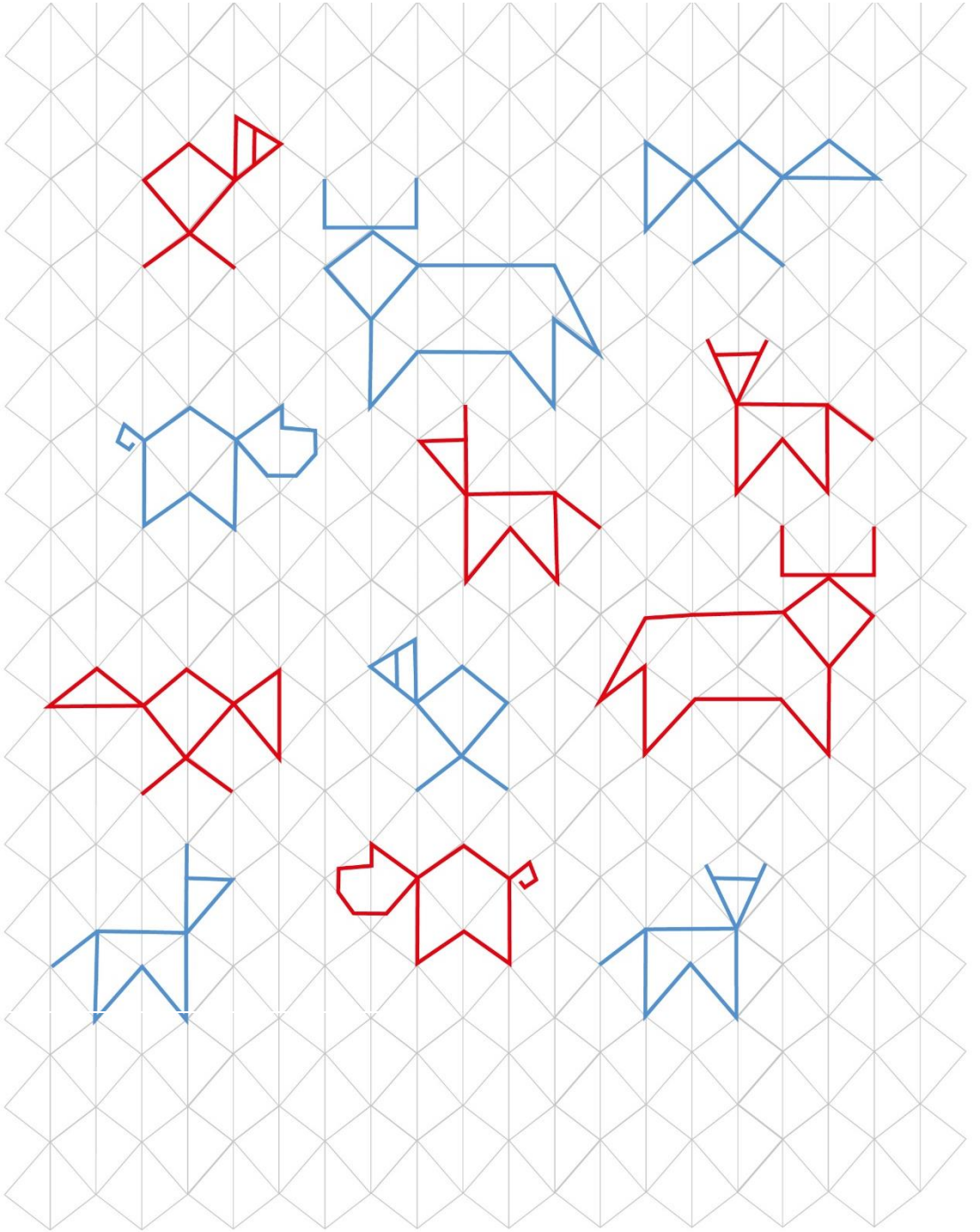
China, Mongolia, and Central Asia Episystem Workshop for Peste des petits ruminants (PPR) eradication



Ulaanbaatar, Mongolia, 1-3 April 2025

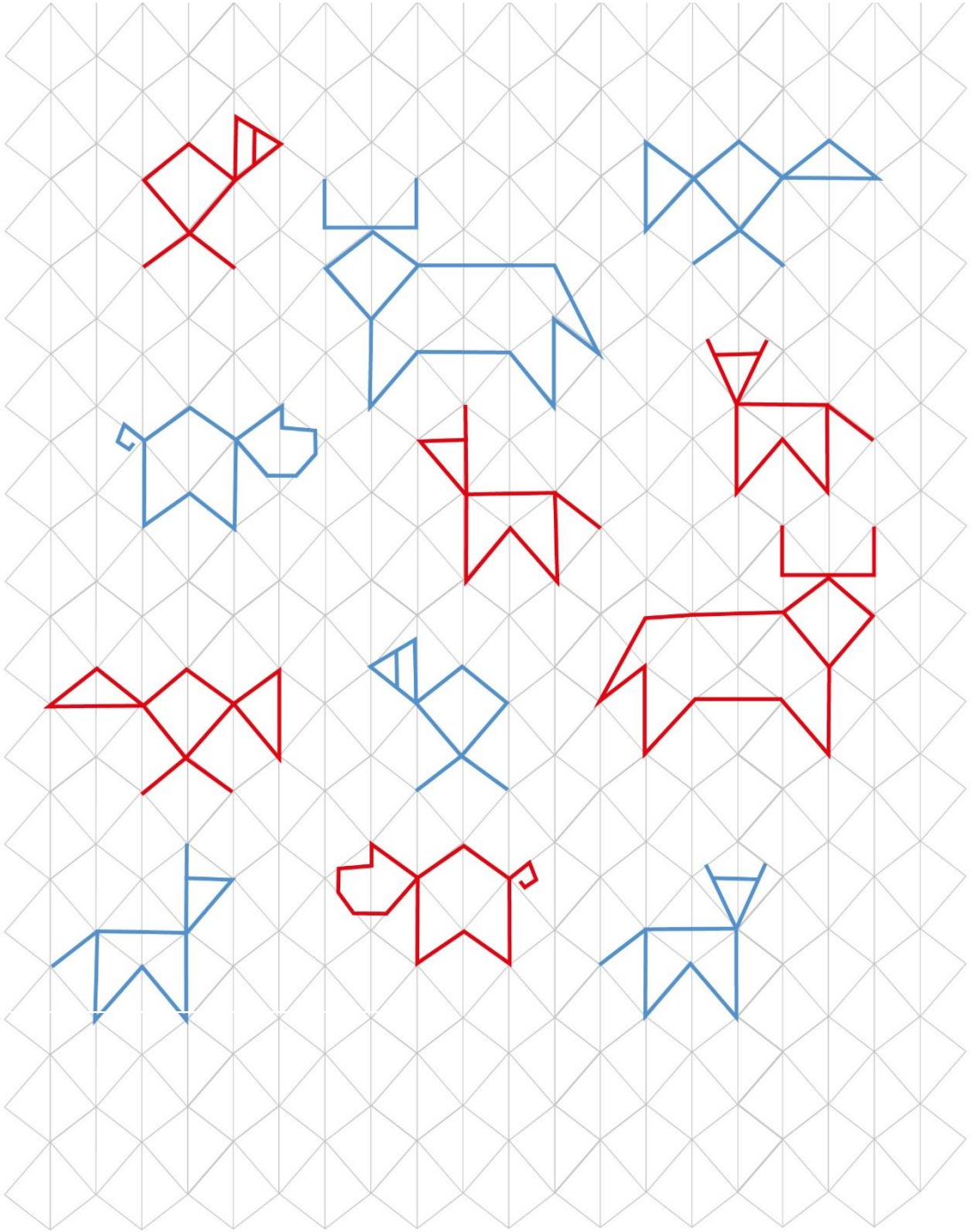
With support from:

中华人民共和国农业农村部
Ministry of Agriculture and Rural Affairs of the People's Republic of China

Co-funded by the European Union

Role of livestock , mobility husbandry systems, and identification for defining episystems

Andrea Apolloni
CIRAD



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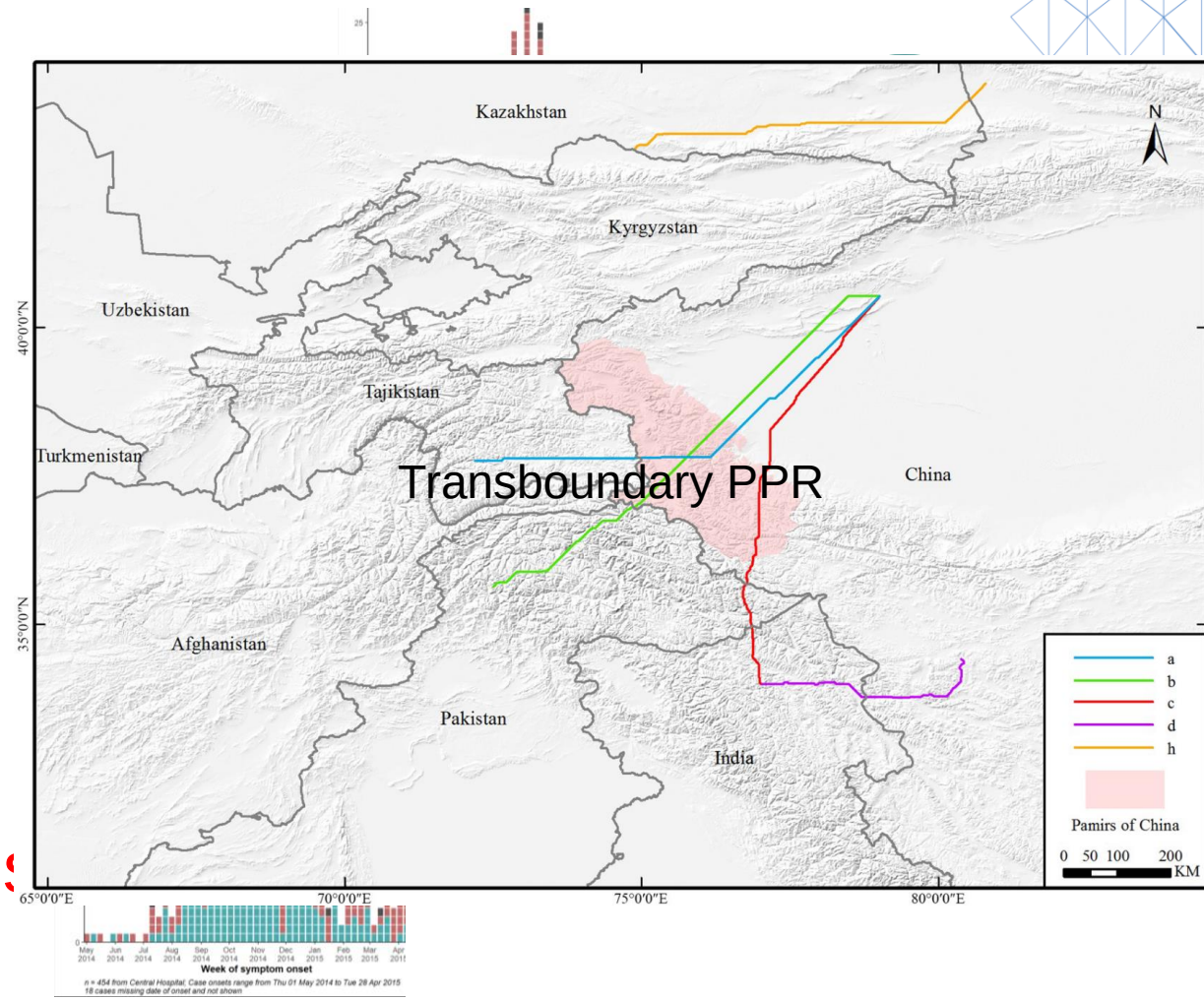
Plan of the Talk

- Why Mobility?
- What is meant by mobility
- Using Network tools to identify and characterize episystems
- How to collected data
- Some success stories
- The role of husbandry practices and identification

Why Mobility?

