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# Comparer et modéliser l'utilisation des sols dans les aires métropolitaines espagnoles

Maxime Lenormand

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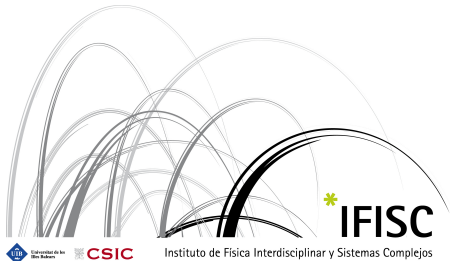
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# Comparer et modéliser l'utilisation des sols dans les aires métropolitaines espagnoles

**Maxime Lenormand**

12èmes Rencontres de Théo Quant, Besançon

22 mai 2015



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Instituto de Física Interdisciplinar y Sistemas Complejos



**Govern de les Illes Balears**  
Conselleria d'Educació, Cultura i Universitats



**Innovative**  
Policy Modelling and Governance Tools  
for Sustainable Post-Crisis Urban Development



Universitat de les Illes Balears

**CSIC**

# Motivation

## Comparer l'organisation de l'utilisation des sols dans les villes

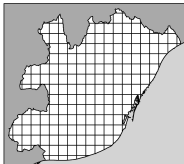
- ▶ Approche réseau pour détecter les différents types d'activités en utilisant des données de téléphones portables
- ▶ Organisation spatiale (entropie, K de Ripley...)
- ▶ Modèle d'utilisation des sols
- ▶ Mélange d'utilisation des sols



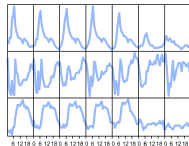
# Méthode utilisée pour extraire le réseau



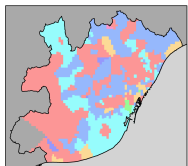
**Metropolitan Area**



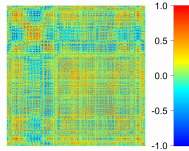
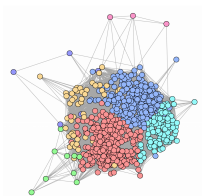
**Recordings sites**



**Time of Day  
Signals**



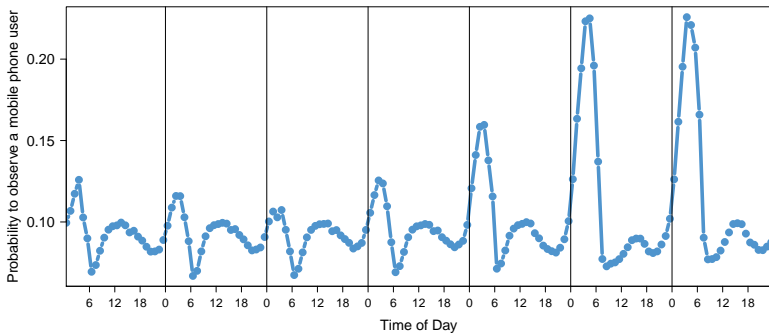
**Functional Network**



**Correlation Matrix**

# Méthode utilisée pour extraire le réseau

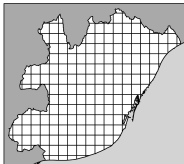
Probabilité d'observer un utilisateur de téléphone portable dans une cellule donnée à un temps donné



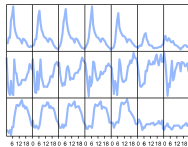
# Méthode utilisée pour extraire le réseau



**Metropolitan Area**

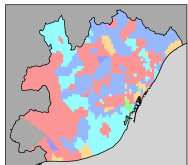


**Recordings sites**

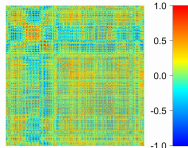
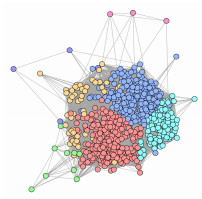


