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The Structure of Livestock Trade in West Africa

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THE STRUCTURE OF LIVESTOCK TRADE IN WEST AFRICA

This paper has been prepared by

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WEST AFRICAN PAPERS

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Abstract

This paper uses network analysis to map and characterise live animal trade in West Africa. Building on a database of 42 251 animal movements collected by the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS) from 2013-17, it describes the structure of regional livestock trade at the network, trade community and market levels. Despite yearly fluctuations in the volumes and spatial patterns of trade, the paper shows that regional livestock trade operates on well-established trade corridors as animals flow in specific directions. The study also confirms that livestock trade is structured around several national and cross-border groups of markets that exchange more animals than expected by chance. Close to two-thirds of all animals are shipped internationally, indicating that regional animal trade in the Economic Community of West African States (ECOWAS) is remarkably cross-border. Finally, the paper finds that the hub markets that concentrate the most shipments also handle more animals and trade with more markets. Additionally, peripheral markets have more defined roles as primarily origins or destinations of animal shipments than markets in the core of the network. Of the nine key markets identified, three are close to borders, highlighting the importance of Nigeria as a livestock consumption destination for regional livestock production.

Key words: cross-border trade, livestock trade, livestock mobility, network analysis
JEL classification: F1, F14, F4, Q1, Q17, Q18, R12

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Note to readers

This Note is published as part of the partnership between SWAC/OECD and the Sahel Research Group of the University of Florida. The collaboration aims to: 1) Reinforce ties between research and policies for sustainable development that can help better anticipate changes within the Sahel and West Africa region. 2) Promote West African expertise by reinforcing links with African researchers and research centres through the Sahel Research Group network.

The Sahel and West Africa Club

The Sahel and West Africa Club (SWAC) is an independent, international platform. Its Secretariat is hosted at the Organisation for Economic Co-operation and Development (OECD).

Its mission is to promote regional policies that will improve the economic and social well-being of people in the Sahel and West Africa. Its objectives are to improve the regional governance of food and nutrition security and improve the understanding of ongoing transformations in the region and their policy implications. SWAC Members and partners are Austria, Belgium, Canada, CILSS, the ECOWAS Commission, the European Commission, France, Luxembourg, the Netherlands, Norway, Switzerland, the UEMOA Commission and the United States. SWAC also has a memorandum of understanding with the University of Florida (Sahel Research Group).

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List of acronyms

AfCFTA	African Continental Free Trade Area
ATP	Agribusiness and Trade Promotion project
CILSS	Permanent Inter-State Committee for Drought Control in the Sahel
E-ATP	Extended Agribusiness and Trade Promotion project
ECOWAS	Economic Community of West African States
OSBP	One-Stop Border Post
USAID	United States Agency for International Development

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Executive summary

Regional patterns of livestock trade remain understudied in West Africa, partly because of data availability. This paper contributes to fill this gap by describing the structure of regional livestock trade using a survey database of animal movements compiled by the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS) with the support of regional trade organisations. Formal analysis is used to represent trade as a network of goods being transferred between places. This relational approach allows for the study of the overall structure of trade, network sub-groups, the role of specific places and dynamics at different scales of analysis. Network analysis shows that livestock trade is structured around regional trade corridors, national and cross-border trade communities, and a few key urban and border markets.

WELL-DEFINED REGIONAL TRADE CORRIDORS

Despite yearly fluctuations in the volumes and spatial patterns of animal trade, regional livestock trade in West Africa operates in well-established trade corridors. Animals flow in specific directions, few shipments are reciprocated and markets trade with only a few other markets but with high frequency. However, trade relationships are not distributed uniformly amongst the markets. A relatively small number of markets, or hubs, concentrate most livestock movements and tend to trade animals with peripheral markets. The study also finds that other spatial factors shape the structure of animal trade, which can include the road network, social and cultural ties, and economic disparities.

NATIONAL AND CROSS-BORDER TRADE COMMUNITIES

Livestock trade is structured around several national and cross-border groups of markets that exchange more animals than expected by chance. National trade communities in Côte d'Ivoire and Burkina Faso are roughly contained by borders and somewhat shaped by the road network. In the rest of the region, livestock exchange relies on international trade communities. This indicates that political borders do not prevent groups of markets in different countries from actively exchanging animals but increase the economic and time costs of doing so. Intraregional livestock movements also highlight the importance of the regional road network for livestock trade.

KEY URBAN AND BORDER MARKETS

West African markets play an important role in livestock trade as primarily the origin or destination of animal shipments. The study finds that hub markets that concentrate the most shipments also handle more animals and trade with more markets. Additionally, peripheral markets have more defined roles as primarily origins or destinations of animal shipments than markets in the core of the network. In agreement with the network-level findings, markets that were more accessible also handled more trade than inaccessible ones, emphasising that both the road network and international borders have an important role in shaping regional trade. Finally, markets whose removal would cause the greatest disruptions to regional trade each year were identified. Of the nine markets identified, five were in urban settlements, three were close to borders and one was an export market. Three were near the Nigerian border, highlighting the importance of Nigeria as a livestock consumption destination for regional livestock production.

Livestock mobility in West Africa

Livestock keeping is an important economic activity in West Africa where 50% of the population is estimated to own livestock (Ilu et al., 2017). Livestock production, marketing and trade generate income for many actors in the value chain: producers, traders, transporters, and resellers. Additionally, the sector is a source of income for those that collect taxes at illegal checkpoints. Beyond generating income, livestock contributes to the food and nutrition security of the region.

Two main types of livestock mobility are practised in West Africa. Transhumance is the seasonal movement of herds to adapt to pasture availability and climatic conditions and is essential for the resilience of pastoral communities in arid and semi-arid regions like the Sahel. Some animals might be sold during transhumant mobility, but animal marketing is not the main driver of this activity. Trade-fuelled movements, on the other hand, are made with the primary purpose of selling animals. Livestock exports — estimated at USD 800 million for ECOWAS — are believed to be the most important in the region (World Bank, 2015). Yet a considerable part of this trade happens extra officially and is not captured by official trade figures (Mitaritonna and Traoré, 2017).

Agricultural production complementarities, ethnic and cultural ties, economic differences between countries and the enforcement of existing regulatory and policy frameworks, spatially shape animal trade in West Africa. Three main trade axes have been identified: the Western basin extends from Western Mali towards Mauritania, Senegal, Guinea, Gambia and Guinea-Bissau; the Central basin includes Central Mali, most of Burkina Faso, Ghana, Côte d'Ivoire and Togo; and the Eastern market shed that encompasses Niger, Benin and Nigeria (Haggblade et al., 2012).

The objective of this paper is to study the long and complex value chains that connect livestock producers mostly in the Sahel with consumers in the coast and urban settlements. Existing evidence suggests that most animals are shipped long distances and across borders, and that spatio-temporal patterns of animal movements are driven by seasonality and some sociocultural events such as Tabaski (or Eid al-Adha), an Islamic holiday during which many Muslim families sacrifice sheep. Yet, because network analysis relies on data, few studies have considered the quantitative study of trade networks in West Africa. To date, animal mobility network research has been conducted in Togo (Dean et al., 2013), Cameroon (Motta et al., 2017) and between Senegal and Mauritania (Apolloni et al., 2018; Nicolas et al., 2018, Jahel et al., 2020).

This paper intends to fill this gap by providing the first formal study of regional livestock movements in West Africa. Building on a database compiled by CILSS, the paper constructs networks of animal shipments by representing markets as nodes and shipments as directed links between nodes. This formal approach to trade networks shows that livestock trade is structured around regional trade corridors, national and cross-border trade communities, and a few key urban and border markets.

Data sources and methods

Data on animal shipments were obtained from the database of livestock movements compiled by CILSS. With the support of regional trade organisations, CILSS has tracked the magnitude and direction of agricultural intraregional trade (livestock, staple and cash crops) in selected trade corridors in West Africa. The data collection effort started under USAID's Agribusiness and Trade Promotion (ATP) and Extended ATP projects in 2009 but more detailed information on the shipments has been collected since 2013. After pre-processing the original database of 122 191 entries, a working dataset of 42 251 animal movements from 2013-17 remained.

