

# Using simulation to infer key parameters of the black rat colonization in Senegal during the elapsed century

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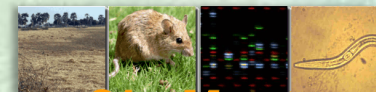
Laurent Granjon (rodent biologist)



# Q: how

do phenomena and processes hang together in the space of a century to explain the colonization of the black rat ?

Evolution of transport and networks



SimMasto

# Q: how do phenomena and processes hang together in the space of a century to explain the colonization of the black rat ?

- Human carriers (decision-making centers)
- Their vehicles
- Vehicle moves from one city to the other
- Black rat moves using vehicles
- Within the Senegalese transport networks,

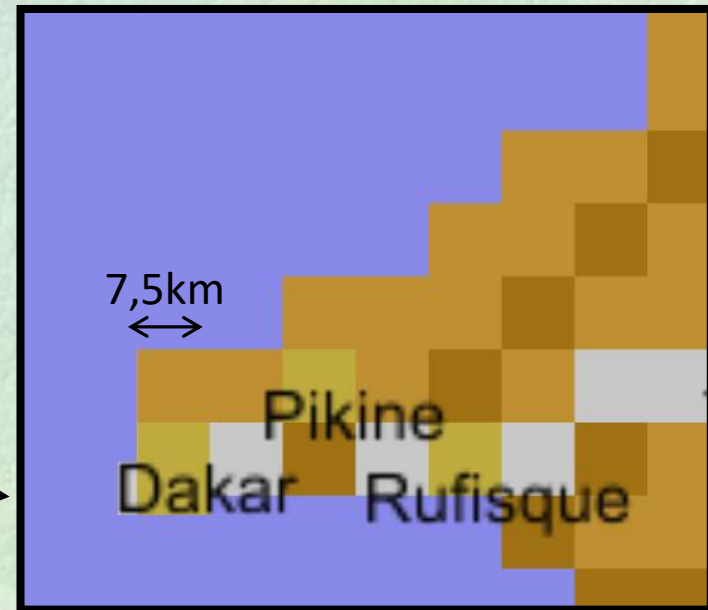


# Mechanistic computer model based on knowledge retrieval

Used for Reconstruction of transportation  
and commercial history of the human  
population in Senegal over the past century



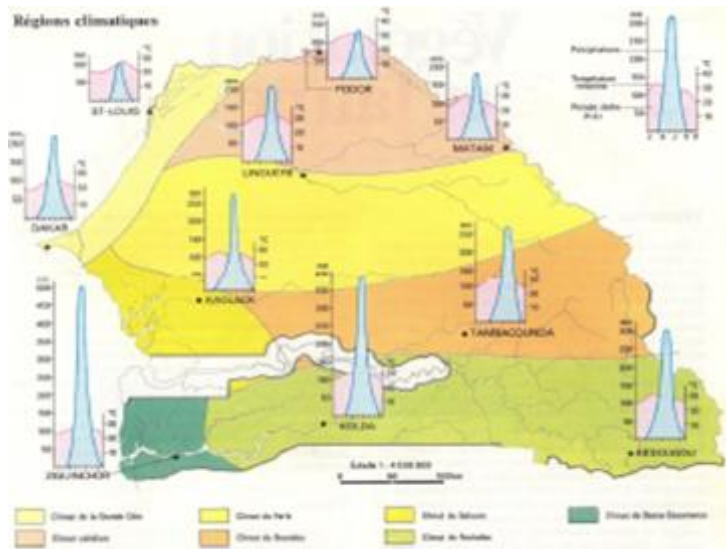
# Digitalization and re-construction of roads graphs



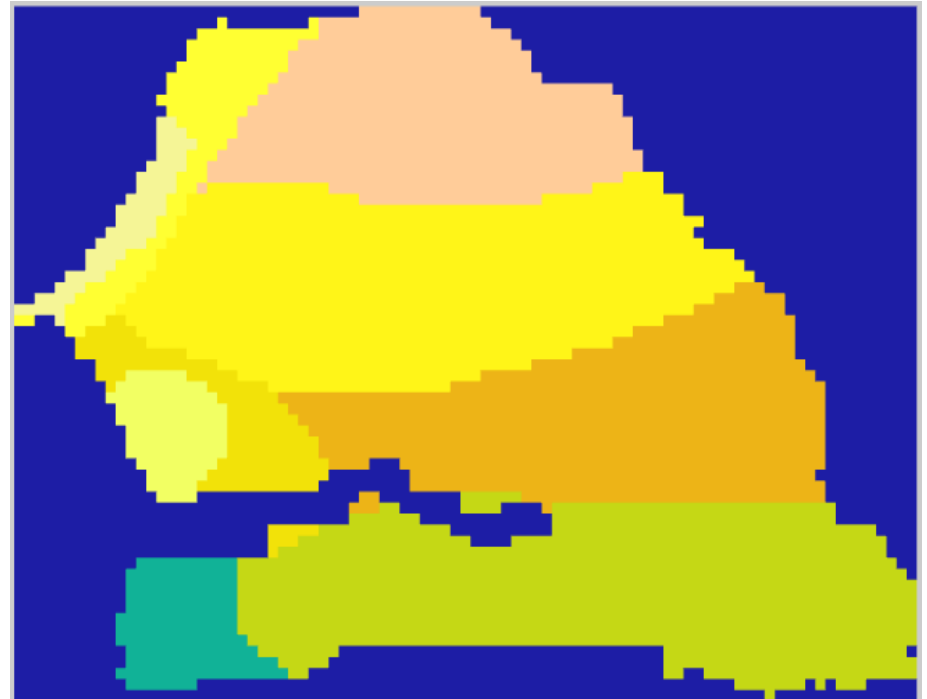
Level of resolution  
offered by the model

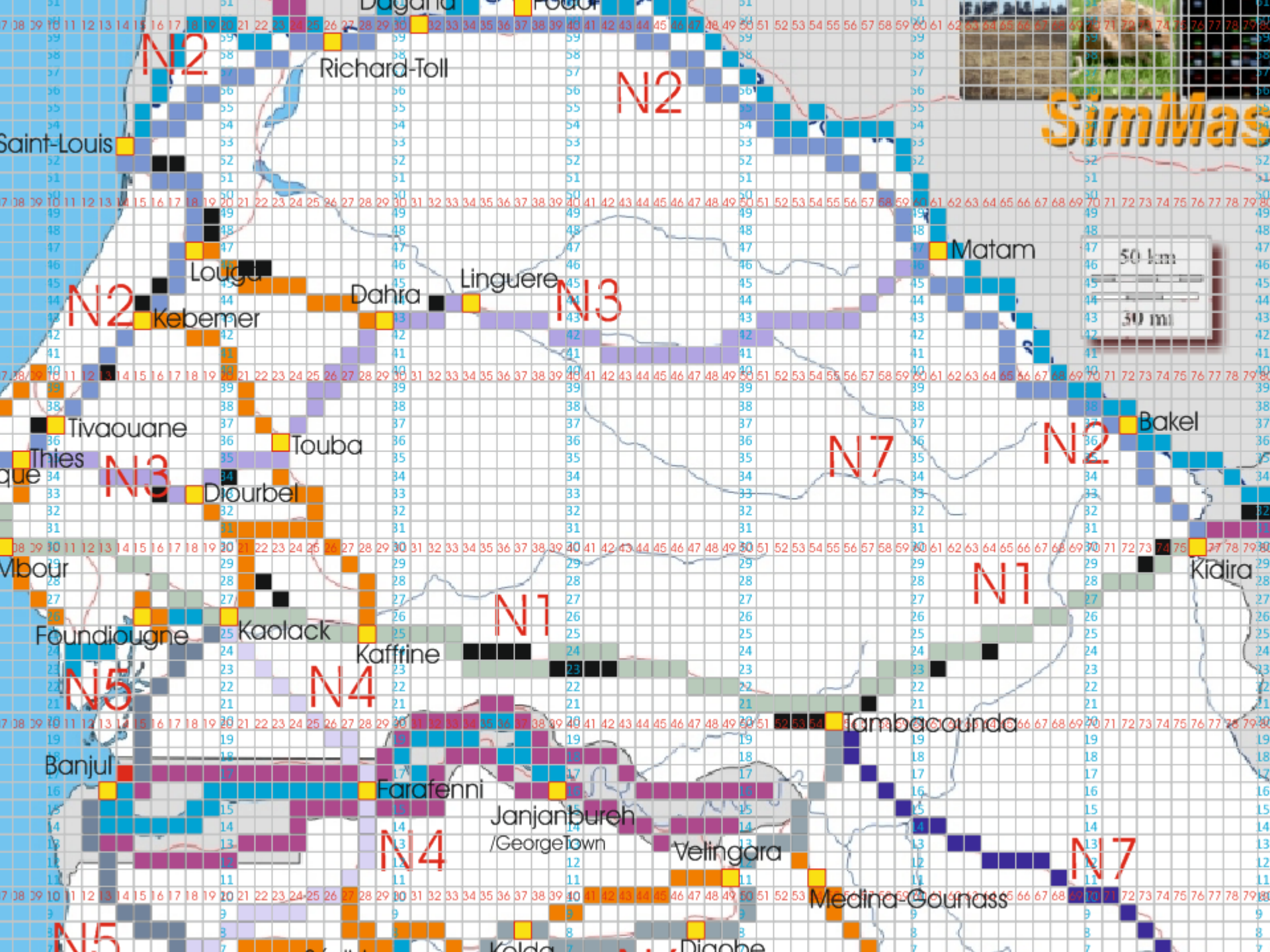
# Bioclimates digitalization (impact on reproductive performance of black rats)

