Importance of the tradenet-structure of the meat production chain in relations to the spread of infectious diseases

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1. Introduction

In case of a disease outbreak, disease management measures like trade restrictions affect all involved parts of the pig meat production chain. *Compartmentalization* and *regionalisation* (or zoning) are concepts which may offer the opportunity to continue trading between those parts the livestock industry which are free from disease during an outbreak in a country or zone. *Regionalization/zoning* applies to an animal sub-population defined on a geographical basis and *compartmentalization* to an sub-population defined by management practices relating to biosecurity. Although laid down by the World Organization for Animal Health (OIE) in its terrestrial animal health code, no generally approved mechanism exists for countries to establish, maintain and control compartments or zones. We investigate data on the movement of animals between animal holdings in Germany to understand the tradenet-structure in the meat production chain. Network analysis tools are used for the investigation.

2. Data sources

Movement data are collected in the HI-Tier database (Herkunfts-und Informationssicherungssystem für Tiere). This database contains information about ca. 120.000 holdings:

- previous and subsequent owner
- date of animal movements
- size of charge (pig)
- type of holding (farmer, slaughterhouses, livestock dealer, livestock co-operatives)

About 5 million movement data were considered during a time period from 2006 to 2008.

3. Network description

A network (also graph) $G = (V, E)$ is a set consisting of vertices (also nodes) V and edges E. Small networks can easily be understood without a complicated mathematical description. Large and complex networks, such as trade networks, need a mathematical representation.

Adjacency matrix. The trade network is represented by an adjacency matrix $\mathbf{A}$, which determines whether two nodes (here holdings) i and j are connected with each other. A connection from i to j does not imply that there's a connection from j to i, hence our network is a directed graph (also digraph). The elements of the adjacency matrix a_{ij} are 1, if there is a connection from i to j, and 0 otherwise.

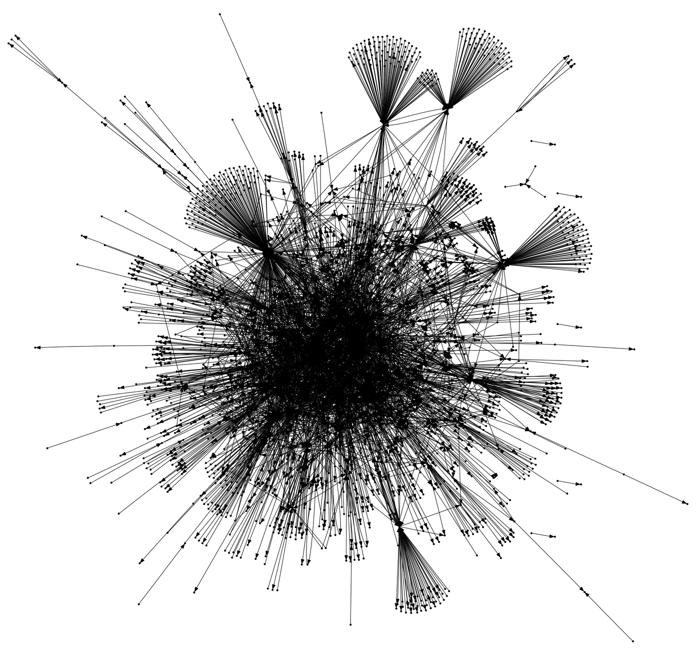

Figure 1: *Livestock trade network of a german county. The nodes represent the holdings and the edges represent the trade connections between the holdings. The position of the nodes doesn't correspond to the geographical position of the holdings.*

The relevance of single nodes can be expressed in terms of centrality measures (in- and outdegree, closeness, range, etc.).

4. Modularity clustering

The German pig trade network consists of different clusters. These clusters are defined by a high density of connections *within* the clusters and only few connections *between* the clusters. Clusters can be found using the modularity matrix (Newman, 2006)

$$B_{ij} = A_{ij} - \frac{k_i k_j}{2m}.$$

Results About 97% of the investigated farms could be allocated in ten mayor clusters.

Cluster ID	Number of farms	Percentage
0	31 273	26.00
270	23 180	19.27
74	22 795	18.95
221	16 235	13.51
103	6 885	5.73
29	4 789	3.98
292	4 674	3.89
751	3 296	2.74
499	1 473	1.22
445	1 337	1.11
Rest	4 330	3.60
Total	120 267	100.00

Table 1: *Modularity cluster identified and number of farms within the clusters. Cluster IDs are arbitrary chosen.*

The identified modularity cluster did not only form compartments, but also distinct geographical regions. Notably for the computation of the communities no geographical information is needed. The geographical information was added after the computation of the communities. All clusters, except cluster 0 and 74, are located in bounded and distinct geographical regions. These regions do not correspond to the Federal State borders. Clusters 0 and 74 show a huge geographical extent. They overlap in central and northern Germany.