Map 1
Geographic location of survey points, origin, and destination markets, 2013-17
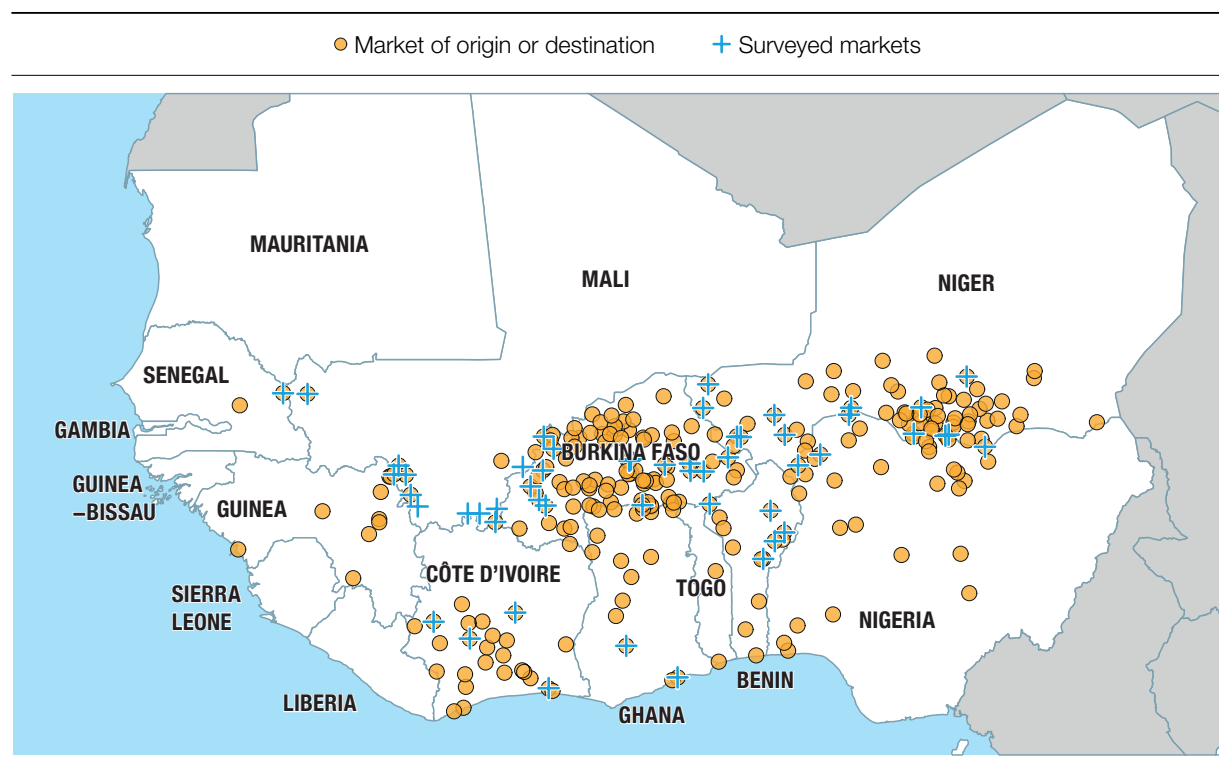
Source: CILSS (2017) and author's calculations.

The following variables were extracted from the livestock trade database: origin, destination and survey markets; origin, destination and survey countries; livestock species; date and size of the cattle, sheep and goat shipments that occurred between January 2013 and August 2017. Each movement was then divided into two shipments: one from the origin to the data collection point, and one from the data collection point to the destination (if this yielded duplicates, they were omitted). After incomplete records were removed, the markets were geolocated. Most survey points were in Burkina Faso, Mali and Niger, with smaller numbers in Benin, Côte d'Ivoire, Ghana and Nigeria (Map 1). In addition to these countries, markets in Guinea, Senegal and Togo were reported as origin or destination of animal shipments.

Yearly networks as well as one overall network were built with the resulting dataset. The nodes in these networks represent markets, while directed links between nodes represent livestock shipments from an origin to a destination market over a specific time period. Each link was weighted by the number of animals involved in the shipment, however, both weighted and unweighted versions of the networks were used in this paper. Thus, in a yearly network, a directed unweighted link between markets A and B indicates that at least one shipment was made during a specific year between those markets, whereas a weighted link indicates the total number of animals that were traded. The trade network was analysed at three spatial scales: network, trade community and market, using the statistics defined in Table 1. Key markets were identified by quantifying the disruption to trade — links, shipments, and volumes — that removing each market would cause for each year. All the analyses and figures were made in "R" (R Core Team, 2017) using the igraph (2006), ggnetwork (2016), and ggplot (2016) packages. Additional packages used are cited under each figure or map (Box 1).

Box 1
Methodology

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This paper analyses the structure of animal trade in West Africa using complete movement records from a database of livestock trade. The results should be interpreted with caution for two main reasons. First, the data collection changed during the study period. For example, few shipments were recorded at the beginning of 2013 — an adjustment period between the end of the ATP and Extended-ATP projects and the revamp of the data collection (Figure 1). Another relevant change is that more locations were surveyed in later years. A second important consideration is that this paper is based on a pre-processed subset of the complete records in the animal trade database and therefore does not represent the entirety of animal trade in West Africa, nor does it perfectly emulate volumes reported in the CILSS trade database (Figure 1). ATP's database records significantly more trade than official figures (Josserand, 2013) especially for animals originating in Burkina Faso and Mali. Our analysis, on the other hand, focuses on livestock exported by Burkina Faso through the central and eastern trade corridors. The findings presented in this paper must be interpreted deliberately, considering these limitations.

Table 1
Statistics used to study the livestock trade network

Scale	Metric	Definition
Network	Survey markets	Number of markets where data collection took place.
	Markets	Number of markets (nodes) that were origins or destinations of livestock shipments (n).
	Movements	Number of animal shipments (s).
	Links	Pairs of markets that traded at least one animal (l); directed link (e.g. shipment from market A -> B is different than from B -> A). Each link defines a pair of trading partners over a period of time.
	Link density	Ratio of links (l) among livestock markets (n) in the network with respect to the maximum possible number of links (2n(n-1)); defined as l/2n(n-1).
	Average partners	Average number of neighbours, or trading partners of all markets in the network (l/n).
	Average shipments	Average number of shipments of all markets in the network (s/n).
	Reciprocity	Measure of the likelihood that two markets trade in both directions.
	Propinquity (p-value)	The tendency of trading markets to be closer than markets that do not trade. Measured with the p-value of a one-sided Mann-Whitney test between two groups of geographic distances: the distances between pairs of markets that traded and those that did not trade.
	Degree distribution	Probability distribution of the number of trade partners of each market over the whole network and study period. Degree: Number of trade neighbours of a specific market over a specific time period.
	Degree assortativity	Correlation between the degrees of linked markets, quantifying the tendency of markets to trade with markets with similar degree centrality (or number of trade partners).
Trade community	Modularity	The percent difference between the links running within communities and those expected by chance (Newman, 2006). The community configuration that maximised the modularity (Q) of the undirected network was determined with the fast and greedy algorithm introduced in Clauset et al. (2004). This community configuration was compared with communities by country. A network with Q>30% is considered to have significant community structure (Girvan & Newman, 2002).
Market	Coreness	The coreness of a market is k if it belongs to the k-core but not to the k+1 core. A k-core is the subnetwork of markets that exclusively trade with at least k-other markets in the same subnetwork (Seidman, 1983).
	Input/output index	The input-output (I-O) index equals -1 if the market only sent animals, 1 if the market only received animals, and 0 if the inputs equated the outputs. Defined as (I-O)/(I+O), where I=inputs and O=outputs.
	Accessibility	In this paper, accessibility is proxied with the proximity of each market to a main road or an international border.
	Degree centrality	Number of markets a specific market is connected to. In- and out-degree refers to the number of markets that ship livestock to a market of interest, and the number of markets that the market of interest sends livestock to, respectively.
	Volume	Livestock volume received or sent by a market.
	Movements	Number of animal shipments(s) each specific market participated in as an origin or a destination.

Note: The aggregated network for the whole study period (2013-17) was used to approximate the degree distribution.

Sources: CILSS (2017), Dubé et al. (2009) and author's adaptation of commonly used network statistics.

