

MAPPING AND NETWORK ANALYSIS OF SMALL RUMINANT TRADE IN SOMALI REGION AND BORENA ZONE, ETHIOPIA: IMPLICATION FOR POTENTIAL SPREAD AND CONTROL OF PESTE DES PETITS RUMINANTS VIRUS

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OUTLINES OF PRESENTATION

- Introduction
- Objectives
- Study Area
- Study Approach
- Data Analysis
- Results
- Conclusion
- Recommendations
- Acknowledgments

INTRODUCTION

- Livestock movements and trade are major drivers of transboundary animal diseases (TAD) spread, including long-distance transmission of PPRV through infected animals.
- Understanding trade structure, routes, volumes, frequency, and risks is essential for designing effective PPR surveillance and control strategies.
- Social network analysis (SNA) provides a powerful tool to study disease spread dynamics, identify key markets, and prioritize surveillance in high-risk nodes.
- Pastoral trading systems are complex and multi-stage, making it necessary to characterize the small ruminant trade network in Borena and Somali regions to understand its role in PPRV epidemiology.

OBJECTIVES

- To quantify and characterize small ruminants' trade movements in Borena zone and Somali region
- To identify key markets and target areas for practical disease surveillance, control, and communication interventions
- To evaluate the vulnerability of trade network to the potential spread of PPRV using available small ruminant movement information
- To explore the association of market network properties with the epidemiology of PPRV

STUDY AREA

- The study was conducted in Borena zone(Orromia RS) and Somali region of Et

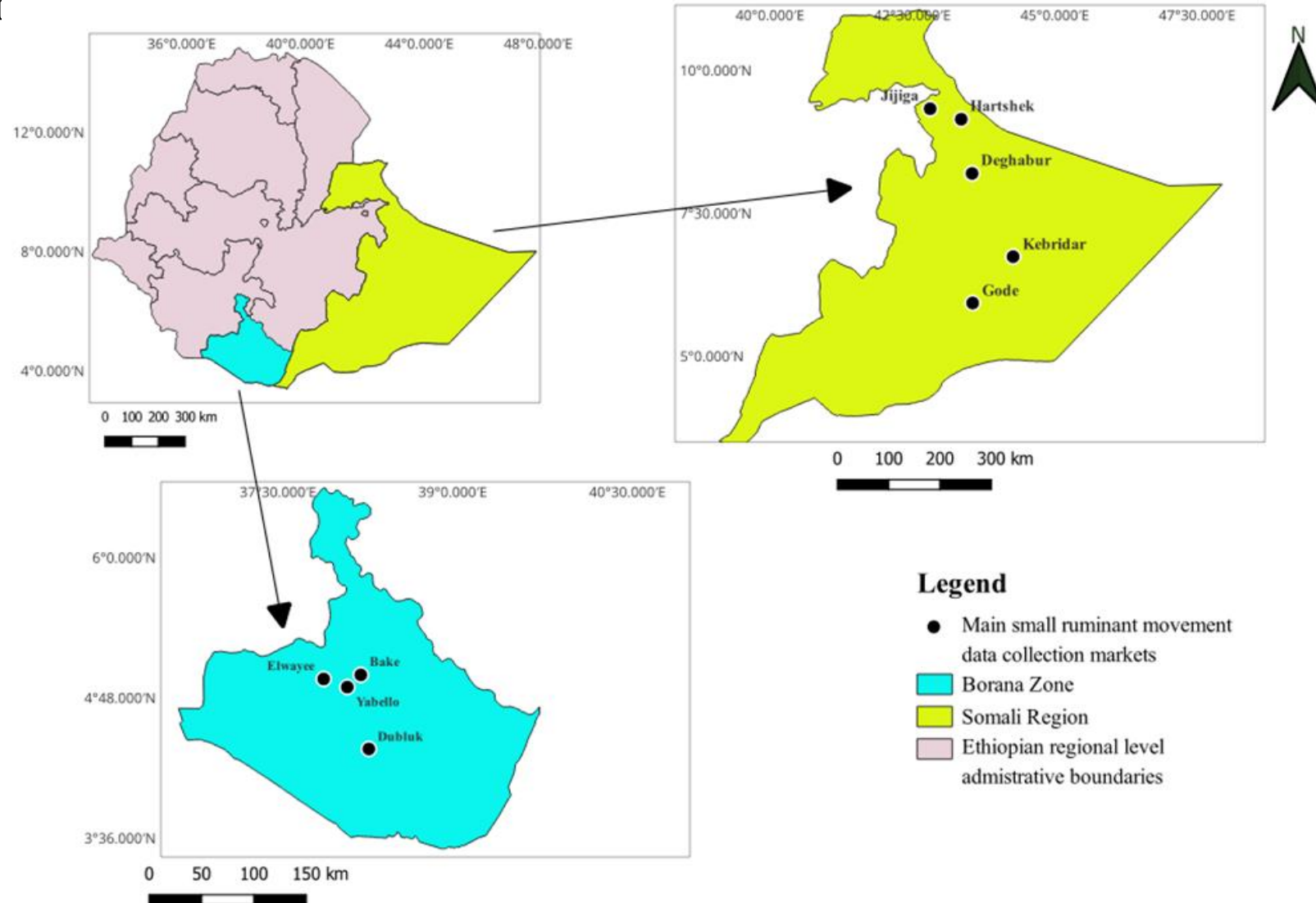


Figure 1: Map showing study area

STUDY APPROACH

- The study adopted a network-based approach, rooted in Social Network Analysis
- Identifying livestock markets for data collection
Eight markets were selected
 - Borena – Bake, Dubluk, Elwaye and Yabello
 - Somali –Deghabur, Gode, Jijiga and Kebridar
- Collection of small ruminant movement data
 - Recording volume of exchange, type of movement, source and destination points
- Retrospective epidemiological data of PPRV (MoA)
 - PPRV outbreaks reports and risk status in 2023
- Key Informant Interview



Figure 2: Direct observation and recording



Figure 3: Key informant interview

DATA ANALYSIS

- Movement data was organized in Excel for analysis.
- Data analysis involved
 - Constructing network maps
 - Computing centrality metrics, and network topology
 - Identifying market clusters
 - Correlation test statistic between nodes centrality measures
 - Percolation analysis to evaluate network resilience
 - Comparing scale of trade activities in different risk category of markets

All network visualization and analysis were performed in R (igraph, circlize, ggplot2, mapMCDA), while map visualization was done using QGIS (v3.30.2).

