Calibration of an urban cellular automata model by using statistic techniques and a genetic algorithm.

Application to a small urban settlement of NW Spain

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Structure of the presentation

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- FLEXIBLE CA BASED LAND-USE CHANGE MODELS.
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- CALCULATION OF SUITABILITY AND NEIGHBORHOOD
- CALIBRATION

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Background.

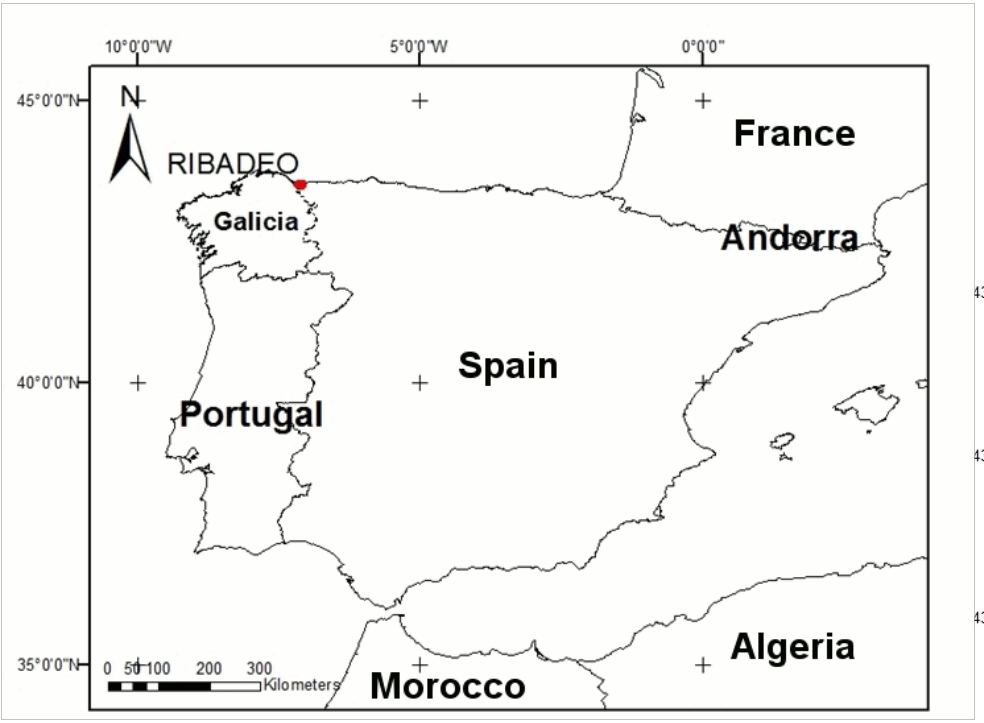
• **Orthodox CA** are not able to capture all the **complexity** of land-use change processes. Therefore, **relaxations** to the formal rule have to be made.

•If **too many relaxations** are made models may result **too complex, lack flexibility or lose the essence of formal CA** rules.

•Most Urban CA were tested in **large urban areas** where **information is abundant** .

•**Urban dynamics** of small urban areas with **slow and low growth** are more **difficult** to simulate.

Study area.


10°0'0"W
5°0'0"W
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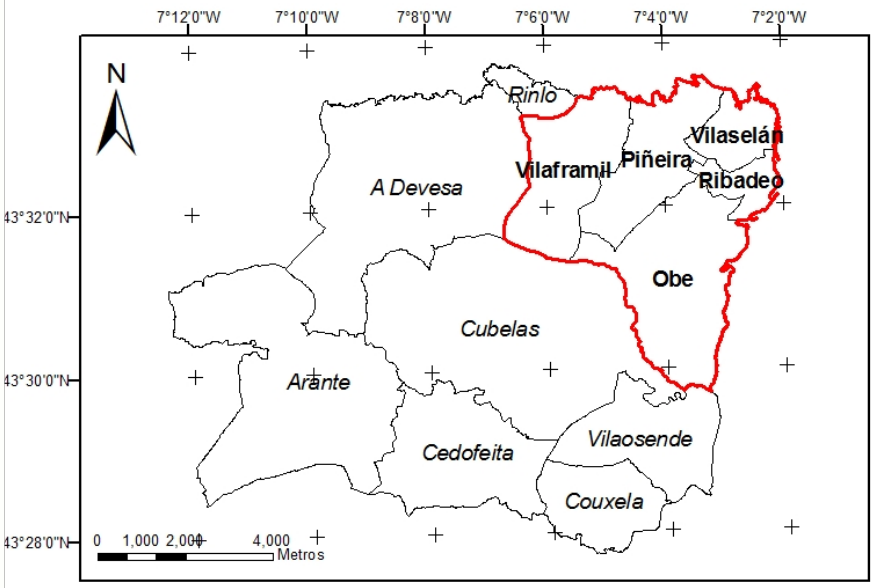
45°0'0"N
40°0'0"N
35°0'0"N
N
RIBADEO
Galicia
France
Andorra
Spain
Portugal
Algeria
Morocco
0 50 100 200 300
Kilometers


