DETECTING LIVESTOCK PRODUCTION ZONES

CARACTERIZACIÓN DE CIRCUITOS PECUARIOS

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Context

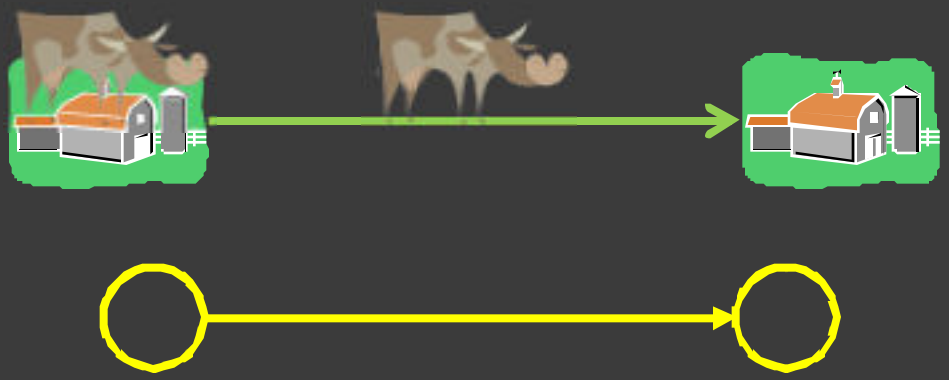
- Guía Técnica de Trabajo – 5ª Reunión Extraordinaria de la Cosalfa:
- Characterization of productive systems
  - "To update the bovine productive systems based on farm premises, population, [....], ***movement patterns*** [...]"
  - "To use the characterization to identify geographic zones [...] that allow subpopulation ***segregation with minimum impact*** on the national productive system"
  - "To perform a detailed characterization of the chosen zones based on ***geolocation and animal movements***"
  - "Animal movement information can be processed by ***network analysis tools*** ..."

Networks in veterinary epidemiology

- How to use network analysis tools in animal movement problems?

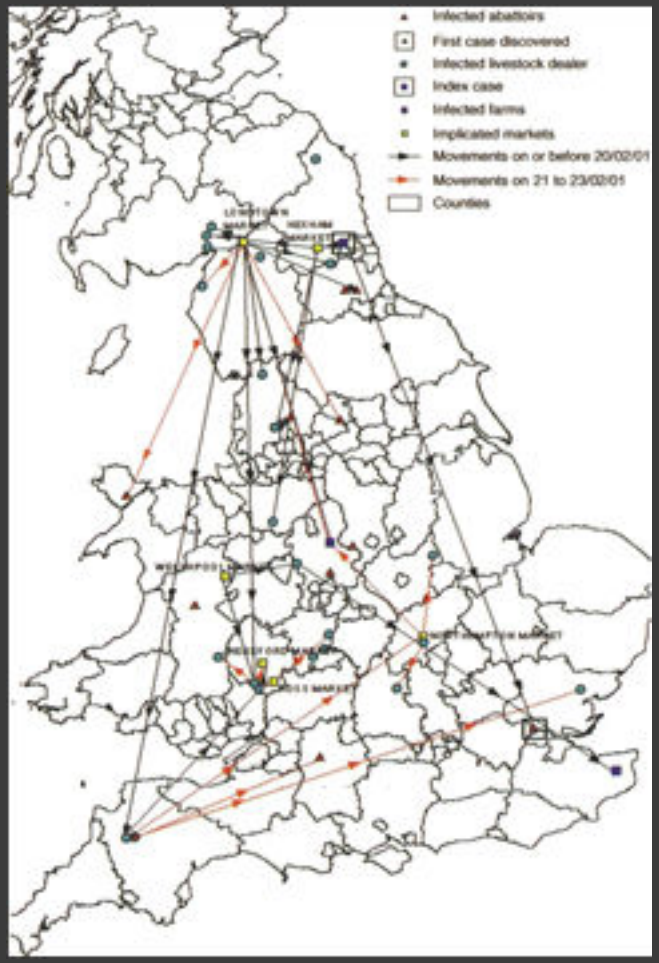
Networks in veterinary epidemiology

Accounts for movement direction and heterogeneity



- Nodes (Circles) = farm premises, counties, states, countries, etc
- Links (Arrow) = animal movement

