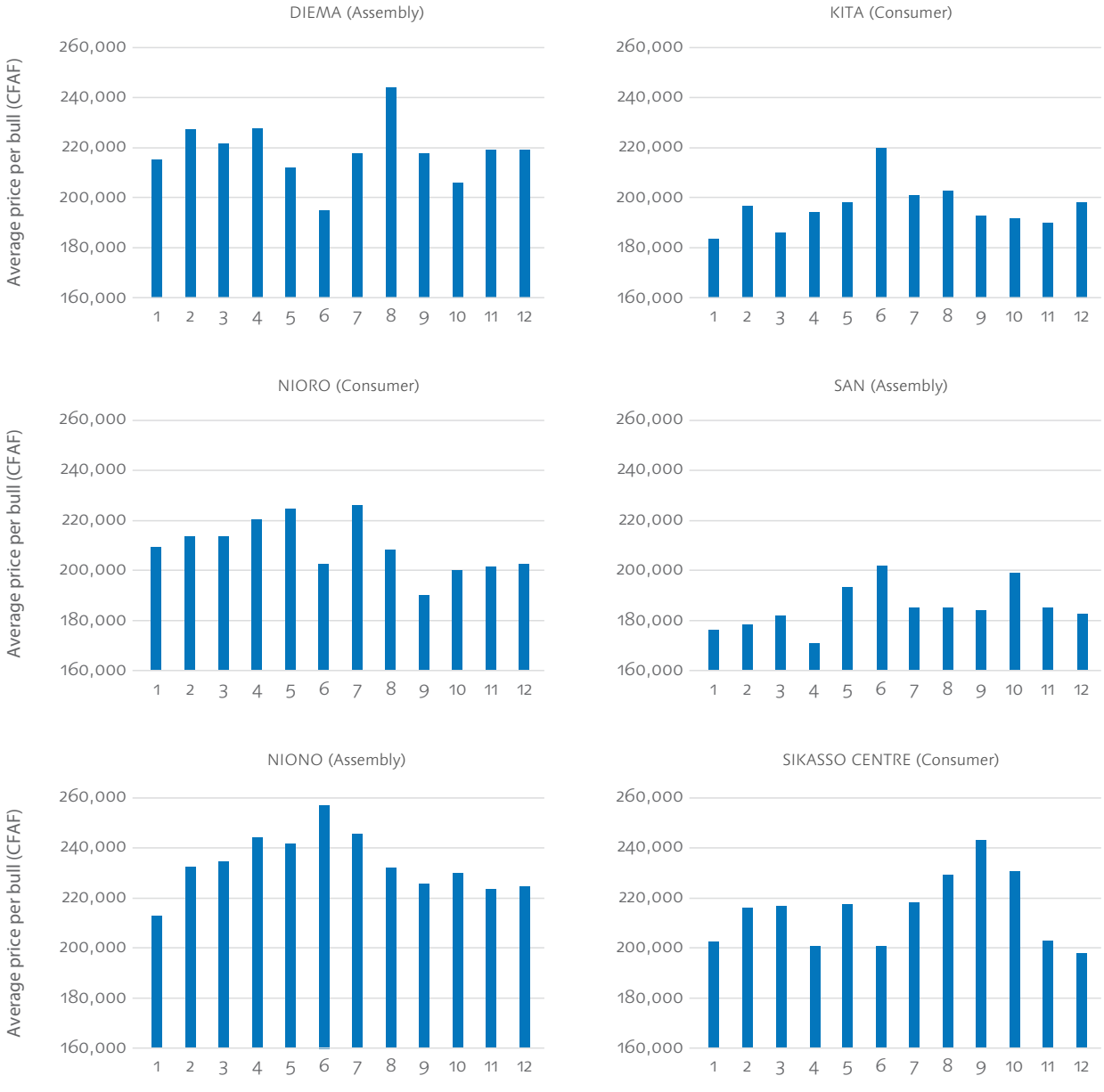
Source: FewsNet (2013) available on https://fews.net/fr/node/14748 (consulted in June 2019)

Table 11: Average seasonal amplitude of livestock prices in Mali (CFAF/head)

Market	Maximum price		Minimum price		Average price	(Max-Min)/Average
Bla	210528	March	187481	September	199172	0.12
Diema	245469	August	194269	June	219430	0.23
Kayes	276586	July	245101	December	256816	0.12
Kita	220056	June	183302	January	195949	0.19
Macina	227138	December	208014	January	218381	0.09
Niono	257384	June	213600	January	234065	0.19
Nioro	227679	July	190939	September	210394	0.17
San	199709	June	172011	April	184828	0.15
Segou	276607	July	243317	October	259044	0.13
Sikasso	241650	September	196939	December	213681	0.21

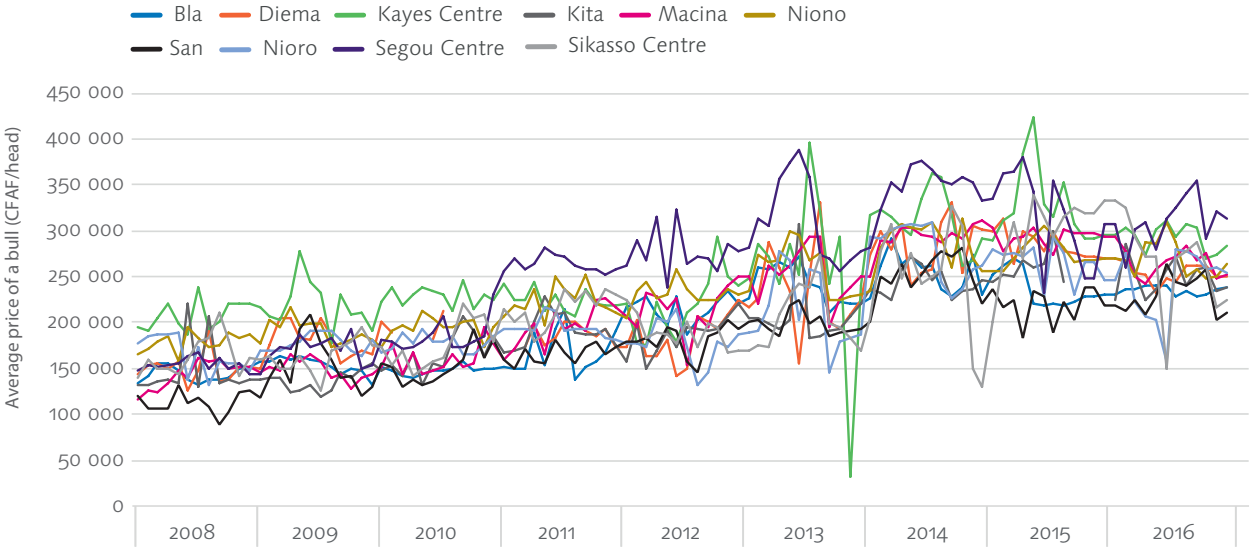
Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 28: Average monthly price in Mali markets (January 2008-December 2016; CFAF/head)



Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 29: Evolution of the average price of a bull per Malian market, 2008-2016 (CFAF/head)

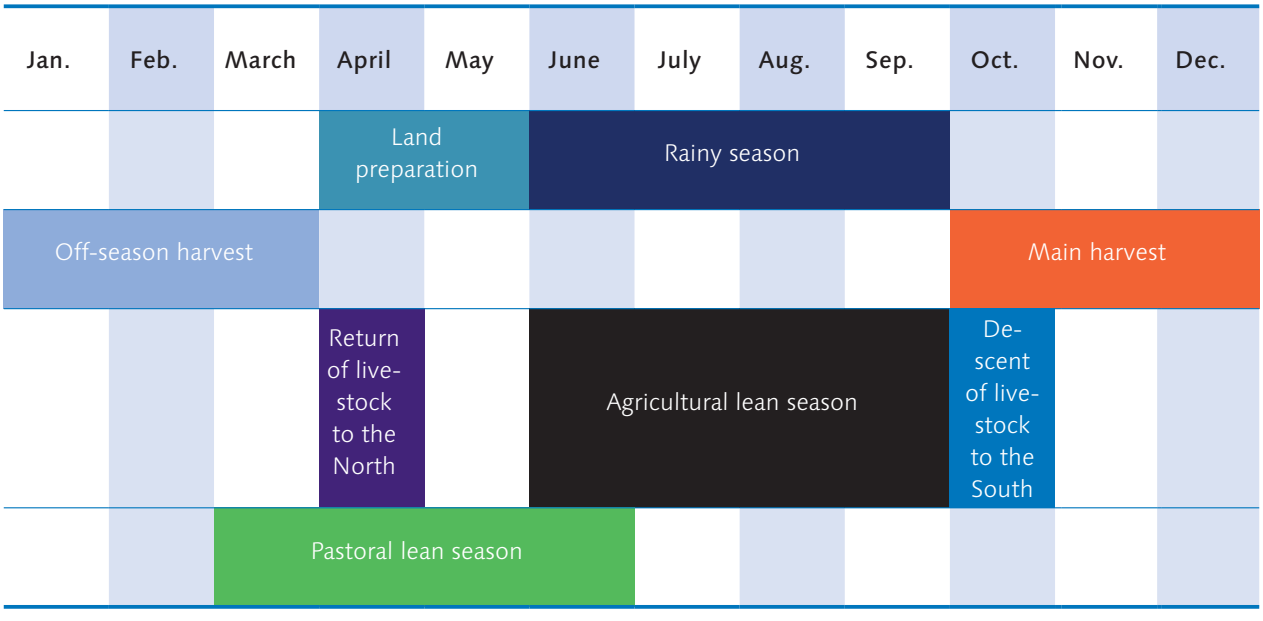


Source: Authors' own, based on CILSS data (consolidated in 2018)

4.3.3 Seasonality of prices in Niger

In Niger, prices reach their peaks between April and August (i.e. when livestock arrives by transhumance). This is probably due to the fact that animals in good health after transhumance sell more. Prices then go down and are at their lowest between July and November.

Figure 30: Cultivation and pastoral calendar in Niger, typical year



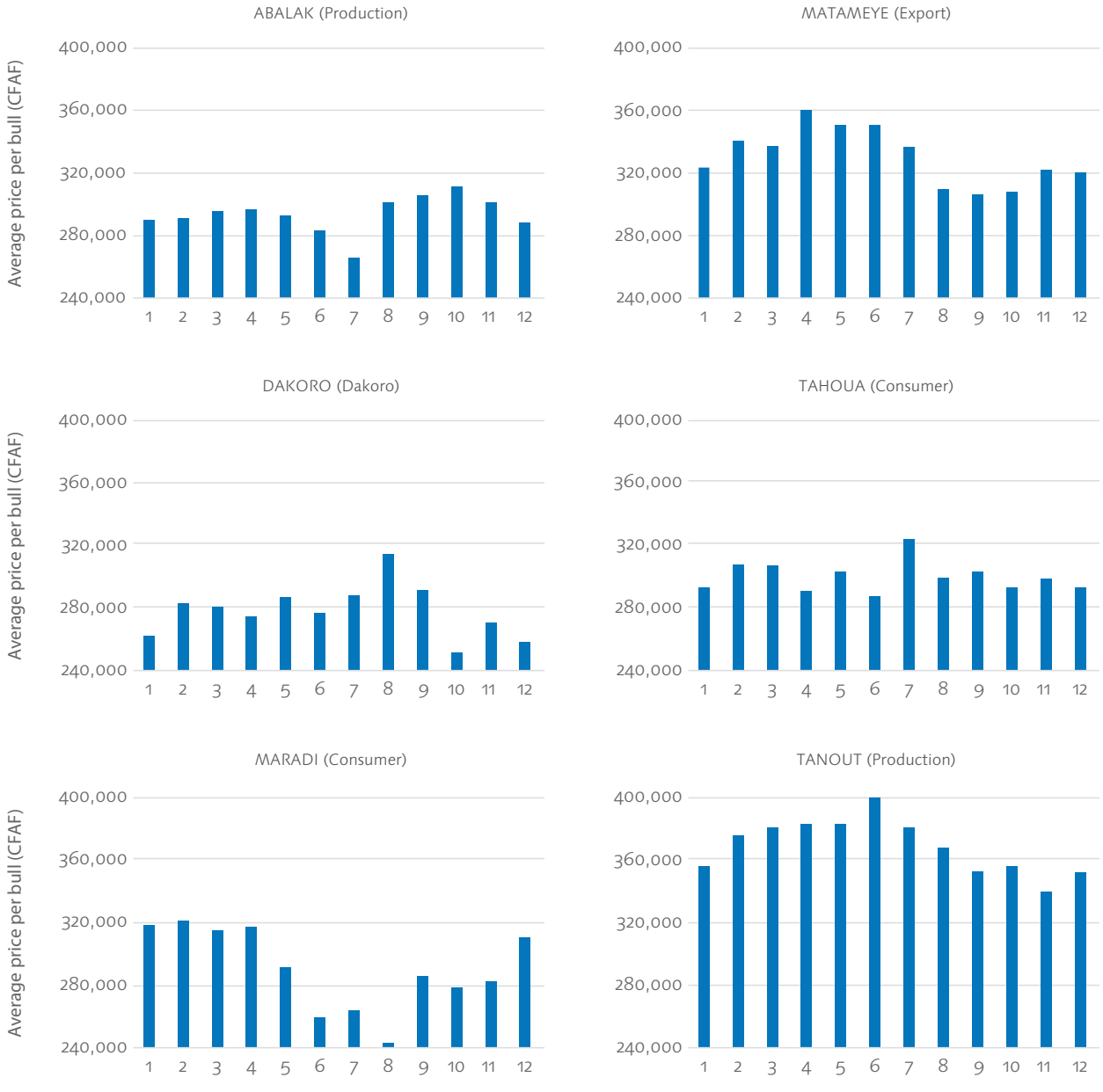
Source: FewsNet (2013) available on https://fews.net/fr/node/14748 (consulted in June 2019)