Time of Day

**Signals**



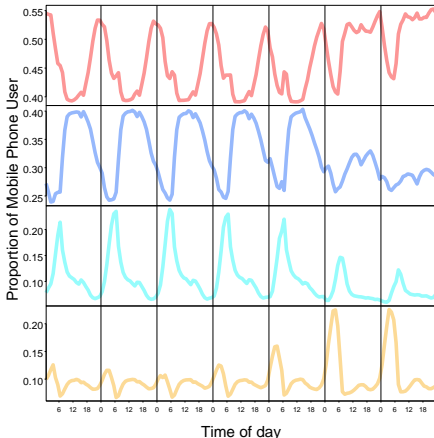
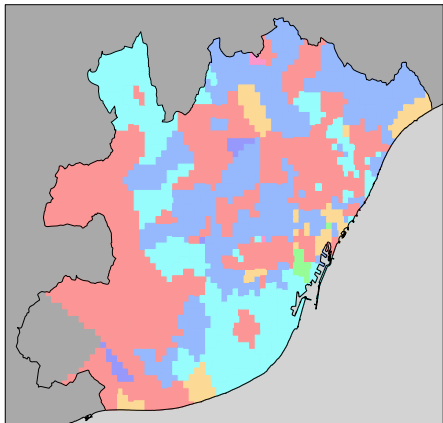
**Functional Network**



**Correlation Matrix**

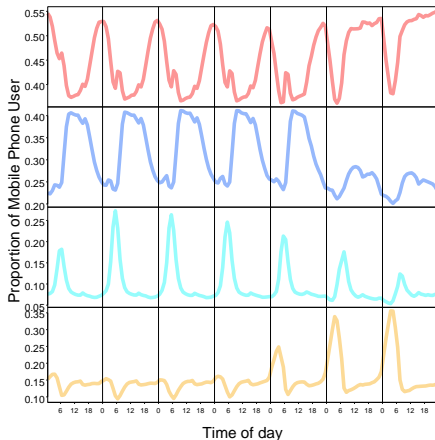
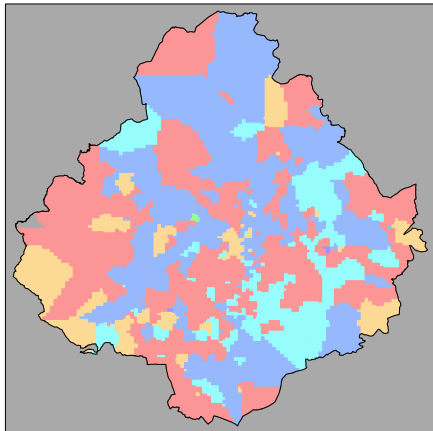
# Type d'utilisation des sols

## Barcelona (PGP = 60%)



# Type d'utilisation des sols

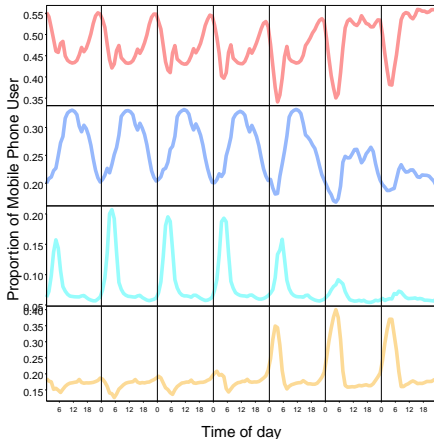
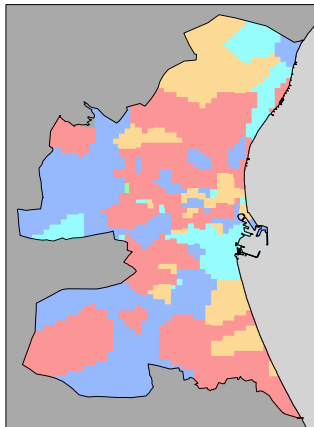
**Madrid (PGP = 65%)**





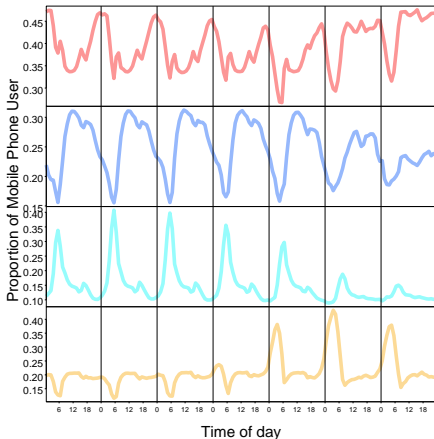
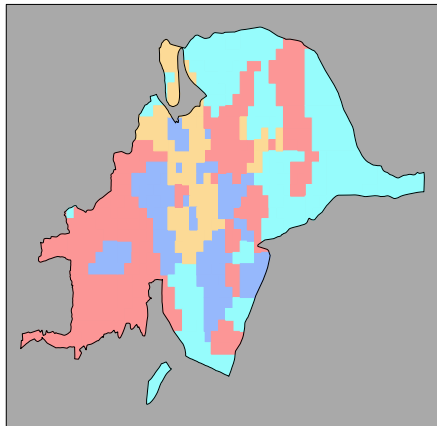
# Type d'utilisation des sols