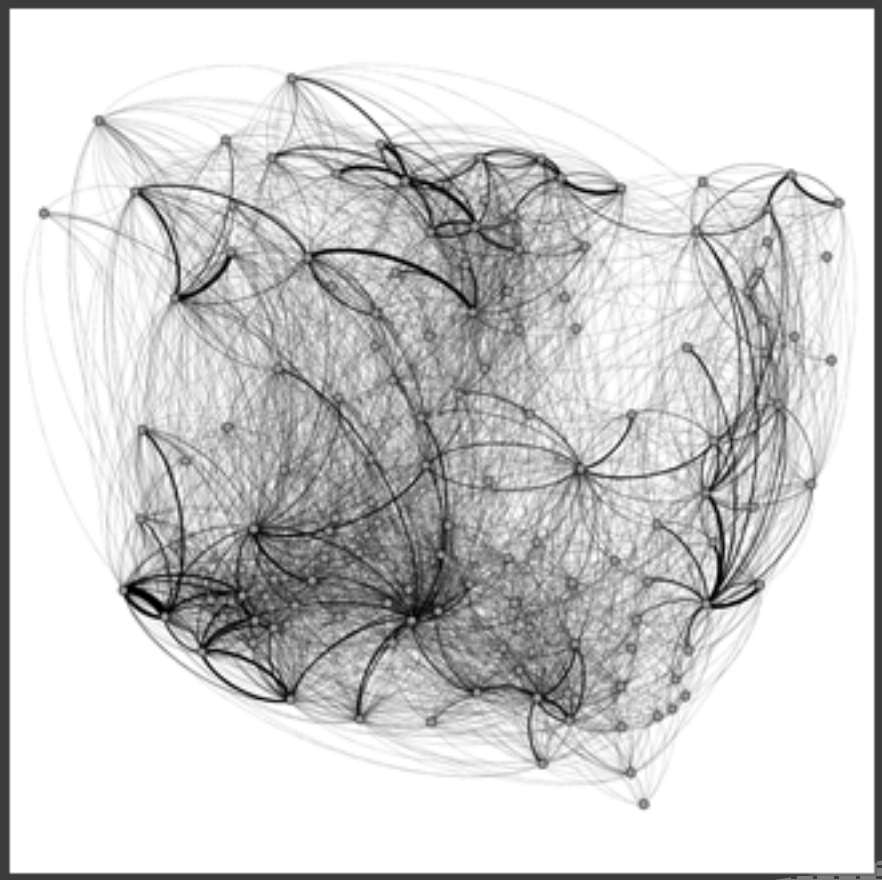
An example



Gibbens et al. Descriptive epidemiology of the 2001 foot-and-mouth disease epidemic in Great Britain: the first five months. **The Veterinary record**, v. 149, n. 24, p. 729–43, 15 dez. 2001.

A small fraction of an animal movement network

An example

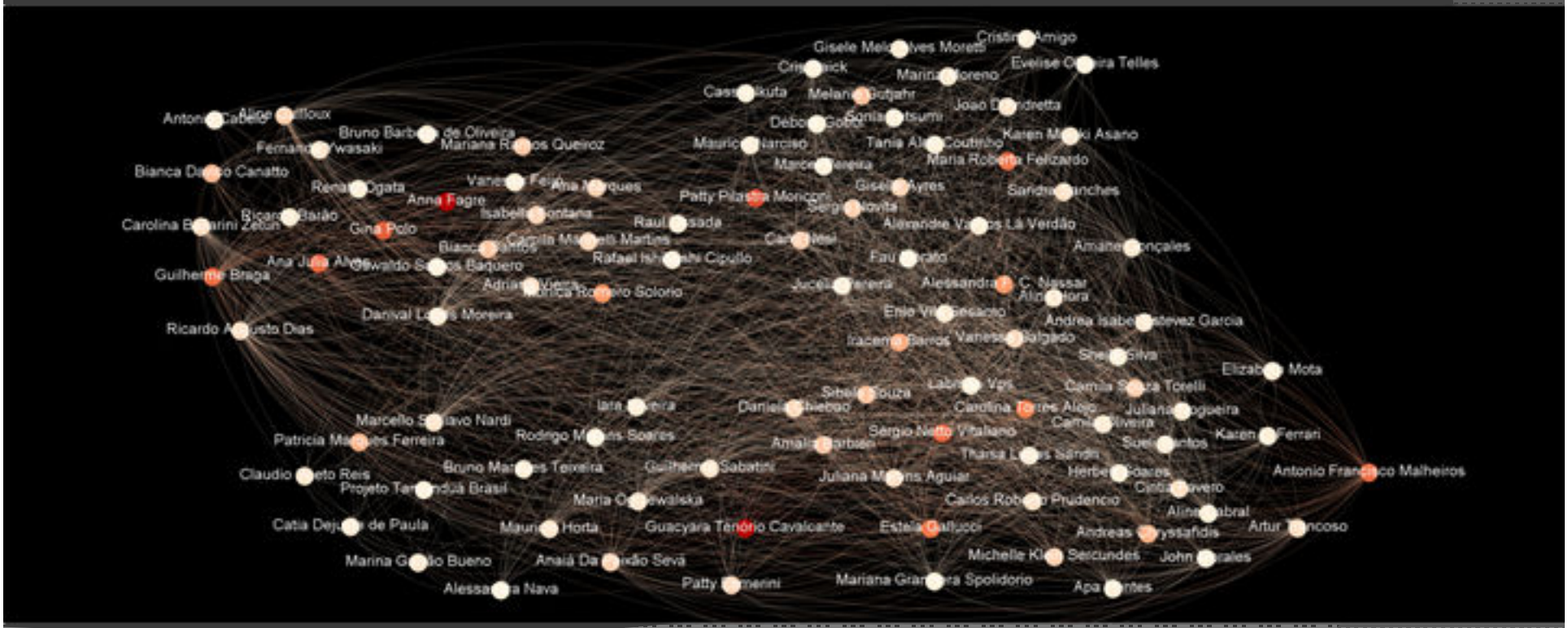


An entire network looks more like this…

Is it possible to split this network into cohesive groups?