Table 12: Average seasonal amplitude of livestock prices in Niger (CFAF/head)

Market	Maximum price		Minimum price		Average price	(Max-Min)/Average
Abalak	310429	October	266952	July	292420	0.15
Ayorou	291437	May	267967	August	280147	0.08
Dakoro	314419	August	254532	October	278263	0.22
Maradi	320195	February	243367	August	291087	0.26
Matameye	359104	April	307413	September	331646	0.16
Tahoua	323700	July	290565	June	300975	0.11
Tanout	409713	June	341117	November	371361	0.18
Tchintabaraden	294615	April	269233	August	279661	0.09
Tera	277097	March	247173	July	264216	0.11
Tessaoua	292679	June	266123	January	276208	0.10
Zinder	331072	August	297974	July	316897	0.10

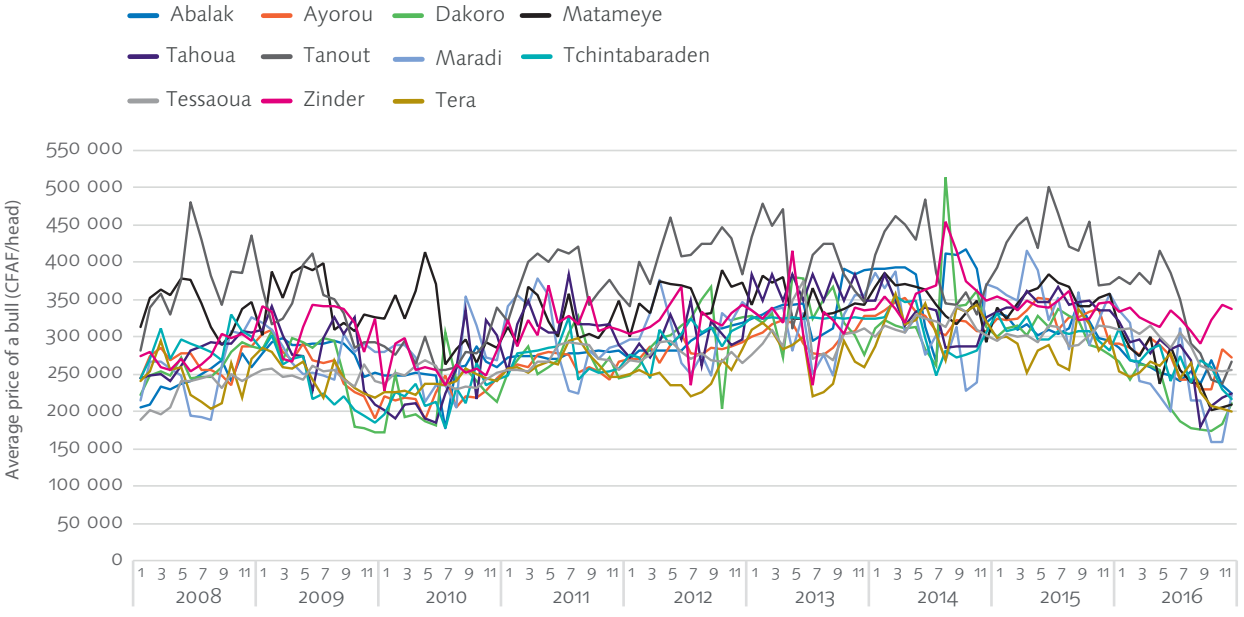
Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 31: Average monthly price in Nigerien markets (January 2008-December 2016; CFAF/head)



Source: Authors' own, based on CILSS data (consolidated in 2018)

Figure 32: Evolution of the average price of a bull per Nigerien market, 2008-2016 (CFAF/head)



Source: Authors' own, based on CILSS data (consolidated in 2018)

The price seasonality analysis draws a more complex picture than the theoretical seasonality profile in; the prices follow the profile, but seasonality is more or less pronounced depending on the type of market (assembly, consumer, export, production). Some authors (Wane et al., 2010) divide the pastoral year into two seasons: a dry season and a wet season. This distinction is reflected in the seasonal analyses.

5. PRICES: EXPLANATORY FACTORS

IMAGE: MARKET DAY IN GAROULÉ MARKET; A VILLAGE LOCATED ON THE PLAINS BELOW THE CLIFFS OF BANDIAGARA PICTURE TAKEN BY: ©IRINA MOSEL/ODI

In addition to the spatial and temporal analysis, the livestock database has been combined with climate and conflict information. This analysis helps explain how conflicts and climate shocks are explanatory factors for the livestock price fundamental.

This analysis makes it possible to justify the price indicator as a proxy for multiple risks such as conflicts and climate. These aspects are essential in building a robust monitoring and warning system based on prices.

This section is based on work done in the same area on the millet price series by Araujo Bonjean and Simonet (2016).