## Valencia



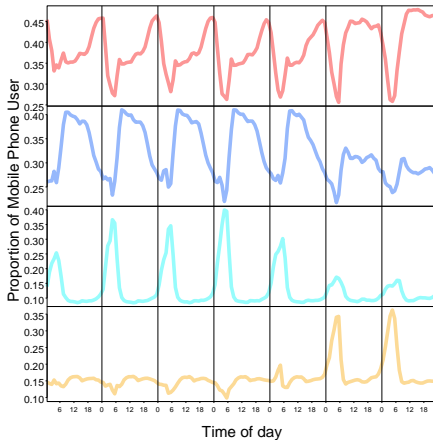
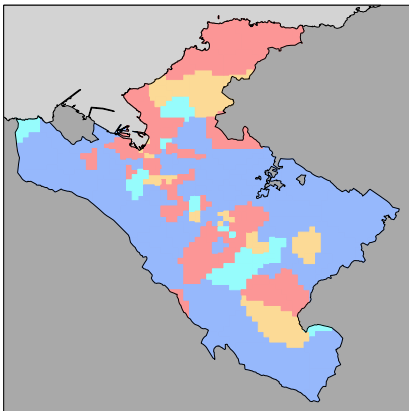
# Type d'utilisation des sols

## Sevilla



# Type d'utilisation des sols

## Bilbao



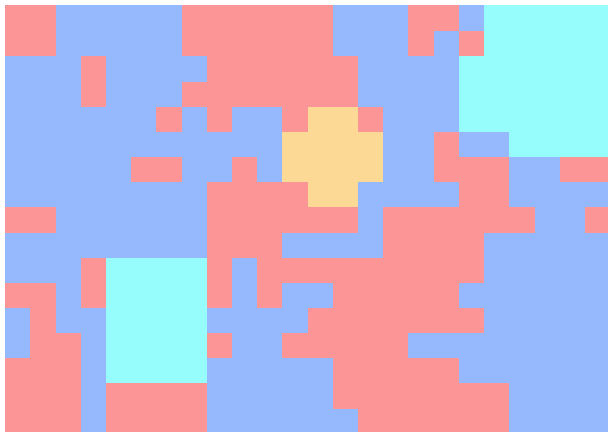
# Organisation spatiale

## Trois mesures pour mesurer l'hétérogénéité spatiale

- ▶ Distribution de la distance entre les cellules et le centre ville
- ▶ K de Ripley
- ▶ Entropie