Figure 1
Number of livestock shipments and survey locations in the CILSS database
versus working dataset, 2013-17
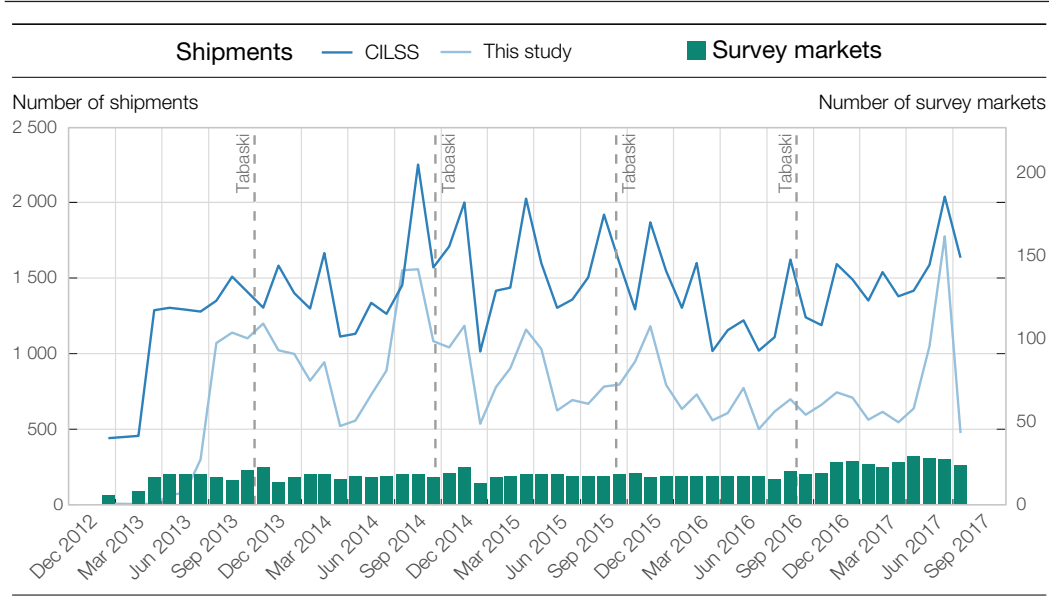
Source: CILSS (2017) and author's calculations.

The advantages of studying trade with the network paradigm include the ability to analyse the overall structure of trade, network sub-groups, the role of specific entities, and dynamics at different scales of analysis (e.g. from a region to the community level). Networks are also adequate to study trade relation-ships because they can exploit the bilateral nature of trade: every commercial transaction between entities implies the movement of physical goods in one direction, and the movement of information or capital in the other direction.

The structure of regional livestock trade

TEMPORAL AND SPATIAL PATTERNS OF LIVESTOCK TRADE

Most shipments consisted of cattle; however, most of the animals transported were sheep (Figure 2). Thus, small ruminant shipments were larger in size than cattle shipments — 225 versus 42 animals per movement. Peaks in sheep movement were recorded in the months preceding Tabaski each year (Figure 2). The majority (94%) of shipments were made by truck, with no important differences by species or season (CILSS, 2017). These findings reflect that CILSS is recording primarily trade movements, as opposed to transhumant movements that are made on the hoof. Seasonal movement peaks have also been identified in Mauritania, where the fraction of animals transported by truck and the mobility network size increase in the month before and after Tabaski (Apolloni et al., 2018).

Temporal variability in livestock volumes and shipments could reflect changes in climatic conditions, violent incidents, changes in data collection, or a combination of these factors. While it is not possible to attribute changes in trade to specific causes in this paper, some context might inform the observed trends. In 2015, a late start to the rainy season and unfavourable pasture conditions for the second year in a row triggered the sale of animals with deteriorated body conditions, including uncommon sales in northern Burkina Faso (FEWSNET, 2015). It is possible that destocked herds from previous years affected the availability of animals (and therefore, trade) during 2016; however, favourable rainfall during the second half of 2016 and into 2017 increased pasture availability, which could explain the increase in shipments for 2017 when compared to the previous year. The inclusion of new markets in the collection sample may also have contributed to the increase in recorded movements. Additionally, Tabaski was observed at the end of August in 2017 so festival-related movements had probably started by the end of the study period, which could explain the increase in sheep movements, and comparable figures for January-August 2017 versus full preceding years (Figure 2).
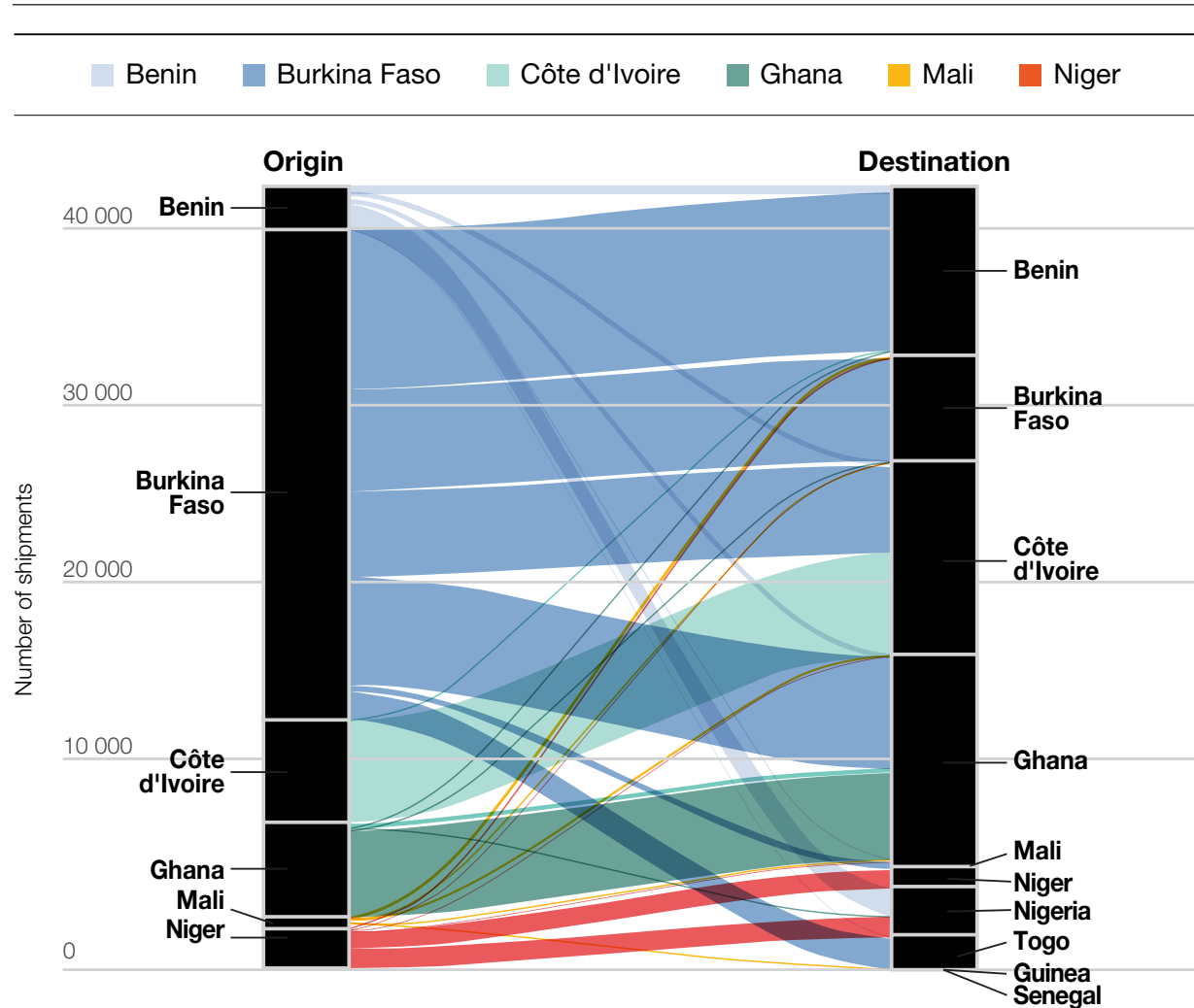
Figure 2
Number of animals and shipments by species and month, 2013-17
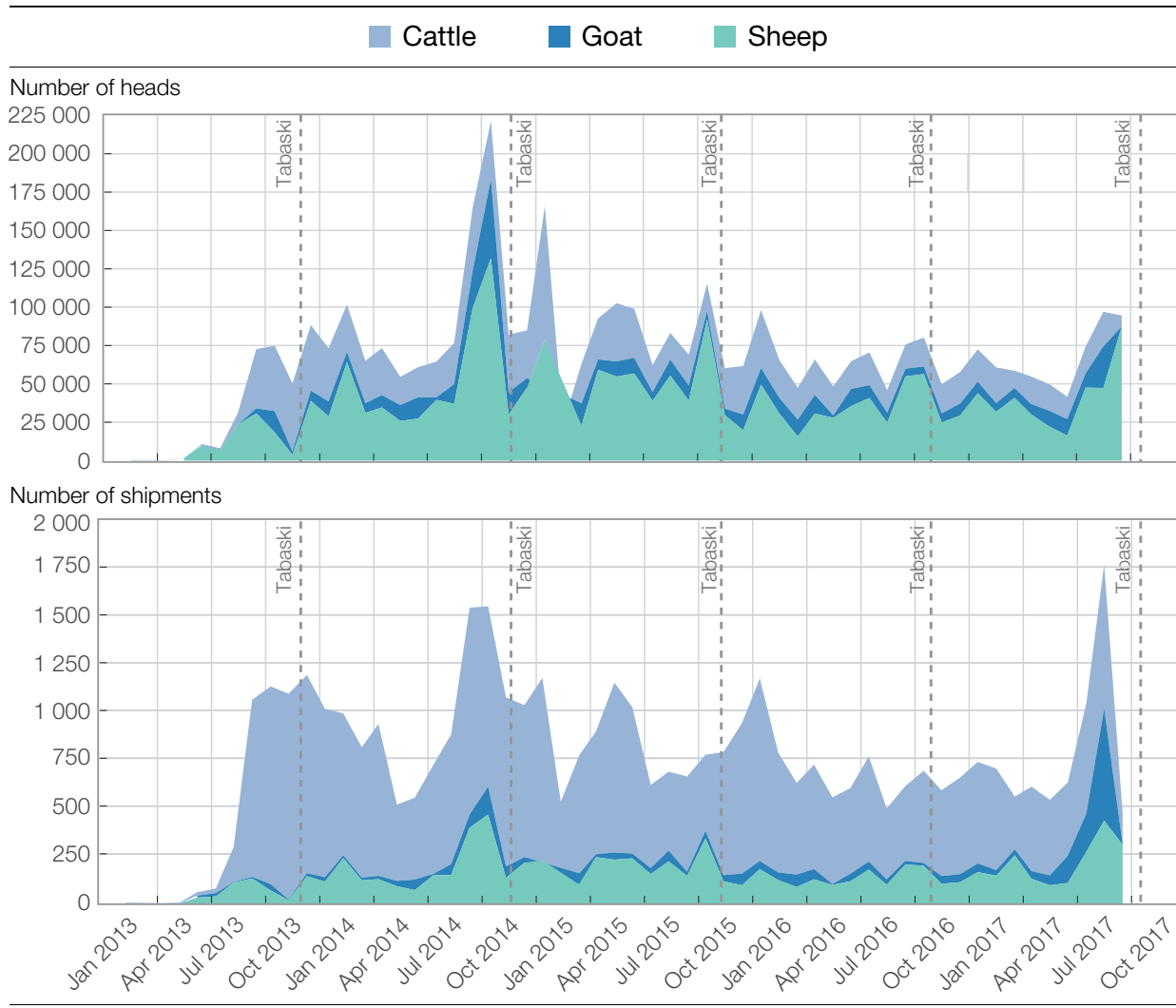
Figure 3
Number of shipments by origin and destination country, 2013-17