5.1. The model

The reference model for our analysis is a simple model for livestock prices with a linear supply and demand, following models by Ravallion (1985), Quddus and Becker (2000), and described by Araujo Bonjean and Simonet (2016).

The net supply of goods in period t is positively correlated with the current price of millet:

$$Q_t = a_t + bP_t + e_t \text{ with } b > 0$$

With:

P_t, the livestock price level at period t;

And a_t, an index that depends on the delayed values of a vector of exogenous supply and demand variables.

Livestock farmers and traders keep the animals out of the market (stocking) if they expect the future price to be high enough to offset the costs of rearing and/or the loss of animals in poor condition. On the basis of risk-neutral actors, the demand for stock in period t is correlated with the price difference between the expected future price and the current price:

$$S_t = c\,(E_t P_{t+1} - P_t) + d_t + w_t \text{ with } c > 0$$

With:

d_t, an index that depends on a vector of variables reflecting the opportunity cost of holding livestock;

$E_t P_{t+1}$, forecast (expected) livestock price for period $t + 1$;

And e_t and w_t are error terms.

The market equilibrium is given by:

$$S_t = Q_t + S_{t-1}$$

With:

S_{t-1}, the initial stock.

According to this model, the current price consists of two components: F_t, a fundamental component, and B_t, a potential rational-bubbles component (Blanchard, 1979; Diba and Grossman; 1988).

$$P_t = B_t + F_t \quad (5)$$

The fundamental component of the livestock price market is linked to the expected value of the exogenous variables determining supply and demand.

In order to determine the fundamental value of livestock prices, we consider current and past values of observable exogenous variables that determine livestock supply and demand, as well as any relevant information on future net supply. In view of good market integration, a unique fundamental price model for the three countries is considered.

Prices are estimated on the basis of a panel of 45 markets (markets for which the coverage level of price data is greater than 80%) for the 2008-2018 period.

The estimated equation is as follows:

$$P_{it} = \alpha_1 Rain_{it} + \alpha_2 CumulRain_{it} + \alpha_3 CPI_t + \alpha_4 Petrol_t + Conflict_{it} + M_1 - M_{11} + e_i + v_{it}$$

With:

P_{it}, livestock price on market i in month t;

$Rain_{it}$, level of monthly rainfall. It is a useful information variable for predicting the health status of livestock in the future;

$CumulRain_{it}$ is the cumulative rainfall during the rainy season (May

to October). It adopts a constant value during the agricultural season. This is an exogenous variable that captures the state of livestock over the current period;

CPI_t, the consumer price index for each country;

$Petrol_t$, the price of petrol in each country. This variable is an approximation of production and exchange costs that vary with the price of petrol;

$Conflict_{it}$, a conflict variable. This variable is an approximation of market supply difficulties.

Monthly dummy variables are added to the model (value taking the values *0* or *1*) that capture the seasonal variations of the prices (*M*):

e_i are regular effects specific to the market;

v_{it} is the error term. It includes all factors not explained by the variables on the right.

5.2. The data

Descriptive statistics of the mobilised data are available in the Appendix.

5.2.1 Climate data

The climate data is taken from the Climate Research Unit (CRU) database (Harris et al., 2013), which is available online.[7] This version, published on November 18, 2018, provides a data set on a monthly rainfall and temperature grid. It covers the 1901-2017 period globally, at a spatial resolution of 0.5° longitude. For each market in the database, temperature and rainfall data were associated on the grid

7 Visit http://www.cru.uea.ac.uk/data (data uploaded in December 2018) for the CRU database.

point in which the market was located. Thus, the market price was associated with a monthly rainfall and temperature value over the 2008-2017 period in question.

On this basis, the data was then calculated for an 'agricultural season'. The cumulative rainfall from May to October of year *t* and the average temperature during the same period are the seasonal data for the May period of year *t* to April of year *t + 1*. The details of the calculations concerning the agricultural seasons are presented by Simonet (2012).