- “Episystem is about connectedness”: anonymous source during Preparation workshop
- If Epidemiological Units are isolated , no PPR diffusion
- PPR directly transmitted disease: hosts are the only vectors for the disease
- Only flows of animals could spread the disease
- Mobility : animals flows between locations
- Introduce Disease in Naive areas
- Expose Susceptible to disease
- Maintaining endemicity in locations by providing new susceptibles

EpiSystem = Locations + Connections



Type of Mob

- Production:
  - Pastoralism animals move to mountain paturages→ seasonal movements Transhumance
  - Extensive husbandry practices: using natural resources in surrounding areas
- Trade Commercial Movement
  - Animals are sold at market till consumption
  - Production and value chain : animals move along premises till slaughtering
- Festivities and cultural events:
  - Consumption of meat in specific time of the years (El Aid, Easter , Christmas)
- Social events: Gift for weddings , Loan to families
- Daily movements fro feeding

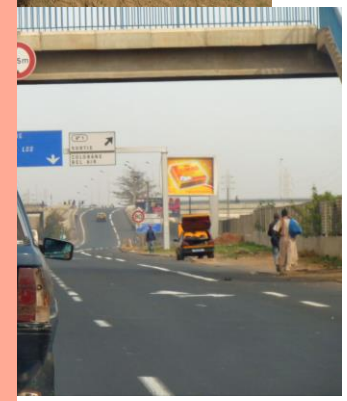
What we talk when we talk about mobility

Interaction

Transportation

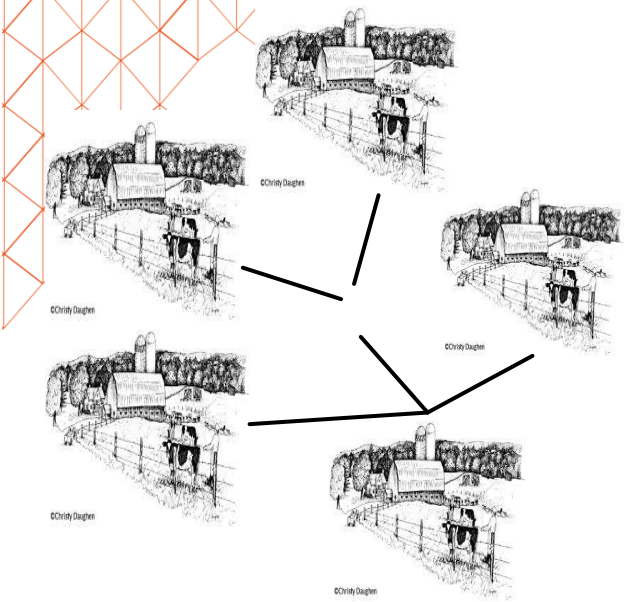
- Develop tools to
- Represents mobility patterns
- Identify Hotspots and central location
- Identify Episystem' membership: which location belongs to which episystem

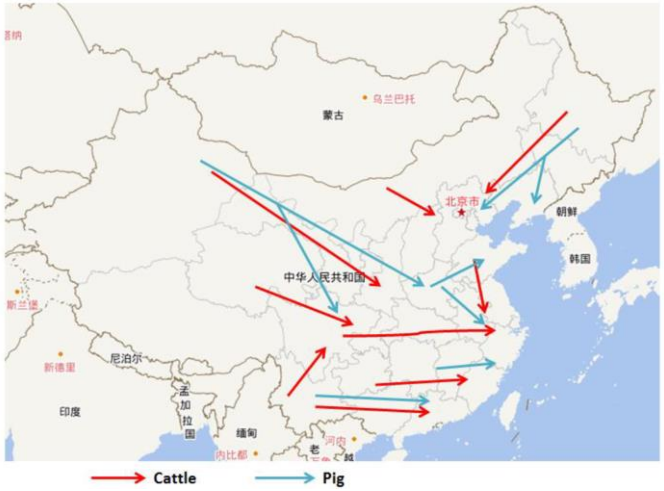
Problem in data collection and centralization



Climate Conditions

Types of mobility





Local mobility: daily movements of animals looking for grazing areas,water. Contacts among animals of different farms/villages: transmission of the disease and local outbreaks

National/Commercial mobility: from farm to markets. Animals can be exposed to disease or introduce diseases in naive areas (*seeding*) Markets bring together animal far away

International/Transhumance mobility: from farms to other countries. Introduce diseases in naive areas (*seeding*) Temporal scale longer (months)

Define Epidemiological Unit: elements of the episystem (single village, or commune)

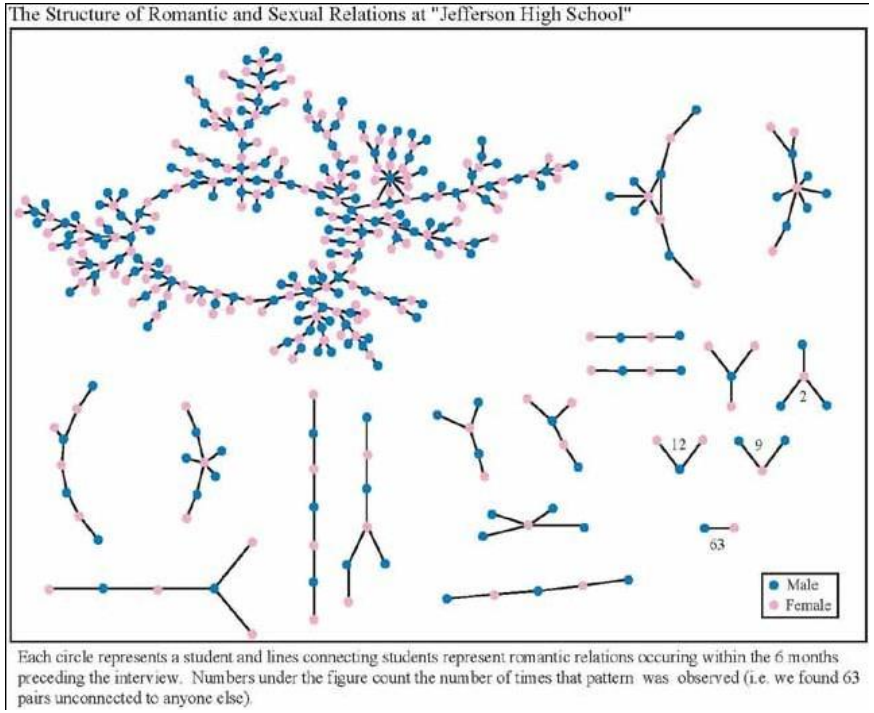
Define Interactions among E.U. and Episystem

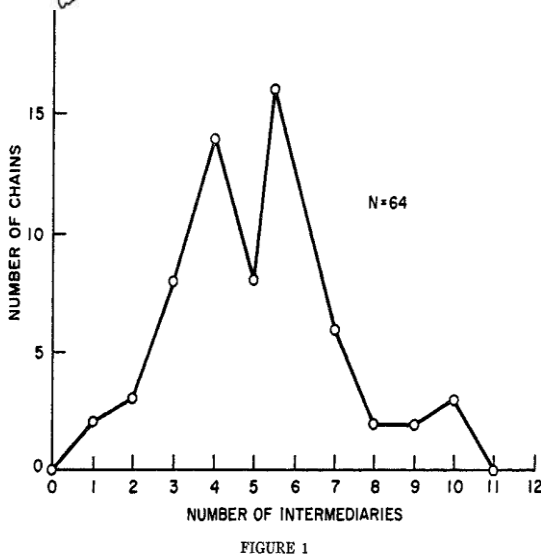
Why network ?

6 degrees of separation

- Left alone , individuals will have their own disease statuts, political view , idea etc… (disorder)
- Individuals interact with few other individuals, a small number compared to the total population
- How disease propagate to all the world and so rapidly?

Network: representation of an interacting system using 2 elements :
Nodes (interacting Units) and links (interaction)