Networks

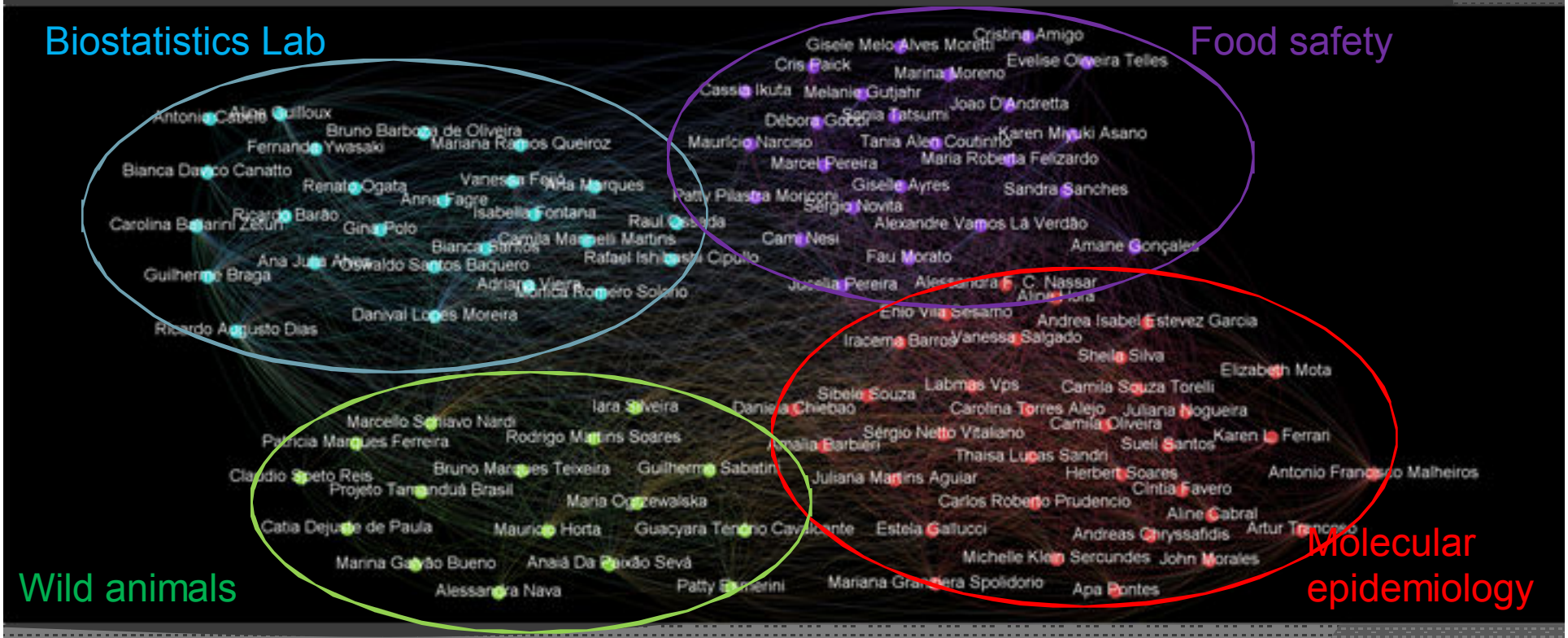
- It all began in the social sciences



My department colleagues' network

Communities

- Sets of nodes intensely connected are called “communitites”



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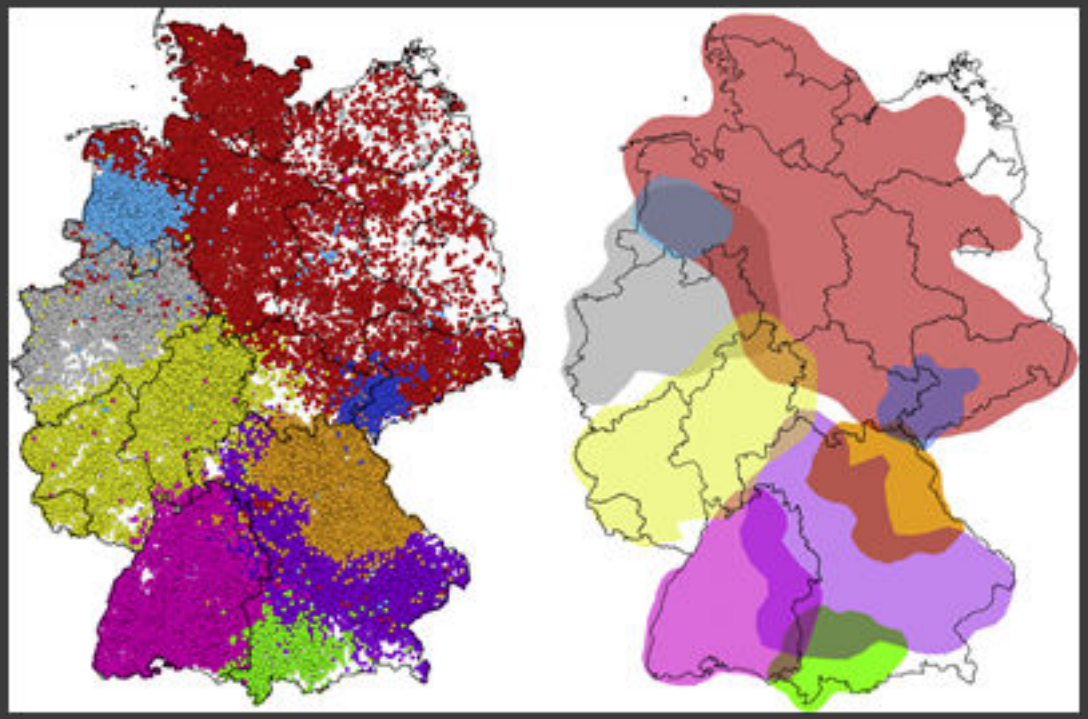
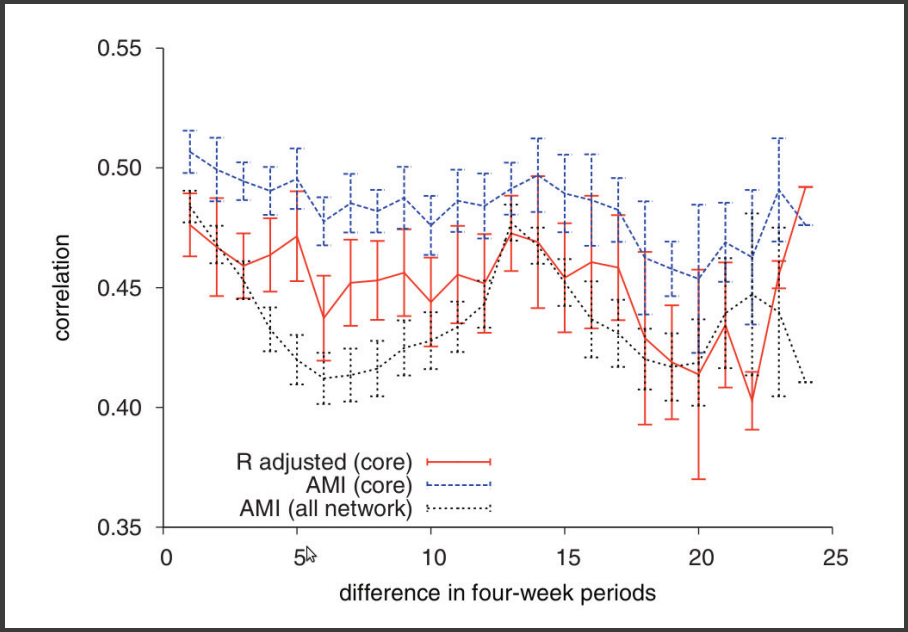
Community analysis in veterinary epidemiology