RESULTS

A total of 365,261 small ruminants were traded through 64 identified markets and 20 other destinations between January and December 2023

Table 1. Summary of animals' head count by destination points and means of transportation

Survey areas	Transport	Destination Points			
		Markets	Slaughter houses	Cross-border	Total
Borena	Vehicle	9,572	20,081	7226	36,879
	Foot	35,097	-	-	35,097
Somali	Vehicle	71,671	-	105,912	177,583
	Foot	82,006	10,146	23,550	115,702
Total		198,346	30,227	136,688	365,261

The peak period of trade exchange was from **July to September**

- Representing nearly 42% of total year trade exchange and 46 % of cross-border movement

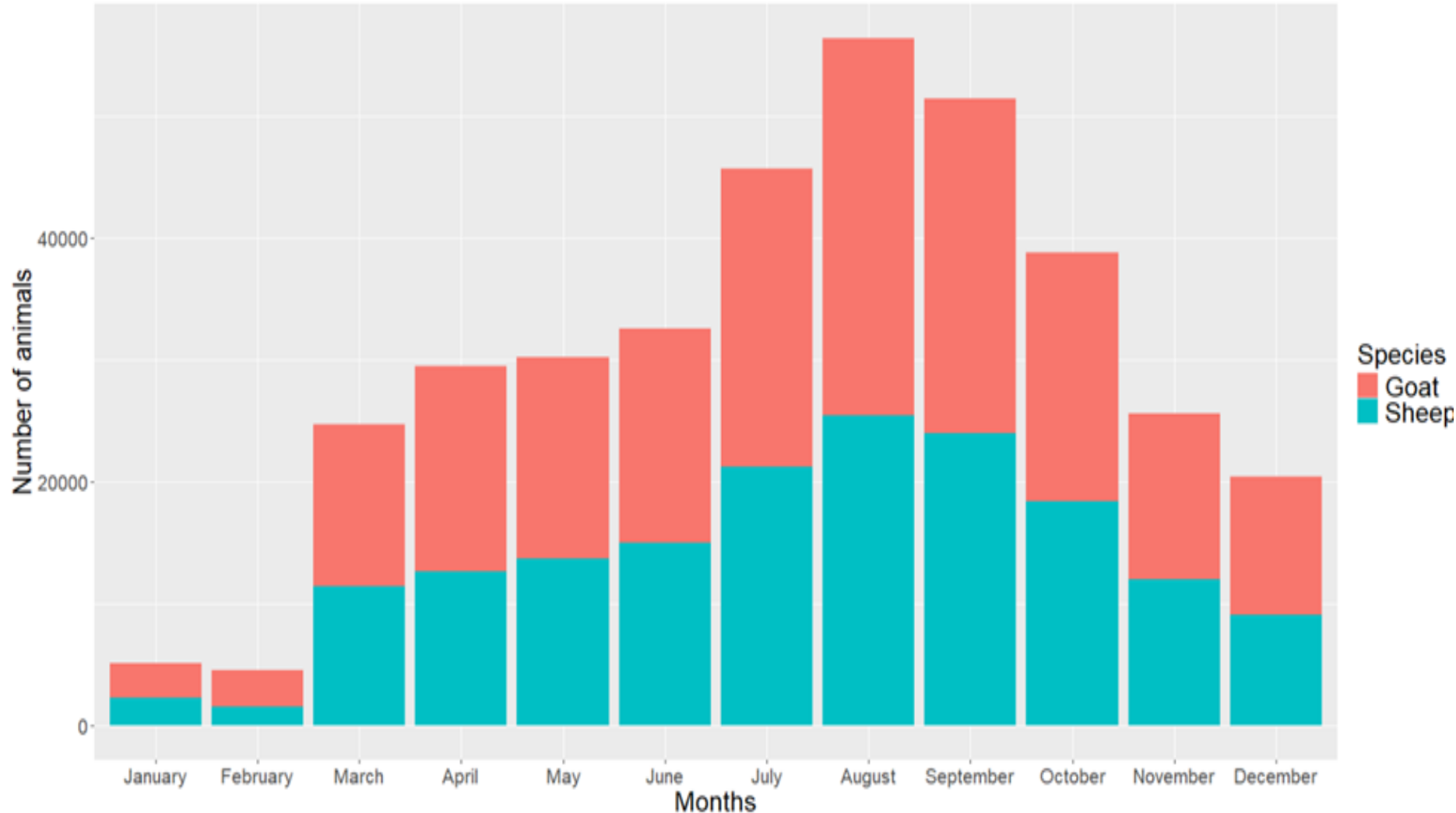


Figure 4: Volume of small ruminants' trade by month

- Each market was connected to an average of 4.1 other markets with 1.96 incoming and 2.2 outgoing links
- Degree distribution was right-skewed