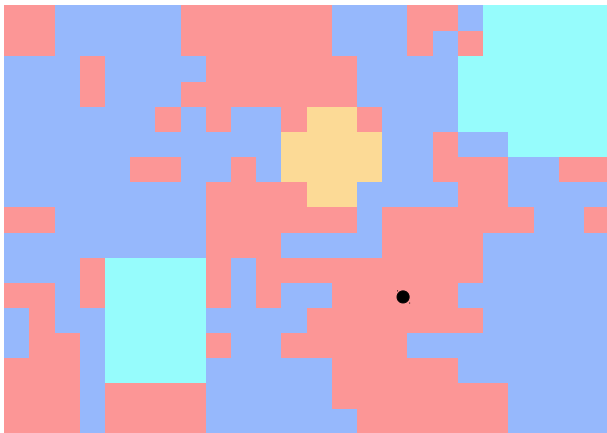
# Organisation spatiale

## Distance au centre ville



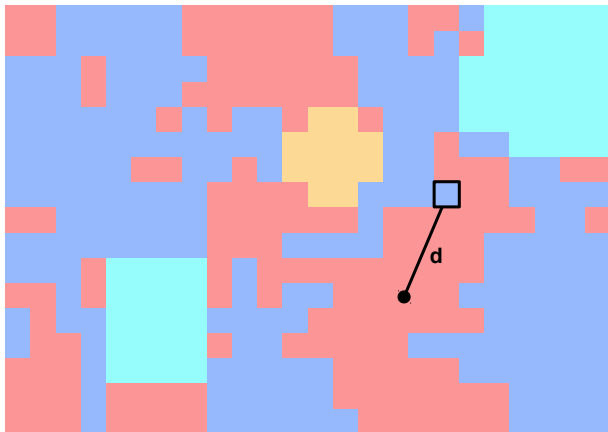
# Organisation spatiale

## Distance au centre ville



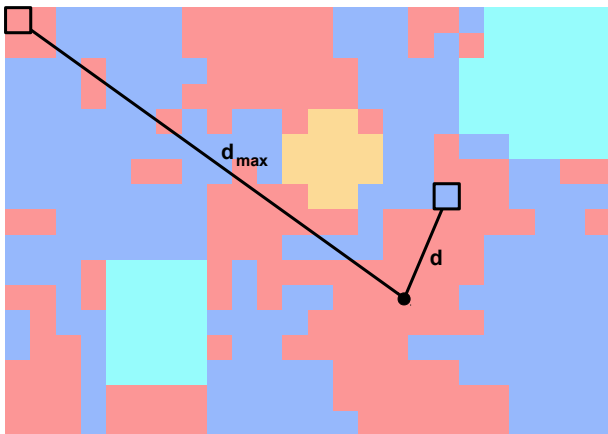
# Organisation spatiale

## Distance au centre ville



# Organisation spatiale

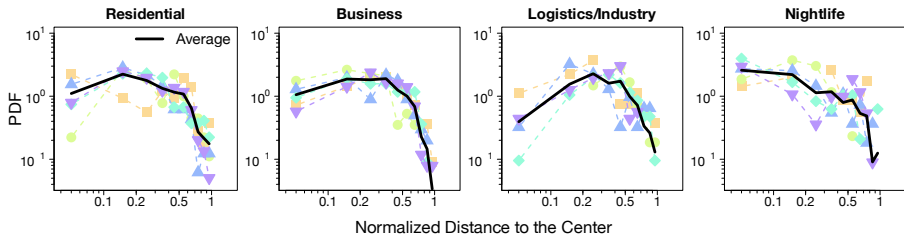
## Distance au centre ville





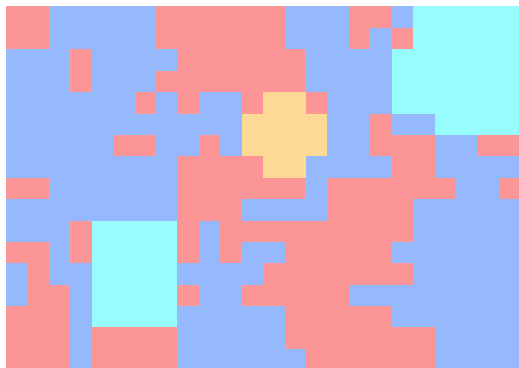
# Organisation spatiale

## Distance au centre ville



# Organisation spatiale

## K de Ripley

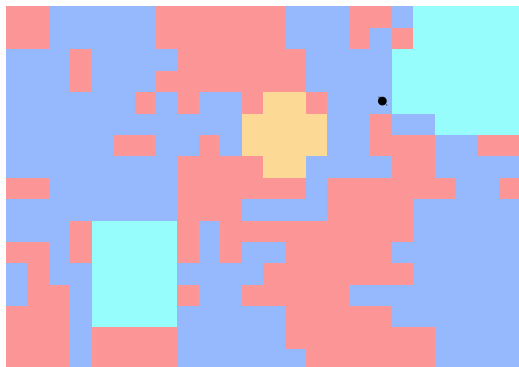


$$K(r) = \frac{A}{n^2} \sum_{i=1}^n N_i(r)$$

$$\hat{K}(r) = K(r)/K(1)$$

# Organisation spatiale

## K de Ripley

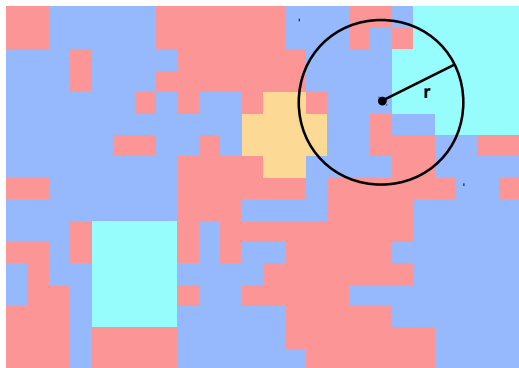


$$K(r) = \frac{A}{n^2} \sum_{i=1}^n N_i(r)$$