Lentz et al. Trade communities and their spatial patterns in the German pork production network. **Preventive veterinary medicine**, v. 98, n. 2-3, p. 176–81, fev. 2011.

Community analysis in veterinary epidemiology



Green et al. Tools to study trends in community structure: application to fish and livestock trading networks. **Preventive veterinary medicine**, v. 99, n. 2-4, p. 225–8, 1 maio 2011.

Livestock production zones and communities definition

- Although the concept of livestock production zone is well understand, it is not so easy to define it.

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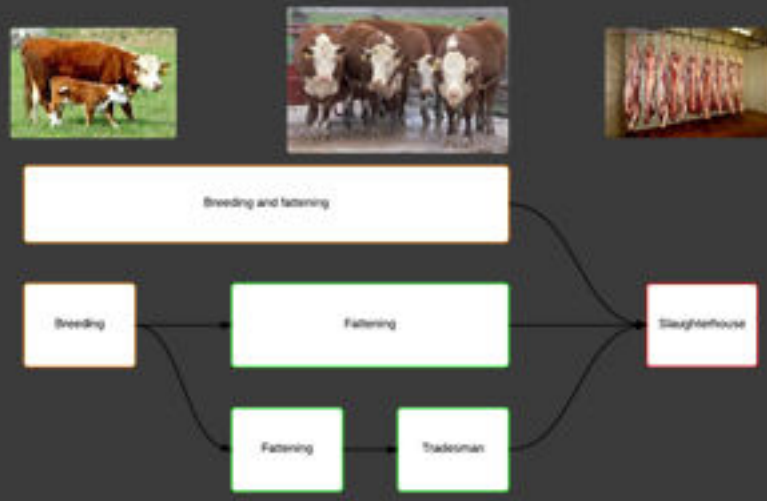

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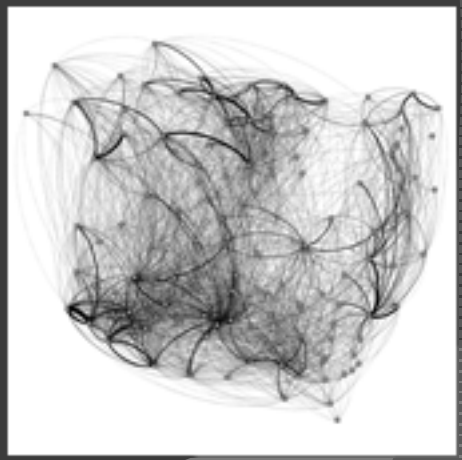

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- A livestock production zone could be defined as:
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Livestock production zones and communities definition

- A livestock production zone could be defined as:
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- Community definition by Kim (2010):
  - "a community is a group of nodes in which a random walker is more likely to stay"

The math behind it

- Modularity:
  - Kim et al. Finding communities in directed networks. **Physical Review E**, v. 81, n. 1, p. 1–9, 2010

$$Q^{lr} = \sum_{ij}[L_{ij} - \pi_i \pi_j]\delta_{c_i c_j}$$

$$L_{ij} = \pi_i G_{ij}$$

$$G_{ij} = \frac{w_{ij}}{w_i^{out}}$$

- Optimization via Simulated Annealing
  - Kirkpatrick et al. Optimization by Simulated Annealing. **Science**, v. 220, n. 4598, p. 671–680,1983

$$P(\Delta E) = \exp(-\Delta E/k_B T)$$

- Validation via Entropy Theory (Variation of Information)
  - Meilă, M. Comparing clusterings—an information based distance. **Journal of Multivariate Analysis**, v. 98, n. 5, p. 873–895, 2007

$$VI(\mathcal{C}, \mathcal{C}') = H(\mathcal{C}) + H(\mathcal{C}') - 2I(\mathcal{C}, \mathcal{C}').$$