Note: Colours identify the country of origin. This figure was made with the ggalluvial package (2019). Origin shipments for Nigeria and Togo are not represented.
Sources: CILSS (2017) and author's calculations.

Close to two-thirds of all animals were shipped internationally, indicating that regional animal trade in ECOWAS is remarkably cross-border. Most movements originated in Burkina Faso and Côte d'Ivoire, while close to one-quarter of shipments were destined to Ghana, Côte d'Ivoire and Benin each (Figure 3). Although it is considered an important consumer market in ECOWAS, less than 5% of shipments were bound to Nigeria. In this regard, the devaluation of the Naira (official currency) in 2016 was unfavourable for livestock exports into Nigeria and triggered the re-routing of animal shipments to other consumer markets in the region and, in some occasions, the reversal of trade shipments between Nigeria and its neighbours (FEWSNET, 2016). Côte d'Ivoire's role as a self-provider reflects both the re-distribution of animals coming from Burkina Faso through the central trade corridor, and the distribution of animals from production areas in the north, where 80% of the country's animals are raised, to urban agglomerations towards the coast (Sokouri, et al., 2014).

WELL-DEFINED REGIONAL TRADE CORRIDORS

In general, animals are traded in a north-south direction with some shipments flowing west towards Guinea reported for 2016 and 2017 (Map 2). There were national and international shipment patterns that repeated over the years. Persisting national movements included those from northern and western Burkina Faso towards the Beninese and Togolese borders, shipments from central Côte d'Ivoire towards consumer markets in the south and flows from northern to southern Ghana. International flows included shipments from Burkina Faso towards the Ivorian, Ghanaian, Togolese and Beninese coasts. Despite these spatio-temporal patterns, there are clear differences between the years. For example, there were more total links and more international links in 2014 and 2017 than in other years (Map 2). More shipments from Niger to Nigeria were reported for 2017 because some of the additional markets surveyed in 2017 were located between these countries.

The network-level statistics presented in Table 2 show temporal changes in the network structure yet suggest a well-established spatial structure through the years. Observed changes include a peak in the number of shipments for 2014, and more pairs of trading markets recorded for 2017, possibly due to more markets between Niger and Nigeria being surveyed during that year (Map 2). A well-defined spatial structure is indicated by

Table 2

Livestock trade network statistics by year

Year	2013	2014	2015	2016	2017
Data collection points	25	30	23	33	41
Markets	112	136	108	122	182
Movements	5 997	11 872	10 098	7 914	6 370
Links	154	286	138	146	297
Link density	1.2%	1.6%	1.2%	1.0%	0.9%
Average shipments	53.5	87.3	93.5	64.9	35.0
Average trading partners	1.4	2.1	1.3	1.2	1.6
Reciprocity	5.2%	5.6%	0.0%	1.4%	8.8%
Propinquity (p-value)	7.6E-05***	0.17ns	2.9E-05***	4.1E-14***	4.2E-60***
Degree correlation (assortativity)	-60%	-61%	-64%	-55%	-55%

Notes: Data for 2017 includes shipments recorded from January until August. Propinquity refers to the tendency of markets to trade with others in their proximity. A significant p-value indicates that markets tend to trade with nearby markets. Assortativity is the tendency of markets to trade with markets that share similar structural attributes as them (in this case, degree centrality). When markets trade assortatively, hubs trade with hubs, and peripheral markets with peripheral markets. *** $p<0.001$; ns not significant.

Source: CILSS (2017) and author's calculations.