$$\hat{K}(r) = K(r)/K(1)$$

# Organisation spatiale

## K de Ripley

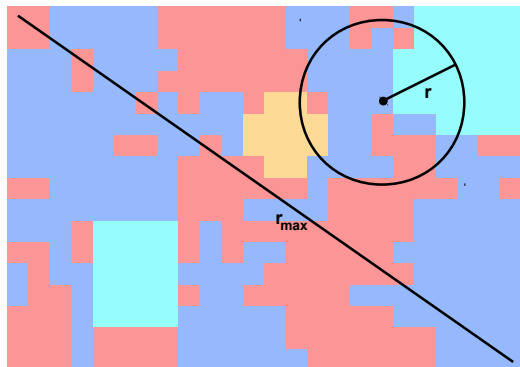


$$K(r) = \frac{A}{n^2} \sum_{i=1}^n N_i(r)$$

$$\hat{K}(r) = K(r)/K(1)$$

# Organisation spatiale

## K de Ripley

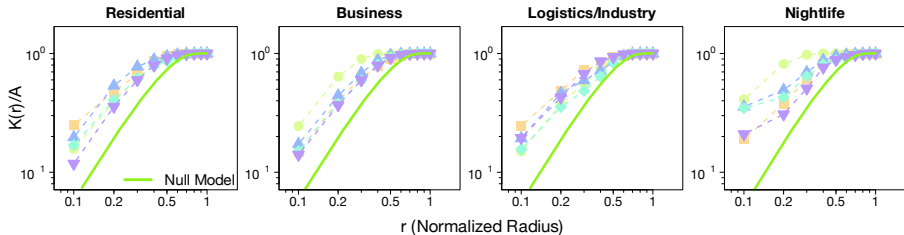


$$K(r) = \frac{A}{n^2} \sum_{i=1}^n N_i(r)$$

$$\hat{K}(r) = K(r)/K(1)$$

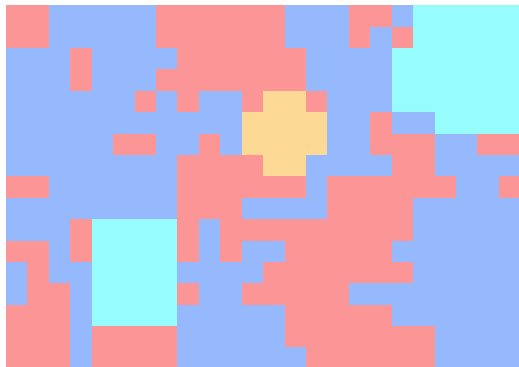
# Organisation spatiale

## K de Ripley



# Organisation spatiale

## Entropie

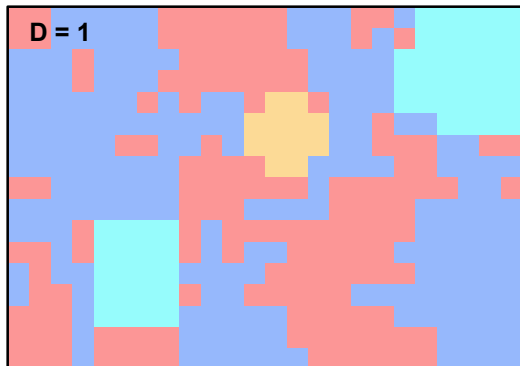


$$E_i = - \sum_{k=1}^4 f_i^k \ln f_i^k$$

$$E(D) = \frac{1}{D^2} \sum_{i=1}^{D^2} E_i$$

# Organisation spatiale

## Entropie



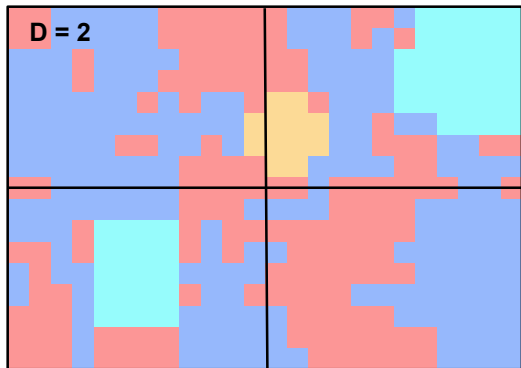
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# Organisation spatiale