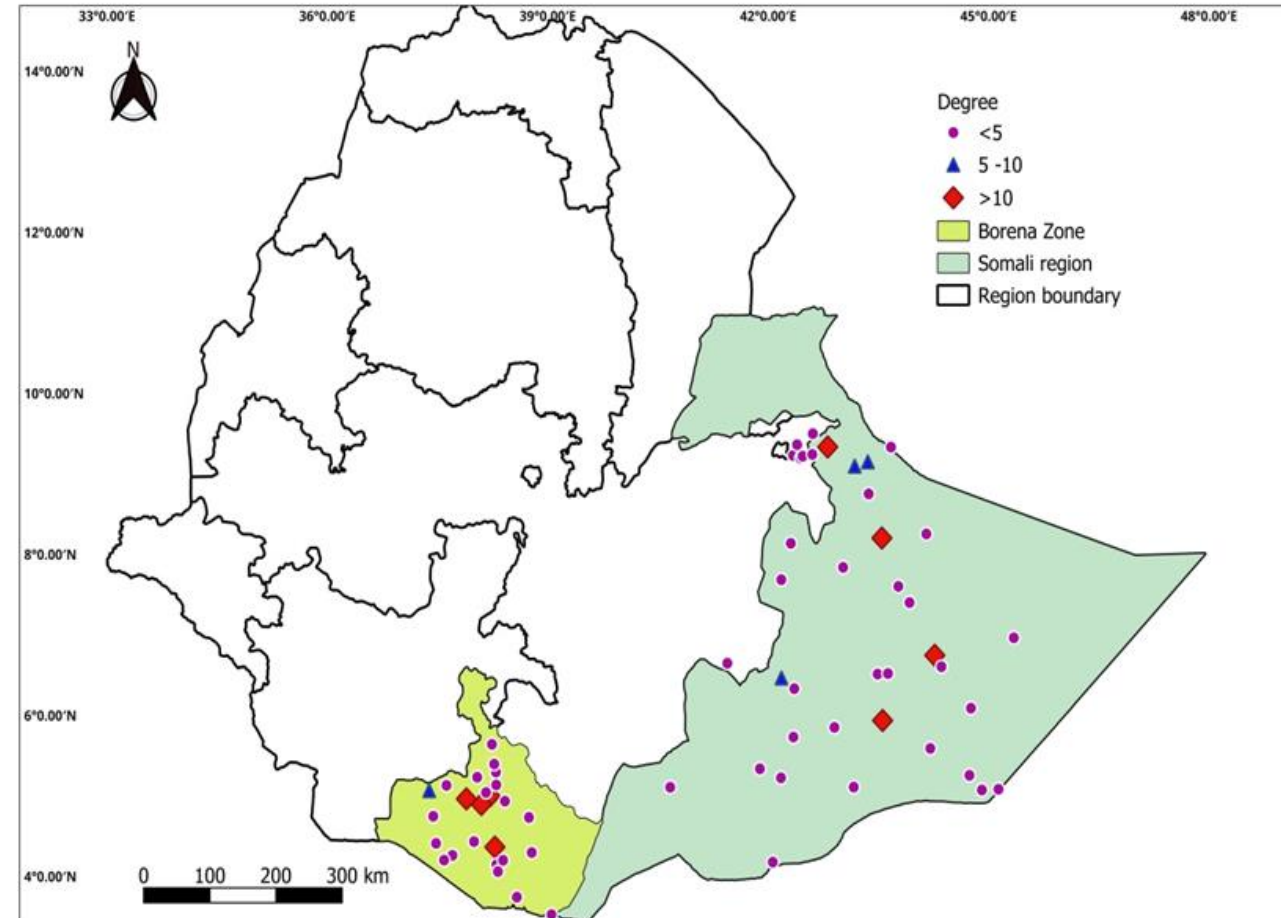
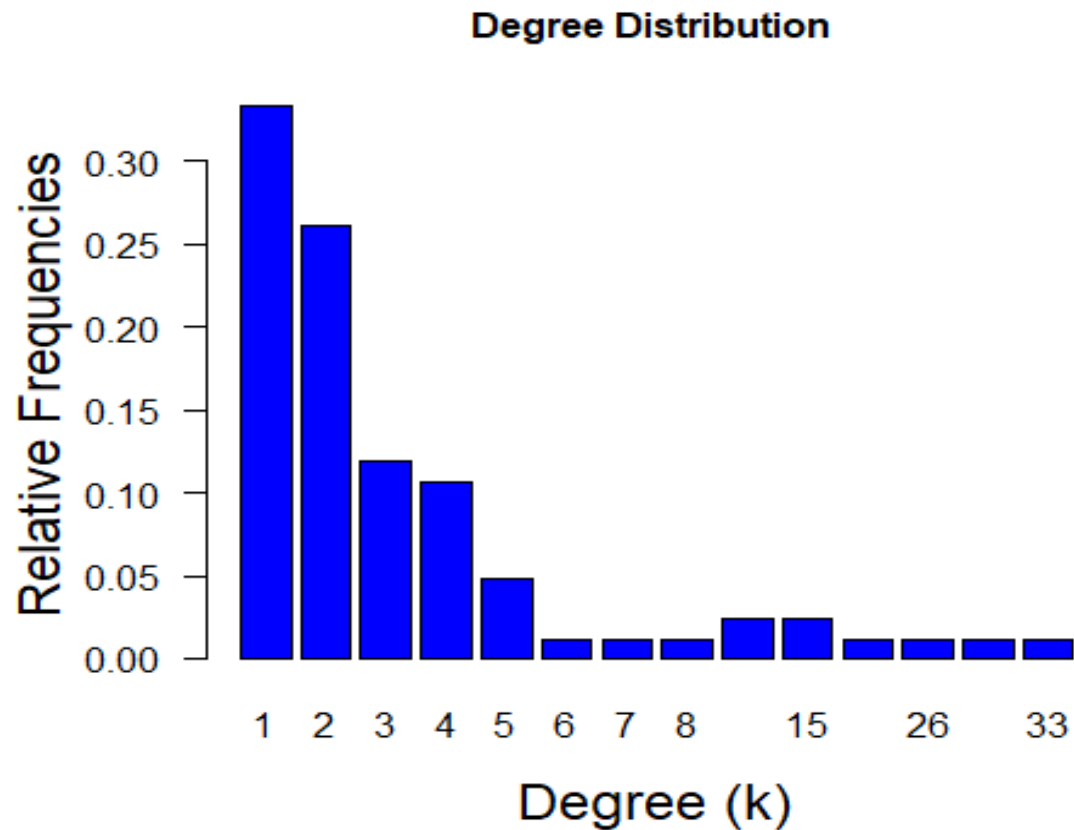


Figure5: Degree distribution of markets

- Out of 171 small ruminant trading routes (links) recorded during entire study period
 - 12 were persistently remained for 10- 12 months (as back bones)
 - 47 links were active for 6 - 9 months (frequent)
 - 42 links remained in network for 3 - 5 months (intermediate)
 - 69 trade routes were only active for two month or less (occasional)