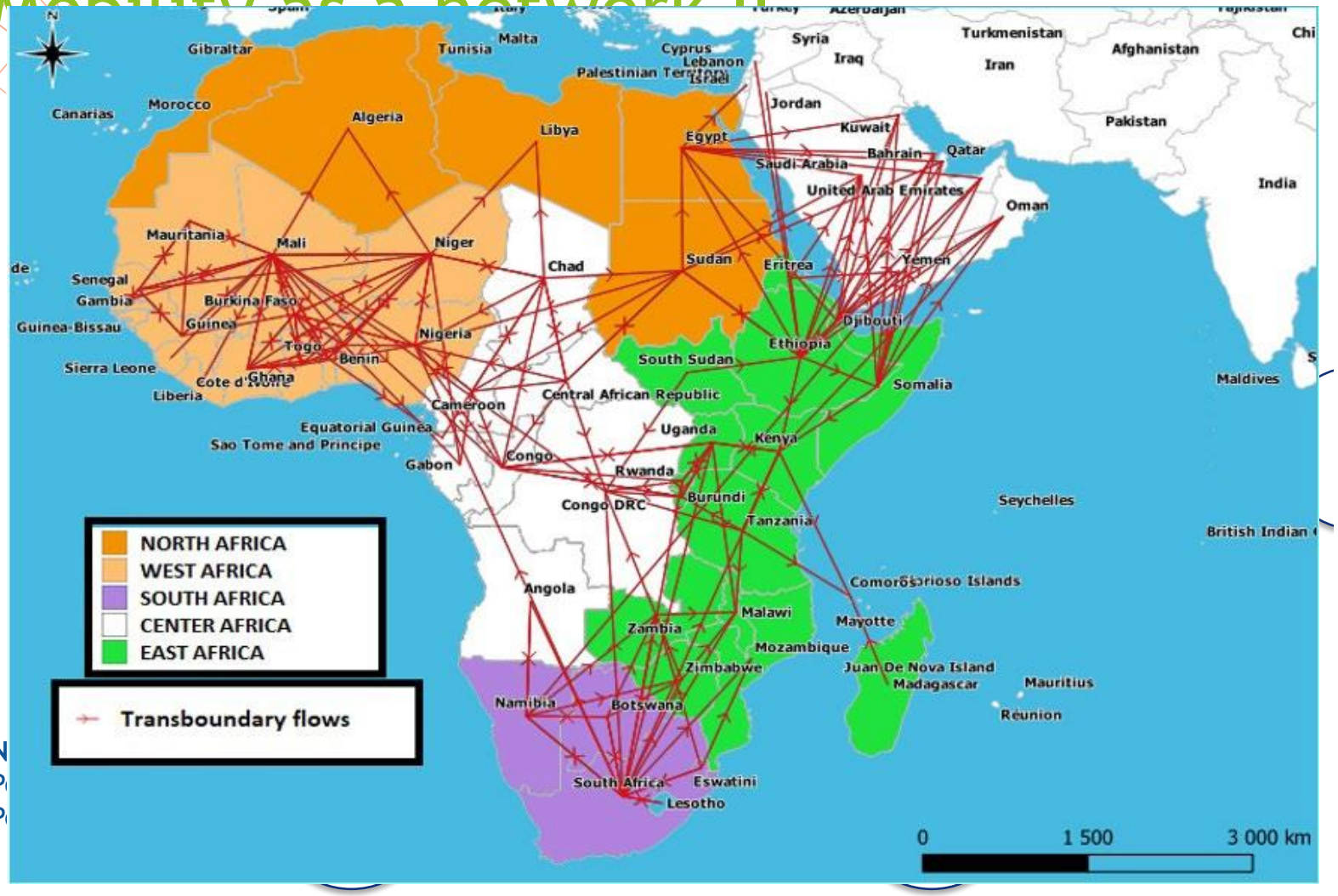
Mobility as a network

Network: representation of an interacting system using 2 elements :
Nodes (interacting Units) and links (interaction)

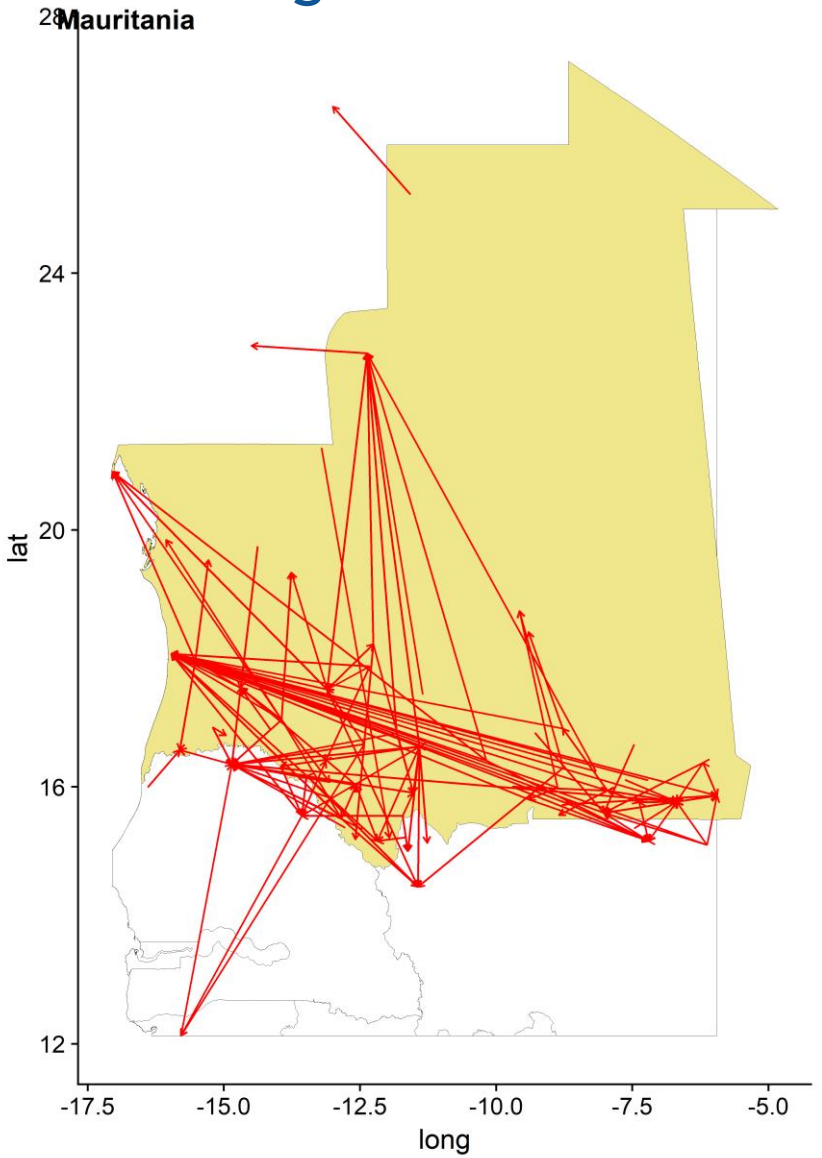
- Node: Origin or destination of a movement (i.e. the commune or the farm)
- Characteristics:
  - **Geographical Position;**
  - **Number of animals;**
  - **Human Population**
  - **Presence of markets/farms**
- Represented by a circle

- Link: indicates a movement between origin and destination;
- Characteristics :
  - **Volume/weight: number of animals moved**
  - **Transportation: mean used**
  - **Active period: when the movement occurs**
- Represented by an arrow (or a segment if not interested direction)

Mobility as a network II



Combining all movements



Network Measures

Node's or Centrality

- Typical of each node but depends on network structure
- Define the importance of the node with respect certain characteristics
- Can widely vary across the network (heterogeneity)

Global

- Measure of the whole network
- In most of the case they are average of node's measures
- They strongly depend on the structure of the network and can be used to compare networks

Through these indicators, we can identify main actors, key places and important flows and the response of the network to the introduction of diseases. These elements may have a significant role in epizootic spread and help identifying area for targeted intervention.

	Indicators	Definitions	Epidemiological interpretation
Centrality Measures	Degree /Strength	Number of links of a node/ volume of animals	Enahance risk of getting infected and srpeading
	In/Out Degree In/Out Strength	Number of Incoming / Outgoing links/volumes	Incoming mobility is a potential factor of disease introduction Outgoing mobility is a potential factor of disease spread. Important for control
	Betweeness centrality	For a node, it is the number of shortest paths using this node to link a pair of other nodes of the network.	it may identify trade crossroads and must be a priority place in terms of surveillance.
	Clustering coefficient (transitivity)	For a node, probability that its linked nodes are also directly connected to each other.	Identifies clusters of densely interconnected places which may enhance disease spread.
	Closeness	For a node the inverse of the average distance from other nodes	Estiamte who get earliest infection. Time detection
Global Measures	• Mean distance • Diameter	• Mean of all the shortests path • Longest path between the 2 more distant nodes	Useful to assess diseases spread. Time to spread between nodes and through all network
	Connectedness	A network is composed by a single group or several disconnected one	Risk of an epidemics of being contained and nodes involved

Connectiveness network

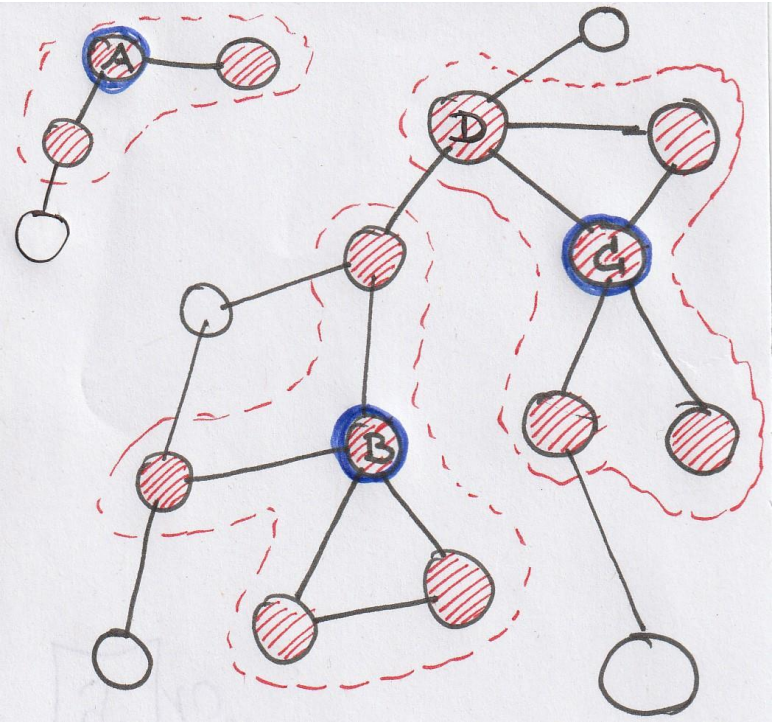
- A network is connected if a path exists that connects all nodes. The network is a unique group. Otherwise, the network has a set of components
- *If network is disconnected , disease can not spread to all nodes but limited to its component*
- *For Directed Network:*