$$H(\mathcal{C}) = -\sum_{k=1}^{K} P(k) \log P(k).$$

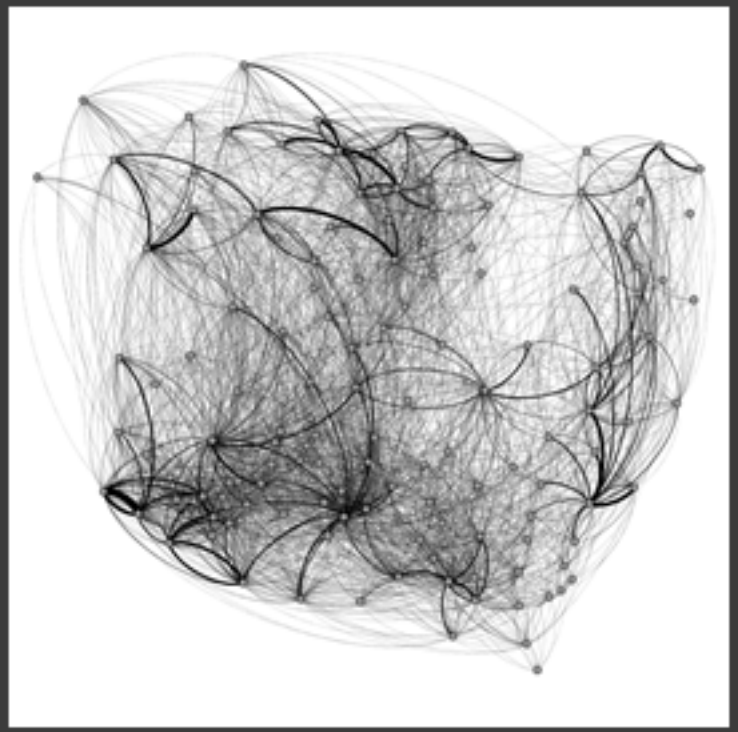
$$I(\mathcal{C}, \mathcal{C}') = \sum_{k=1}^{K}\sum_{k'=1}^{K'} P(k,k') \log \frac{P(k,k')}{P(k)P'(k')}.$$

Community detection example

- State of Mato Grosso:
  - Largest herd of Brazil
  - ~ 30,000,000 bovines
  - vast majority in beef herds

Grisi-Filho et al. (2013) Detecting livestock production zones. **Preventive Veterinary Medicine**, 110, 3-4.

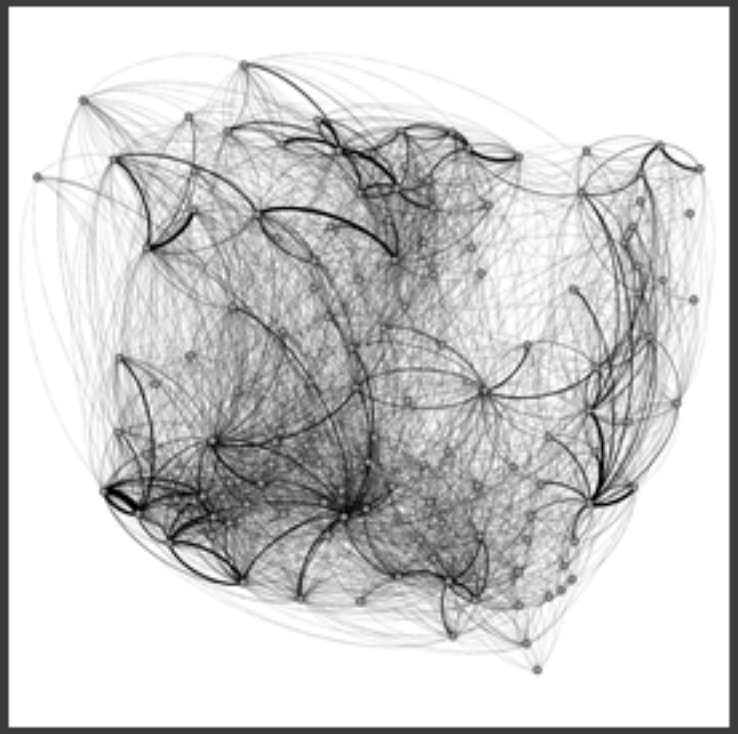
Community detection example



- State of Mato Grosso:
  - Largest herd of Brazil
  - ~ 30,000,000 bovines
  - vast majority in beef herds
- Animal trade network (2007)
  - 87.899 premises
  - 521.431 movements
  - 15.844.779 animals moved
  - Animal trade was aggregated by county, resulting in an network with 141 nodes and 3,980 links.

Grisi-Filho et al. (2013) Detecting livestock production zones. **Preventive Veterinary Medicine**, 110, 3-4.