**original**



**simulation**





# Chronology of asphaltting

Apparition de routes bitumées											
	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
3 Dakar Diourbel	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume
1 Dakar Kaolack	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume	bitume
2 Dakar Rufisque	piste	piste (1924)	bitume	bitume	bitume	bitume	bitume	bitume	bitume	bitume	bitume
8 Kaolack Gossas	piste	piste	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume
7 Kaolack Guinguinéo Mbar	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume	bitume	bitume
4 Kaolack Kaffrine Malem Hodar	piste	piste	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume
6 Kaolack Koungheul	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume	bitume	bitume
17 Kaolack Ziguinchor	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume	bitume
5 Malem Hodar Tamba	piste	piste	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume
13 Mekhe Bambey Fatick	piste	piste	piste	piste	piste	piste	piste	piste	piste	bitume	bitume
16 Podor Bakel	piste	piste	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume
10 Saint-Louis Rosso	piste	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume
15 Tambacounda Kedougou	piste	piste	piste	piste	piste	piste	piste	piste	bitume (1996)	bitume	bitume
14 Tambacounda Kidira	piste	piste	piste	piste	piste	piste	piste	piste	piste	bitume	bitume
11 Thies Mboro / Kayar	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume
9 Thiès Saint-Louis	piste	piste	piste	piste	piste	bitume	bitume	bitume	bitume	bitume	bitume

↑  
Road stretch

1910

2010



DIRT TRACK

TARRED ROAD





# Vehicles fleet evolution

- railways

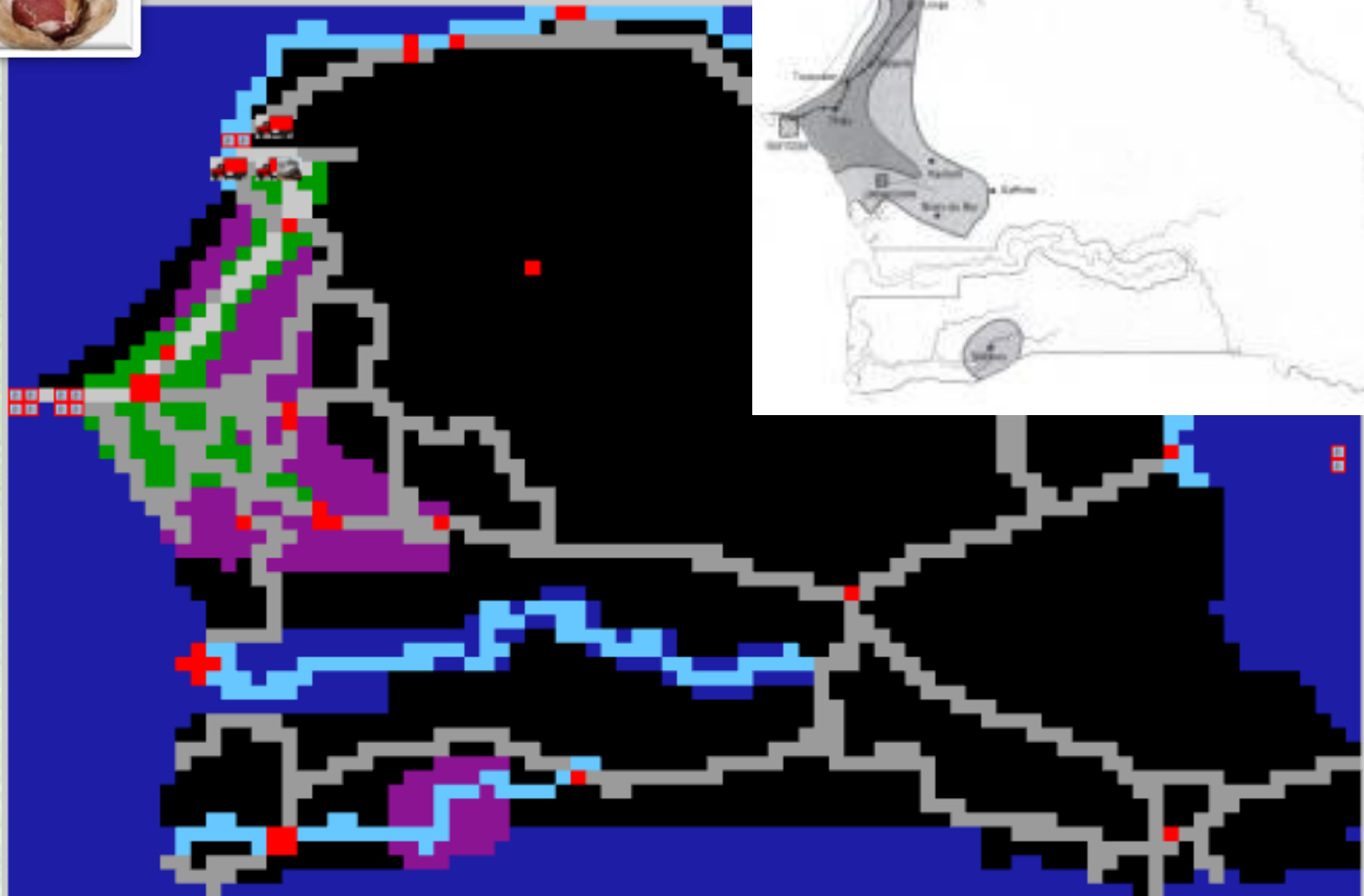
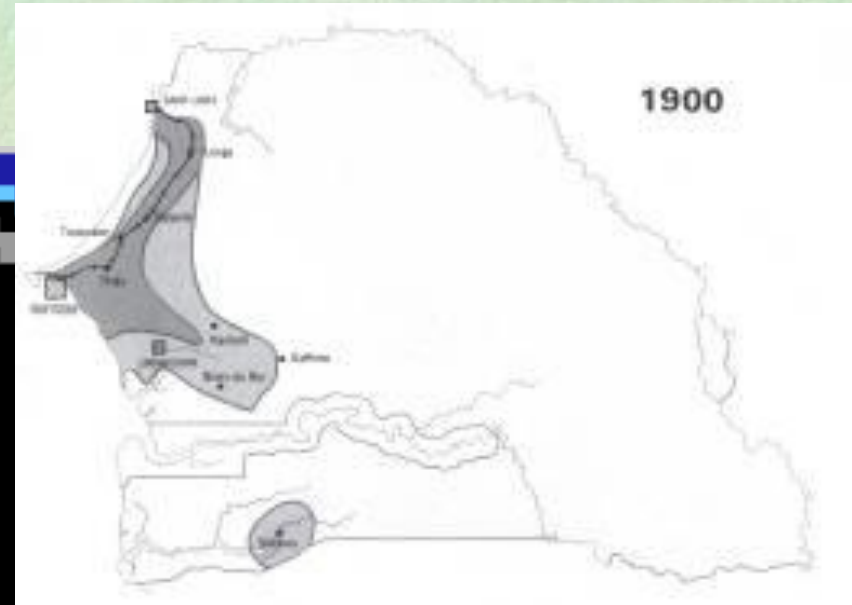