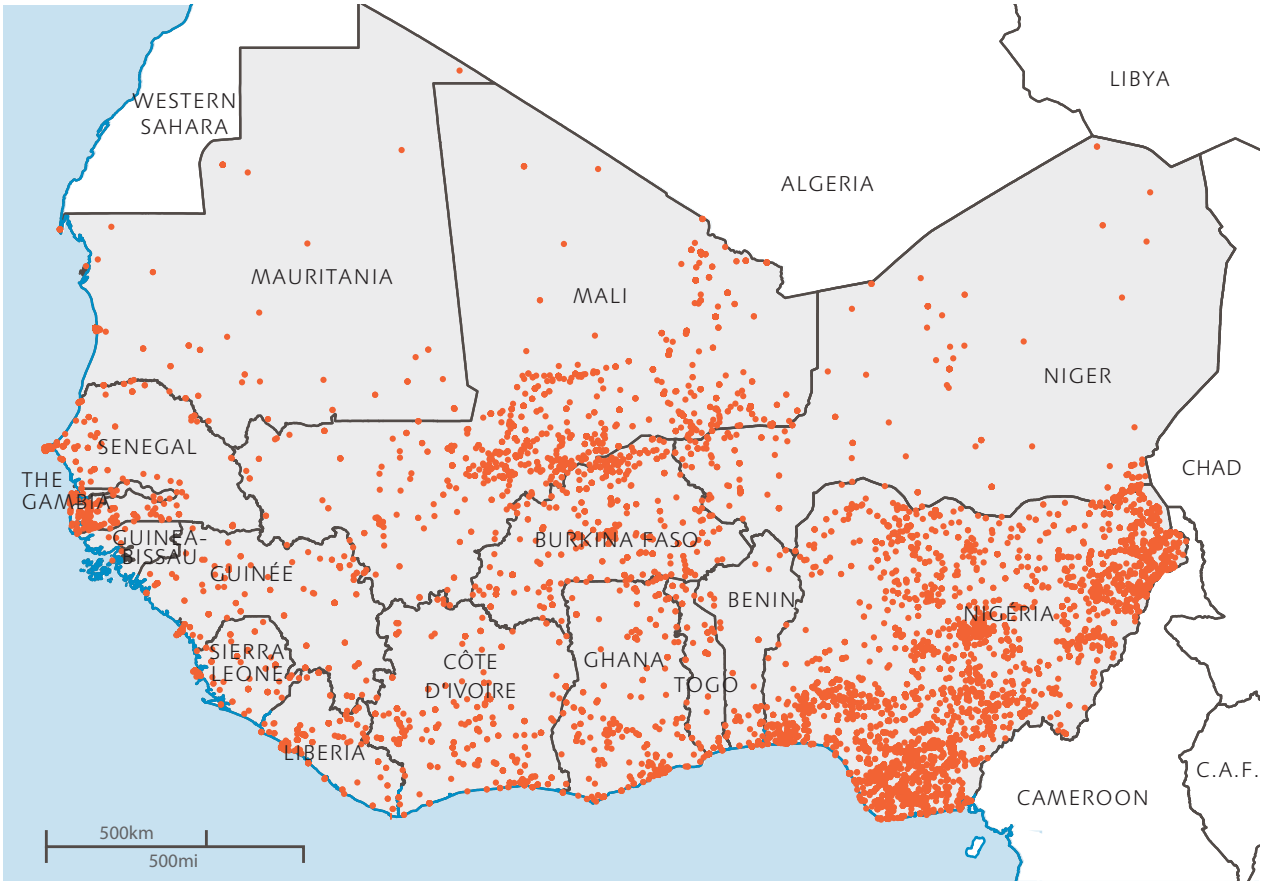
5.2.2 Conflict data

Conflict data is taken from the Armed Conflict Location & Event Data Project (ACLED).[8] ACLED provides a disaggregated database of conflicts and crisis mapping. All conflicts are geolocated and dated. ACLED is considered the highest quality, most widely used source of real-time data and analysis on political violence and protests in developing countries. The database lists the dates, the geolocation of conflicts, and the actors involved. For each event, the data base (in excel format) contains a columb of notes that explicit the known details of the respective incidents. The number of deaths and sources of information are also listed.

From the geolocation of the market, we matched the number of events within a radius of less than 150km from each market in the database. If several events took place in the same month, those events were all considered (we cumulate the number of events and the number of deaths within the same month). Then, an average of the distance from the studied markets was calculated. Sensitivity tests were carried out on the distance (within a radius of 30, 50, 70 and 100km).

8 Visit https://www.acleddata.com/ (data uploaded in November 2018) for the ACLED database.

Figure 33: Map of conflicts in West Africa recorded over the 2007-2018 period



Source: Authors' own, based on ACLED data

Figure 34 summarises the database combination work that was done. It involves assembling the CRU data by presenting rainfall in the area on a grid (the blue histogram on the graphs and the tinted area on the map) with conflict data (represented by red circles on the map; number of conflicts in a 100km radius), and price data (the black curve on the graphs). This view[9] shows that the marginal and less connected markets are the most directly affected by conflict, in particular those involving al Qaeda in the Islamic Maghreb (AQIM). The econometric analysis should allow us to better investigate these potential correlations.

5.3. Estimation results

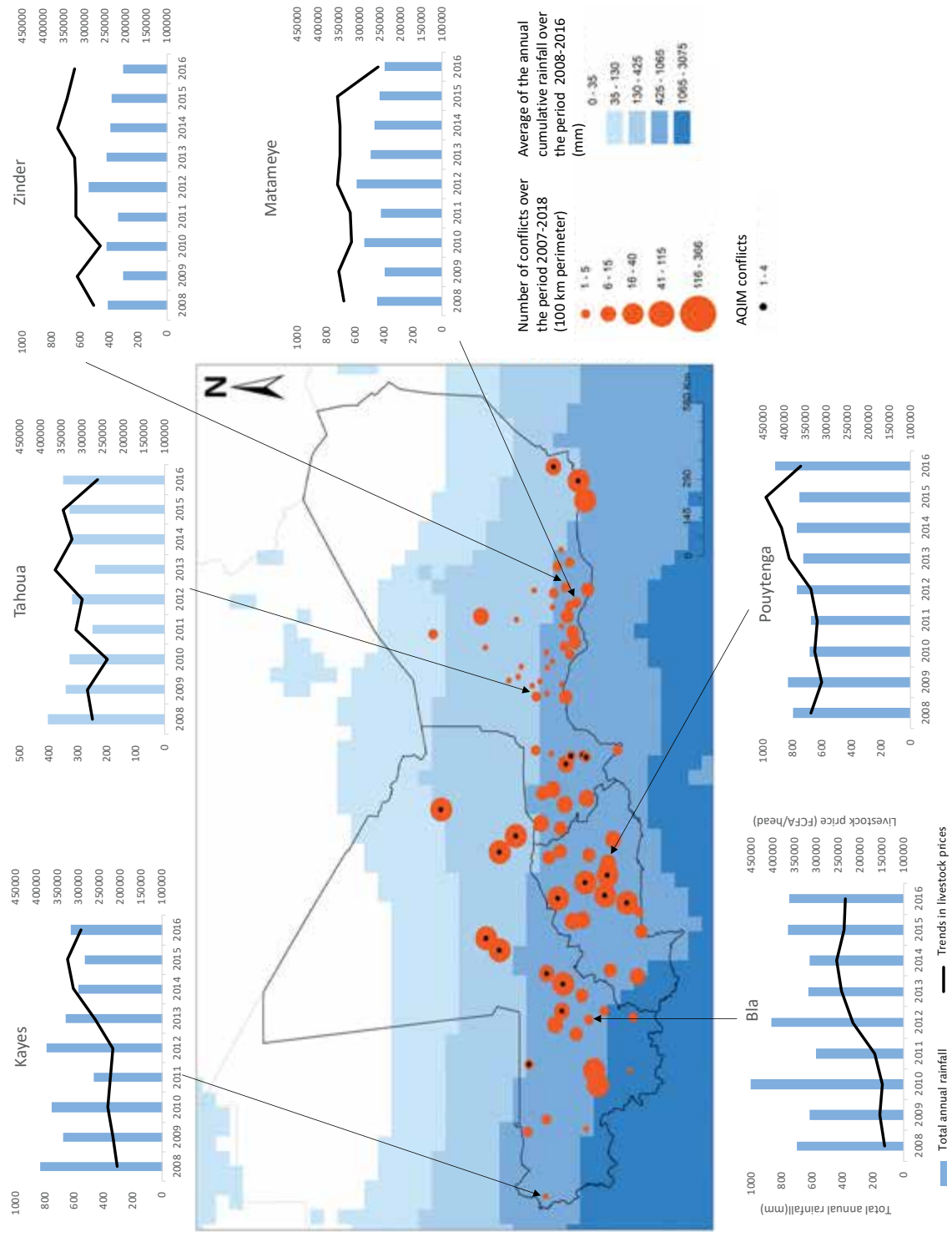
Regressions are performed using the ordinary least squares (OLS) estimation method. Following the model presented above (section 4.1), the control variables are the season's cumulative rainfall, the season's average temperature, the consumer price index, the price of petrol and the number of conflicts in the area. Monthly dummy variables are also introduced, as well as regular effects by market; the set of errors is corrected for national clusters.[10]