Map 2

Livestock trade network by year and type of trade relationship (cross-border or national)

| Trade relationship | International —— | National —— |

2016

| Trade relationship | International —— | National —— |

2017
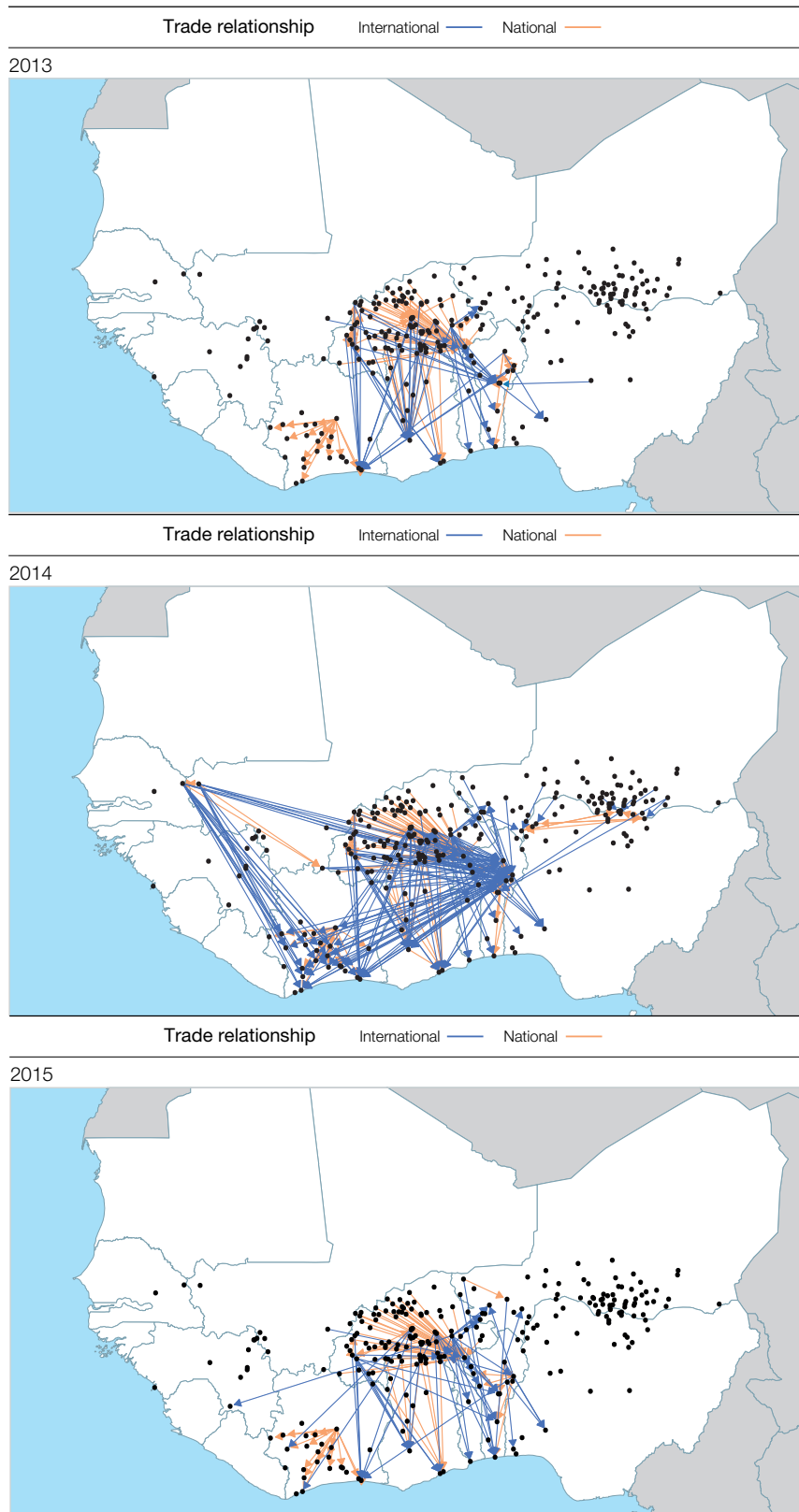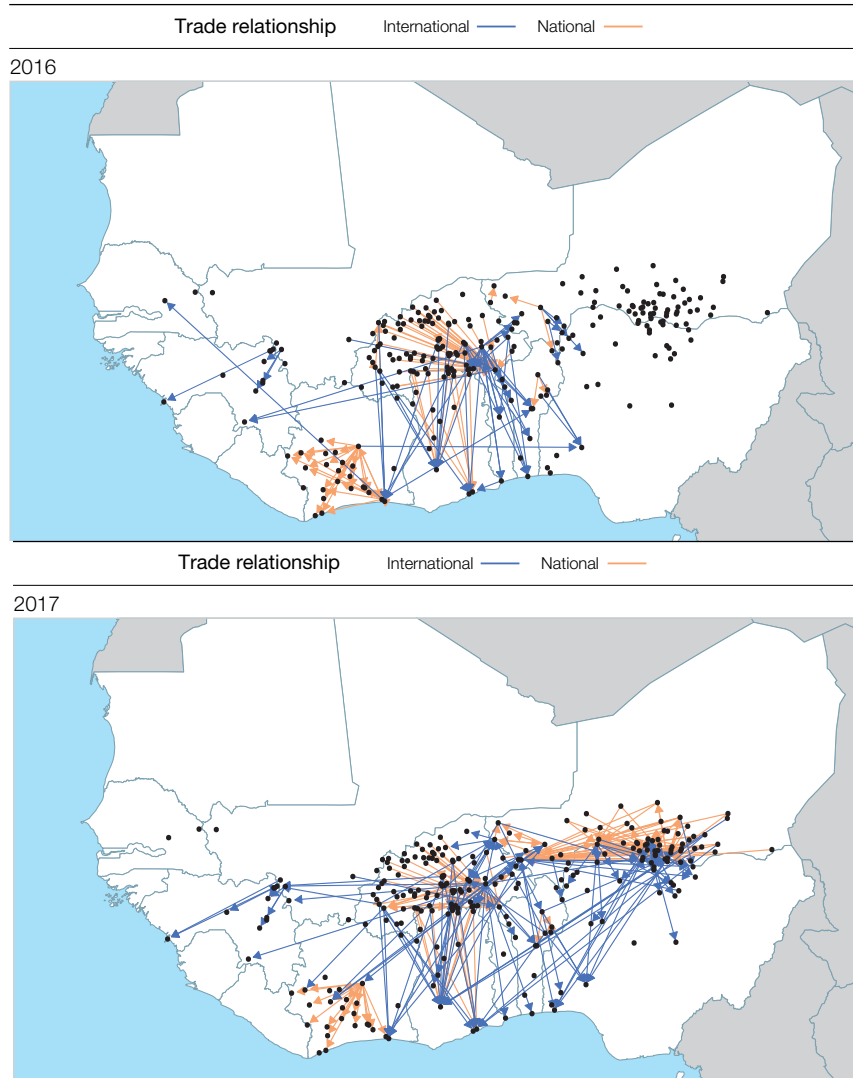
Notes: A link between two markets represents that at least one trade movement happened between them in the direction of the arrow over a specific year. The link color indicates if the trade relationship was cross-border or national, while black circles mark the origin/destination markets.

Sources: CILSS (2017) and author's calculations.

low link reciprocity and density, and frequent trade interactions (every 4-10 days) with few (1-2) other markets. In other words, animals are traded through few of all the possible links, and mostly in one direction, roughly coinciding with the gradient of demand and the negative gradient of livestock production (Map 2).

The network-level results reflect the heterogeneity of the trade network. Most years, pairs of markets that traded animals were significantly closer than those that did not. Moreover, the markets traded disassortively (Table 2). Simply put, the markets tended to trade with others nearby, and markets with very few trade partners tended to trade with other markets with many trade partners. Presumably, peripheral, less central markets are either village or collection markets, where animals are aggregated before being shipped to bigger, more central markets, in urban centres, near borders or on a trade corridor. The existence of very central, hub markets is also suggested by the shipment and trade partner or link distributions, which followed a power law (in which one varies as a power of the other) and a lognormal distribution (Table 3). These results indicate that markets have distinct roles in the network. Market roles could depend on their geographical location in the region and/or structural position in the livestock distribution chain.

Table 3

Plausible distributions for the shipment and link degree sequences of the aggregated trade network (n=261)

Sequence	Shipment	Degree
Distribution	Power law	Log-normal
Xmin	84	1
Coefficient (α)	1.66	-1.65
Hypothesis p-value	0.41	0.30

Notes: Following Clauset et al. (2009), distributions with a p-value > 0.10 are considered as plausible source distributions for the empirical data. The distributions were fit using the power law package (2015).

Sources: CILSS (2017) and author's calculations.

NATIONAL AND CROSS-BORDER TRADE COMMUNITIES

This section investigates national and cross-border spatial patterns of trade for the most recent year (2017). It first assesses whether markets form trade "communities" — defined as sub-groups of connected markets with higher trade link density than expected if the markets traded at random. It also addresses if these communities are shaped by international borders. To do so, the trade network is partitioned into the community configuration that maximises the modularity "Q". This partition is then contrasted with market communities by country.

