Temporal information plays an important role in the shape of the cattle movement network in Great Britain

or

You can't get a cow in a TARDIS

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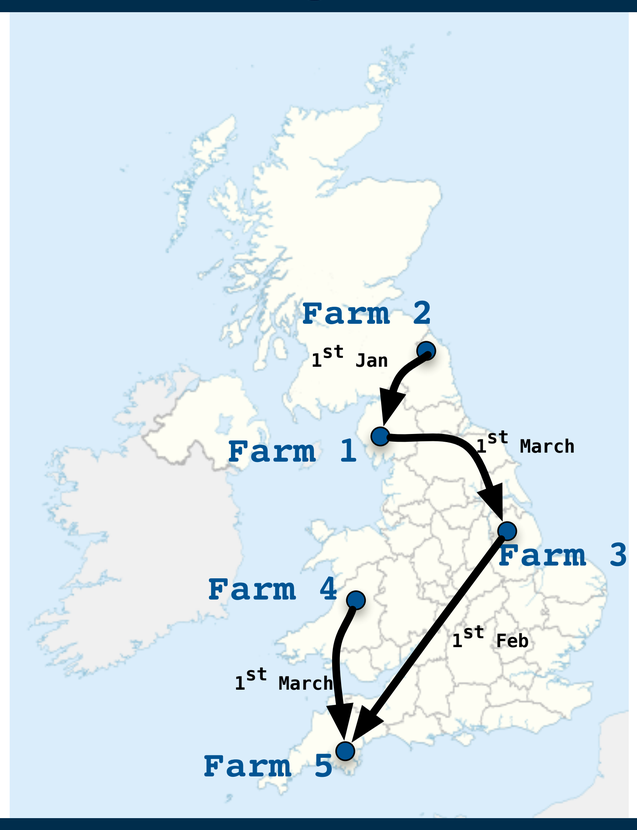
The Cattle Tracing System (CTS) dataset records cattle movements in Great Britain. The dynamic nature of this network is important for its shape. Ignoring temporal information and using only snapshots can give a deceptive view of distances between holdings in the trade network.



There are multiple measures of network distance between two holdings. Most depend on the length or number of paths between those holdings.

The network distance between two holdings serves as a proxy for disease flow by animal trade between them.

If we **ignore** the timing of movements: There is a path of three hops from Farm 2 to Farm 5

If we **consider** the timing of movements: There is **no** path from Farm 2 to Farm 5

In the first case, we might worry about Farm 2 transmitting disease to Farm 5. In the second case, it's impossible.

In a **snapshot** of a dynamic network like the CTS network, we choose a timeframe and make a static network containing all trades in that timeframe. Within the timeframe used for the snapshot, the timing and order of the trades are ignored.

Snapshots are a common way of dealing with a dynamic animal trading network and may be sufficient for identifying relevant population-level properties. Unfortunately, this has not yet been exhaustively tested, and snapshots are likely to contain temporally impossible paths - like the one from Farm 2 to Farm 5.

We want to know how big a problem temporally impossible paths are in snapshots of the CTS network.

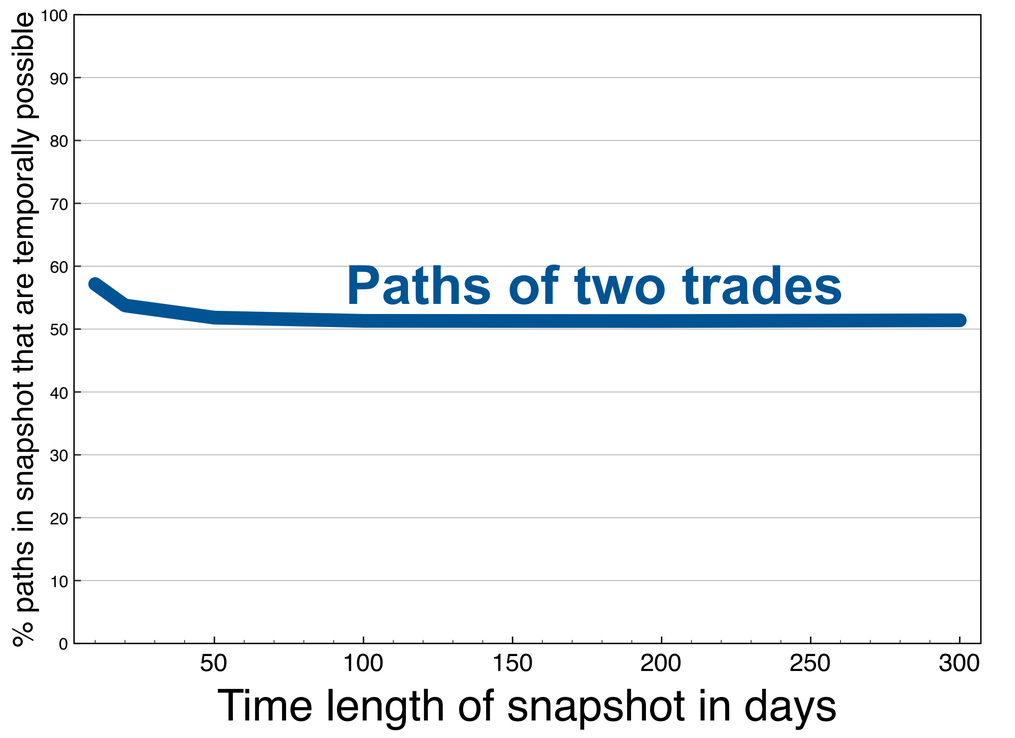
Q: What fraction of paths in a snapshot of the CTS network are temporally impossible?