Community detection example



- And after all this:

$$Q^{lr} = \sum_{ij}[L_{ij} - \pi_i \pi_j]\delta_{c_i c_j}$$

$$L_{ij} = \pi_i G_{ij} \qquad G_{ij} = \frac{w_{ij}}{w_i^{out}}$$

$$\boldsymbol{P(\Delta E) = \exp(-\Delta E / k_B T)}$$

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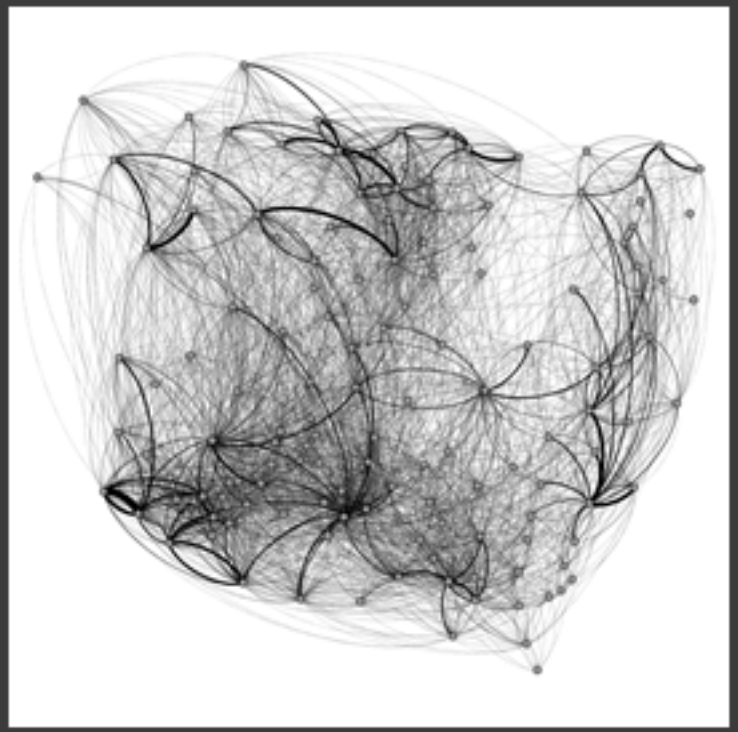

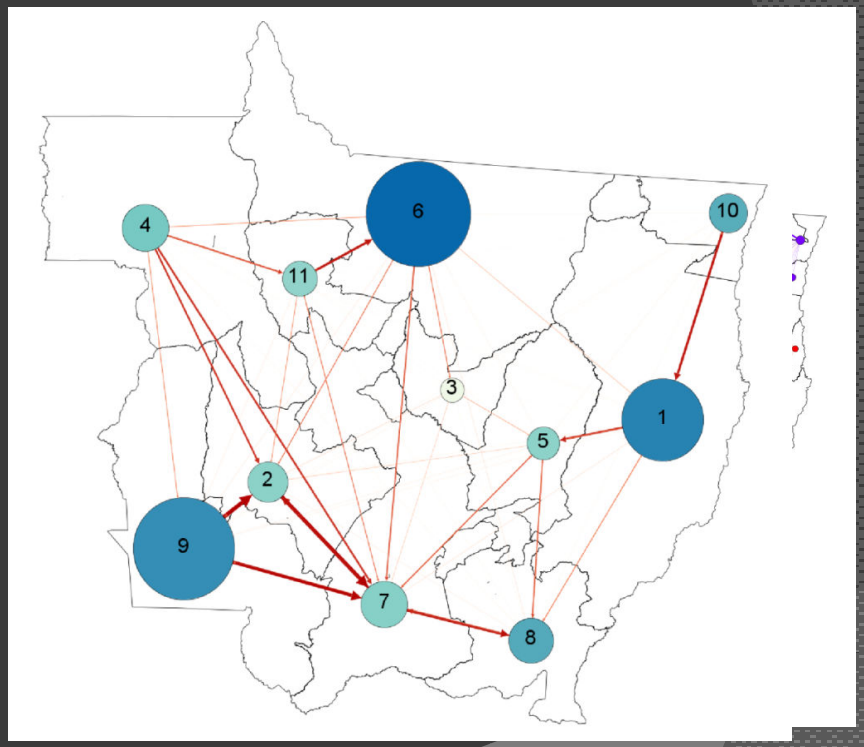

Size and color proportional to internal trade

Node size is proportional to the internal trade

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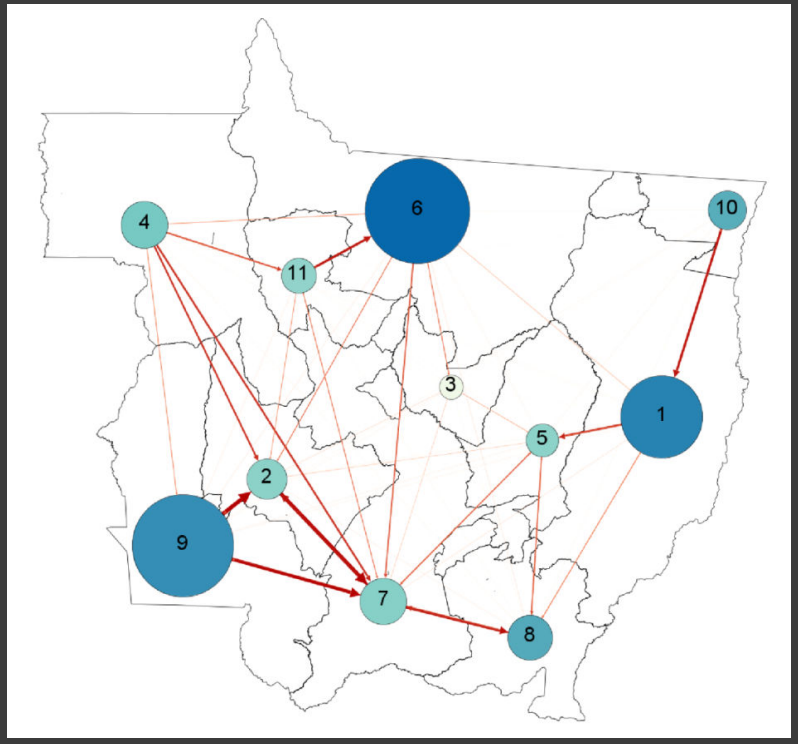
Community detection example



- Predominant flows:
  - North-South
  - West-East
  - Due to exports to other States
- B
  tr
  d
  re

Grisi-Filho et al. (2013) Detecting livestock production zones. **Preventive Veterinary Medicine**, 110, 3-4.