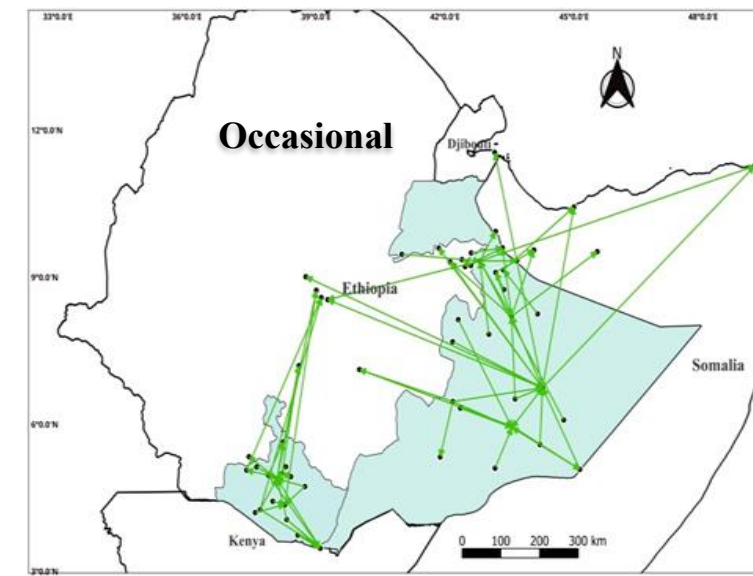
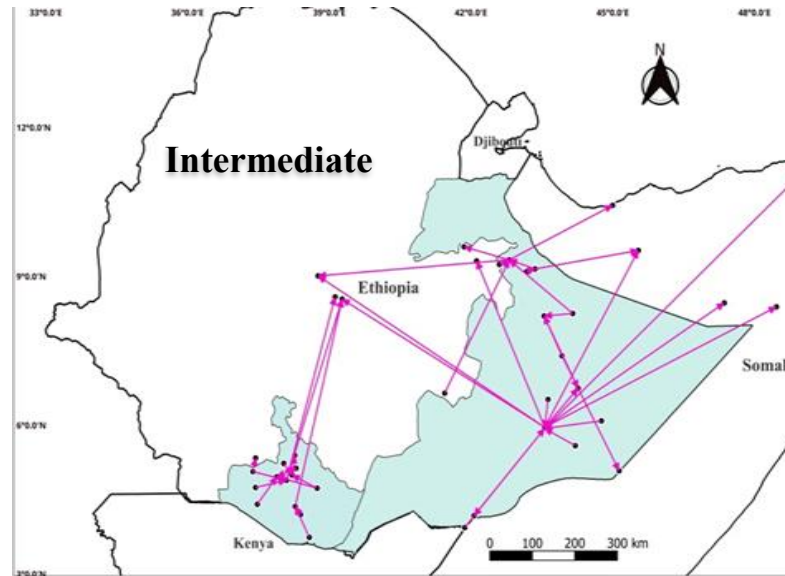
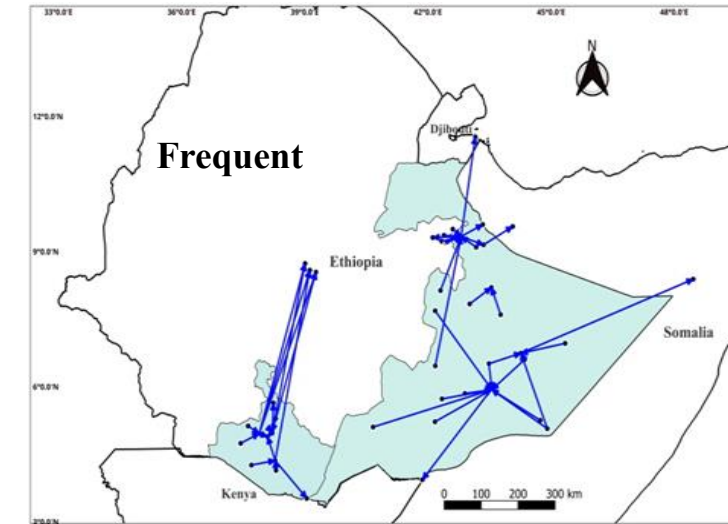
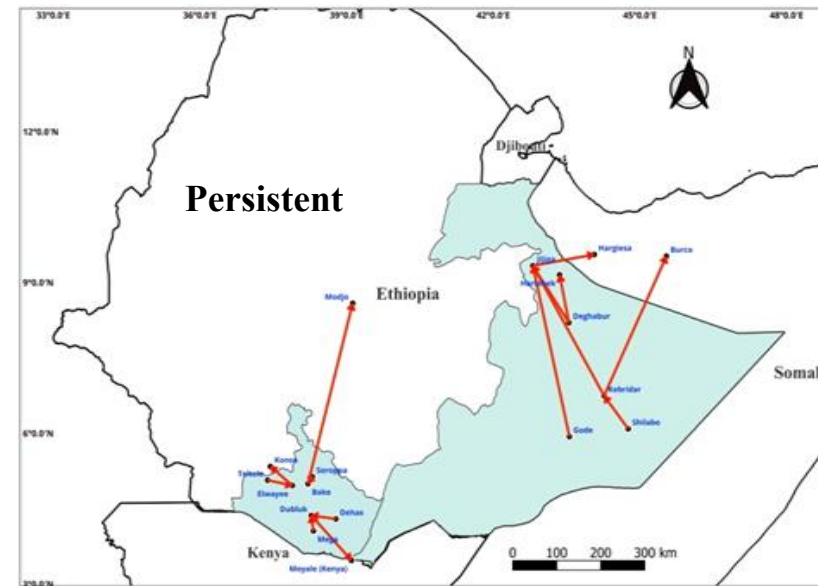


Figure6: small ruminant trade network links by frequency of activities over the year

GENERAL DESCRIPTION OF NETWORK TOPOLOGY

Table 3 Summary table of graph (network) level small ruminant trade network metrics

Network level metrics	Borena	Somali	Full network
Density	0.0667	0.037	0.0242
Diameter	3	5	5
Average path length	1.846	2.31	2.31
Clustering Coefficient	0.61	0.808	0.729
Degree of assortativity	-0.549	-0.649	-0.517
Reciprocity (%)	6.25%	12.3%	10.4%

- While average PL and CC of 1000 simulated random networks was 3.22 and 0.047 respectively
 - Indicates, the network characteristic was consistent with small-world network topology (Wang *et al.*, 2012)

NETWORK COHESIVENESS AND CORE-PERIPHERY STRUCTURE

- The whole small ruminant trade network was structured around eight core markets and 76 periphery markets each connected to different cores