- River boats

- truck fleet

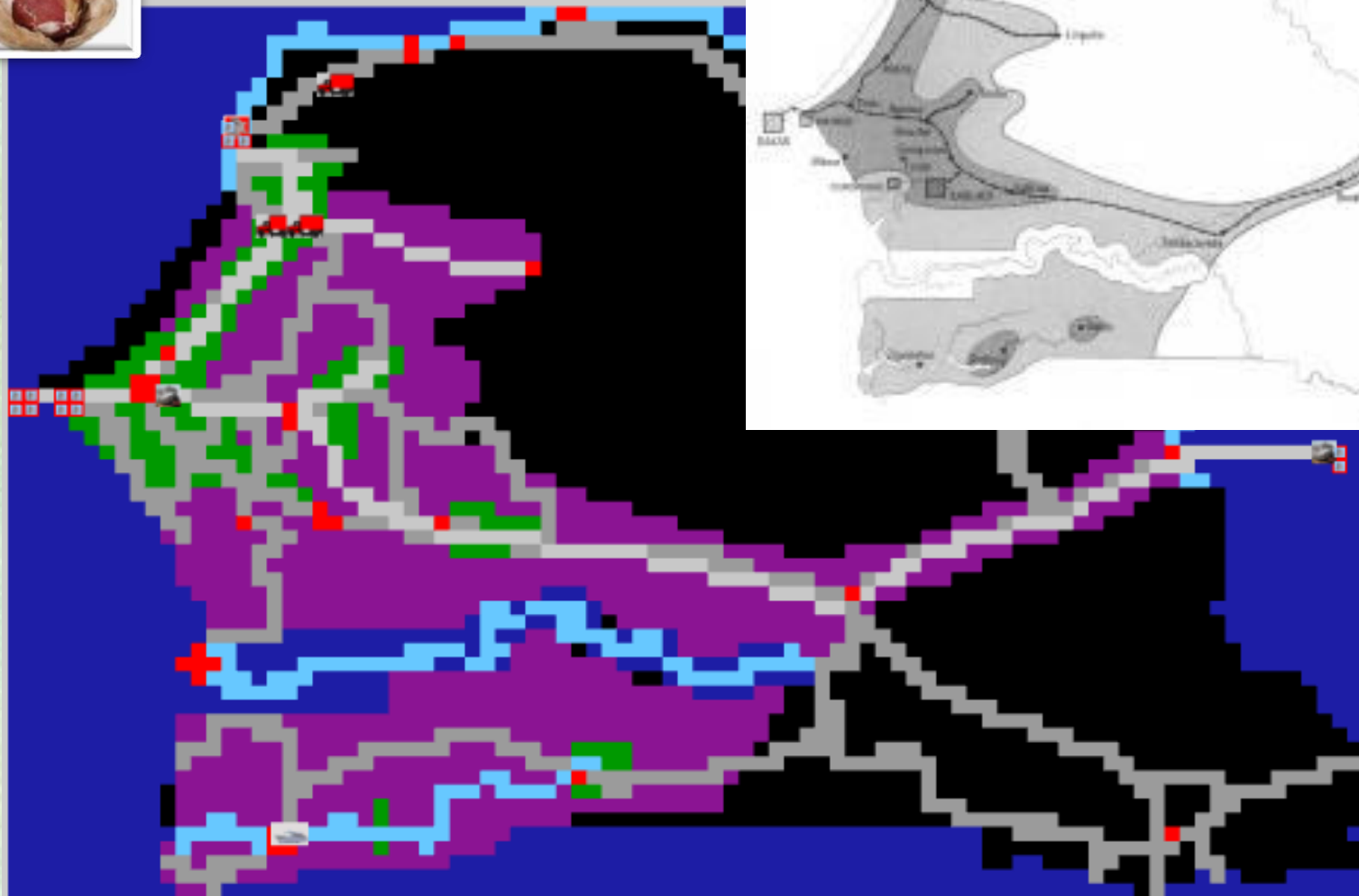
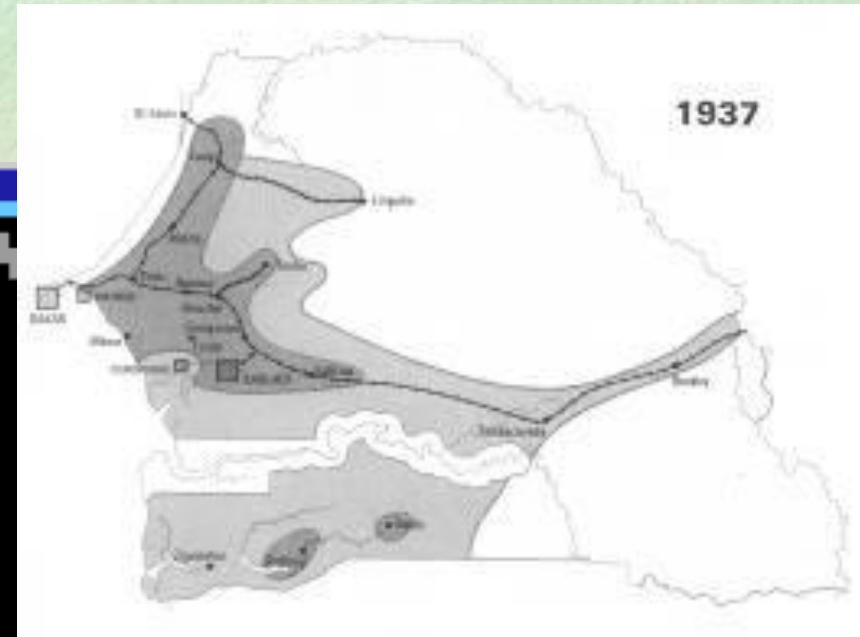


# Integration of groundnut trade evolution 1910



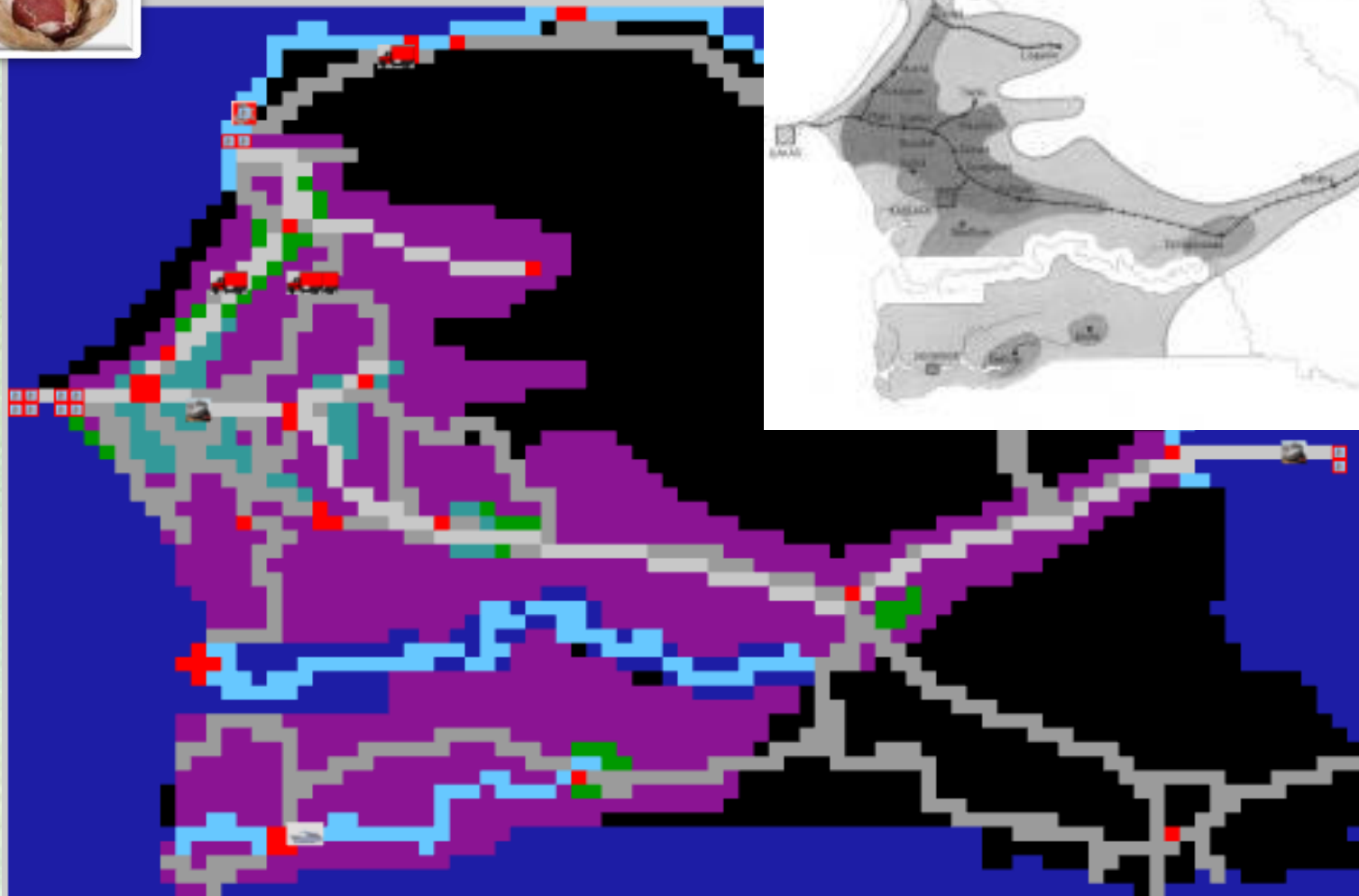
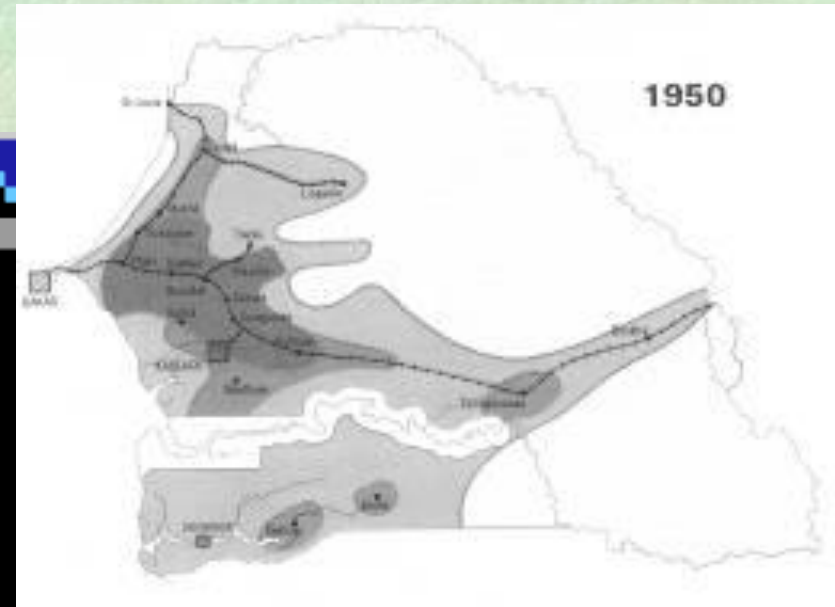
+ Mersadier 1956, Lericollais 1983, Freud 1997