## Entropie

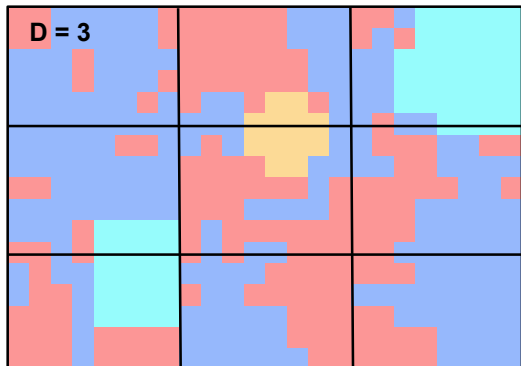


$$E_i = - \sum_{k=1}^4 f_i^k \ln f_i^k$$

$$E(D) = \frac{1}{D^2} \sum_{i=1}^{D^2} E_i$$

# Organisation spatiale

## Entropie

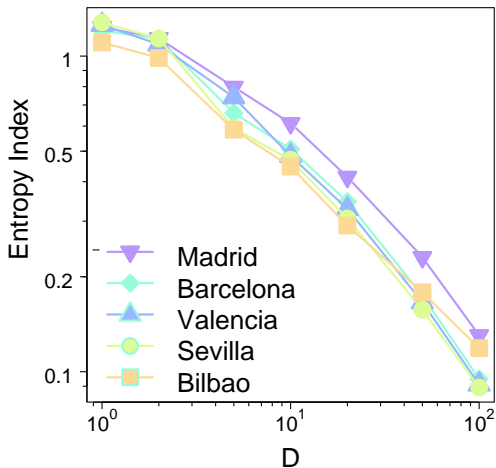


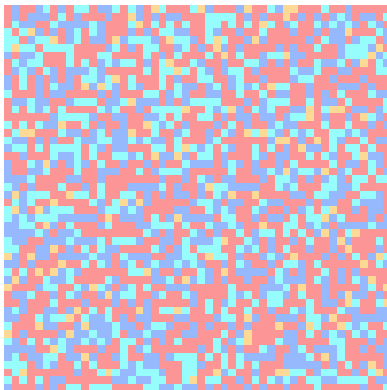
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# Organisation spatiale

## Entropie



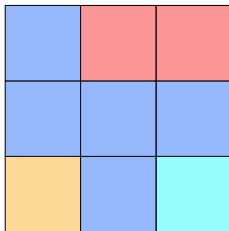


# Modèle

## Indice de satisfaction

Indice de satisfaction  $S_{ij}$  d'une cellule dépend du type d'utilisation des sols des cellules voisines