Country-communities show significant structure, sharing more intracommunity ties than expected by chance (Q=30%). However, the configuration that maximises within-group trade ties includes mostly cross-border market groups (Q=63%). In this alternate configuration, trade communities in Guinea, Côte d'Ivoire, and Burkina Faso are roughly contained by borders (groups 3, 4 and 6 in Map 3b). Strong cross-border trade ties are present in the rest of the trading communities: between Niger and Nigeria (groups 1 and 5), extending from western Niger to Guinea (2), between Togo and Nigeria (7), and between Burkina Faso and Ghana (9). While international borders do not definitively spatially shape trade in the region, they do have some effect over its spatial organisation.

Map 3
Geographic structure of the livestock trade network, 2017 (n=182)

○ Benin   ■ Burkina Faso   △ Côte d'Ivoire   ● Ghana   ▪ Guinea   ▲ Mali   ○ Niger   ▪ Nigeria   △ Togo
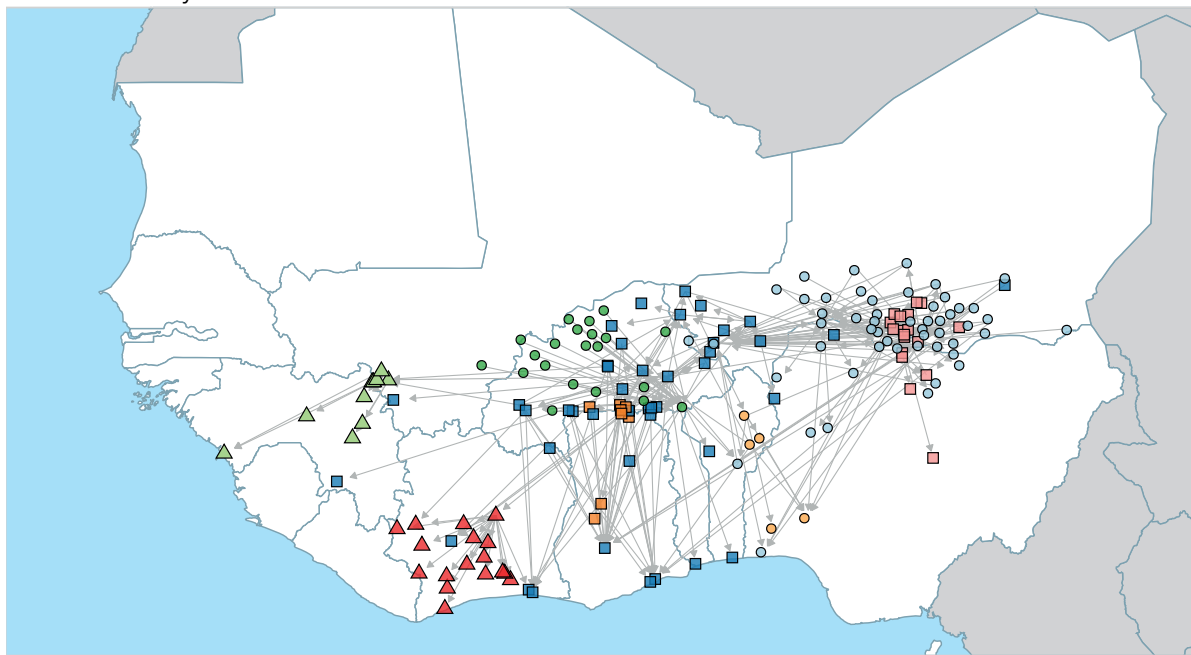
A - Country
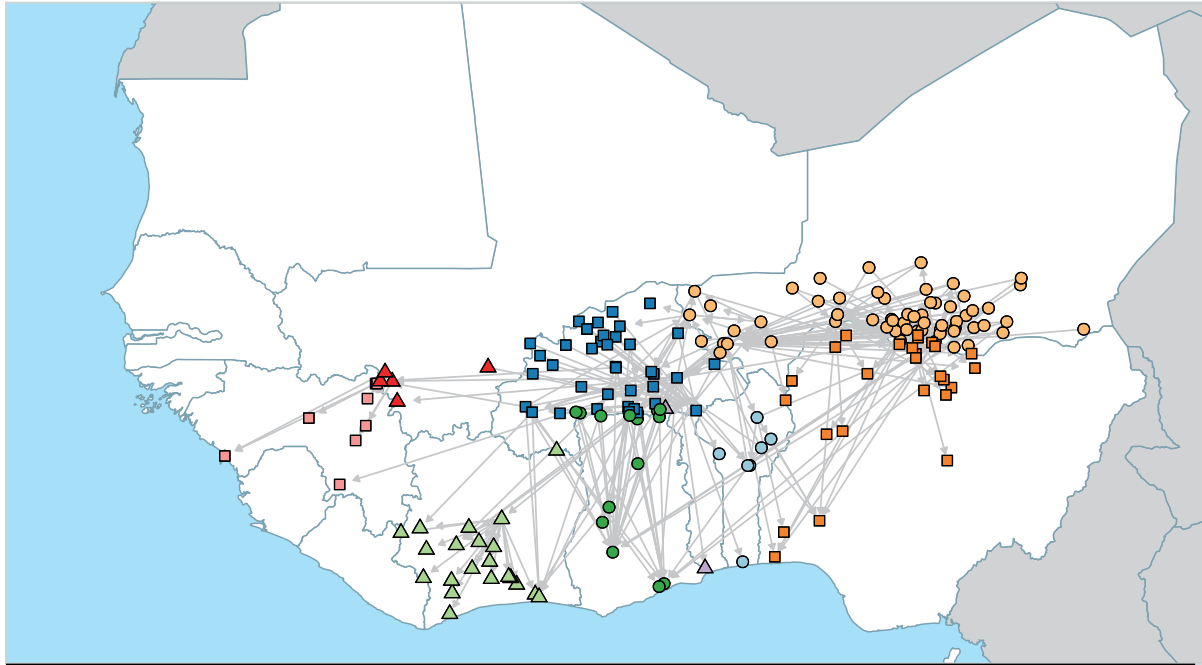
○ 1   ■ 2   △ 3   ● 4   ▪ 5   ▲ 6   ○ 7   ▪ 8

B - Community

Notes: A) Country market communities. B) Market community configuration obtained by maximising intra-community trade ties with respect to an arbitrary grouping.

Sources: CILSS (2017) and author's calculations.

KEY MARKETS: BORDER AND URBAN TRADE HUBS

Markets can play different roles in livestock trade depending on the overall structure of the regional network. In heavily centralised networks, for example, most flows tend to be directed to a few central hubs. This type of organisation is very efficient in arranging animal flows but also more susceptible to be disrupted by external shocks than a decentralised network in which each market is connected to multiple other markets of different sizes. Understanding the roles markets play is therefore of crucial importance to characterise the effectiveness of the regional network and its possible resilience to disruptions. This section investigates how both network and sub-regional patterns translate into the individual markets. It identifies a number of roles played by West African markets, discusses the role of roads and borders in their development, and identifies key nodes for the livestock business.

The findings at the whole network and trade community levels are used to identify the roles of individual markets. In a previous section of this paper, some markets were found to concentrate significantly more trade relationships and shipments than most of the markets in the network. It was also established that markets with many trade relationships tend to trade with peripheral ones, and that animals flow in specific directions. These findings suggest that markets in the core of the network are involved in more transactions, trade with more markets, and/or manage larger animal volumes than peripheral markets. They also suggest that markets in the periphery have a more marked role as primarily senders or receivers of animal shipments than markets in the inner layers of the network. Consequently, the coreness and input-output (I-O) balance of each market can be useful in visualising the market roles. The coreness will be higher for markets that belong to the inner layers or core of the network, while the I-O index will equal -1 if the market only sent animals, 1 if the market only received animals, and 0 if the inputs equate the outputs (Figure 4).