# Integration of groundnut trade evolution 1937



+ Mersadier 1956, Lericollais 1983, Freud 1997

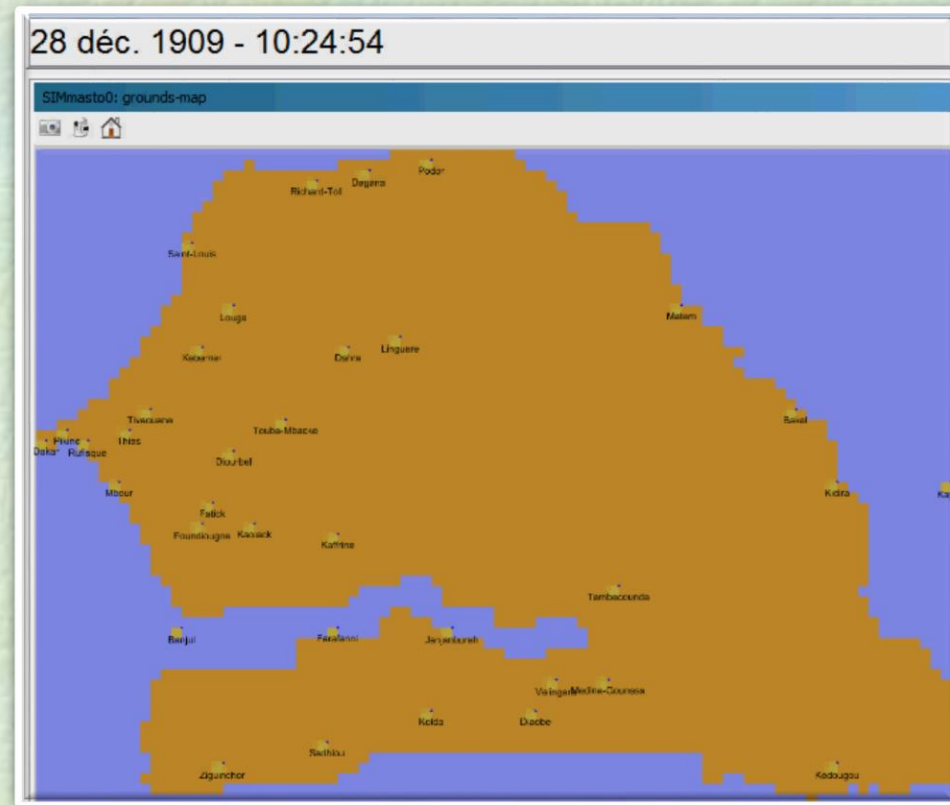
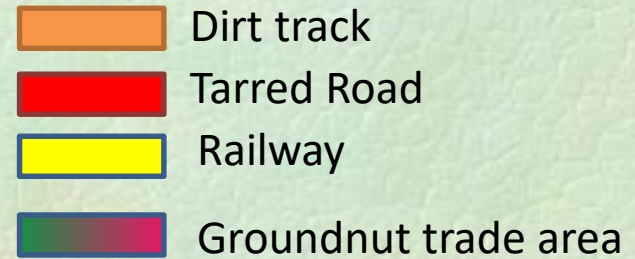
# Integration of groundnut trade evolution 1950



+ Mersadier 1956, Lericollais 1983, Freud 1997

# Realization of a historical timeline of transportation in Senegal over a century

- 5447 events concerning :
  - Landscape changes
    - CITY
    - RIVER
    - DIRT TRACK
    - ROAD
    - RAIL
    - GROUNDNUT TRADE WEAK
    - GROUNDNUT TRADE MEDIUM
    - GROUNDNUT TRADE HEAVY
  - Human carriers fleet
    - TRUCK
    - TRAIN
    - BOAT
  - Populations
    - RAT
    - POPULATION



# Simple activity processes of the agents



1. Human carriers choose their destination depending on :
  1. Cities sizes (gravitatory model)
  2. The type of circuit they were attributed (commute, groundnut trade area, all over the country)



## 2. Black rats 'reproduce'

1. If they find partners experiencing mate  
*The life cycle (maturity, reproduction, pregnancy ...) is formalized*
2. up to the human population of the localities

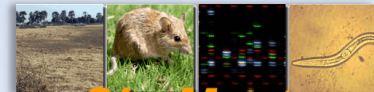
They try to invest a vehicle,

1. If they perceive it,
2. If they have never been loaded

**Daily simulation of each agent over a century -> 36,525 decisions / individual actions in different contexts and in a changing environment -> complex patterns**

# Implementation

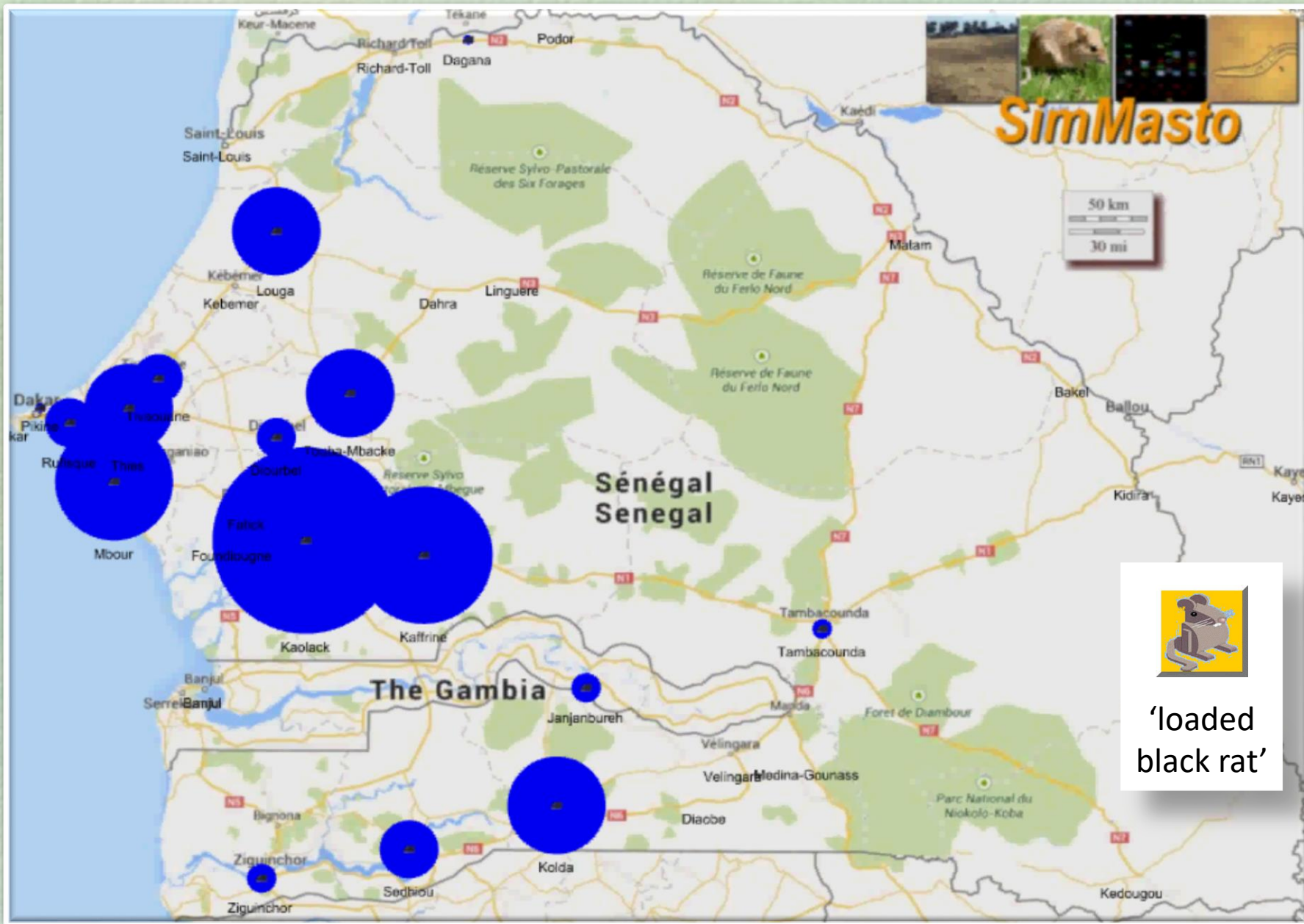
Simulation of the history of commercial transport and colonization of the black rat over a century



**SimMasto**



# Evolution of trade distribution (demo: by day then by min.)



11 : Trafics Journaliers Moyens Annuels (JMA) :  
 Campagne nationale de comptage et d'enquêtes origine - destination.  
 Ministère de l'équipement et des transports terrestres / GIC, 1996