  Weakly: we don't consider direction of the links. The same as undirected case

  A-B-C-D-E-F-G and L-M-N a weak component

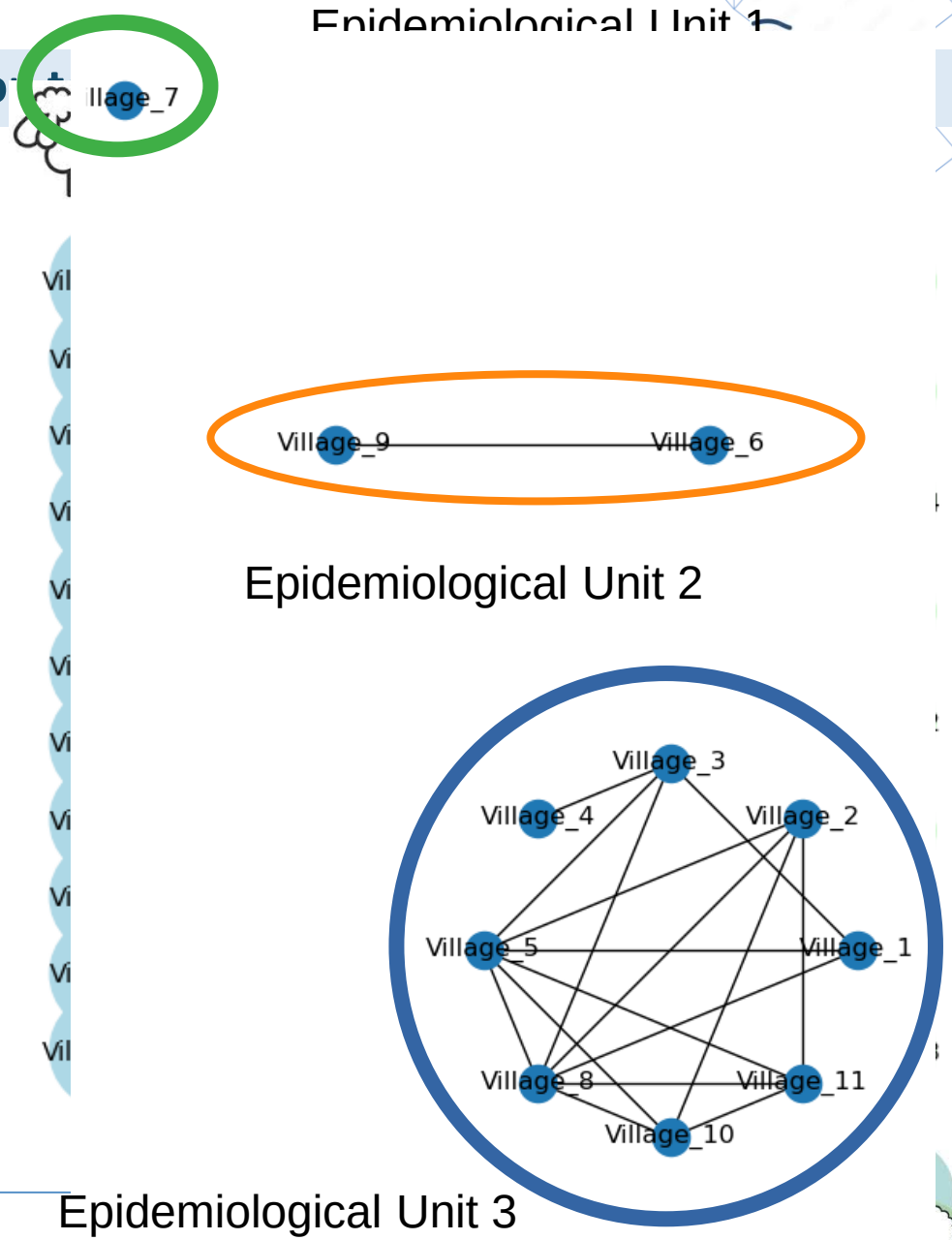
  Strong: each node in the component can reach the other nodes following the direction of links:

  E-F-G-H strong component



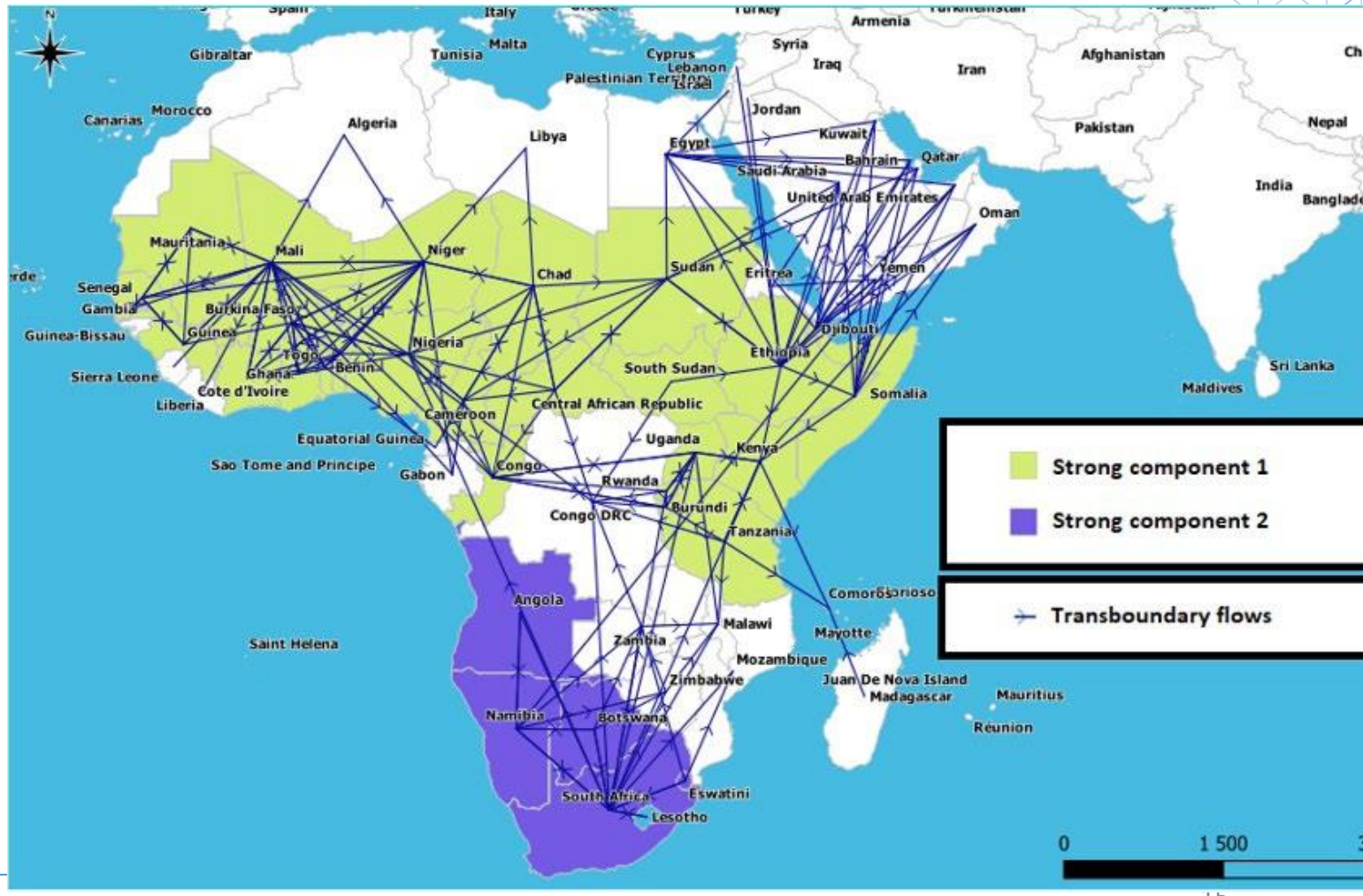
Using local Mobility Information

- Identification of single element constituting Episystem: single herd? Village? Set of close villages?
- Choice depends on how strong herds/villages interact routinely
- Sharing of same resources → increase contact among villages/herds→ Homogeneity→ Node of the network
- In Episystem/ Network: nodes correspond to area routinely and daily interacting among them



Connectiveness for undirected network

- A single Weakly Connected Components and 2 Strong connected Components in Africa
- Once disease in a component can spread only to nodes in the component
  - Strong component extension→ Minimum Extension of epidemics
  - Weak components→ maximum extent
-
-