7°12'0"W
7°10'0"W
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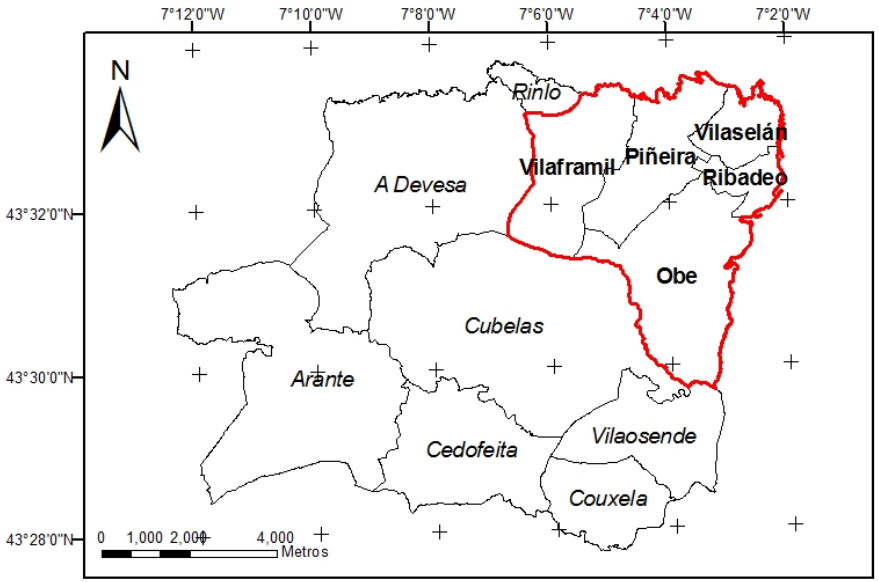
7°4'0"W
7°2'0"W
43°32'0"N
43°30'0"N
43°28'0"N
N
Rinlo
Vilaselán
Vilaframil
Piñeira
Ribadeo
A Devesa
Obe
Cubelas
Arante
Vilaosende
Cedofeita
Couxela
0 1,000 2,000 4,000
Metros

Study area.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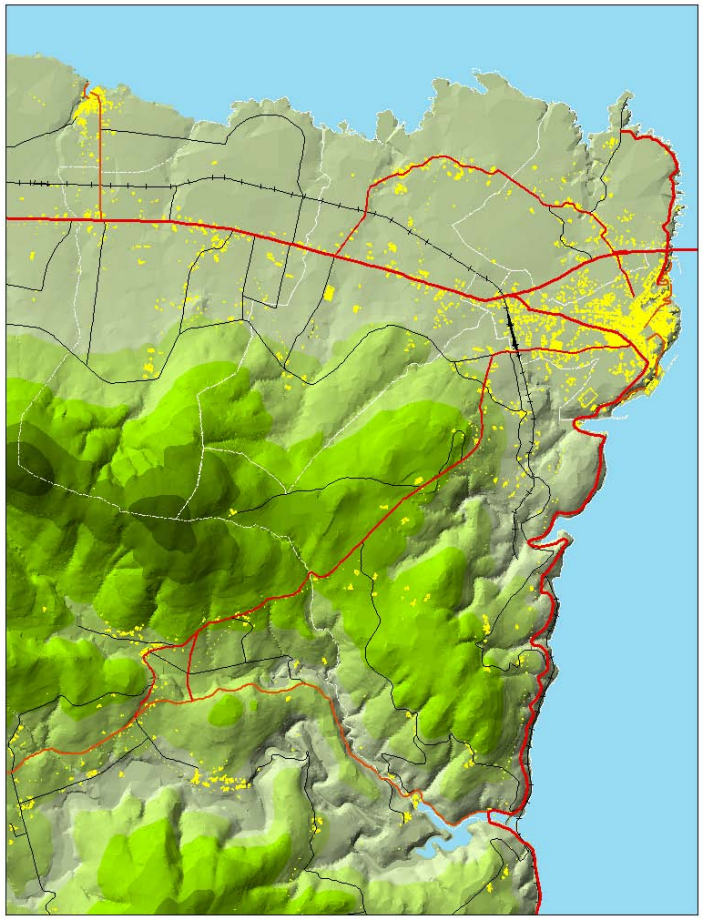


Flexible CA based Land-use change models.

- **Model of White:**

presents and extended circular neighbourhood where the influence of several land uses is taken into account.

- **Advantages:**
  - **Keeps the essence of orthodox CA.**
  - **Allows to simulate the influence of several land uses.**
  - **Allows to simulate the dynamics of several land uses.**
  - **The two previous advantages give this model a lot of flexibility.**
- **Shortcomings:**
  - **Has a lot of coefficients which makes it difficult to calibrate.**

Objectives

- **Modify** the model of White to **reduce** its number of parameters and make it more easy to **calibrate**.