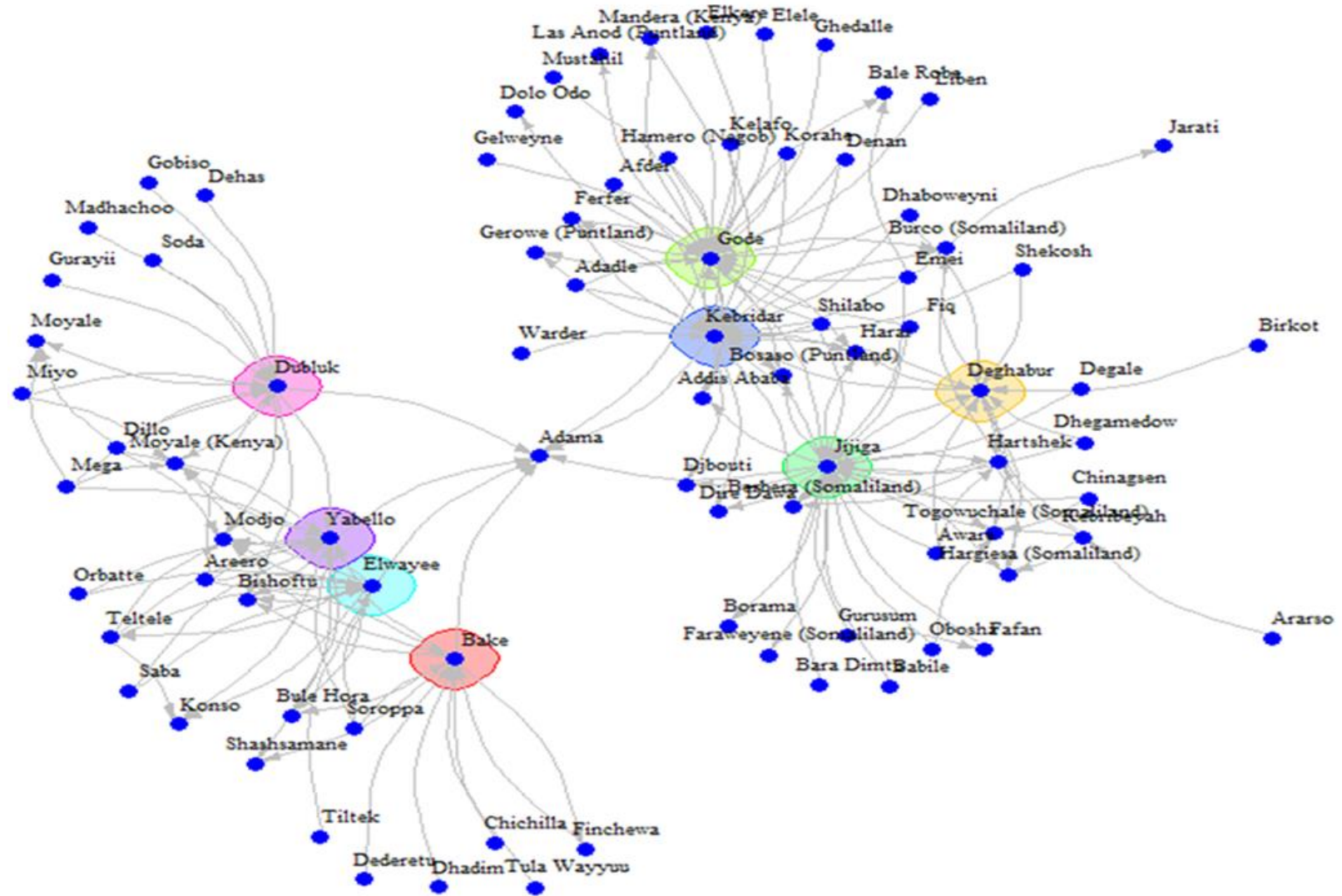


Figure7: Core –Periphery structure of small ruminant trade network

- All markets in the network were included in GWCC and the network comprises 76 GSCC with varying sizes
- The largest GSCC included 7 markets while others consist of 1 or 2 markets

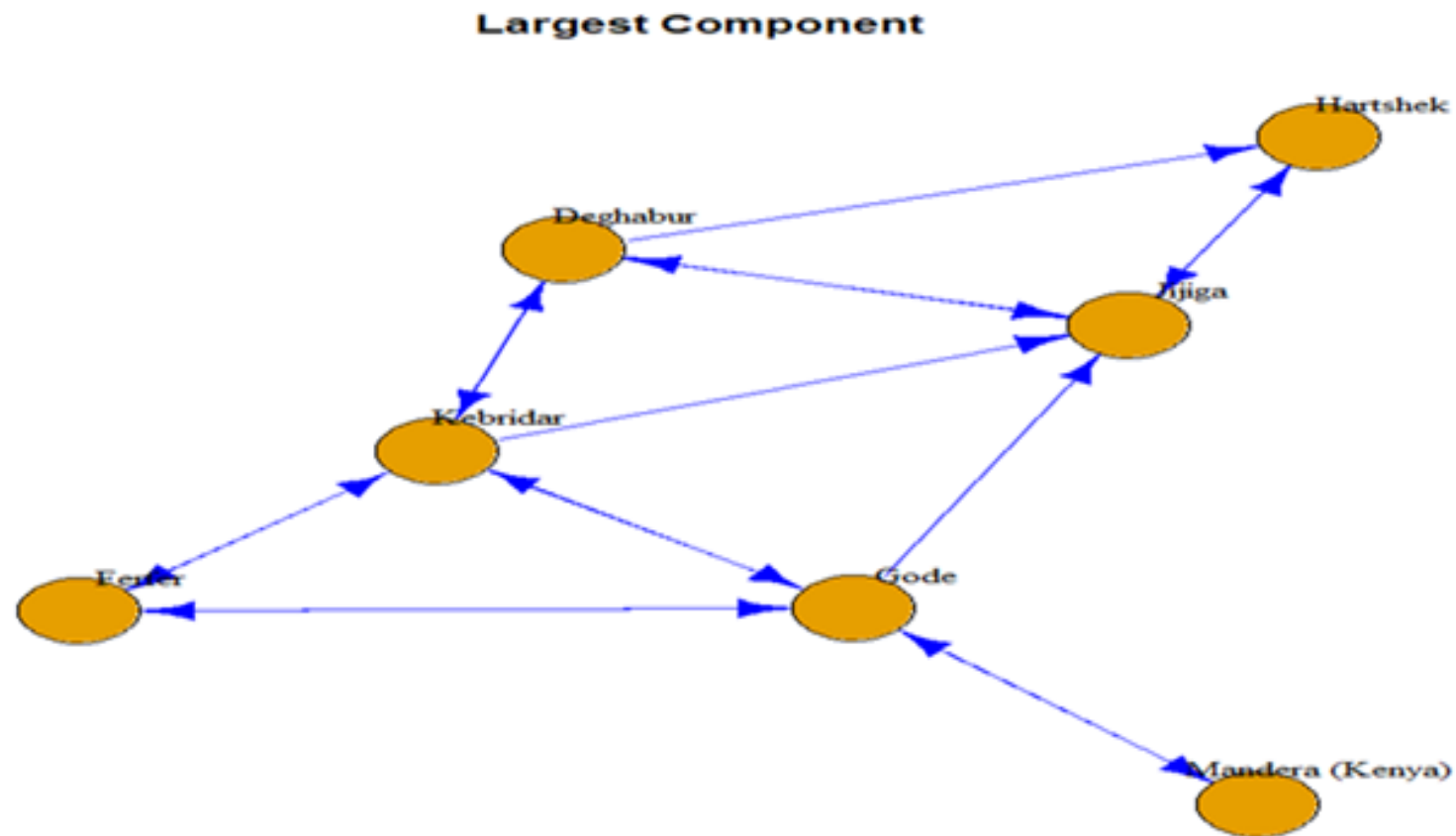


Figure8: Largest GSCC

- Community detection based on **Infomap community** detection algorithm identified 8 distinct clusters of markets with strong internal connections