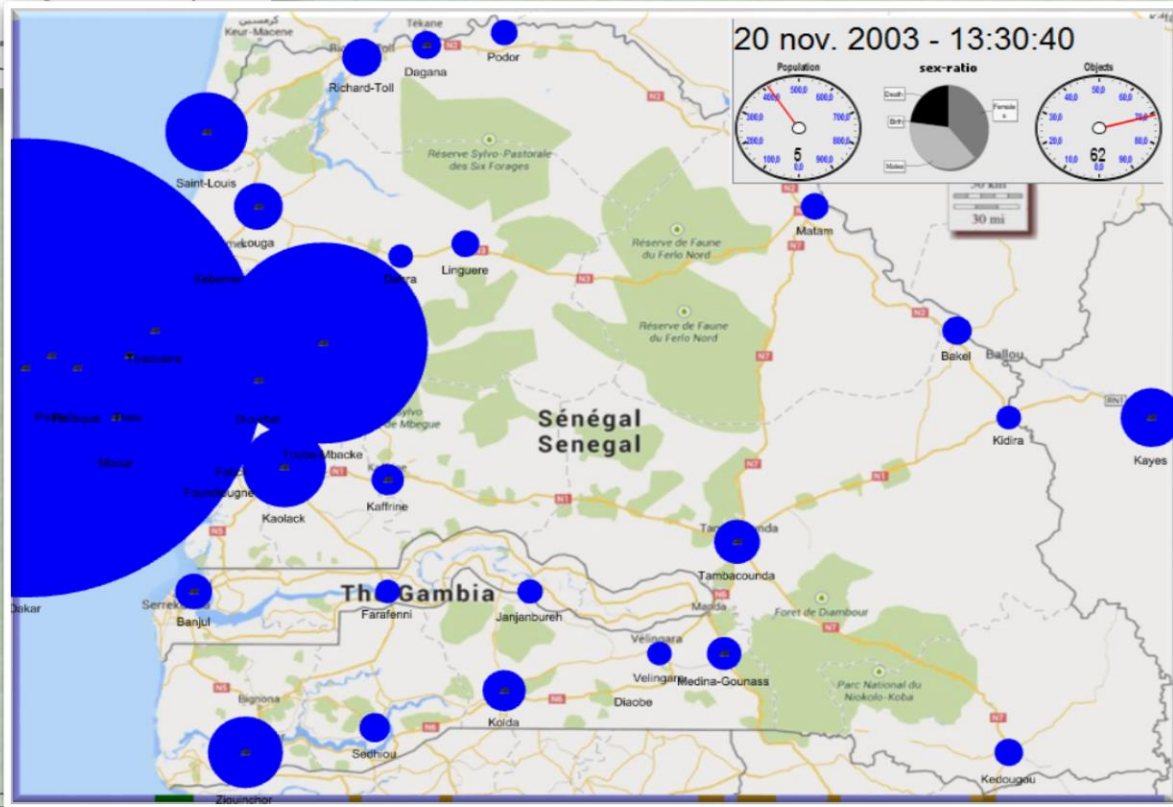


Carte 11 : Trafics journaliers moyens annuels (GIC, 1996)

Carrier distribution is close to observation

Average annual daily Transport (Ninot, 1996)

Relative number of carriers parked by locality



reconstruc

# Distribution of simulated rodents

1930-1990: Expansion of overland trade



Hubert et al 1973,  
Duplantier et al, 1991

Not viable; a couple at least (or a pregnant female) is needed for the establishment of a population

1970



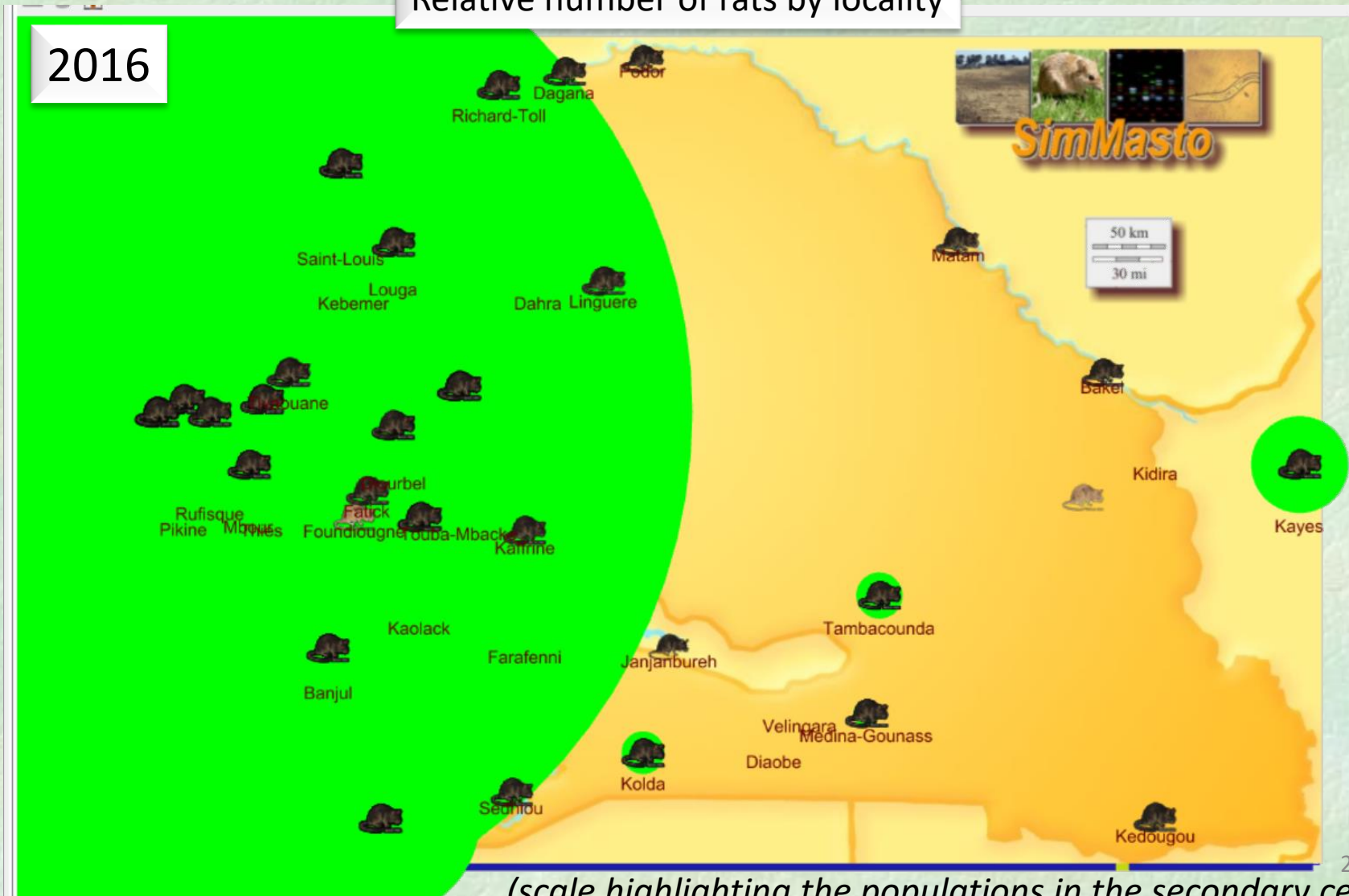
Isolated rodent

Established population

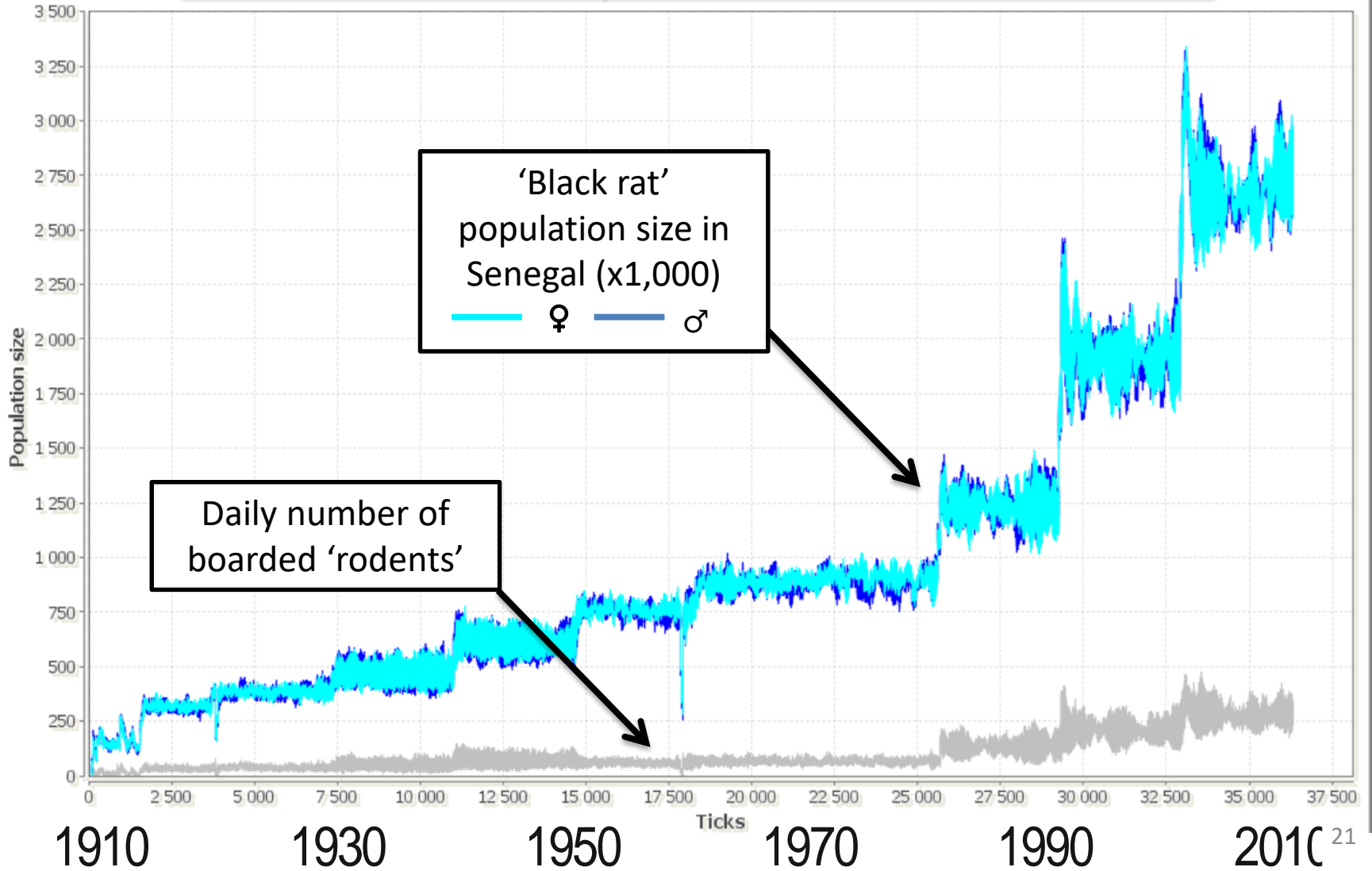
# Senegal's reality : supremacy of Dakar