Markets in the core of the network handle significantly more shipments, animals and links than peripheral ones (Spearman's rhos >0.76, p<0.001). Hub markets on the upper left corner of Figure 4 primarily send animal shipments, like Ouagadougou, Fada N'Gourma and Bouaké. Hub markets that receive and send similar numbers of shipments are towards the upper center (like Abidjan), while hubs near consumption centres such as Port-Bouët and San Pedro are on the upper right because they mostly receive animal shipments. Many of the providing hubs are in Burkina Faso, a historically important livestock exporter to the region. Similarly, receiving hubs are near the coast and in urban areas, where the consumer demand

Figure 4
Livestock market by coreness and input-output shipment index, 2013-17
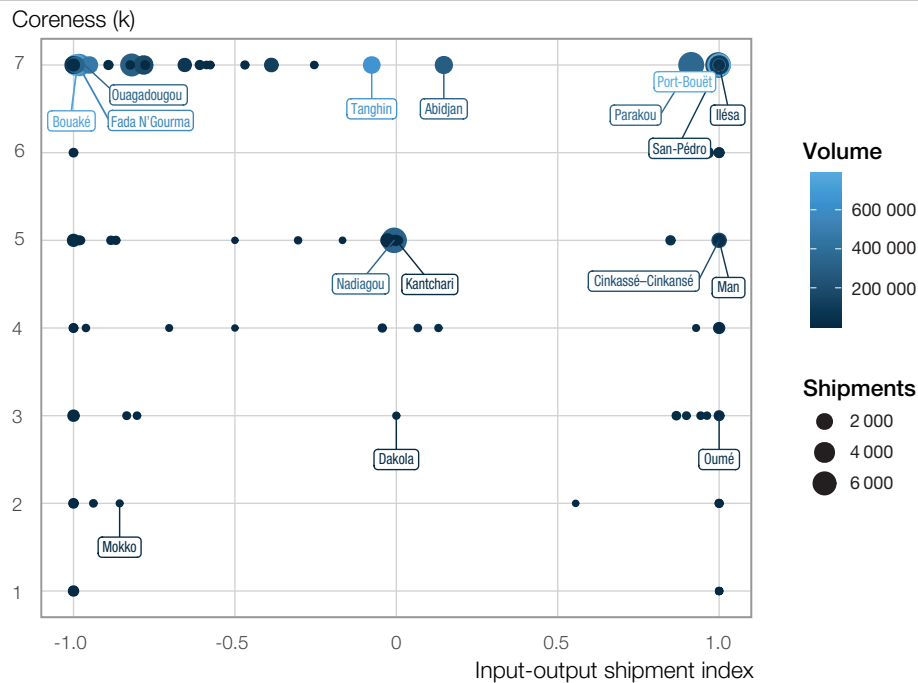
Notes: Nodes sizes are proportional to the number of shipments that the markets handled, and the colour tone to the volume of animals involved in those shipments. The I-O shipment index equals zero if a market sent and received equal numbers of animal shipments, -1 if the market only sent shipments, and 1 if the market only received shipments.

Sources: CILSS (2017) and author's calculations.

concentrates. Markets in the periphery, on the other hand, have more defined roles as primarily sources or destinations of livestock shipments (lower right and left areas of Figure 4). Thus, market roles are related to the geographic as well as the structural location of markets in the regional value chain.

Market roles could also be associated with market accessibility, which can be proxied using the position of markets relative to spatially-embedded features like borders and roads. International borders can make markets less accessible because much like travelling on a road in bad conditions, there are time and economic costs associated with crossing borders in West Africa, and border crossings reduce the population base reachable by international animal shipments (OECD/SWAC, 2019a). Similarly, there are costs associated with transporting animals to a main road, and these costs are higher, or a market is less accessible, the further away is it from a main road or a border.

More accessible markets (those closer to a road or a border) tend to trade more animals, with higher frequency, and/or with more markets than less accessible markets (Spearman's rho ≤ -0.13, p<0.05). Though borders condition the role of markets, accessibility by road might play a more important part, as many of the hubs that belong to the structural core of the network — like Bouaké, Fada N'Gourma, Nadiagou and Port-Bouët — are virtually on a main road (Figure 5). In a trade system that operates under much uncertainty, it is expected for large hubs to emerge as an adaptation to the local conditions of unequal accessibility and fragmented infrastructure. A similar reliance on important trade brokers has been found in cross-border social networks in the Gaya-Malanville-Kamba and Birni N'Konni-Illela regions of West Africa (Walther, 2015).

Figure 5
Livestock market location with respect to international borders and primary or secondary roads
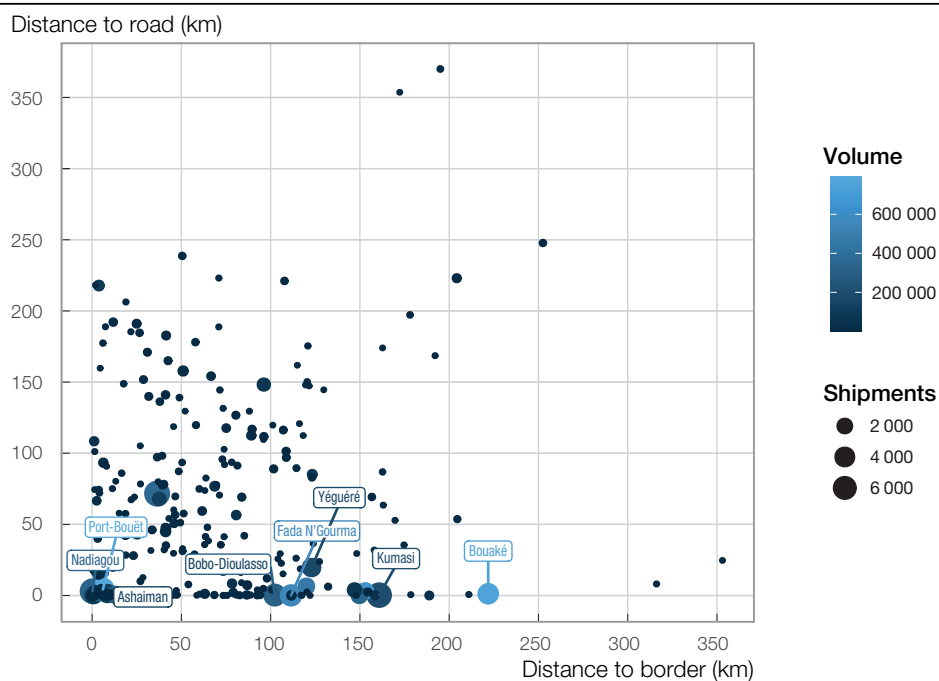
Notes: Nodes are coloured by the volume of animals they handled during the study period, and their size is proportional to the number of shipments they were involved in. The volume and number of shipments of the markets are negatively correlated to the distance to a road and the distance to a border (Spearman's test p-values<0.05). The OECD's model map files, OpenStreetMap's road shape files (2018) for the study countries, and the geosphere "R" package (2019) were used to calculate the distance to a border and a road.

Sources: CILSS (2017), OpenStreetMap (2020) and author's calculations.

Nine key markets that are either border markets (within 50 kilometres) in large urban centres or export markets (Map 4) are identified. Hub border markets dominate the in-degrees and include Nadiagou (Burkina Faso, Benin), Dan Barto (Niger, Nigeria) and Derassi (Benin, Nigeria). Out-degree leaders are predominantly big urban and export markets, that also serve as hubs but connecting international production to consumer markets in urbanised areas and the coast. Port-Bouët (Côte d'Ivoire), Bouaké (Côte d'Ivoire), Kumasi (Ghana) and Bobo-Dioulasso (Burkina Faso) are in or near urban settlements. Parakou in Benin is another important urban market near Nigeria. The remaining key market is Fada N'Gourma (Burkina Faso) through which livestock mainly destined for export flows. Although previously unappreciated in the country-level summary of animal shipments, three of the nine identified key markets are close to the Nigerian border, highlighting Nigeria as an important regional consumption market for livestock.

