Cattle network analysis in Paraguay: first step for potential disease spread prevention and control

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Background

Beef exports make up a significant part of Paraguay's agriculture sector: it is the 7th largest meat exporting country in the world! The movement of cattle in Paraguay constitutes a high-risk activity for the possible spread of diseases which may have a significant impact on the country's economy.

Materials and Methods

1 Data retrieved from the database on cattle inventory of the Veterinary Services for 2014 to 2018 was used to create density maps.

2 Database from SENACSA recording cattle movements in Paraguay was used to construct the movement network including all data from 2014 to 2018.

3 The holding level (farm / market) was considered as a node and each movement of cattle between two holdings was considered as a link.

4 Network analysis was performed using the R Igraph package to generate the "static" network and calculate network parameters

Compared to randomly simulated network parameters with the same number of nodes and links

In Paraguay 2018 :
✓ ~14 millions cattle
✓ 145 025 cattle farms
✓ 54 markets
✓ 532 slaughterhouses
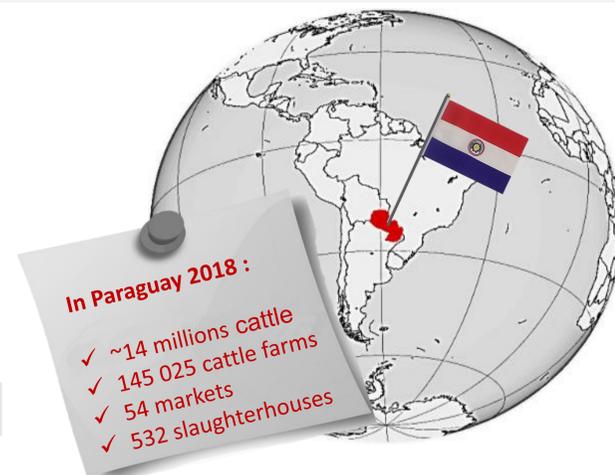
Results

A total of 1,402,410 cattle movements with 29,385,414 moved animals were recorded from 2014 to 2018.

Fig.1 Mean density of cattle farms per km^2 (a) and location of markets and slaughterhouses (b) at the district level
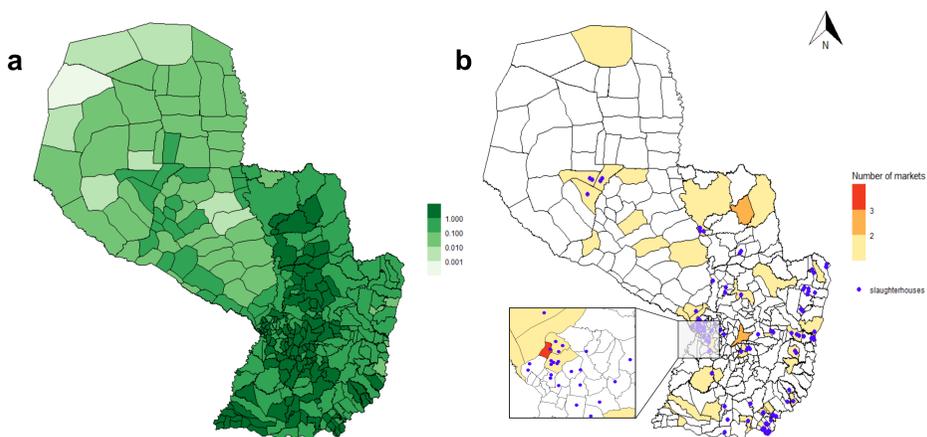
Farm density and number of markets and slaughterhouses are higher in the eastern region.

Table.1 Parameters of the cattle network

Number of nodes	72, 096
Number of links	366,626
Assortativity	-0.04
Average path length	5.5
Clustering coefficient	0.02

- **Assortativity** was negative: highly connected nodes are linked to weakly connected nodes.

- **Average path length** was three times higher than that of the random network.

- **Clustering coefficient** was 2 times higher than that of the random network.