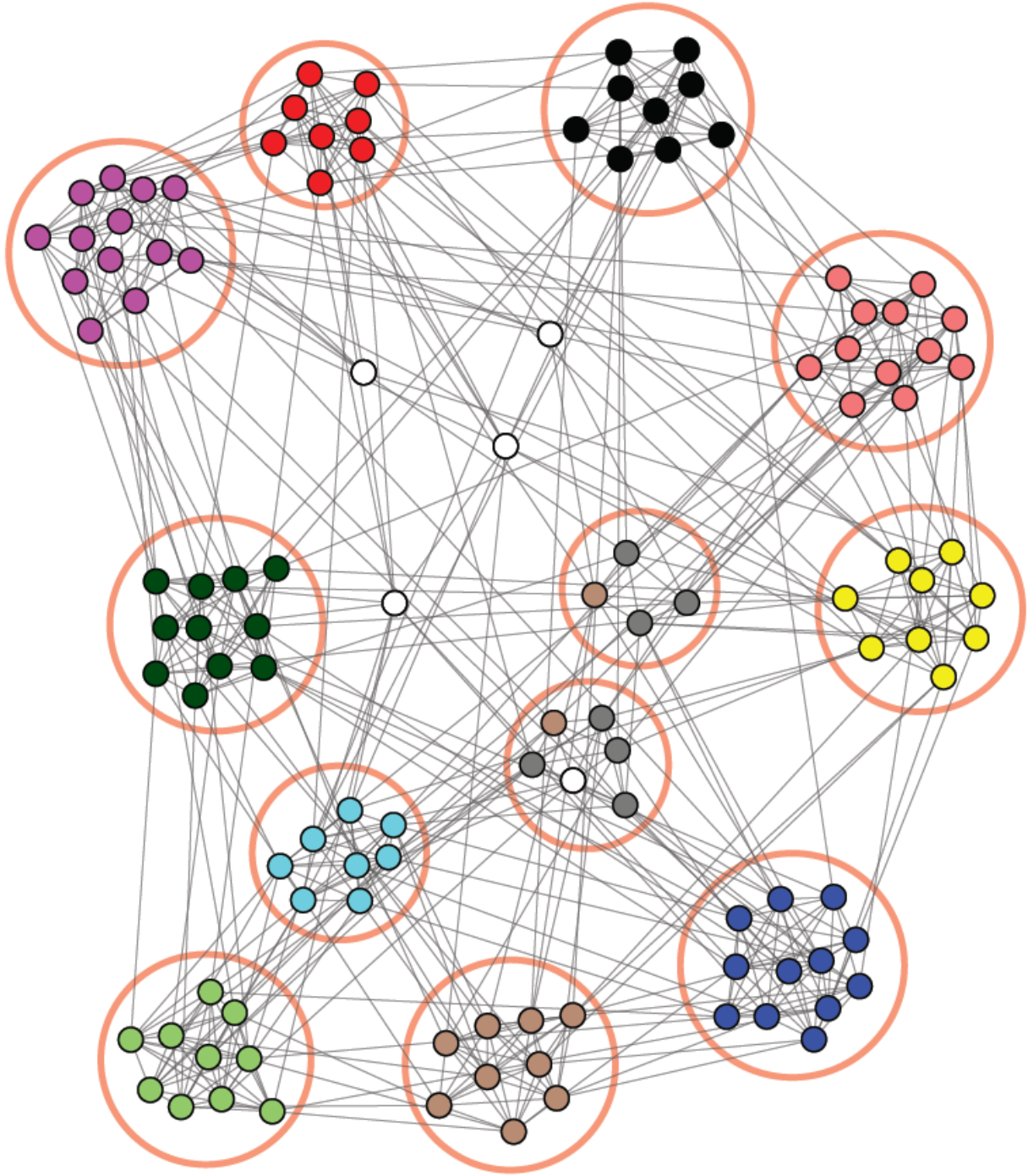


Community structures in network

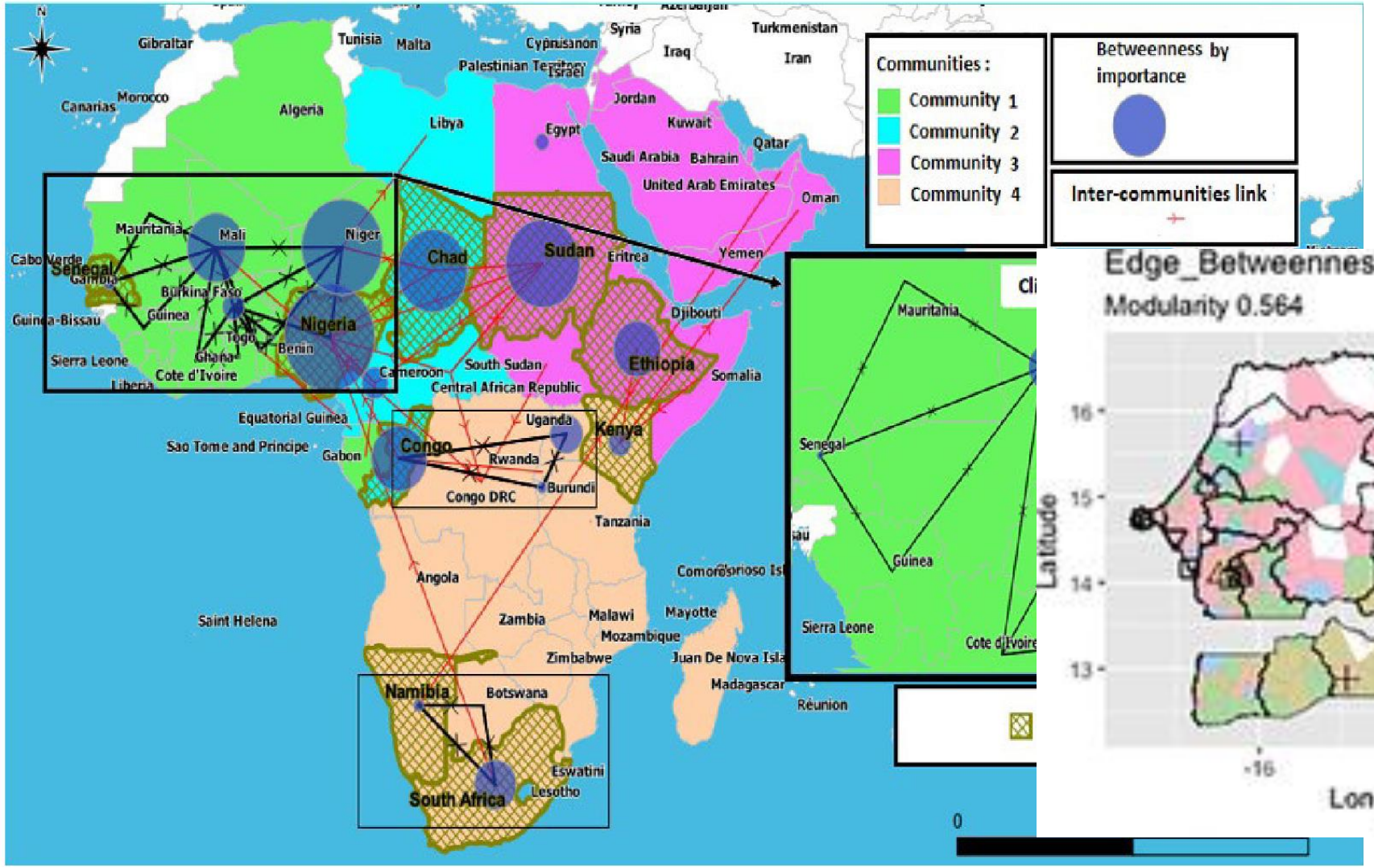
Communities: subset of nodes that are tightly connected among them compared to other network.

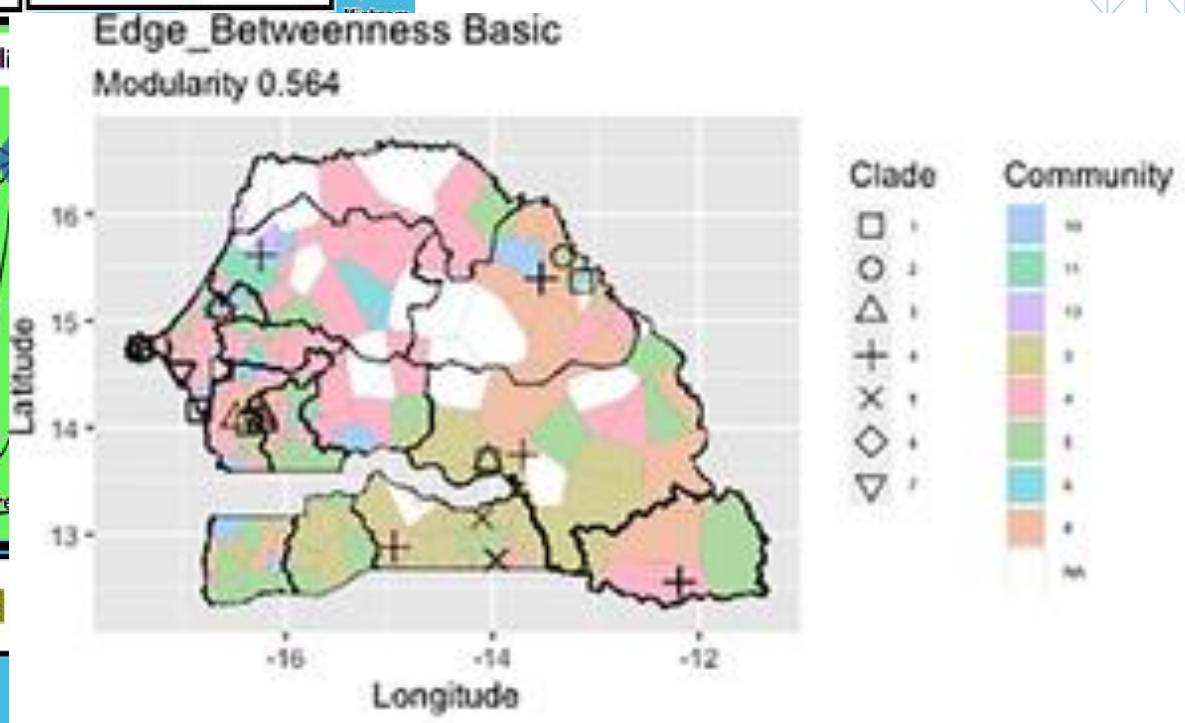
- Identify strongly connected areas with specific dynamics for example locations connected through value/production chain
- Existence of communities facilitates the spread of disease once entering a community
- Identification of cluster of outbreaks: outbreaks can occur within the same community.

COMMUNITY = EPISYSTEM : set of locations strongly interacting among themselves compared to other one for whiche epidemiological/ genetical similarity



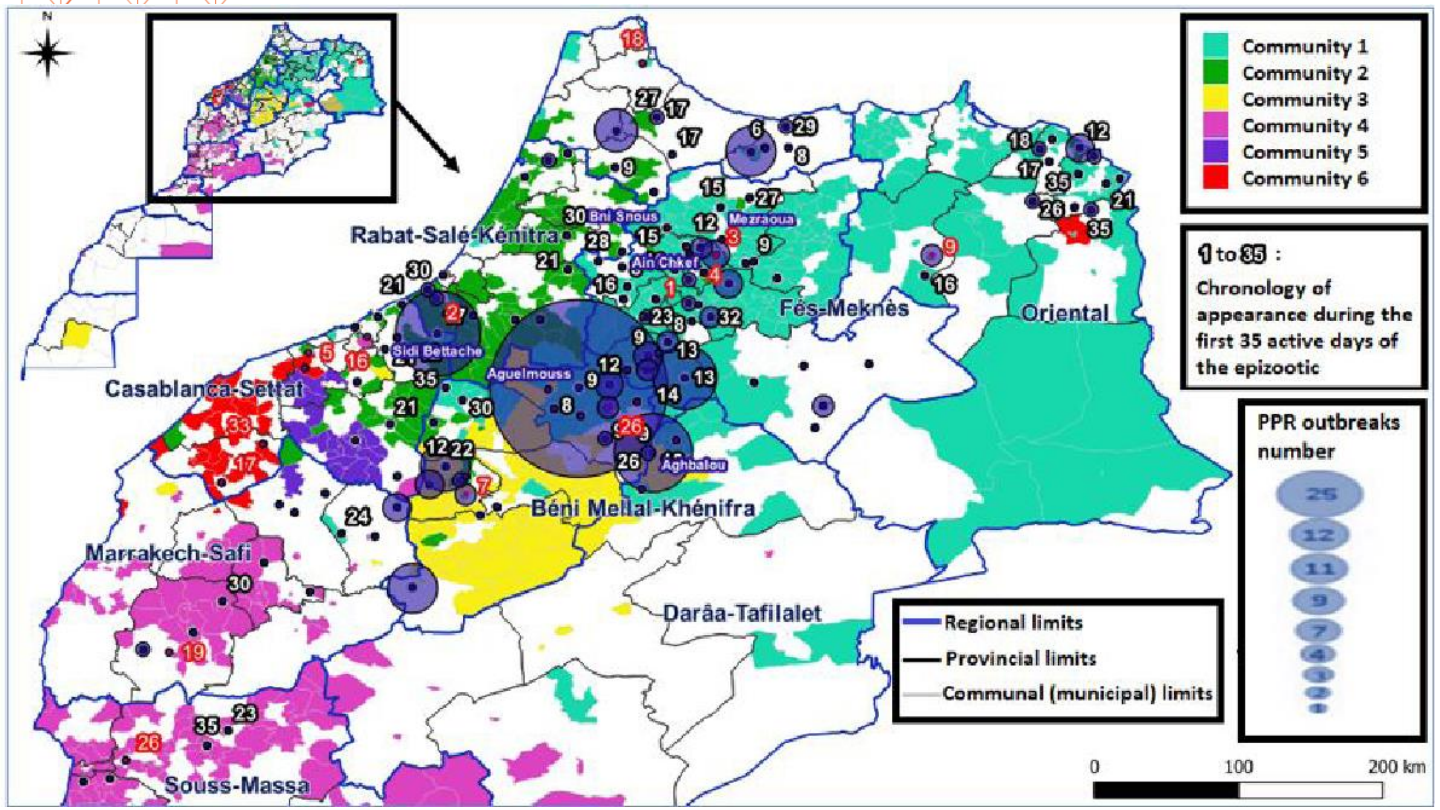
PPR in Senegal





Explain patterns of introduction of strains in Africa

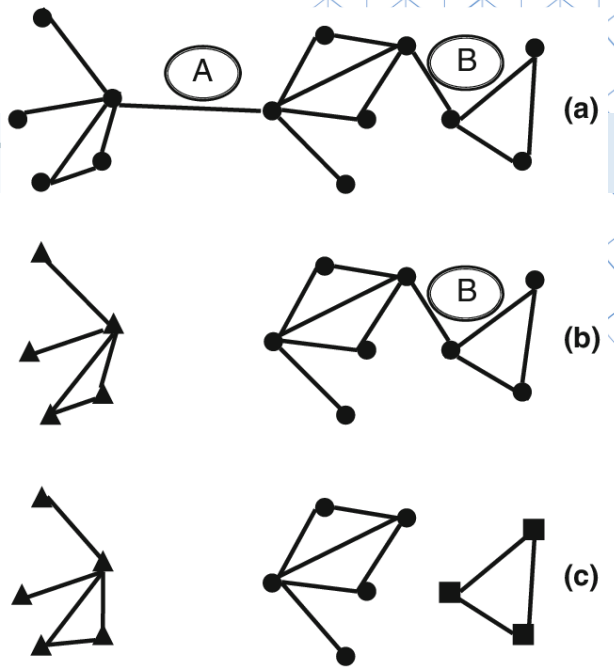
O.R. Ratio of being in the same clade if in the same community 1.57-3.8