Map 4
Geographic location of key markets, 2013-17
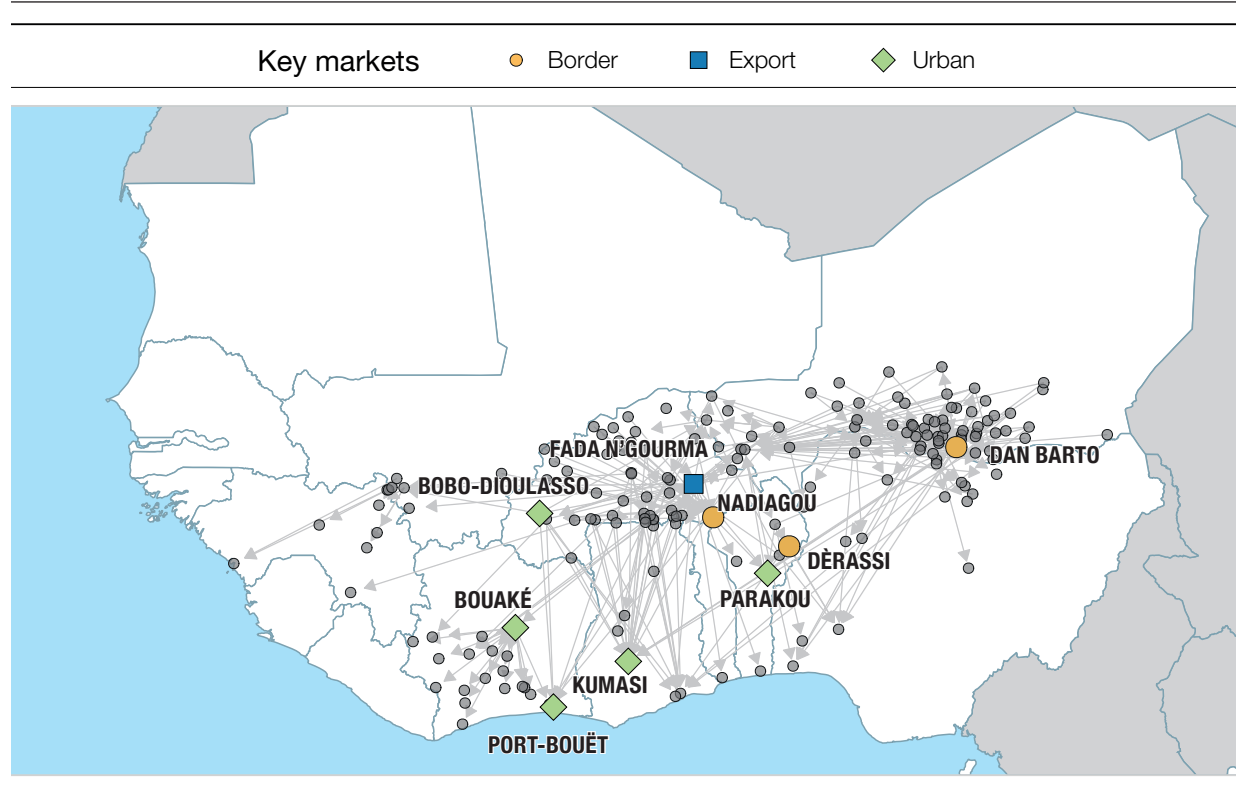
Sources: CILSS (2017) and author's calculations

Identifying important markets for the livestock trade network has special relevance because of its structure. Networks with hubs that concentrate considerably more activity than most nodes such as the present network of livestock trade, are more robust to random node removals yet more vulnerable to targeted attacks than networks where relationships are established randomly (Albert et al.,2000). In the context of West Africa, a partial or total market removal can be understood as a physical or other type of barrier that prevents a market from trading. This can be due to seasonal floods, deteriorated road conditions, or reduced agricultural activity after a violent attack. Long-lasting and possibly cascading effects can be triggered if specific markets are removed from the trade network, which can deteriorate the economic, food security and nutrition conditions in the region, extending well beyond the geographic location of the market.

Perspectives

Few quantitative studies of regional trade exist for West Africa, partly because the necessary mechanisms to collect, process, store and analyse trade data are not streamlined across the region (Mitaritonna and Traoré, 2017). This is the case for livestock trade research. Initiatives that have used network methods to study animal trade, albeit from different countries and using different data sources and methods, have shown that a substantial number of the animals moved in the region cross at least one international border. In this paper, network analysis was used to map and describe regional livestock trade in West Africa for animals originating primarily in Burkina Faso, but including origins and destinations in Benin, Côte d'Ivoire, Ghana, Guinea, Mali, Niger, Nigeria, Senegal and Togo.

Altogether, our findings reflect the fragmentation of the road network inherited from the colonial period and the poor accessibility of many peripheral markets in the region. Animal trade relies on a handful of paved roads in each country and on a limited number of transnational routes that help connect the Sahel to main consumption centres (OECD/SWAC, 2019a). Because most shipments are made by truck and cross borders, the findings of this study advocate for increasing the density and quality of the road network to support the intraregional trade of livestock and other products, one of the main objectives of the African Continental Free Trade Area (AfCFTA). Due to population growth, rising incomes, and urbanisation, the livestock market network will likely be supplying greater numbers of animals in the future. Border areas should be prioritised as their infrastructure is not prepared to withstand increasing regional trade movements and will likely constrain them (OECD/SWAC, 2019a, 2019b).

Political borders do not prevent different countries from actively trading animals yet increase the monetary and time costs of doing so. The results of this study substantiate eliminating border tariffs and delays that contribute to the higher cost of food in West Africa when compared to other regions of the world (Allen, 2017). One way forward would be to operationalise existing one-stop border posts (OSBPs) in important cross-border areas that have been identified in this study. However, some of the OSBPs that have been built remain inoperative or underutilised, indicating that addressing the lack of border trade infrastructure is not the sole solution to increase intraregional trade. Though adjusting trade infrastructure to the needs should be a priority.

Findings on the structure of livestock trade have two other important policy implications. The existence of trade hubs is relevant for value chain interventions such as vaccination, disease monitoring and control strategies. Given the characteristics of trade in West Africa (long-distance, cross-border, transport by truck), livestock diseases could potentially travel long distances over short periods of time. Animal health initiatives are often resource-limited; therefore, knowledge on the structure of trade is useful to identify important markets where efforts could focus or where pilot programmes could be carried out.

The second implication has to do with the regional security situation. In some parts of West Africa, markets and their surrounding areas appear to be common targets of violent attacks (Van Den Hoek, 2017). Networks where hubs exist are resistant to random node removals, but vulnerable to targeted ones, where a removal can be understood as the cessation of market activity for any reason, including physical impediments, and other non-physical causes. More research is needed to assess how vulnerable or robust the trade network is, considering the proportion of trade that is reported in existing datasets and how well it reflects the reality of trade in the region.

Finally, as regional trade integration is pursued, network approaches to study trade can help assess the implications of removing trade impediments. Those implications include time and economic opportunity costs and the potential risk of increased spread of disease. Recent developments in network reconstruction, comparison and modelling can also help inform other regional trade policies for livestock and other agricultural products. Future efforts to study animal mobility in the region should exploit the bilateral nature of trade by streamlining research initiatives and sharing methods, data, findings, and lessons learned. Opportunities also exist to synthesise knowledge from different sources and fields such as remote sensing products, infrastructure maps, market information systems, household surveys and more local, qualitative studies. Given its importance

as a consumption market for the region, an effort should be made to better understand live animal shipment patterns into Nigeria, a country that is not covered by the CILSS database despite being the largest market in the region. Finally, using data-informed simulations, previous work has concluded that the risk of regional disease transmission is high in West Africa (Dean et al., 2013; Motta et al., 2017). A network approach such as the one developed in this study could contribute to better understand the risk of regional disease and develop surveillance and control measures based on observed animal movements across the region.

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West African Papers

The Structure of Livestock Trade in West Africa

This paper uses network analysis to map and characterise live animal trade in West Africa. Building on a database of 42 251 animal movements collected by the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS) from 2013-17, it describes the structure of regional livestock trade at the network, trade community and market levels. Despite yearly fluctuations in the volumes and spatial patterns of trade, the paper shows that regional livestock trade operates on well-established trade corridors as animals flow in specific directions. The study also confirms that livestock trade is structured around several national and cross-border groups of markets that exchange more animals than expected by chance. Close to two-thirds of all animals are shipped internationally, indicating that regional animal trade in the Economic Community of West African States (ECOWAS) is remarkably cross-border. Finally, the paper finds that the hub markets that concentrate the most shipments also handle more animals and trade with more markets. Additionally, peripheral markets have more defined roles as primarily origins or destinations of animal shipments than markets in the core of the network. Of the nine key markets identified, three are close to borders, highlighting the importance of Nigeria as a livestock consumption destination for regional livestock production.

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