In order to respond to any concern about endogeneity, various robust regressions are performed using the generalised method of moments (GMM) methodology. These preliminary analyses will then have to be triangulated with other test estimates on different sub-samples so as to reinforce the initial results presented in this paper.

9 The histograms are presented for leading markets at the regional level and the Burkina Faso market that causes the most markets at the regional level.

10 National clusters are used to check for systematic errors in price measurements. Indeed, since the collection of price data is done on the national level, the clusters make it possible to control price differences between countries that may be associated with this data collection.

Figure 34: Conflicts, rainfall and prices for leading markets in the sub-region



Estimations yield an R^2 of about 0.24. The joint non-significance test of factors (F-test) is rejected for all proposed specifications. It seems that rainfall in the current agricultural season has a negative and significant effect on prices. This result is consistent with the hypothesis that a good rainy season has a negative effect on livestock prices, essentially lowering them. On the other hand, there is no significant effect of current rainfall on the price of the same month. The signalling role played by rainfall on millet markets in Niger is not found here (Araujo Bonjean and Simonet, 2016). Further investigation is needed to assess the definition of the livestock production area.

The price of petrol is slightly significant according to specifications (between 10% and 15%). The consumer price indicator is significant and positive. This result is stable in all specifications tested and is consistent with the literature.

When it comes to price, the number of deaths in a conflict (estimation 1) has no significant impact, whereas the distance of conflict from the market plays a significant positive role (i.e. the more the conflicts that occur far from the market, the higher the prices). Prices in the market decline when conflicts are closer; this effect may be due to the absence of animals (estimation 3). If conflicts are very close to the market, access to the market for livestock and buyers may be severely disrupted. The number of events within a 150km radius generally has no impact. When distinguishing conflicts related to terrorism or AQIM[11] attacks from other conflicts. AQIM conflicts have a significant positive effect on prices (estimation 5). As these attacks are mainly listed in isolated areas, it would be appropriate to perform sensitivity tests on this result for further analysis.

11 In order to do this, conflicts can be identified by mentioning 'al-Qaeda in the Islamic Maghreb', 'AQIM' or 'terrorism' in the ACLED database.

Several sensitivity and robustness tests were performed on the results. Firstly, the introduction of religious holidays, which play an important role in the seasonality of prices, reinforces the results (estimations 4 and 5). The end of the Ramadan period does not seem to influence prices. On the other hand, the Eid and the Magal period play a significant role, positive for the former and negative for the latter, which confirms the importance of the role of the Muslim calendar has in forming livestock prices.

The introduction of market clusters instead of country clusters does not change the results obtained for the marginal effect of rainfall or for AQIM conflicts; however, the number of conflicts (of any type) and the distance of conflicts is no longer significant.

In order to align with the literature, we introduce seasonal dummy variables (two seasons: rainy from May to October and dry from November to April). The obtained results are the same as those from the monthly dummy variables. The F-test and R2 are similar in value to the results presented in Table 13.

When sensitivity tests are performed on the role of distance, results are maintained but do not appear significant when the radius in question is less than 70km. This is certainly due to the low number of conflict events listed in a radius smaller than 70km from the markets.

Table 13: Estimations of the price fundamental

VARIABLES	Estimate (1) livestock_ priceaverage	Estimate (3) livestock_ priceaverage	Estimate (5) livestock_ priceaverage	Estimate (6) livestock_ priceaverage	Estimate (7) livestock_ priceaverage
Cumulrain	**-24.921* (6.611)**	**-25.233* (6.880)**	**-25.852* (7.392)**	**-28.329** (5.179)**	**-28.832** (5.560)**
Rain	25.112 (9.025)	24.656 (9.929)	26.443 (9.333)	25.230 (11.482)	26.985 (10.514)
Petrol	107,034.313 (94,934.127)	108,106.341 (94,549.086)	108,697.605 (94,985.876)	107,859.831 (94,600.087)	108,296.012 (94,944.572)
CPI	6,632.345** (869.956)	6,600.420** (861.182)	6,620.658** (864.981)	6,586.982** (863.002)	6,610.722** (865.634)
Number of deaths during conflict	83.569 (167.504)				
Average distance from conflict		**30.769** (4.477)**		**33.238* (8.231)**	
Number of AQMI conflicts			**104,966.440* (32,542.856)**		**101,077.761* (31,243.650)**
End of Ramadan				4,222.815 (1,739.833)	4,160.070 (1,715.235)
Eid date				4,894.879** (841.242)	5,001.054** (955.971)
Magal date				-19,039.204* (5,732.360)	-18,713.740* (5,803.831)
Constant	-536,723.928*** (30,355.421)	-534,700.667*** (29,341.012)	-537,926.237*** (31,395.518)	-527,144.393*** (29,059.540)	-530,631.504*** (31,690.250)
Observations	2,517	2,517	2,517	2,517	2,517
R^2	0.239	0.239	0.242	0.248	0.250
Number of markets	45	45	45	45	45

Note: Standard deviations in parenthesis, *** p <0.01, ** p <0.05, * p <0.1, monthly dummy variables and regular market effects, robust and clustered errors at the country level.

Source: Authors' own, based on ACLED data, CRU data and CILSS data (consolidated in 2018)

6. CONCLUSIONS AND NEXT STEPS

IMAGE: LAST RESORT CATTLE STAND BY A RESERVOIR, OFTEN THE LAST WATER POINT DURING THE HOTTEST & DRIEST MONTHS OF THE YEAR, IN ZORRO VILLAGE, BURKINA FASO. PICTURE TAKEN BY: ©OLLIVIER GIRARD/CIFOR

6.1 Analysis results

This analysis is based on livestock price information at market level in West Africa. It mobilises a unique database, collected by national and regional institutes over a long period and at a high frequency (every 10 days and monthly). Despite the limitations of the analysis, mainly due to inconsistencies in national data collection systems and the irregularity of data collection for certain markets, it has been possible to highlight current regional livestock market dynamics.