Communities are good predictors for epidemic clusters (2008 PPR in Morocco)

Communities help optimizing surveillance

Technical comments : Several algorighms to identifiy comm



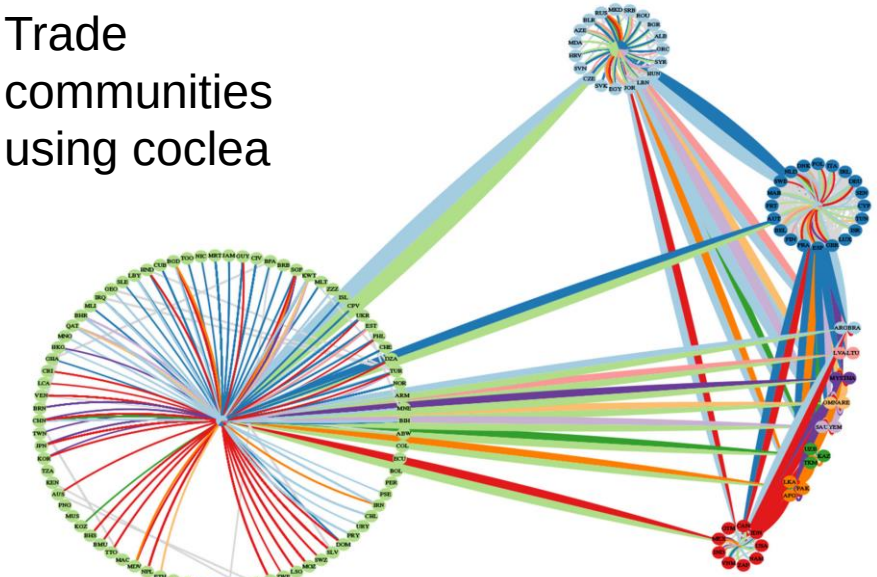
Removing link for identifying communities

- Membership to communities is not given, but analyzing network structure with algorithms identify communities and its members

1) Edge betweenness: structural ; eliminate links with higher betweenness that connect communities

2)Coclea Algorithm: through simulation of disease identify those nodes that mutually infect each other

Trade communities using coclea



Mobility data at local scale : what to collect

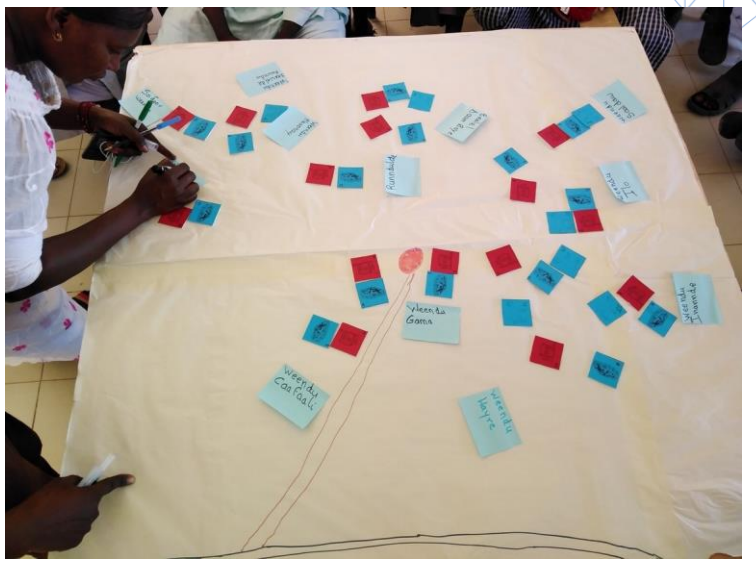
Aims :

Identify contacts among local heards and/or external ones

Identify movement of naimals towards and from areas

Basic information to collect:

- **Herds distribution (villages)**
- **Resources available**
  - Water sources
  - Grazing aras
  - Markets
  - Transhumance camps
- **Frequancy of use**
- **Variations along the year**



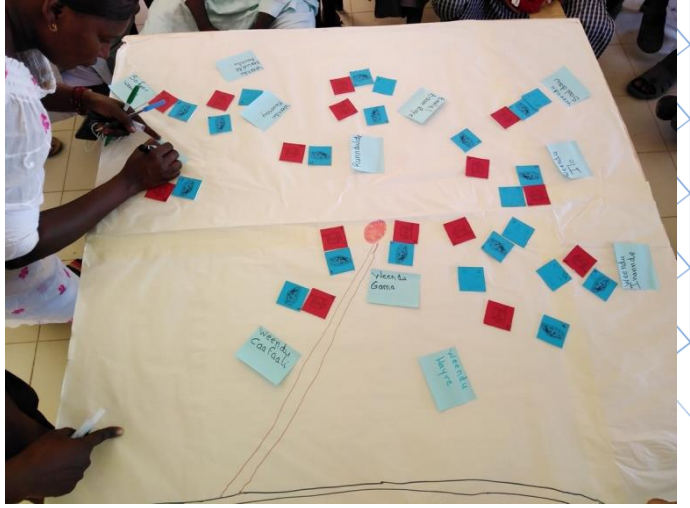
Mobility data : where to find

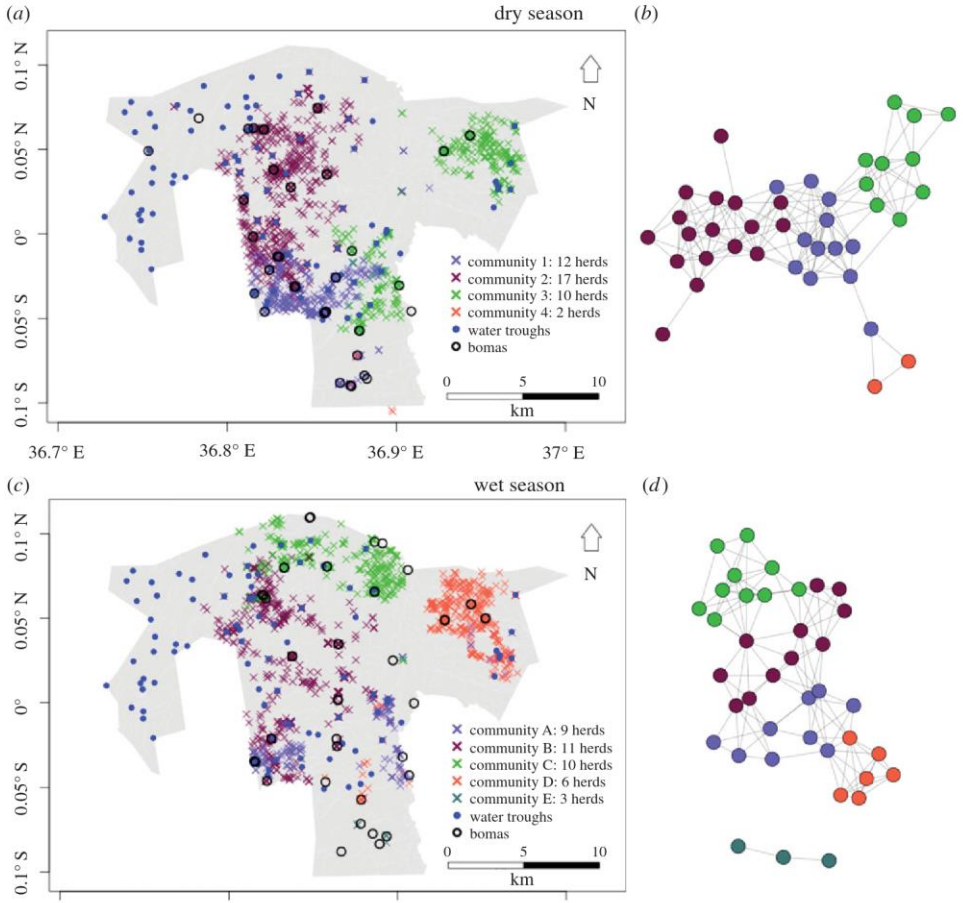
Where to find (preliminary part):

- Bibliography
- Reports of Vet Services and/or statistical services
- Workshops (FGD) with local actor

Local Movement (ad hoc activities):

- FGD and partipatory mapping :
  - Identify interactions among herd/wildlife
  - And local market's bassin (village level)
- GPS follow-up
  - Confirm previous results
  - Harmonise
- Survey at local markets :
  - Where are you coming ? Where are you going ?
- Survey of transhumant in the area
  - Where are you coming ? Where are you going ?
  - How long it takes ? How long you stay ?





Mobility data at large scale : what to collect

Basic information to collect:

- **Origine and Destination** (national international) at the chosen scale :
  - Names of the village of Origin and Destination
  - Administrative Unit villages belong to
- **Species and Quantity**
  - How many heads per species
- **Period of the year/Date**

Other information to collect:

- Trasportation (trucks, car, foot)
- **Seasonality/frequence** (variations along the year)
- **Type:** commercial (towards market/slaughterhouse); legal/illegal; transhumance

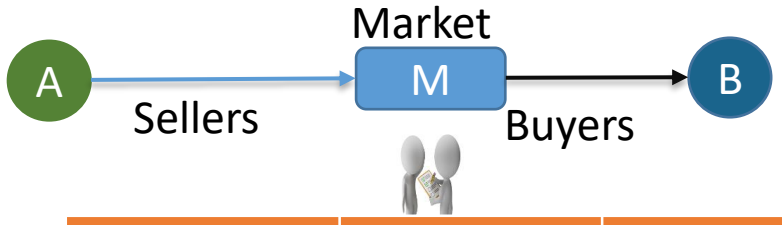
Country_ Origin	Region_ Origin	Origin	Country_ Destination	Region_ Destination	Destination	Species	Headcount	Period	Transport	Type
Mauritania	Nouakchot	Nouakchot	Mauritania	Trarza	Rosso	Goats	10	March	Truck	Commercial
Mauritania	Trarza	Rosso	Mauritania	Trarza	Rkiz	Sheep	5	April	Foot	Transhumant
Senegal	Dakar	Dakar	Mauritania	Trarza	Rosso	Goats	20	March	Truck	Commercial

Formatting the data (2 types of survey)