$$p = (p_1, p_2, p_3, p_4)$$



# Modèle

## Indice de satisfaction

### Logistique/Industrie

$$S_{ij} = p_3$$

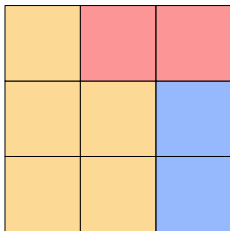

$$S_{ij} = 0$$


# Modèle

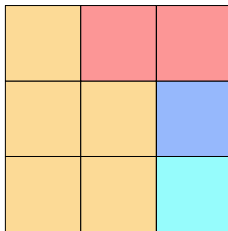
## Indice de satisfaction

### Vie nocturne

$$S_{ij} = p_4$$



$$S_{ij} = 0$$



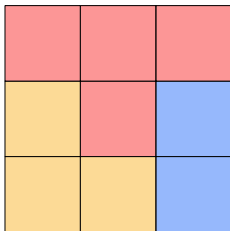
# Modèle

## Indice de satisfaction

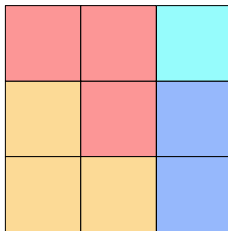
### Résidentiel

$$rand() \geq \gamma$$

$$S_{ij} = p_1$$



$$S_{ij} = 0$$





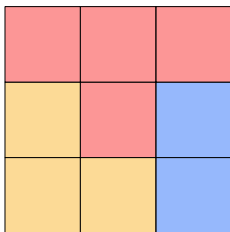
# Modèle

## Indice de satisfaction

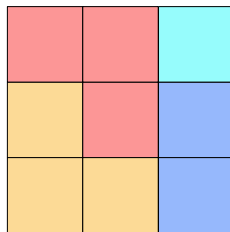
### Résidentiel

$$\text{rand}() < \gamma$$

$$S_{ij} = 1$$



$$S_{ij} = 0$$



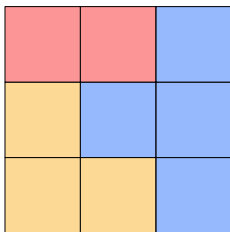
# Modèle

## Indice de satisfaction

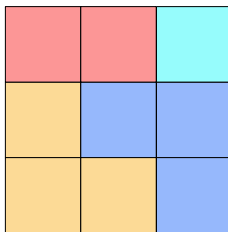
### Commercial

$$rand() \geq \gamma$$

$$S_{ij} = p_2$$



$$S_{ij} = 0$$



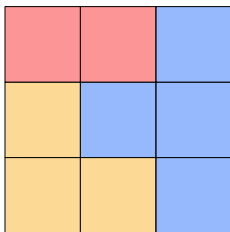
# Modèle

## Indice de satisfaction

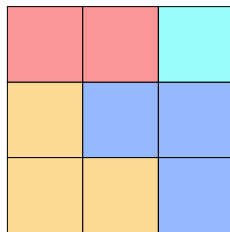
### Commercial

$$\text{rand}() < \gamma$$

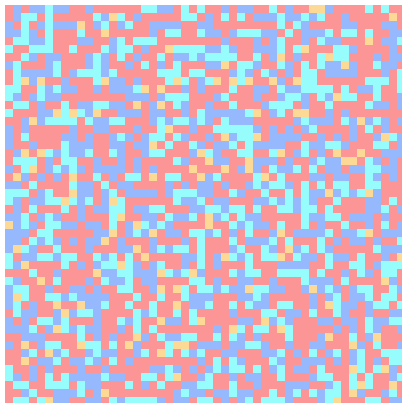
$$S_{ij} = 1$$



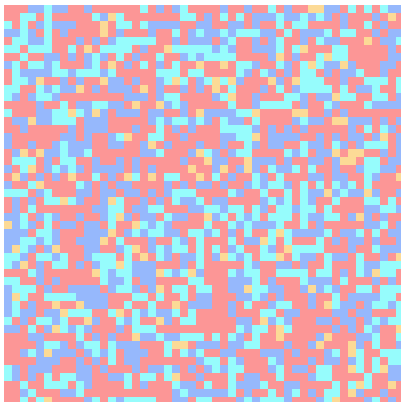
$$S_{ij} = 0$$



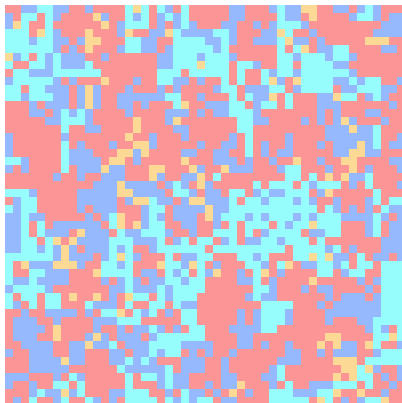
$t = 1$



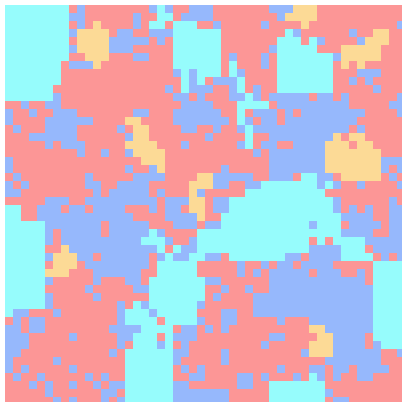
**t = 1,000**



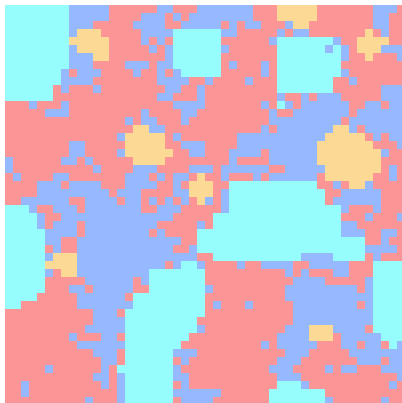
**t = 10,000**



**t = 100,000**



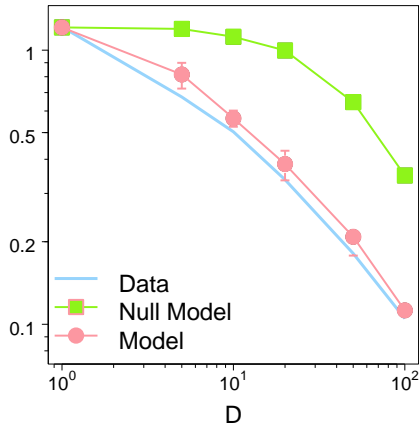
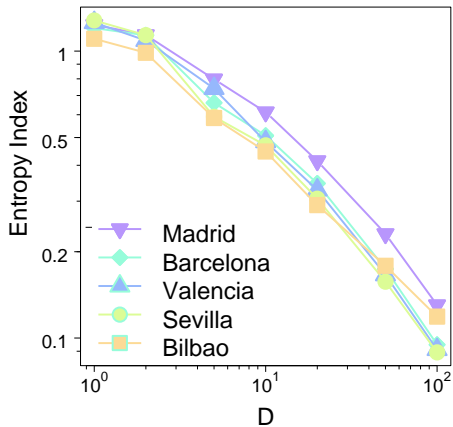
**t = 300,000**