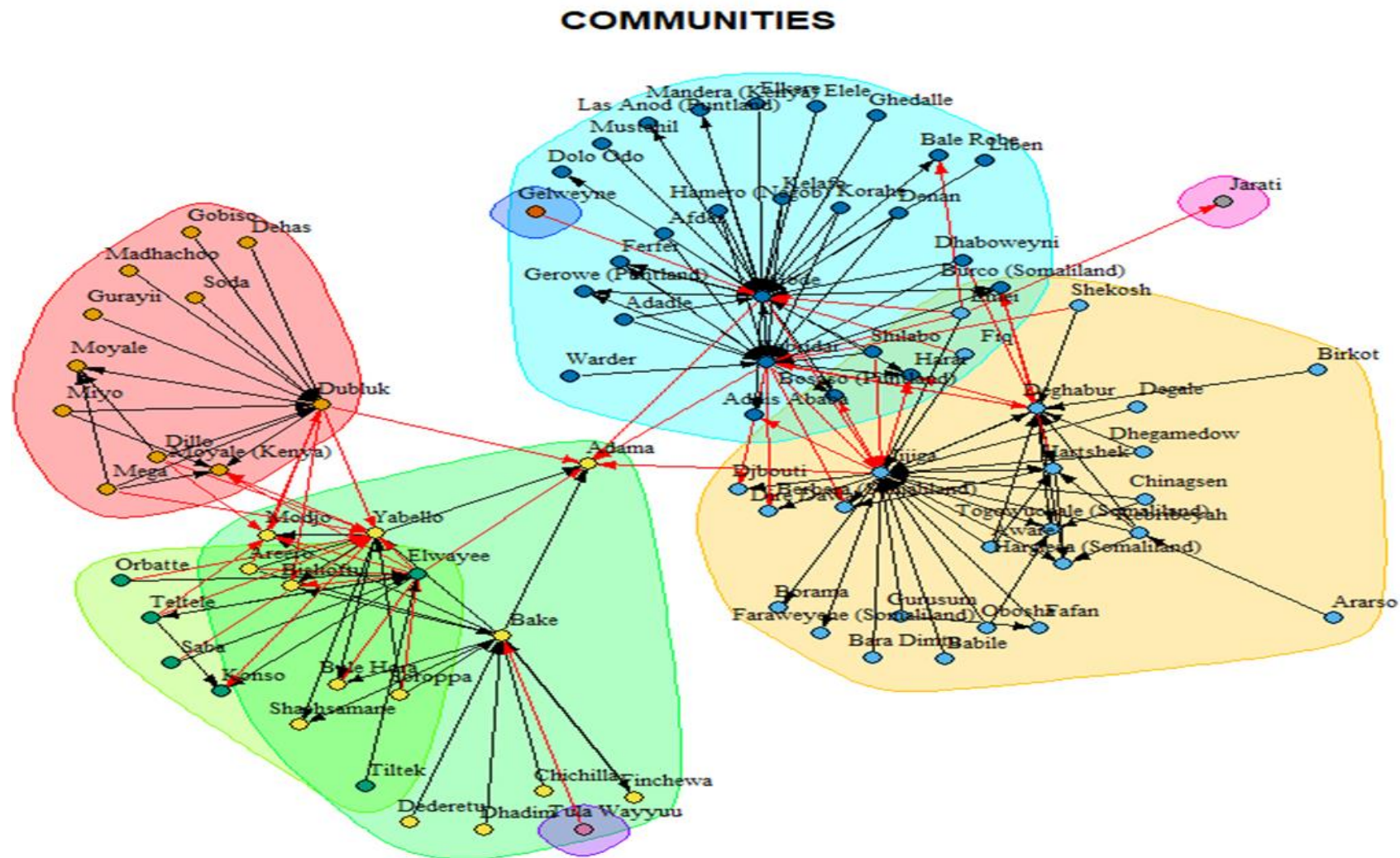


Figure9: Community structure

KEY ACTORS' ANALYSIS

- Ten Markets were detected as critical in the structural functionality of the small ruminant trade network

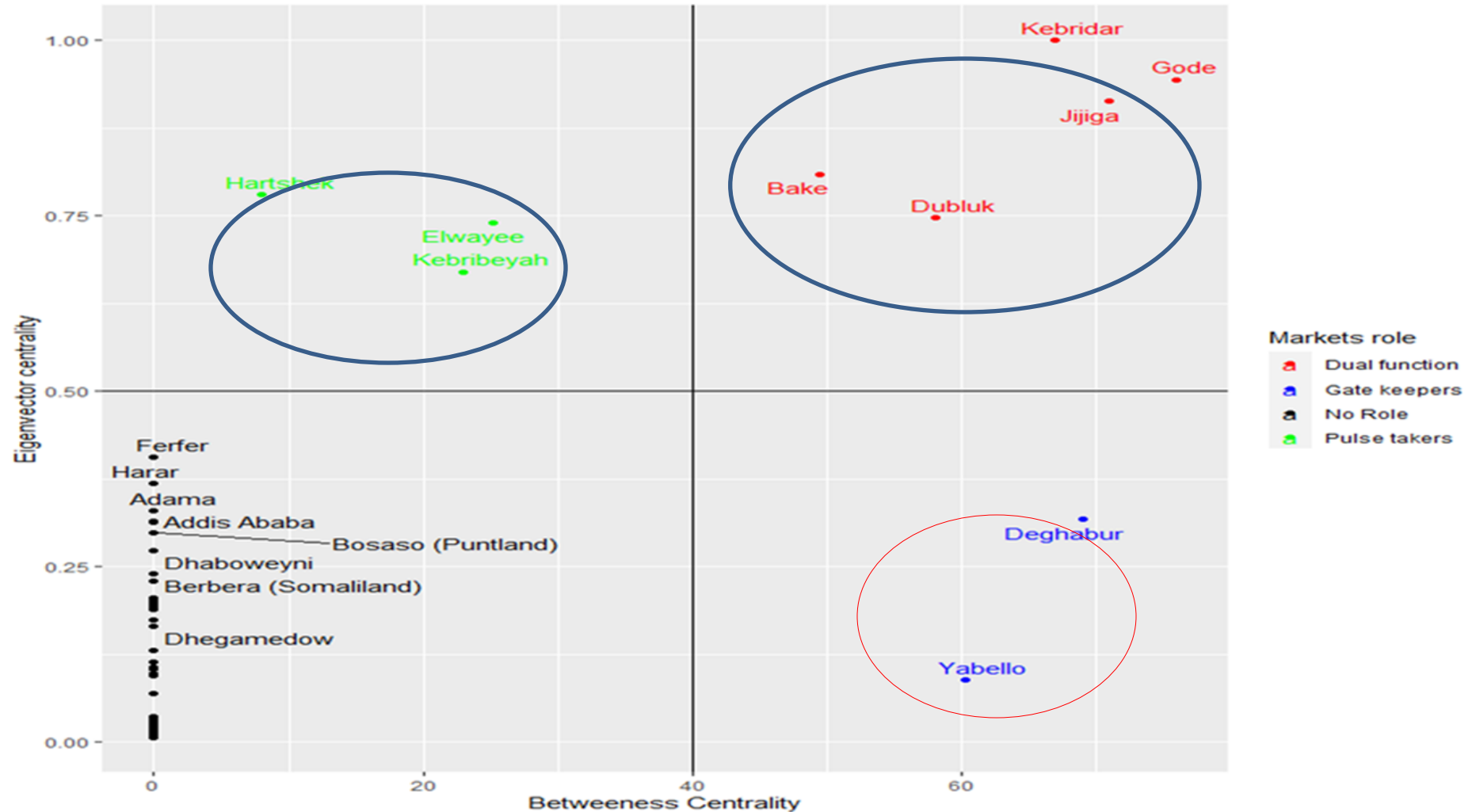


Figure10: Key actors' analysis

RISK OF DISEASE DIFFUSION OVER THE COURSE OF THE YEAR

- Analysis of threshold parameter (q) suggested that the whole small ruminant network was prone to the risk of disease spread with average $q = 0.392$ and $R_0 = 2.75$