- Origin-Destination:
  - bibliographic searches
  - Movement certificates
  - Survey of herder
  - Survey at border point
- Respondents declare their origin and destination of the movement

ORIGIN	DESTINATION	HEADCOUNT
DEPARTMENT_A	DEPARTMENT_B	500

- Market survey:
  - Done at market or commercial points
  - Respondent are either selling (sellers) or buying (buyer) animals
- Sellers declare where the animals are from, and destination is the market
- Buyers declare where they bring animals, origin is market
- Need to format in Origin-Destination



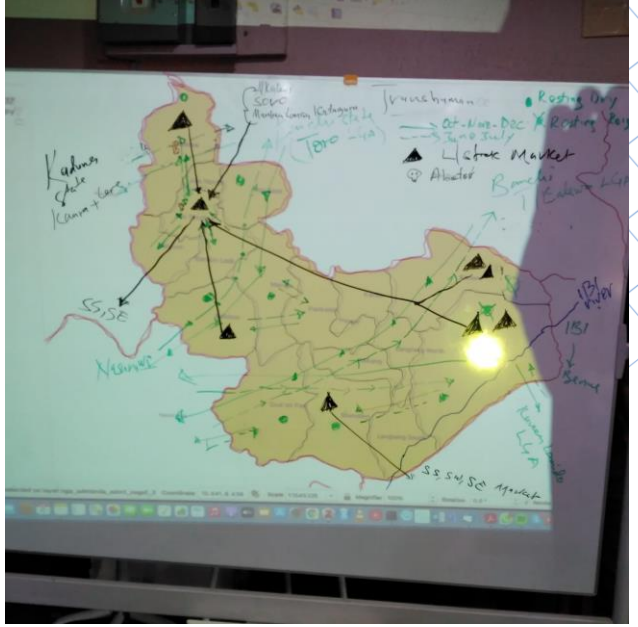
MARKET	LOCATION	RESPONDENT	HEADCOUNT
DEPARTMENT_M	DEPARTMENT_A	SELLER	500
DEPARTMENT_M	DEPARTMENT_B	BUYER	1000

ORIGIN	DESTINATION	HEADCOUNT
DEPARTMENT_A	DEPARTMENT_M	500
DEPARTMENT_M	DEPARTMENT_B	1000

Mobility data : where to find

Where to find (preliminary part):

- Bibliography
- Reports of Vet Services and/or statistical services
- Workshop with competent bodies/expert



National Movement (ad hoc activities):

- FGD :
  - Identify markets, value chain premises (expert)
  - Identify transhumant paths
- Survey at markets and/or along the value chain :
  - Where are you coming ? Where are you going ?
- Border points/ Transhumance on the way
- Veterinary services system records :
  - Official movement indicating path planned
- Animal identification system :
  - Contain all life of animal . Extract and aggregate

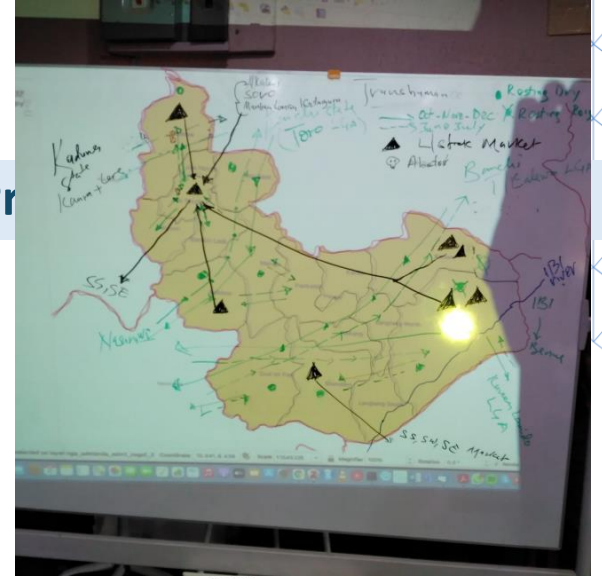
SURVEYS

Objective: Which target?

Type of movement	Data sources or assembly areas
International	FAOSTAT / UNCOMTRADE/ Statistics Office PIF / Azzalets, Veterinary posts, Regional inspections, Ports, Airports
Legal	*Markets, Sales outlets, Breeders* *Fattening centers, cooperatives, specialized companies (intensive breeding),* Slaughterhouses, Holding yards, Ports, Airports
	Veterinary posts, Regional Inspections
Illegal	*Maquignons, Farmers*, Illegal entry, Fines
	Breeders, Crossing points, Water points
Transhumant	

➔ We can also target more :

- By value chain
- By high-density zone
- On outbreak areas
- …

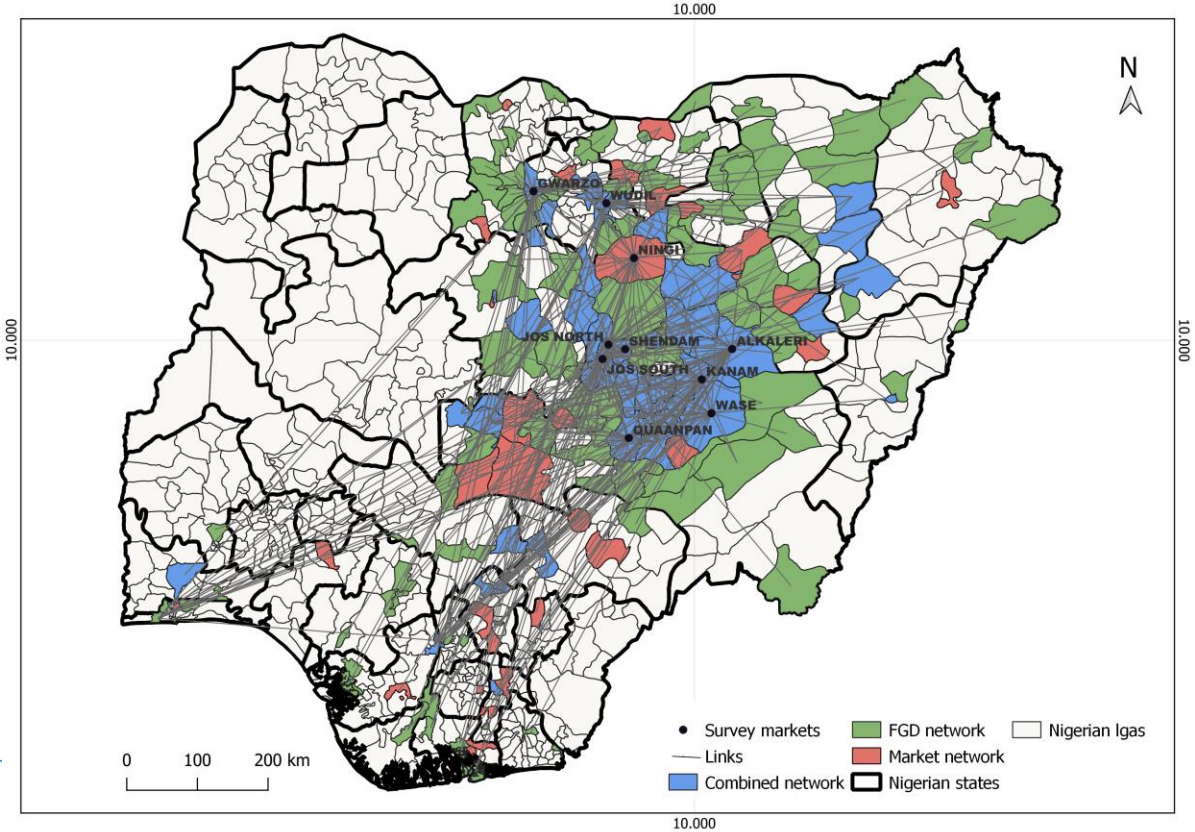


- **Combining Participative and and Ad-hoc activities**

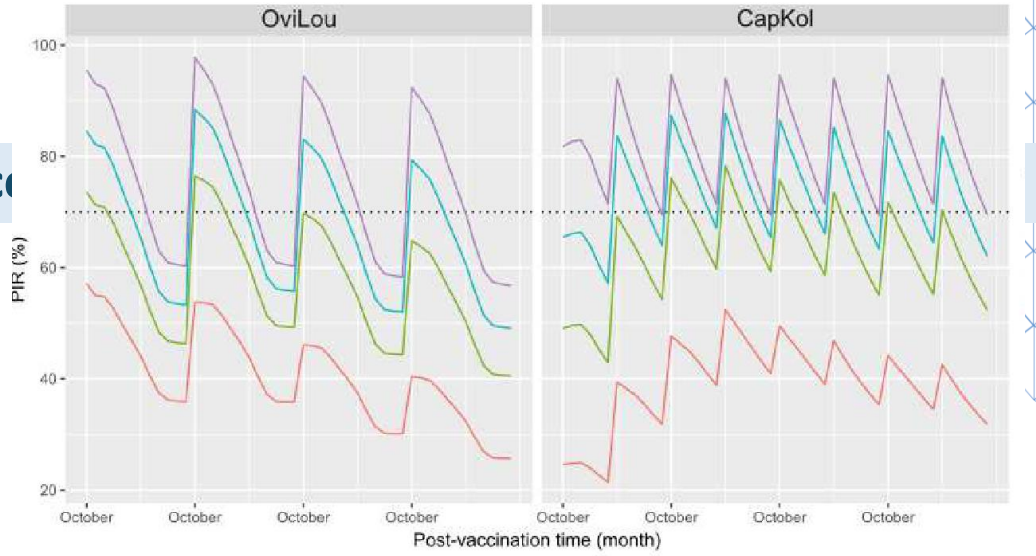
1) Focus Group Discussion with expert from 3 States (Bauchi, Kano and Plateau)
   - Reconstruction flows
   - Identification of 10 markets in3 states

2) Market activity:
   - Survey (1065 participants)
   - FGD with market operators

3) Data combination and analysis
   - Movement between 31/37 states
   - Discrepancies between FGD and market survey (66% in common)



Husbandry Practic



- **Define local and global dynamics**

1)Underline the movement dynamics: differences between production in steppe (Uzbekistan Tajikistan) and in temperate areas (Uzbekistan)

- Transhumance
- Fattening

2) Variation of contacts among herds

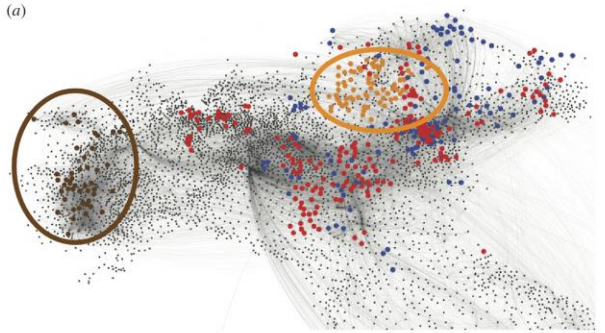
3) Size of herd

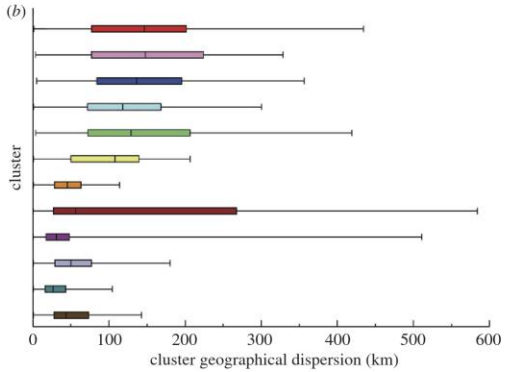
4) Herd's renewal ; migration; movement→ maintaining disease circulating:

