Social network analysis to inform disease control on an imputed network generated from livestock movement patterns in northern Tanzania

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Introduction

- Livestock movements provide an opportunity for disease transmission
- This work is part of the 'Social, Economic and Environmental Drivers of Zoonoses' project in northern Tanzania. **Presentation** by de Glanville, Salon C-D, Monday 25 June, 10:30-12:15
- Social network analysis (SNA) is used extensively in human and veterinary epidemiology to identify contacts and transmission routes, informing targeted and efficient, disease control interventions.
- We applied this approach to an imputed Tanzanian livestock market movement network.
- Please see poster 744, Johnson *et al.* for details of the study area and data used for network generation

Methods

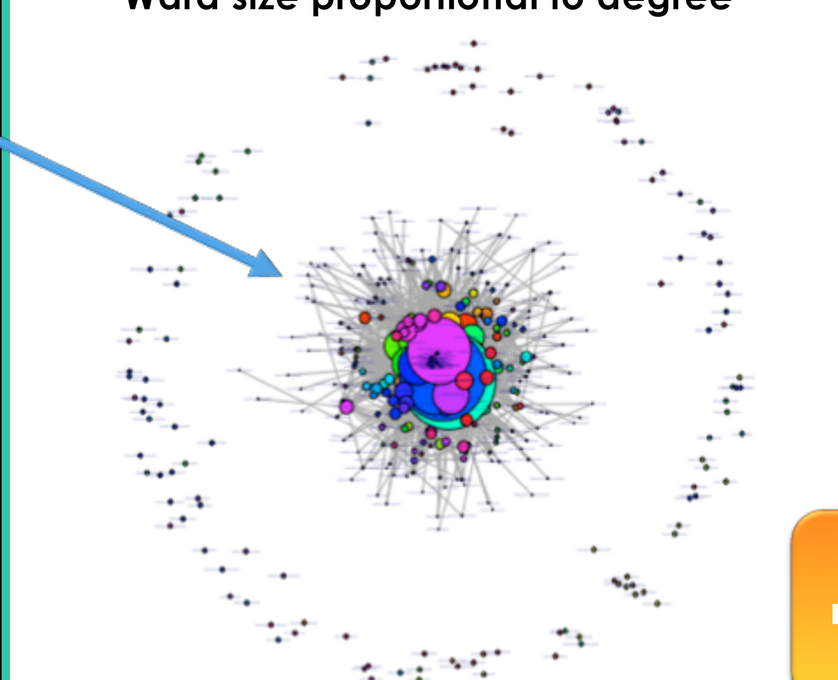
- Movements represent inter-ward movements and a ward is an administrative unit of on average 12,000 people.
- SNA was applied to monthly and aggregated year networks using 'igraph' package in R version 3.4.4
- Characterization of node and network properties.
- Identification of when and where to target interventions such as vaccination and increased surveillance to reduce livestock disease burden.
- Analysis of market movements impact on disease transmission in the study area in addition to spatial spread, with varying values of disease transmissibility

Node measures important for disease transmission;
In-degree/Out-degree = number of ingoing/outgoing contacts
Betweenness = a 'centrality measure'; the number of times a node lies on the shortest path between two other nodes

Results from 'mean Month' and 'Year' SNA

1 All wards connected by livestock movements are shown in the middle of the graph. Wards around the edge are not connected to other wards via livestock market movements. Node size on the graph is proportional to ward degree; **High degree** nodes are at **highest risk of acquiring and transmitting infection**. This is where **interventions** should be **targeted**.

Cattle aggregated year market movement network
Ward size proportional to degree



2 The **Year** NW is more connected than the month networks and more edges appear when considering the entire year (see table 1). This means interventions should be carefully targeted throughout the year. The **Year** NW edge density and clustering coefficient are also higher. Thus a more slowly transmitting disease could spread as extensively as a faster one even if the transmission rate is lower. The Year and month networks consistently show some wards have much higher centrality measures than others. These represent possible targets for interventions.

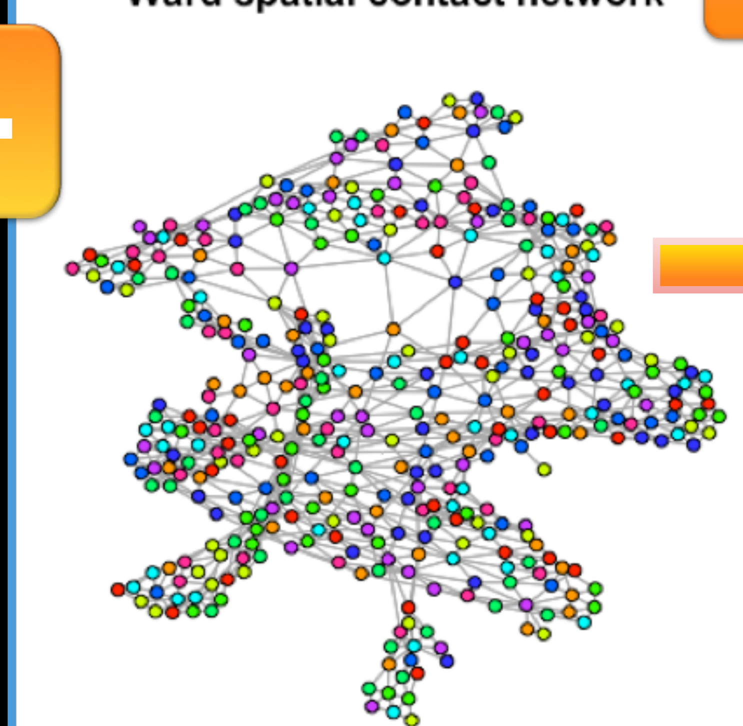
Network Measure	Month	Year	Spatial	Transmission
Giant Strongly CC	7.5	52	398	398
Giant Weakly CC	135	260	398	398
Number of edges	280	1396	2222	3525
Edge Density	0.002	0.009	0.014	0.022
Clustering Coefficient	0.10	0.20	0.39	0.23
Diameter	6.5	7	18	12