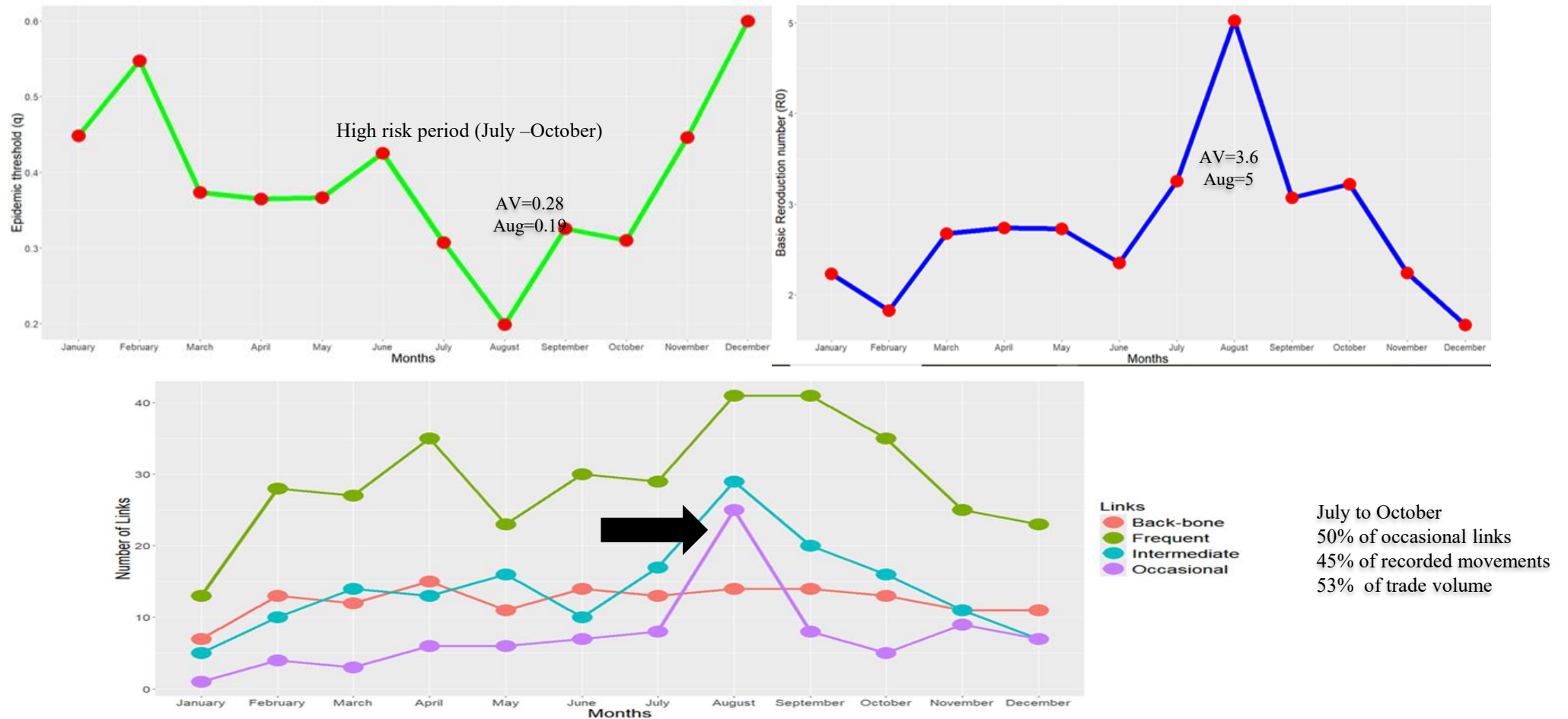


Figure11: Monthly variations of epidemic threshold and network structure

NETWORK VULNERABILITY AND RESILIENCE

- Targeted removal of markets based on score of in-degree, out-degree, and betweenness centrality showed remarkably faster reduction in GSCC