- 1-2 picks of births
- Vaccination cadynamicsmpaign period

5) Using participatory calendar and mapping

Identif





- **Livestock identification required by GCES**

1)Identify origin of animals:

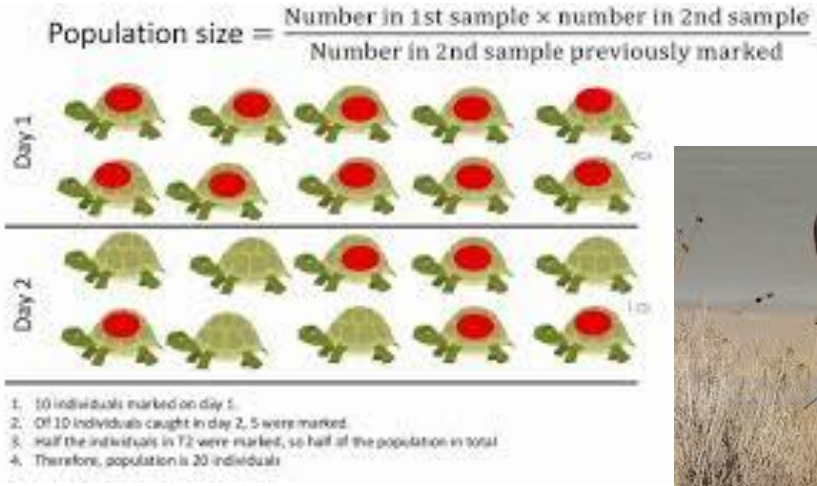
- Vaccination status
- Risk of introduction

2) Could help identifying mobility pattern a d could help redefining episisytem and surveillance control measure

- Depending on production chain , regular connections among premises

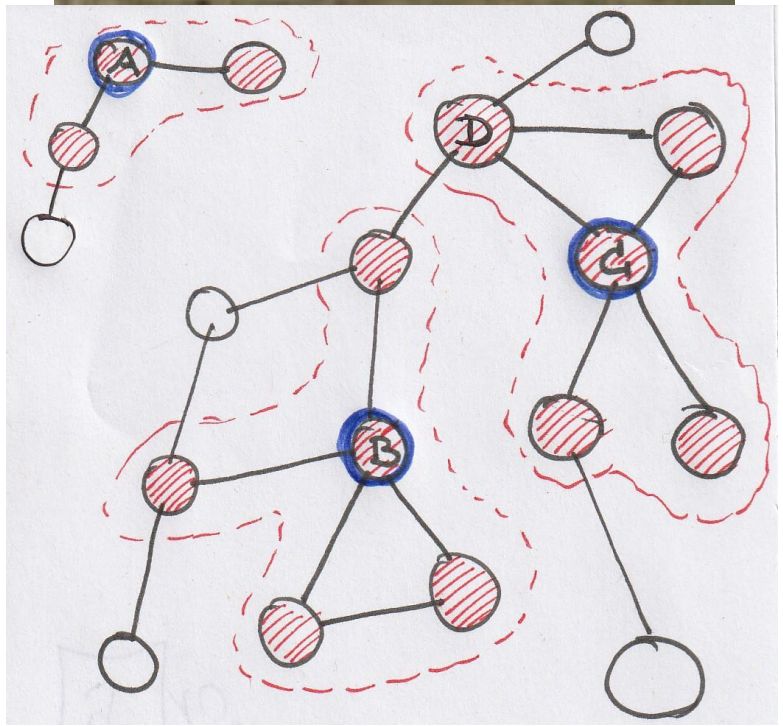
3) Important for wildlife:

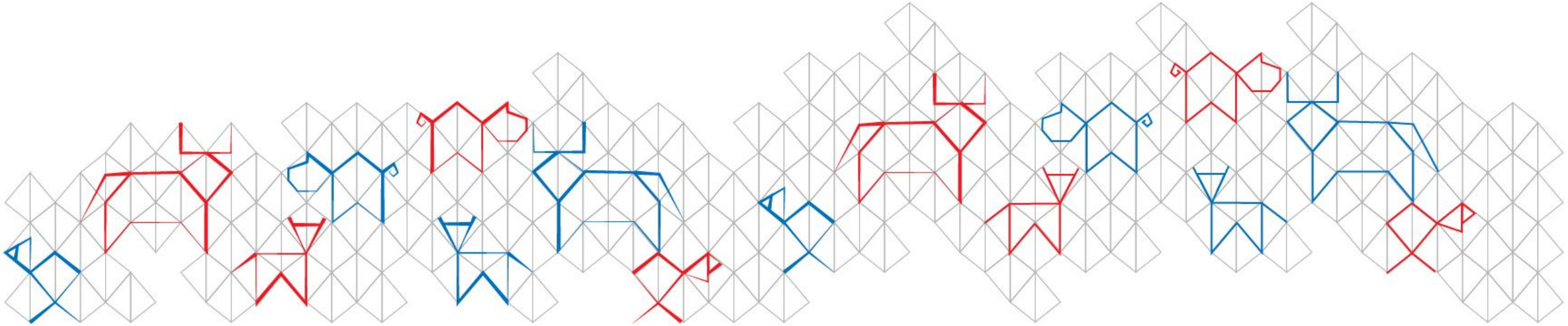
- Identify corridors
- Estimate population
- Estimate Prevalence using Capture



Conclusion

- *Mobility*
  - *one of the key factors to identify episystems and improve control and surveillance*
  - *pattern depends on several factors : environmental, social and economical*
  - *Variation in time are related to environmental changes ,but also to husbandry system*
  - *Use of participatory + network tools better collect data and describe mobility pattern*
- *Husbandry practices :*
  - *impact contact and dissemination at local scale*
  - *Impact flows of animals*
- *Animal identification*
  - *Useful for epidemiological considerations*
  - *Depending on the context could improve understanding of episisytem structure*





Thank You

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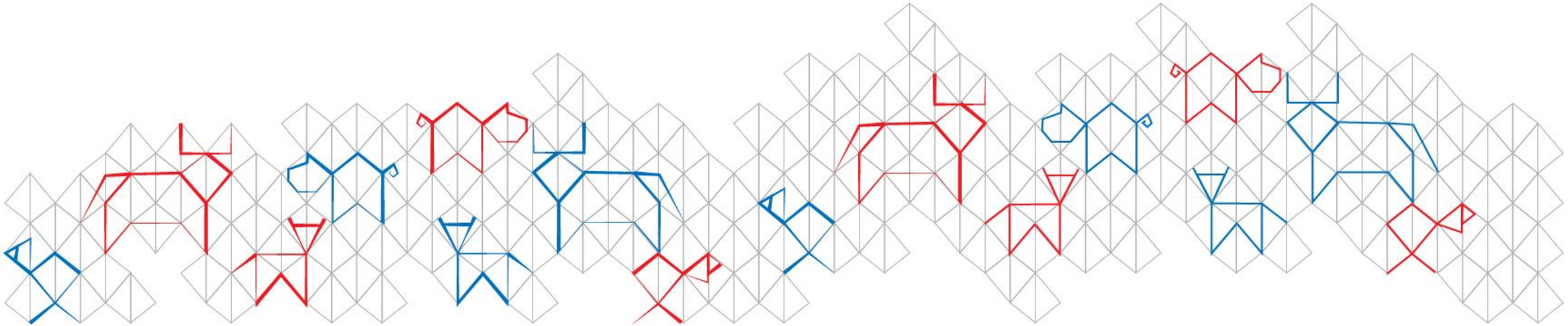
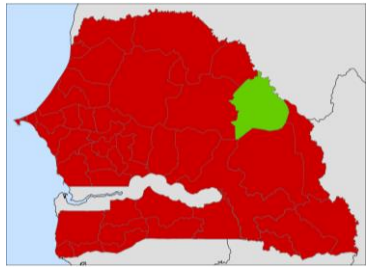
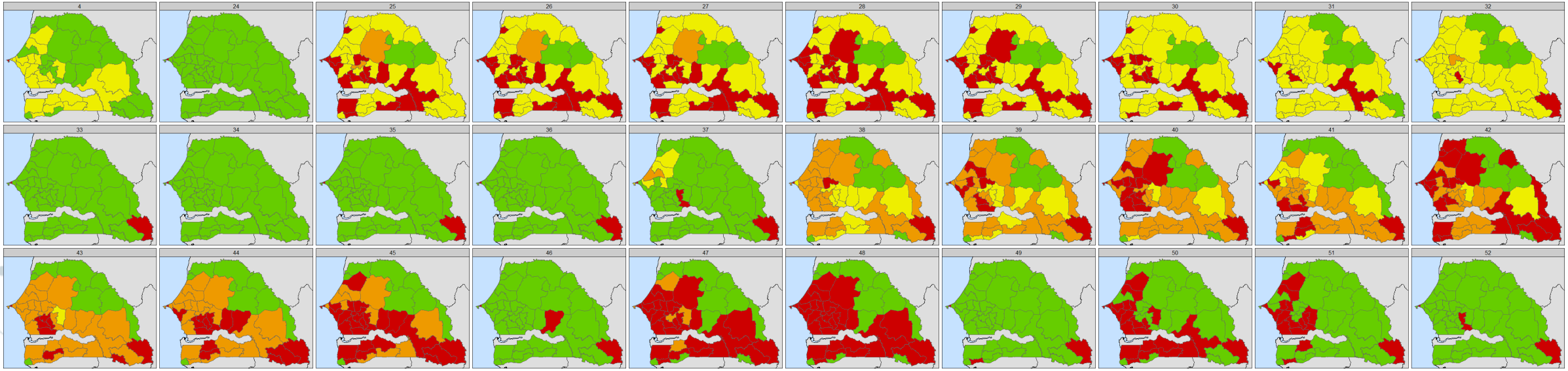


Comparison in terms of reachability and infection time: static network VS temporal network



- **Influence of temporality** on network structure and message passing
- **Static network** analysis **overestimates** reachability and infection time
- Most critical period: weeks before and around **Tabaski** and **Grand Magal of Touba**



Risk of epidemic

- The possibility of a disease to spread depends on the probability of transmission among animals (q) and the characteristics of the network
- Indicator R*: R_0 for network
- average value indegree/weight
- Certain nodes are more important to transmission than others:
- Importance of a node: removing a out-connection of a node and re-estimating