Firstly, the national spatial price dispersion has gone down in all three countries. Markets are therefore increasingly integrated on a national level. Mali is the sample country characterised by the strongest price dispersion between markets. This dispersion has been considerably reduced over the 2014-2016 period. Inter-country price dispersion is expected to be stronger than intra-country price dispersion, however it is important to note that the latter has been decliningover the recent period. Price dispersion between Burkina Faso and Niger is not much higher than the price variation within each country, which shows good regional-level integration.

Tests conducted at the regional level confirm the weak integration of Burkinabé markets and their lack of impact on Nigerien and Malian markets. Regional-level analyses highlight the decisive role Malian markets play in influencing price in Burkinabé markets and so transmitting prices shocks. However, Malian markets only have a moderate influence on price in Niger. National-level leading Nigerien markets do not appear to be leaders on a regional level. These results demonstrate the importance of sample selection for regional analysis. The lack of information on coastal country markets certainly limits the analysis. However, the results confirm the dynamics of transhumance and the preponderant role of Mali as a major producer in the zone.

The estimation of the price fundamental, made on the basis of a panel of 45 markets using monthly data over the 2008-2018 period, confirms that climate and conflict variables play a predominant role in the explanation of price dynamics. Rainfall has a significant negative effect on prices. Conflicts on the market peripheries significantly influence price formation, and distance between conflicts and markets plays a particularly significant role. The analysis should be supplemented by sensitivity and robustness tests to quantify the impact of this effect.

The results of the statistical analyses lead to the conclusion that markets are well integrated at the national and regional levels. This integration is most certainly supported by transhumance movements favouring the circulation of goods, people and information. Production areas in Mali and Niger play a key role in the zone's market dynamics. The lack of information on coastal terminal markets limits the analysis, and does not allow for a full evaluation of the role these markets play. Lastly, climate conditions and conflicts both play key roles in the formation of livestock prices. Rainfall and conflicts of terrorist origin particularly have significant impacts on livestock prices.

6.2 Recommendations

To date, the analysis confirms lack of understanding of pastoral crises and a growing need for such kind of work. In order to do this, the integration of indicators based on market price information into a monitoring and EWS seems relevant to us. This information is valuable, and its collection represents a real cost for national and regional institutes with limited staff and financial capacities. This study makes three recommendations:

1. Better consideration of pastoral specificities in existing crisis monitoring and management systems.

Pastoral matters are definitely on the regional agenda; the topics of security, climate and demographic issues are driving the focus and search for specific solutions. The specificity of pastoral issues needs to be recognised and integrated into analytical frameworks and measures that have been proven in the management of other crises.

To not further marginalise a population and a key socio-economic sector for the region, it is essential that pastoral specificities be integrated into pre-existing crisis monitoring mechanisms and

management frameworks. Such an approach would reinforce the systematic consideration of pastoral and transhumance issues during the lean season without creating any new institutions or mechanisms.

2. Support for ongoing initiatives to harmonise data collection and market monitoring systems at a regional level

To date, PRAPS has committed to greater harmonisation of livestock MIS. This step, which has already been performed for grain MIS, is essential in providing consolidated regional analyses. Considering its regional extension, the livestock sector should benefit from this harmonisation. However, these adjustments are expensive and time consuming. They must be accompanied by a capacity-building surveyor in order to harmonise data collection and digitisation practices. This great deal of work, carried out mainly within PRAPS, will have to be continued beyond the programme and extended to include the coastal countries. Only then will it provide a complete regional view of the livestock market situation. The increasing tensions between coastal and Sahelian countries over transhumance issues must be analysed in light of the objective information produced by national-level market monitoring systems. It is important that coastal countries, supported by the region and donors, follow the example of Sahelian countries on transhumance isssue and mobilise their technical and financial resources in order to better monitor livestock markets.

3. Structural, stable and consistent support for institutes in charge of collecting information

This analysis would not have been possible without the data collection work that was carried out for more than 10 years by the national and regional monitoring institutes. The daily work done by these organisations must be recognised here. These institutes often lack the financial means (payment of collector salaries),

techniques (PRAPS has recently launched an initiative to digitise data collection systems, which must be continued), and capacity (in terms of personnel and time) to carry out this very complicated task. Geographical coverage is a real challenge for these teams, especially in fragile areas affected by conflict.

Also, one of the first aims of this study was to recognise the value of the existing information collected by these institutes, even when incomplete, and to demonstrate the strength and richness of the existing data in order to support these valuable data collection systems in a more structural and sustained way. The procurement of accurate data is a real challenge, and it is essential to strengthen and support any existing data and monitoring systems. Some programmes and projects (European Union programmes, PRAPS, etc.) are moving in this direction. However, in order to ensure any real sustainability in data collection activities, massive financial/budgetary support for these institutes is necessary.

4. Support for the application of transhumance regulations, a source of stability and sustainable development

Market integration and transhumance are two essential factors of pastoral resilience. Also, the application of transhumance regulations at the regional level is essential in facilitating the resilience of livestock populations. To the greatest extent possible, it should be applied in a uniform way at the regional level in order to allow animals free circulation between markets, guaranteeing proper market integration and price stability.

Beyond ECOWAS trade regulations, transhumance is also supported by the Nouakchott Declaration (2013) signed by 6 Sahelian countries (Burkina Faso, Chad, Mali, Mauritania, Niger and Senegal) which recognize that pastoralism is a "vector of growth, peace and stability".

The main challenges facing these countries are twofold:

- Dedicating appropriate financial resources; human and technical resources for the implementation of the Nouakchott Declaration[12] (part of which is supported by the PRAPS programme);
- To extend this policy to coastal countries, transhumance should be addressed at regional level, encompassing coastal countries, and ECOWAS should support this upscaling.