Fig.2 Distribution of degrees and betweenness (farms *vs* markets)
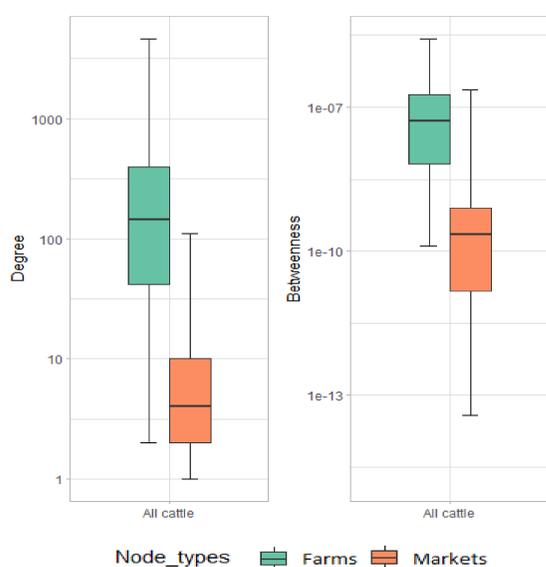
Degrees (number of links attached to a node) and **betweenness** (proportion of shortest paths passing through a node) were higher for **markets.**

Fig.3 Spatial distribution of holdings included in the largest strong component per district
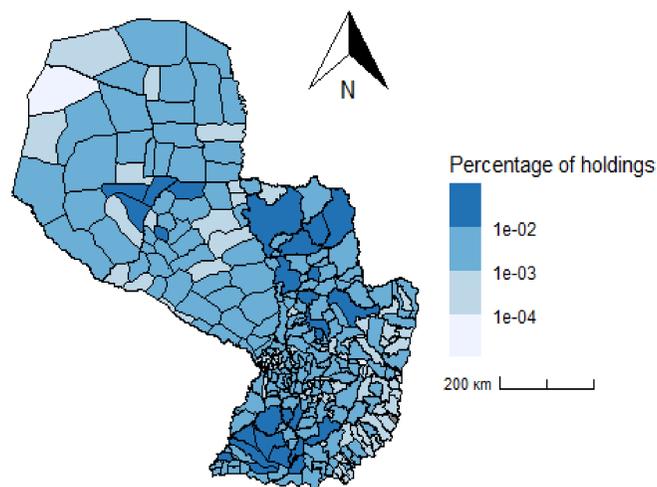
Size of the **largest strong component**: **32,149** nodes (*44% of total nodes*)

Fig.4 Distribution of degrees
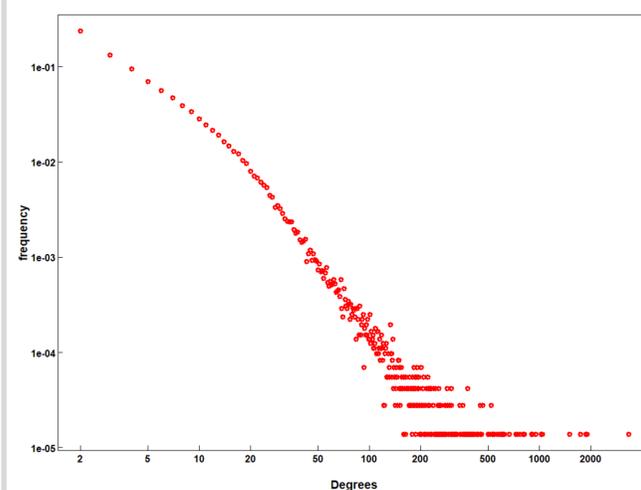
Linear trend in the distribution of degrees plotted in a logarithmic scale.

Discussion and perspectives

Linear distribution of nodes and values obtained for **assortativity, average path length and clustering coefficient** suggest that the cattle movement network in Paraguay is **scale-free:** disease spread can occur faster due to the presence of high degree nodes (**hubs**). Higher centrality parameters for markets show that markets may play an important role in a disease propagation. Holdings included in the largest strong component were located all over the country: every holding can be reached from every other holding via one or several directed paths. All these findings indicate that to prevent the spread of a bovine emerging disease, **effective surveillance and control systems should be implemented in Paraguay**.