A: It depends on the length of the path and the size of the timeframe.

Only about half of the paths of two trades are temporally possible for timeframes over a week. A substantially smaller fraction are temporally possible for longer paths.

The fraction of paths that are temporally possible decreases slightly as longer timeframes are used for the snapshot (see right).

Distance in a snapshot therefore may **not** be a good proxy for disease flow by animal trade between two farms.

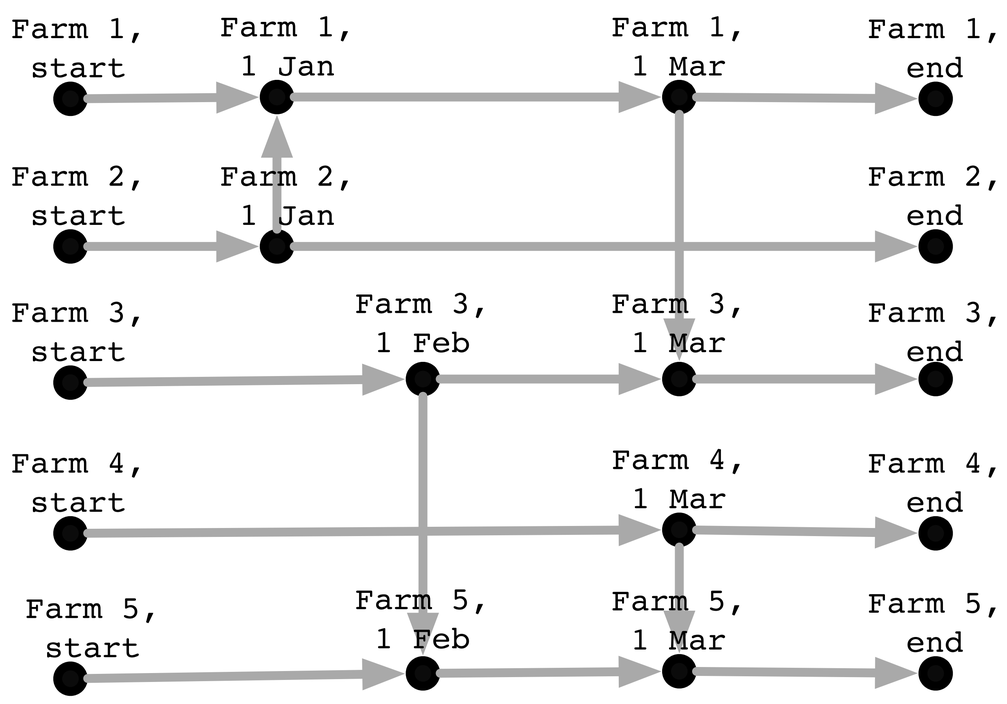


A proposed solution:

We propose an adaptation of a network that results in a static network such that paths and flow in the adapted network are closely correlated to temporally possible distances in the original network.

We create a node for each date on which a farm traded and for the start and end dates of the timeframe we're interested in. Then we add links to reflect the trades on the dates they took place and links between nodes for the same farm on different dates. We call this the **time-expanded network**. Possible flows of animals in this network are the same as temporally possible flows in the original network.

We show an example of the time-expanded network of the trading network shown on the map above.



Conclusion

A snapshot of the cattle trading network in Great Britain is likely to include a large fraction of temporally impossible paths of infection between farms. We propose an adapted network that, while larger in size, only includes temporally possible paths of infection while appearing as a static network.

Considering temporal dependence will enhance our understanding of the true risk of transmission across the cattle trading network, and help to better identify critical points of control for disease spread.

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