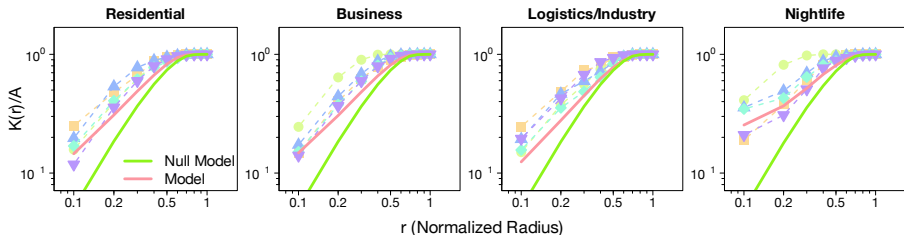


# Modèle

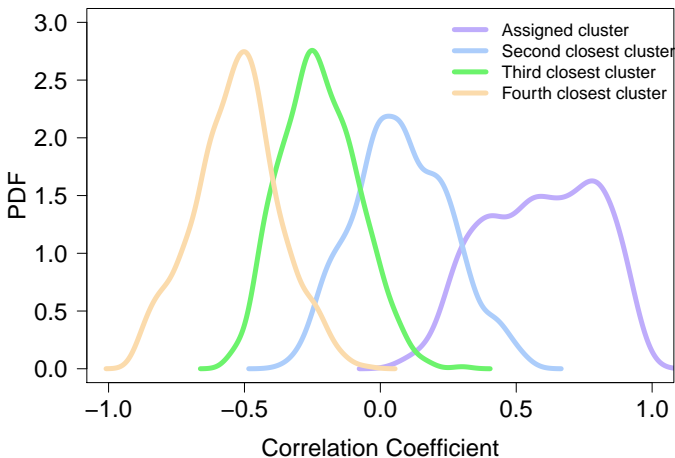
## Calibration de $\gamma$



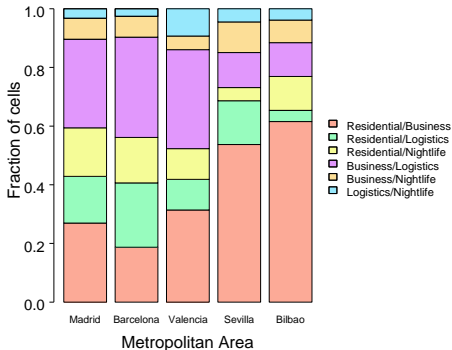
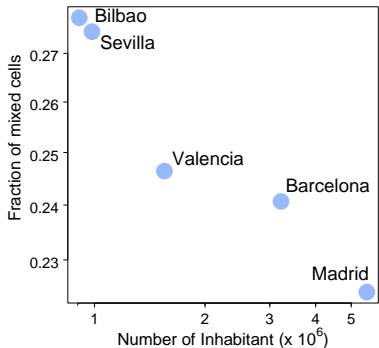
# Modèle K de Ripley



# Mélange d'utilisation des sols



# Mélange d'utilisation des sols



# Conclusions

- ▶ Approche réseaux pour détecter les différents types d'activités en utilisant des données de téléphones portables;
- ▶ Quatre types d'utilisation des sols (Résidentiel, Commercial, Logistique, Vie nocturne);
- ▶ Similarité dans l'organisation spatiale de l'utilisation des sols au sein des villes;
- ▶ Modèle se basant sur des règles d'attraction et de répulsion entre les types d'utilisation des sols;
- ▶ Mélange d'utilisation des sols.



Miguel  
Picornell



Oliva  
Garcia Cantu



Thomas  
Louail



Ricardo  
Herranz



Marc  
Barthelemy



Enrique  
Frías-Martínez



Maxi  
San Miguel



José Javier  
Ramasco

**Lenormand *et al.*** Comparing and modeling land use organization in cities. *Arxiv e-print*,  
arXiv:1503.06152.