Community detection example

Table 1
Outgoing moves (%). $A_{ij} = (W_{ij})/(s_i^{out})$, where W_{ij} is the total amount of animal movement from community i to community j, and s_i^{out} is the amount of community i outgoing animals. The found communities show a clear preference to sell animals internally. The animal trade made by the 2 ungrouped counties is not shown.

	1	2	3	4	5	6	7	8	9	10	11	Total # of animals
1	91.60	0.02	0.00	0.00	3.68	0.69	0.27	1.44	0.02	1.56	0.00	2,519,752
2	0.02	71.31	0.13	0.54	1.35	0.80	19.21	0.17	6.26	0.00	0.08	924,083
3	0.00	10.54	39.23	0.00	23.73	10.69	14.72	0.04	1.05	0.00	0.00	89,107
4	0.00	6.53	0.00	76.02	0.01	2.17	7.04	0.02	2.41	0.00	5.80	1,228,075
5	5.56	0.30	0.73	0.00	70.91	0.27	8.78	10.57	0.42	0.00	0.01	523,644
6	0.08	1.11	1.07	0.19	0.00	94.70	1.74	0.18	0.14	0.00	0.74	3,371,829
7	0.28	9.44	0.14	0.17	3.23	1.11	72.46	9.73	2.77	0.00	0.37	1,265,583
8	2.14	0.42	0.00	0.02	3.39	0.20	8.17	83.66	0.78	0.01	0.01	1,016,299
9	0.02	5.31	0.01	0.22	0.02	0.07	4.50	0.16	89.60	0.01	0.07	3,439,689
10	15.18	0.00	0.02	0.00	0.22	0.33	0.00	0.03	0.01	82.57	0.01	724,604
11	0.00	4.10	0.05	3.26	0.00	16.66	5.52	0.01	0.57	0.00	69.83	656,241

Table 2
Incoming moves (%). $A_{ij} = (W_{ij})/(s_j^{in})$, where W_{ij} is the total amount of animal movement from community i to community j, and s_j^{in} is the amount of community j incoming animals. The animal trade made by the 2 ungrouped counties is not shown.

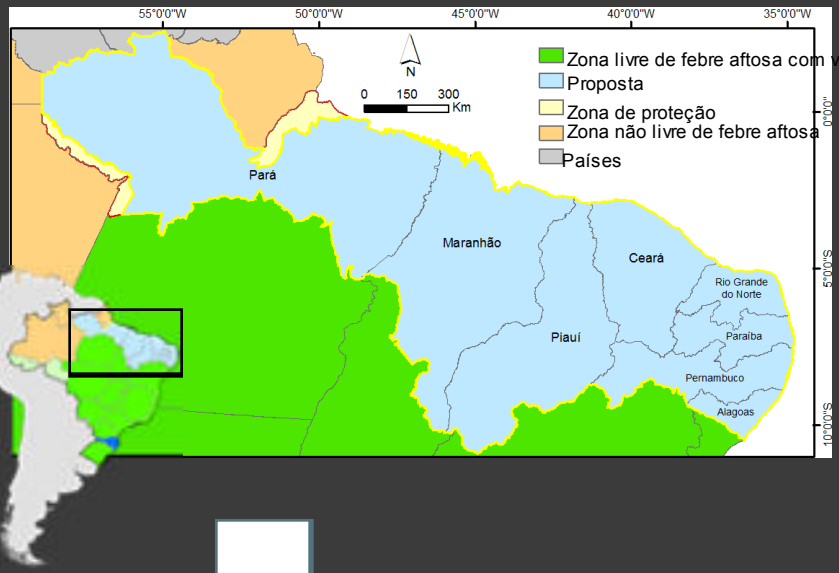
	1	2	3	4	5	6	7	8	9	10	11
1	92.38	0.05	0.01	0.00	15.88	0.52	0.43	3.32	0.01	6.08	0.01
2	0.01	58.75	1.51	0.51	2.13	0.22	11.19	0.14	1.79	0.00	0.12
3	0.00	0.84	44.54	0.00	3.62	0.28	0.83	0.00	0.03	0.00	0.00
4	0.00	7.15	0.03	95.60	0.02	0.78	5.45	0.02	0.92	0.00	12.67
5	1.16	0.14	4.89	0.00	63.59	0.04	2.90	5.05	0.07	0.00	0.01
6	0.10	3.34	45.79	0.67	0.03	94.19	3.71	0.54	0.14	0.00	4.41
7	0.14	10.65	2.18	0.22	6.99	0.42	57.81	11.23	1.09	0.00	0.82
8	0.87	0.38	0.04	0.02	5.90	0.06	5.23	77.57	0.25	0.01	0.02
9	0.03	16.30	0.42	0.78	0.14	0.08	9.76	0.49	95.58	0.03	0.46
10	4.40	0.00	0.15	0.00	0.27	0.07	0.00	0.02	0.00	92.58	0.01
11	0.00	2.40	0.44	2.19	0.00	3.23	2.28	0.01	0.12	0.00	81.47
Total # of animals	2,498,589	1,121,681	78,501	976,503	583,919	3,390,257	1,586,209	1,096,007	3,224,366	646,296	562,458