The general phenomenon resulting is spreading of a proliferating source population in the remaining of the country

Relative number of rats by locality

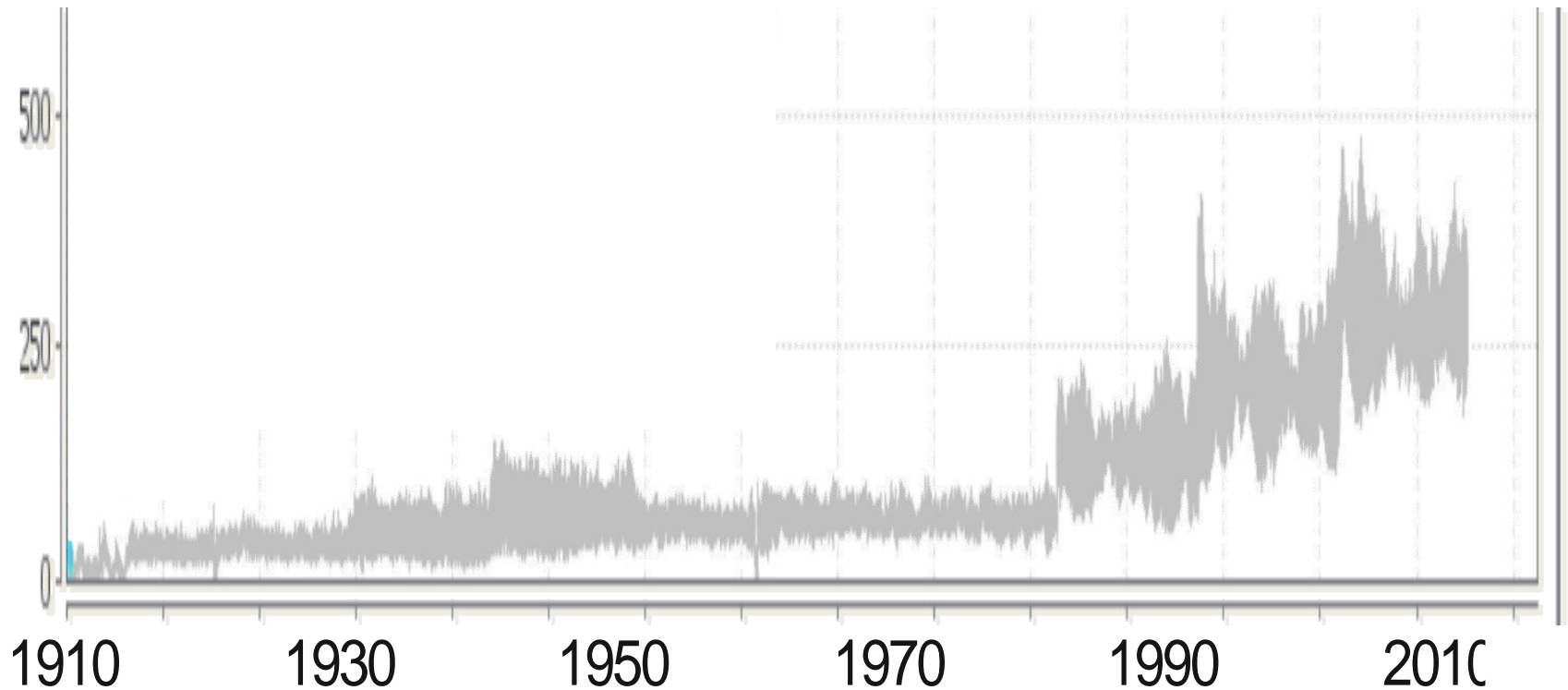


# Black rat population dynamics over the century



**Evolution of the population of rodents is congruent with that of the human population**

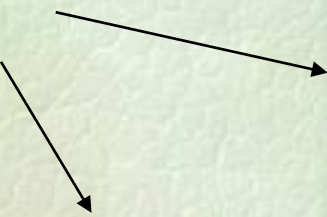
## Daily number of boarded 'rodents'



Loading varies as a combination of trading area changes, fleet dynamics, black rat population establishment and human population growth

# Using the model to decipher an unknown parameter :

## What are the chances of black rat boarding when faced to a vehicle ?



Prob. loading success = 0,6; 0,7; 0,1; .0001 ?



Prob. loading success = 0.0000000001 ?

# Sensitivity analysis of the black rat boarding probability

Selected values :

1/100

1/1,000

1/10,000

1/50,000

1/100,000

1/500,000

1/1,000,000

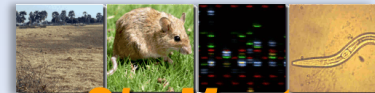
1/2,000,000

1/5,000,000

1/10,000,000

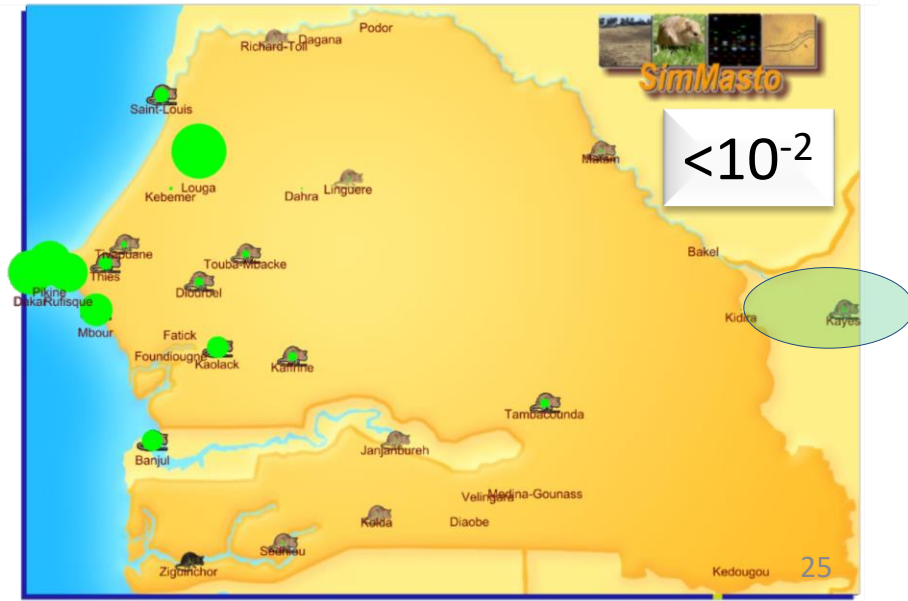
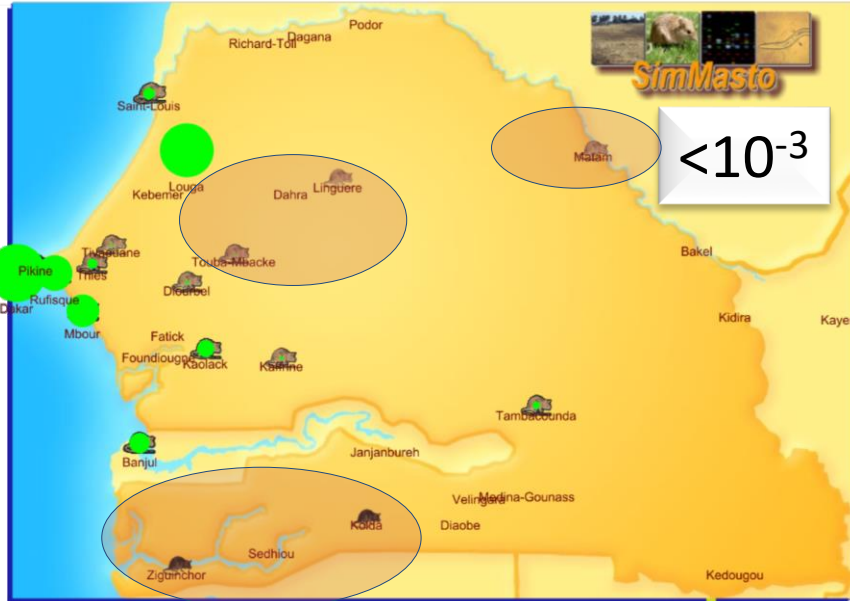
1/50,000,000