7 Table 1. Network metrics comparing the movement NW (over a month or a year), the spatial network, and the multiplex. The giant strongly and weakly connected components (GSCC/GWCC) are indicators of the possible extent of a disease outbreak. The number of edges tells us how many unique connections exist between wards, and the edge density how many there are per ward. The clustering coefficient tells us how likely two neighboring wards share a neighbor over the network. The diameter tells us the maximum number of connections required to get from any one ward in the network to any other.

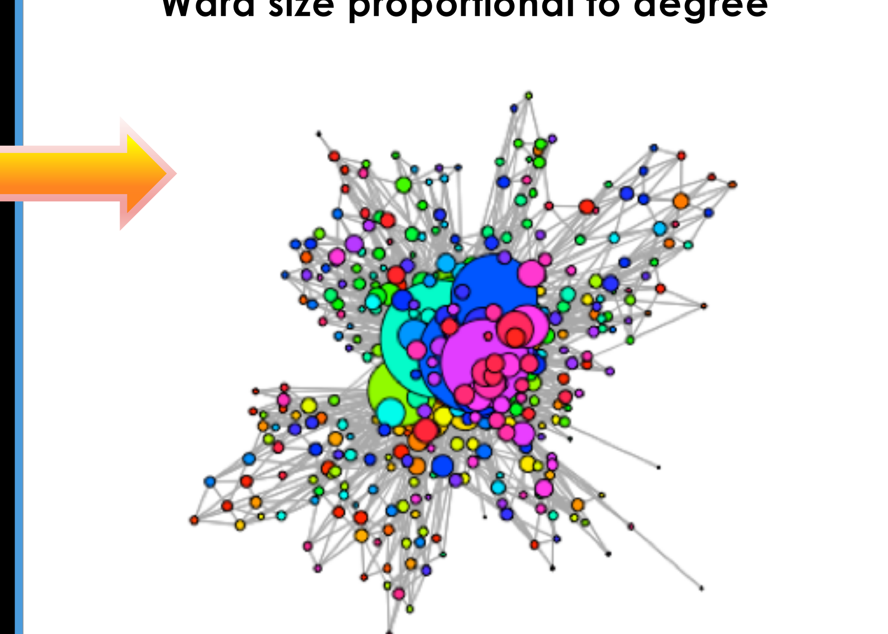
3 Adding spatial connections to the year NW to create an example multiplex NW

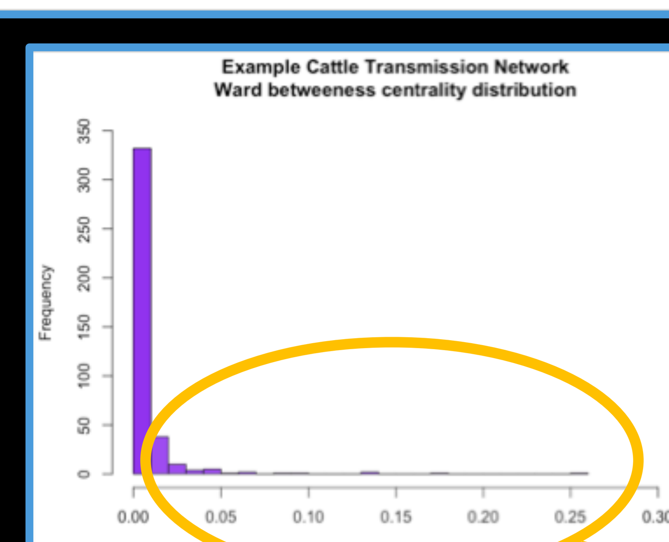
Disease can also transmit via mechanisms other than livestock market movements (e.g. mixing during movements to grazing and watering) - here we consider a scenario where transmission between neighboring wards is as likely as transmission via livestock movements.
This kind of multi-layered network is called a **multiplex**

Ward spatial contact network



4 Multiplex Network considering both livestock movements and spatial proximity of wards
Ward size proportional to degree





5 Comparing the spatial and movement networks, for all wards connected in one year, 92% of wards are more closely connected via market movements, and could allow disease to spread faster over the region.

6 There is a right skew of all ward centrality measures in the transmission network. Here we show betweenness centrality, which could be used to target interventions.

Conclusions

In our multiplex, a disease outbreak starting from one ward has the potential to reach any other ward in the system, greatly reducing the number of transmission events required to do so compared to the spatial network alone, and potentially causing bigger, and more rapidly spreading outbreaks than the movement NW alone.

Varying the probability of transmission on the spatial and market movement networks will allow identification of when and where to focus interventions to control different diseases.
This analysis will help to identify whether market movements play a role in transmission of specific diseases in this study area or whether control interventions should be focused on other types of movement such as spatial mixing at grazing and watering points and purchasing or gifting of livestock into households.