Observations

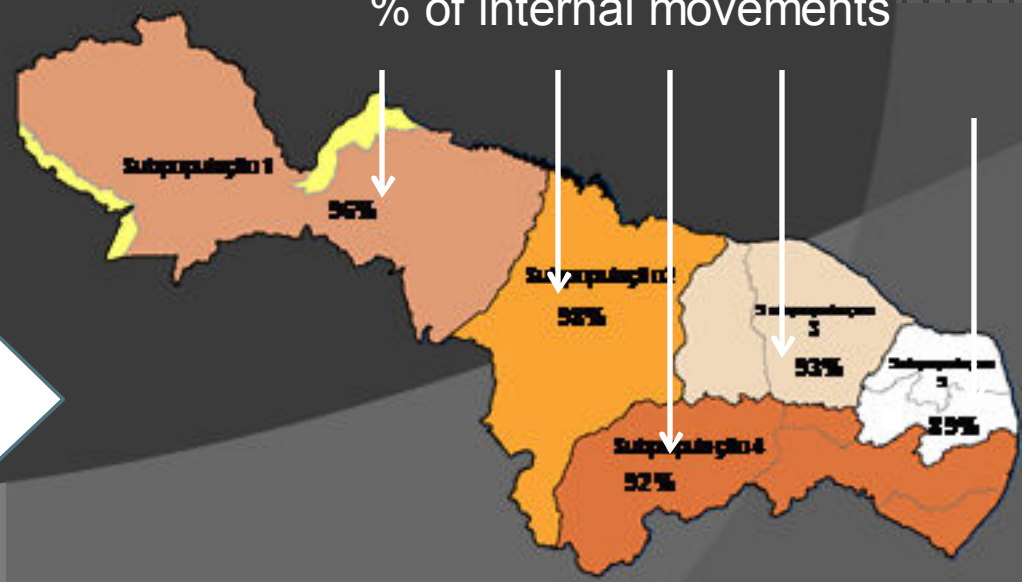
- It is possible (and recommended) to aggregate other sources of information:
  - Surveillance system structure
  - Population structure
  - Livestock system
  - Expert opinion
  - etc

Recent applications

Moraes, Barbosa Jr, Costa, Araújo, Teixeira, Grisi-Filho, Amaku, Gonçalves.
Animal movement analysis and risk characterizaton in studies to evaluate Foot-and-Mouth virus circulation in vaccination areas. *Manuscript in preparation*



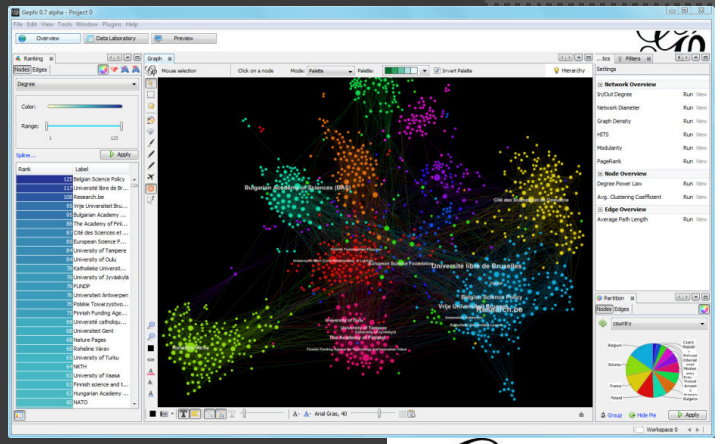
"Independence degree":
% of internal movements



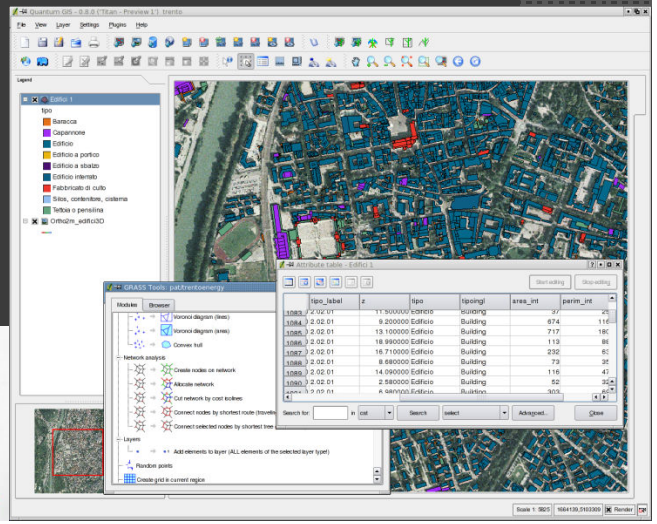
What do we need?

- A good information system
  - Animal movements and farm premises
  - Integrity, accuracy, consistency, completeness
- Technological infrastructure
  - Large storage and processing capacity
- Human resources
  - Trained in epidemiology and network analysis

Open Source Softwares



Gephi



Quantum GIS

Final remarks

- We can reveal the trade patterns in an animal movement network
  - Leads to a better understanding on the trade relationship between production zones
- Can be used in
  - risk-based surveillance systems
  - stratified sample design
  - target areas for sanitary programs
  - segregate subpopulations with minimum trade impact
  - …

Acknowledgments

- INDEA (Instituto de Defesa Agropecuária do Estado do Mato Grosso – Local Veterinary Office)
- MAPA (Ministério da Agricultura, Pecuária e Abastecimento – Ministry of Agriculture)
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THANK YOU
GRACIAS