1/100,000,000

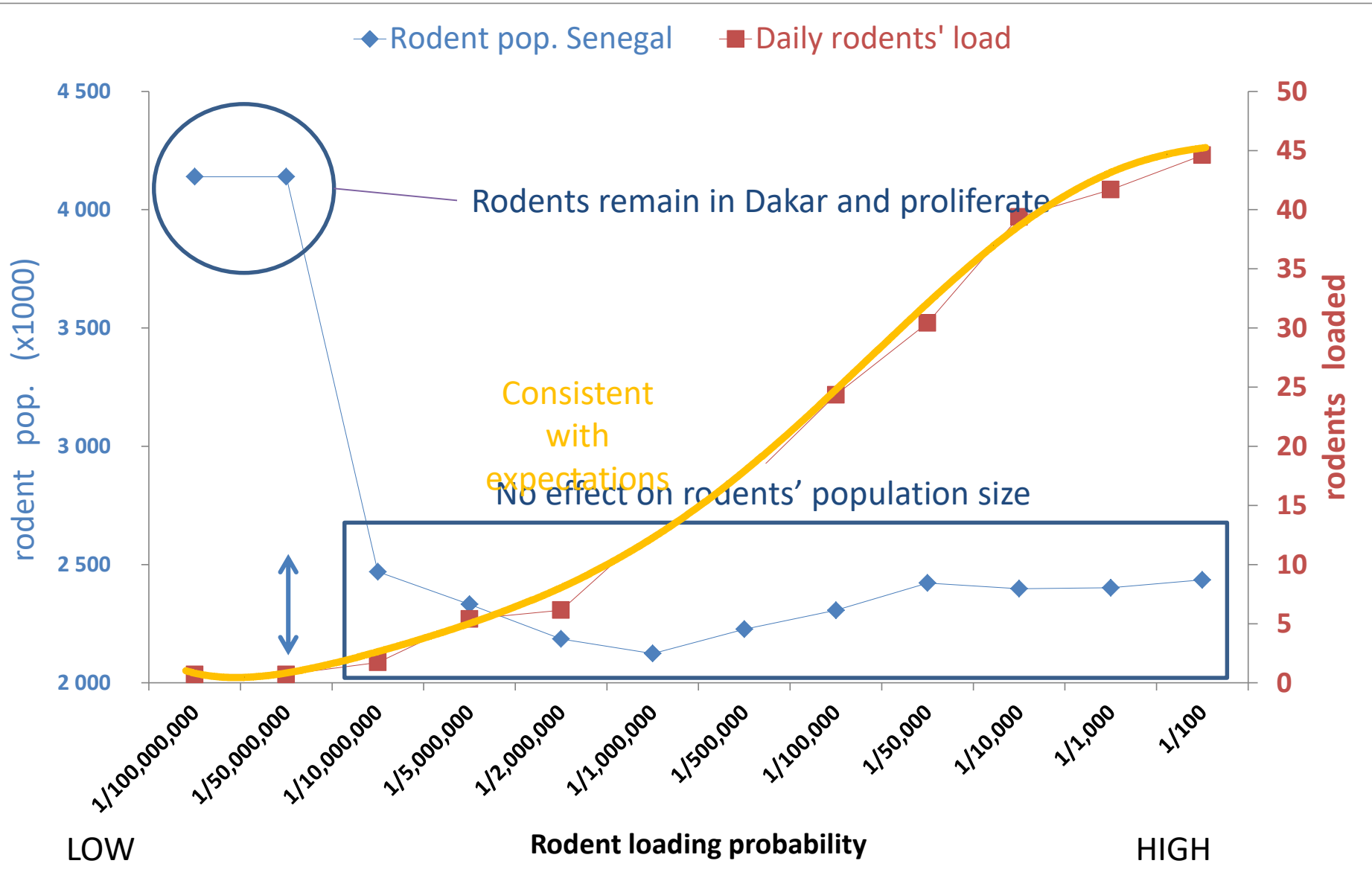




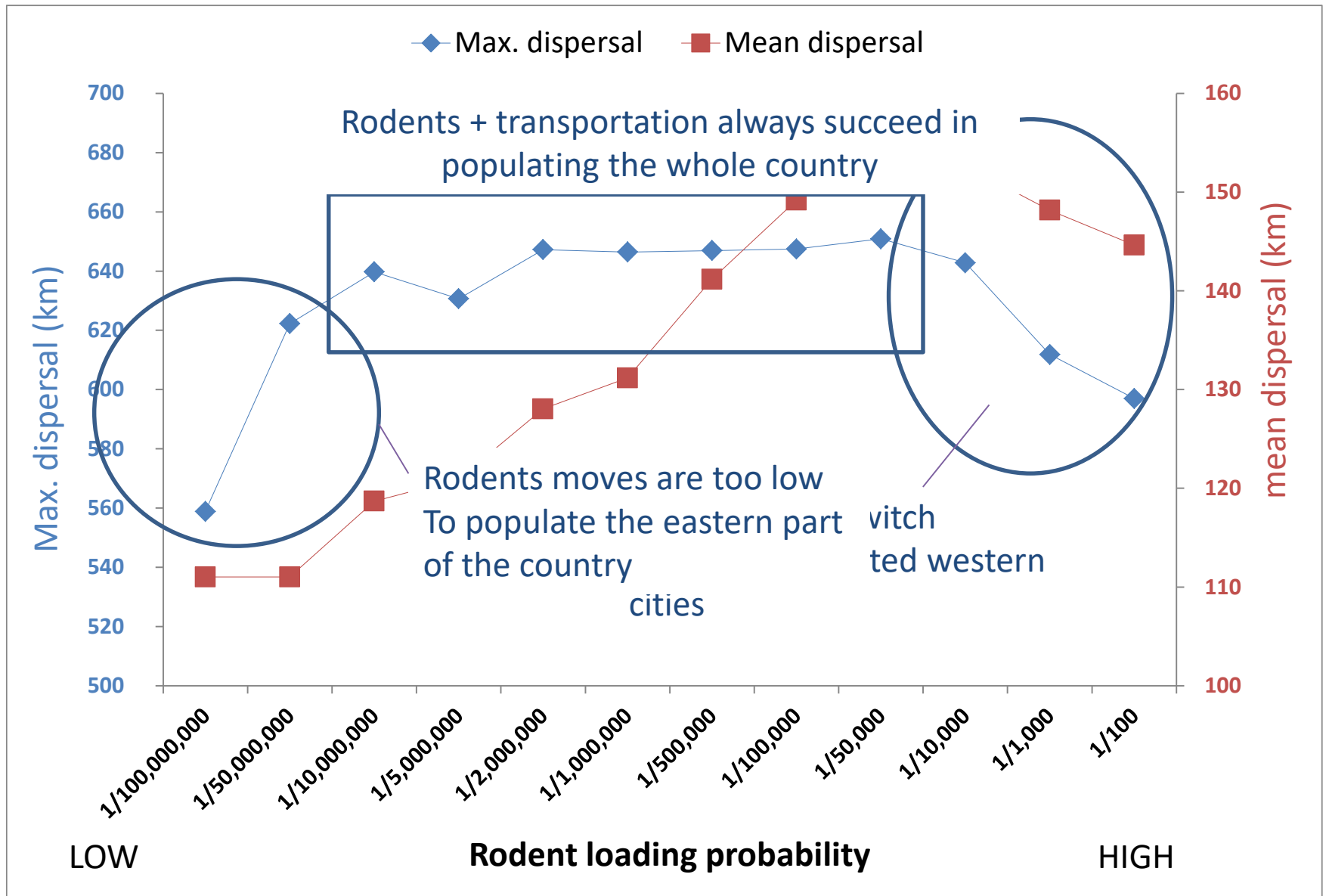
# Simulation state on 1<sup>st</sup> april 1950 with different values (arbitrarries) of prob(boarding/opportunity)