6.3 Following steps

These steps are only intermediate points on the way to a more detailed analysis of the information collected. The BRACED programme has helped to strengthen collaborations with researchers from such institutes as CILSS. After this analysis, the exchange and transfer of skills on the subject should continue. In particular, the following analyses would help to complete this study:

1. Extend analysis to other countries in the region

To date, the databases that are mobilised and immediately available are those of Burkina Faso, Mali and Niger. While other countries in the region, such as Senegal, do have grain and livestock price collection systems, data is collected manually and is not systematically digitised. National MIS and regional institutes would need great support in the organisation and digitisation of existing information before any the study could begin.

It is important to include costal markets in the analysis of regional integration because coastal country urban centres are the first consumers of beef. But, another limitation of such an analysis is the

12 The Nouakchott's Declaration on pastoralism - 29 october 2013.

current lack of consolidated costal country price series data. So, while an extension of the analysis to coastal countries would better complete this study, it will first need to be accompanied by the support for such data collection.

2. Mobilisation of other data collected by MIS on livestock markets

Most national MIS collect other types of data at the livestock market level (number of animals, animal health, price of feed or fodder). This data has already been collected and is readily available, yet it is subject to few analyses. If that were to change, it should provide a better understanding of livestock market dynamics. For example, price analysis, supplemented by analyses of volumes and flows, will provide a better understanding of the role played by transhumance in market integration.

3. A more accurate analysis of price behaviour in the face of conflict and climate risks

To date, the analysis proposed in the last section is a preliminary study that will have to be completed more precisely in order to quantify the role and impact of climate and conflict on prices. We are considering several courses of analysis to confirm the results of the last part of the study.

- Review the price model mobilised for this study. This storage model is based on speculative behaviour, such as that which is found in grain markets. But with pastoral dynamics being more complex, another model could be developed or mobilised to explain the formation of livestock prices.
- Perform more sensitivity tests and supplement the analysis with other control variables that may influence the obtained results (consumer price or oil price data could then be controlled by other alternatives).

- Integrate climate change into analysis: from the analysis and quantification of the impact of climate on prices, we could carry out a qualitative analysis on the basis of climate change forecasts in order to allow a better understanding of the expected impacts of climate change on livestock markets.

- Analyse the livestock/grain exchange rate and the impact of conflict on this indicator: the livestock/grain exchange rate is an indicator that is monitored at the regional level under the PREGEC Charter. Since the indicator has not been the subject of an econometric analysis, it would be interesting to better understand the role climate and conflict have on the dynamics of this exchange rate, which is considered to be an indicator of pastoral food security.

- Study the existence of speculative behaviours, as they have been highlighted on the grain markets in Niger.[13]

4. Creation of relevant warning indicators that could be integrated into a pastoral warning system.

Lastly, this study constitutes the preliminary phase in defining warning indicators that based on price data and that could be integrated into a regional pastoral alert system. As with grain prices, livestock prices, or the livestock/grain exchange rate, could be used as a basis for creating a regional pastoral warning system. This work, currently underway at PRAPS, may use this study to identify leading markets that can act as sentinels in a regional EWS.

13 For more details on this work, see: Araujo-Bonjean C., et Simonet C., (2016), Are grain markets in Niger driven by speculation? *Oxford Economic Papers*, 68:3,pp. 714-735.

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Appendices

Table A1: Unit root test (January 2008-December 2016)

Market	ADF P-Value	PP P-Value	KPSS LM-Stat	Unit root?
Bobo Colma	0.00	0.00	0.22	I(0)
Djibo	0.06	0.05	0.15	I(0)
Fada	0.32	0.06	0.24	I(1)
Gorom Gorom	0.00	0.00	0.13	I(0)
Kaya	0.00	0.01	0.22	I(0)
Pouytenga	0.09	0.10	0.14	I(0)
Youba	0.08	0.12	0.13	I(0)
Bla	0.02	0.02	0.17	I(0)
Diema	0.00	0.00	0.13	I(0)
Kayes	0.00	0.00	0.14	I(0)
Kita	0.00	0.00	0.07	I(0)
Macina	0.00	0.00	0.15	I(0)
Niono	0.00	0.00	0.10	I(0)
San	0.00	0.00	0.07	I(0)
Nioro	0.00	0.00	0.11	I(0)
Sikasso	0.00	0.00	0.10	I(0)
Segou	0.01	0.01	0.20	I(0)
Tera	0.00	0.00	0.21	I(0)
Tessaoua	0.00	0.00	0.18	I(0)
Dakoro	0.03	0.00	0.20	I(0)
Tchintabaraden	0.22	0.03	0.22	I(0)
Ayorou	0.06	0.06	0.13	I(0)
Abalak	0.03	0.03	0.17	I(0)
Maradi	0.00	0.00	0.16	I(0)
Tahoua	0.10	0.00	0.22	I(0)

Market	ADF P-Value	PP P-Value	KPSS LM-Stat	Unit root?
Zinder	0.00	0.00	0.07	I(0)
Matameye	0.01	0.01	0.14	I(0)
Tanout	0.01	0.01	0.16	I(0)

Table A2: Descriptive statistics for regressions

Variable	Obs	Mean	Std. Dev.	Min	Max
livestock_priceaverage	4,56	266031,30	66446,19	88750,00	869224,50
CumulRain	4,86	619,35	227,73	136,10	1318,00
Rain	4,86	53,19	76,89	0,00	418,70
Petrol	2,70	1,19	0,20	0,88	1,47
CPI	4,86	103,64	3,69	96,53	110,31
Number of deaths during conflicts	4,86	0,40	3,64	0,00	186,00
Number of conflicts	4,86	0,36	1,38	0,00	28,00
Average distance from conflict	4,86	9,57	27,34	0,00	135,98
Number of AQIM conflicts	4,86	0,00	0,04	0,00	1,00

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BRACED aims to build the resilience of more than 5 million vulnerable people against climate extremes and disasters. It does so through a three year, UK Government funded programme, which supports 108 organisations, working in 15 consortiums, across 13 countries in East Africa, the Sahel and Southeast Asia. Uniquely, BRACED also has a Knowledge Manager consortium.

The Knowledge Manager consortium is led by the Overseas Development Institute and includes the Red Cross Red Crescent Climate Centre, the Asian Disaster Preparedness Centre, ENDA Energie, ITAD, and the Thomson Reuters Foundation.

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Cover image: ©Chris de Bode. Cows and goats in the dry pastures of the Sahel near Yola, Nigeria.
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