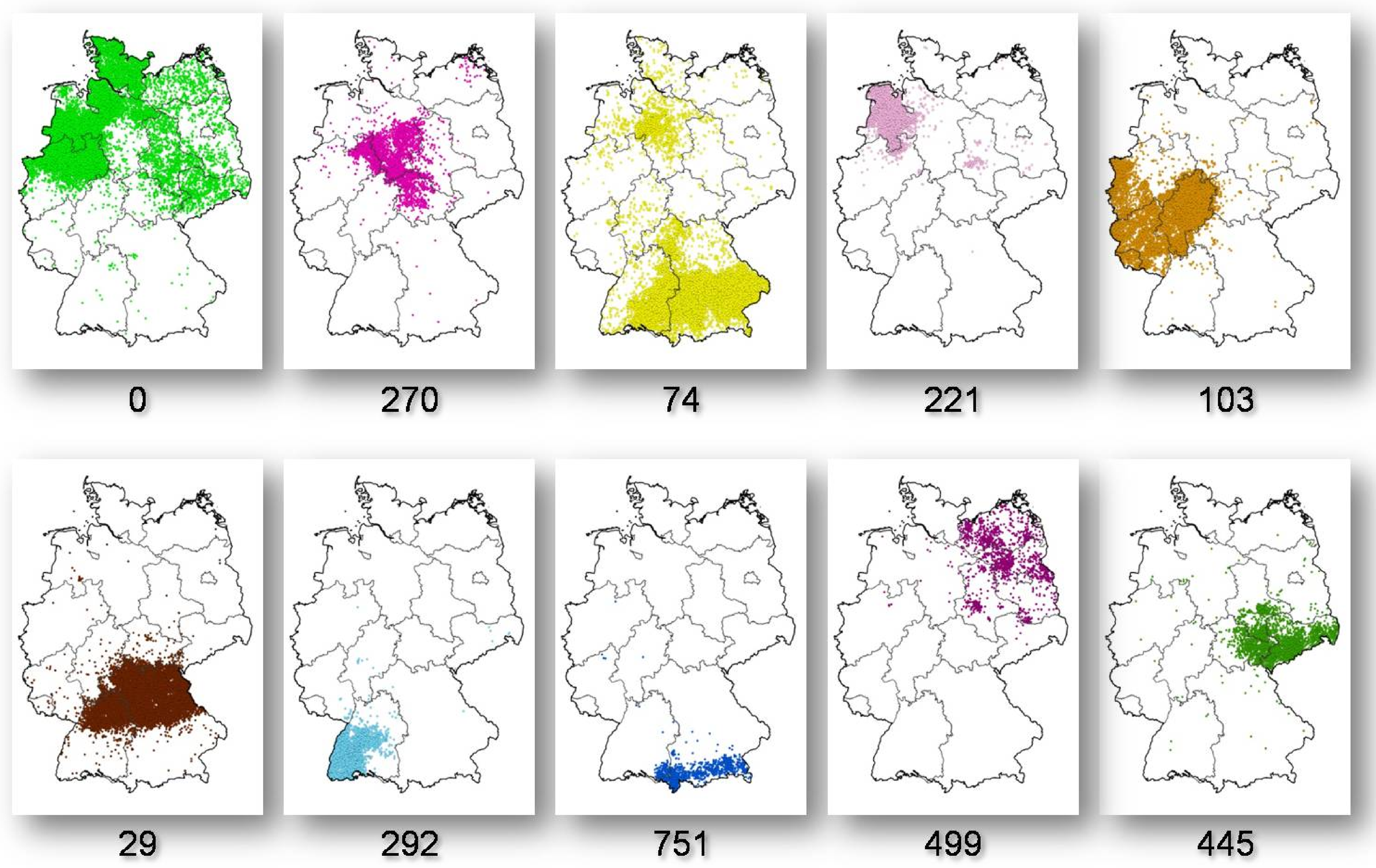

Figure 2: *Clustering of the German pig trade network. Separate illustration of the geographical distribution of the 10 biggest cluster. Cluster IDs are arbitrary chosen.*

5. Conclusion

By modularity community structure inference algorithm ten mayor trade clusters were identified within the German trade network of pig holdings and related enterprises. Interestingly, these clusters do not only form compartments but can also be attributed to specific regions within the territory of Germany. Further analysis, including the simulation of spread of infectious diseases on the trade network and analysing the characteristics of the identified compartments or zones, will reveal whether trade clusters can contain infectious diseases in a compartment or zone. The analysis may indicate relevant pathways for the exchange of an infectious disease between trade clusters which may require special attention.

6. Acknowledgment

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