# Mean results for the last year of the century simulated



# Mean results for the last year of the century simulated

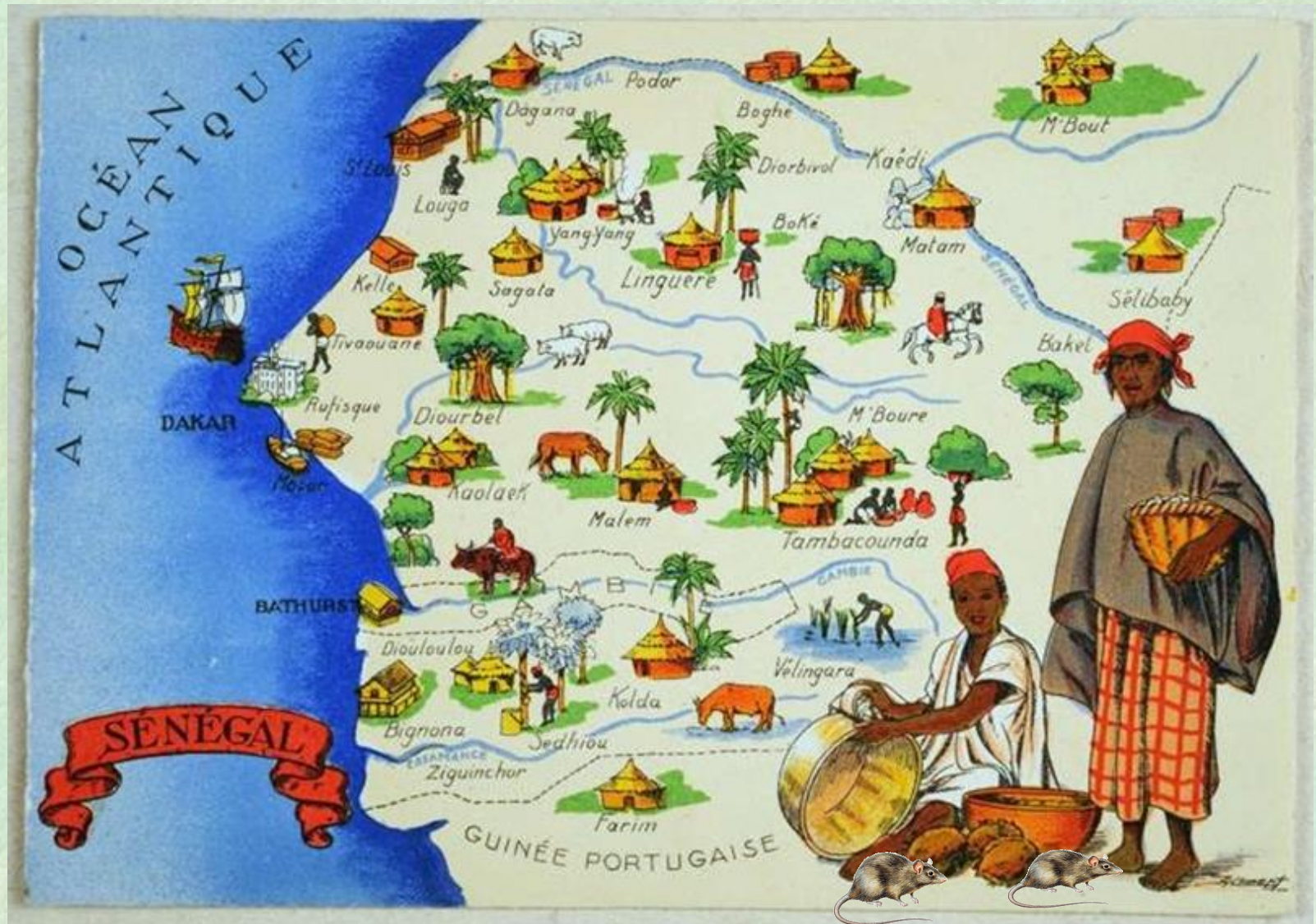


# Some conclusions

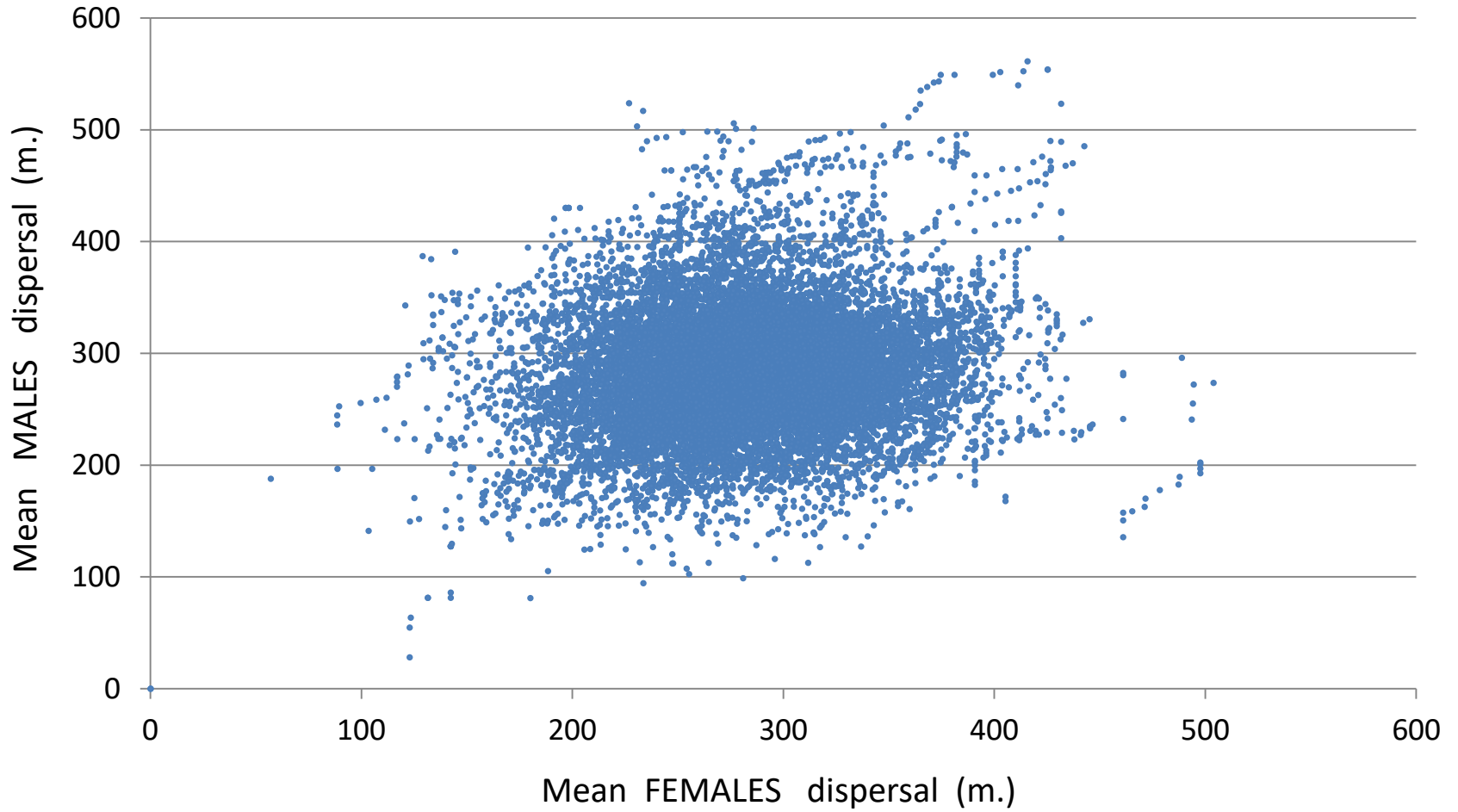
## ! drawn from this exploratory model

- Even with low loading probability, the tremendous number of events occurring counteract and always leads to invasion of the country by the black rat
- The extreme values of loading probabilities may be ruled out and hence (begin to) provide a plausible magnitude for the loading probability (*e.g.*, between  $1E-6$  to  $1E-3$  ?)
  - Indeterminacy of what is occurring within cities impedes the validation of this assessment (see *e.g.*, Fossati et al.) .
- Loading varies as a combination of trading area, fleet, rat population and human population level
- The model is not valid (☺) since recent surveys suggest that the black rat population is decreasing instead of spreading
  - The main drivers to this situation could be competition with new invasive house mouse and changes in the cities structure (not accounted for).

Thank you for your kind attention

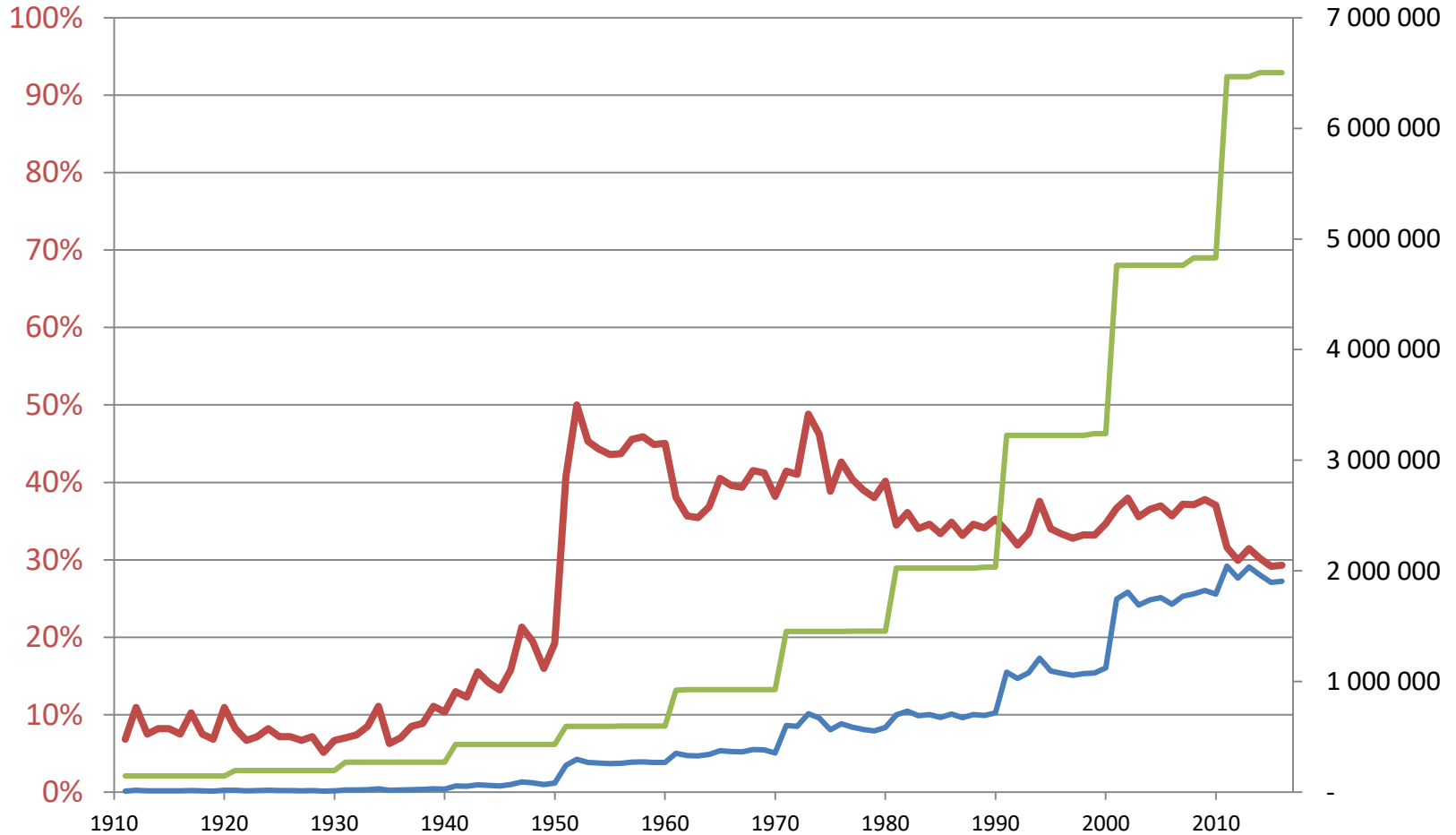


# VARIABILITY OF RODENTS MOVES WITHIN A SINGLE CITY ("daily sampling")



**Prob. load = 1/2.000.000 - "yearly sampling"**

— occupation rate (left scale)    — Rodent pop. Senegal (right scale)    — Hum. Pop Senegal (right scale)



# Relationship with the size of the fleet