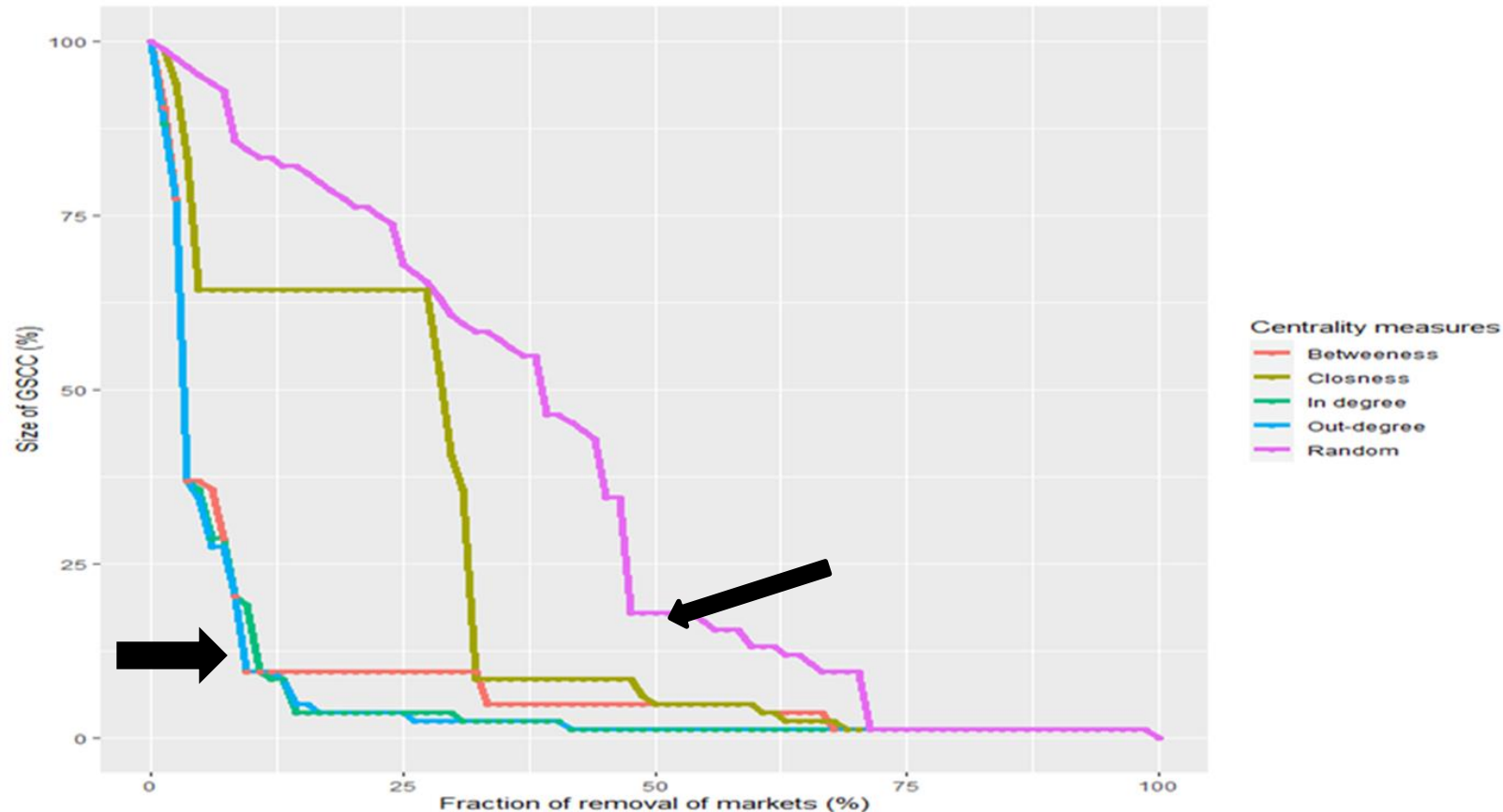


Figure 12 Node centrality measures-based percolation

OUTBREAKS AND RISK STATUS

- According to MoA disease surveillance of year 2023 in study areas
 - 22 PPR outbreaks were reported
 - 19 districts are endemic to PPR, 32 districts are at high risk and 12 districts are relatively risk free

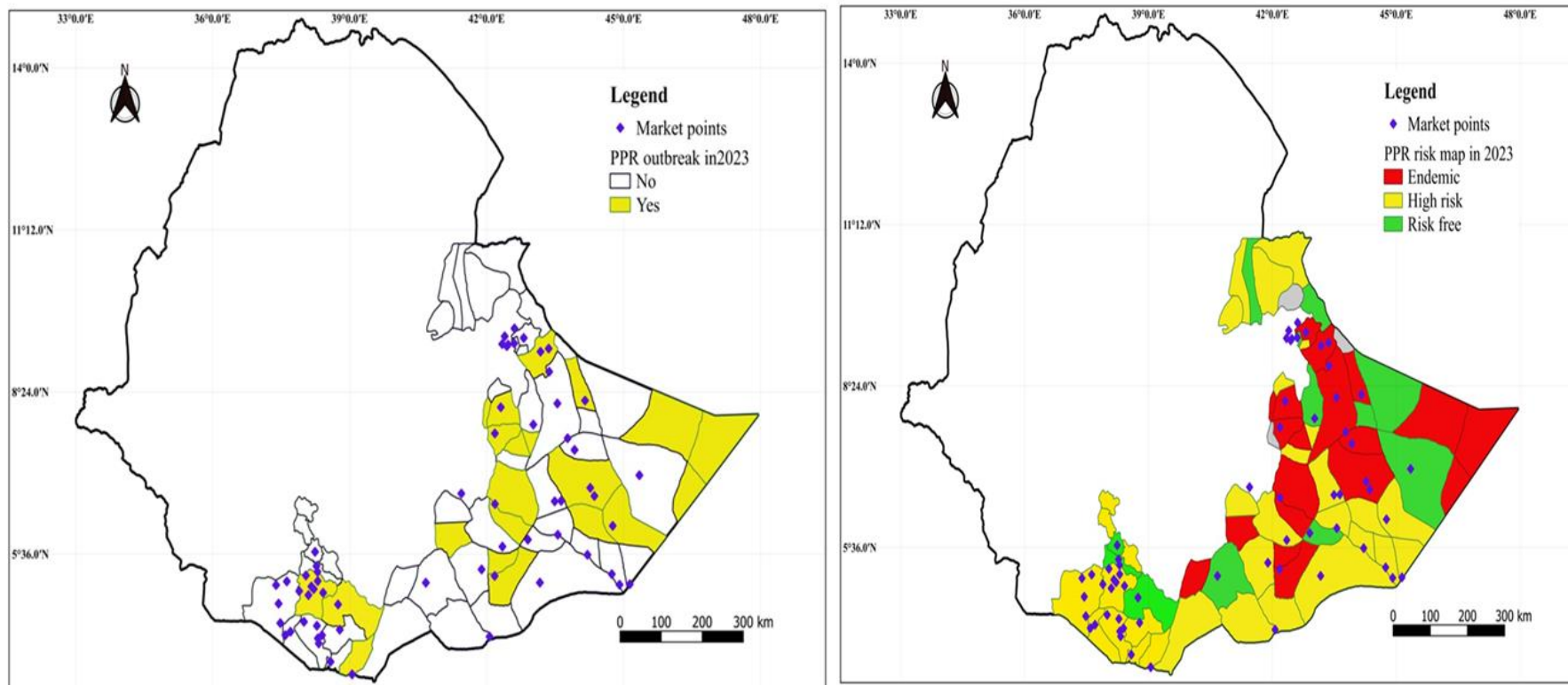


Figure 13: PPR outbreak distribution and Risk map in 2023

- PPR endemic and high-risk areas accounted for more than 90% animals traded through trade network
- More than 92% recorded trade routes were either within or starting from PPR endemic and high-risk areas

Table 5 Kruskal-Wallis test for markets centrality metrics by PPR risk status

Market level centrality metrics	Chi squared (X^2)	p-value
Out-degree (Outgoing links)	7.8208	0.020**
Out-weight (Outgoing volume)	6.1099	0.047**
In-degree (Incoming links)	0.7961	0.671
In-weight (Incoming volume)	1.2309	0.541
Betweenness	5.1526	0.076
Closeness	3.0079	0.222
Eigenvector	13.665	0.001**

CONCLUSION

- **Trade network risk:** The small ruminant trade network in Borena and Somali regions is prone to PPRV incursion due to its short diameter, low epidemic threshold, and highly connected markets acting as super-receivers or super-spreaders.
- **Animal sources:** Over 90% of animals traded in the network originate from PPR-endemic and high-risk areas.
- **Control opportunities:** Disassortative mixing and node-level centrality metrics indicate that targeted disease control interventions, early detection, and better resource allocation are feasible.
- **Empirical focus:** The study successfully mapped and analyzed small ruminant movements through markets.
- **Epidemiological insight:** Findings enhance understanding of small ruminant movement patterns and their potential role in PPRV epidemiology in the studied regions.

RECOMMENDATIONS

- Animal trade movement should be considered as key component when planning and implementing surveillance and disease control activities
- Targeting highly connected markets for epidemiological surveillance could provide opportunities for early detection of threats, reduce cost, enhance preparedness and rapid response
- Reinforcing biosecurity and health checks during transportation could minimize the risk of disease transmission even though, these strategies may be difficult to implement on ground
- Characterizing multilayer networks including grazing-oriented, transhumance and movement of other animal species should be aim for future investigations

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Thank You

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