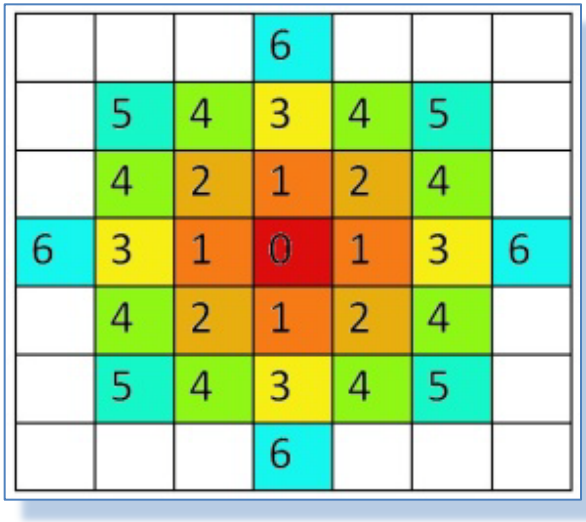
- Calibrate the model with an **Genetic Algorithm**.

- Increase **flexibility** and **accuracy** of the model.

- **Test it** simulating urban growth in a **small village**.

Transition rule of the model of White

- Fixed land-uses
- Active land-uses.



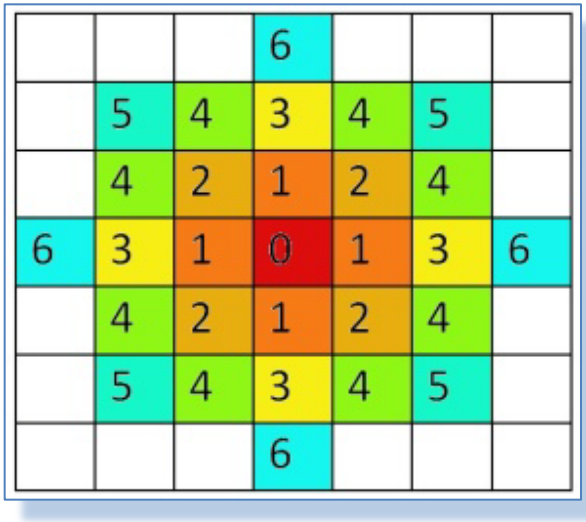
$$P_{hj} = v \times s_j \times \left(1 + N_j\right) + H_j$$

$$v = 1 + (-\ln(rand))^{\alpha} \qquad N_j = \sum_{k,i,d} m_{kd} I_{id}$$

Transition rule of the proposed model

- Fixed land-uses (forest & agriculture).
- Active land-uses (commercial, industrial and residential).

$$P_{hj} = R_j \times v \times s_j^{\beta} \times \left(1 + N_j\right)_j$$



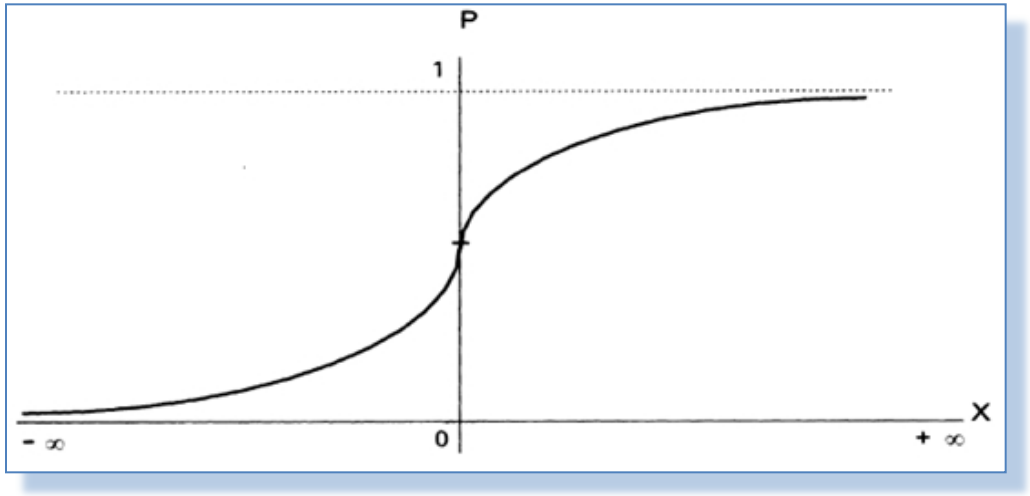
$$v = \exp(-\alpha(1 - rand)) \qquad N_j = \sum_{k,i,d} m_{kd} I_{id}$$

Calculation of suitability.

The suitability was calculated using a **logistic regression:**

1. Identify the most significant variables for each land-use Pr>|z|.

2. Calculate de suitability for each land-use with the most significant variables.



$$P(y=1 \mid X) = \frac{\exp(\sum BX)}{1+\exp(\sum BX)}$$

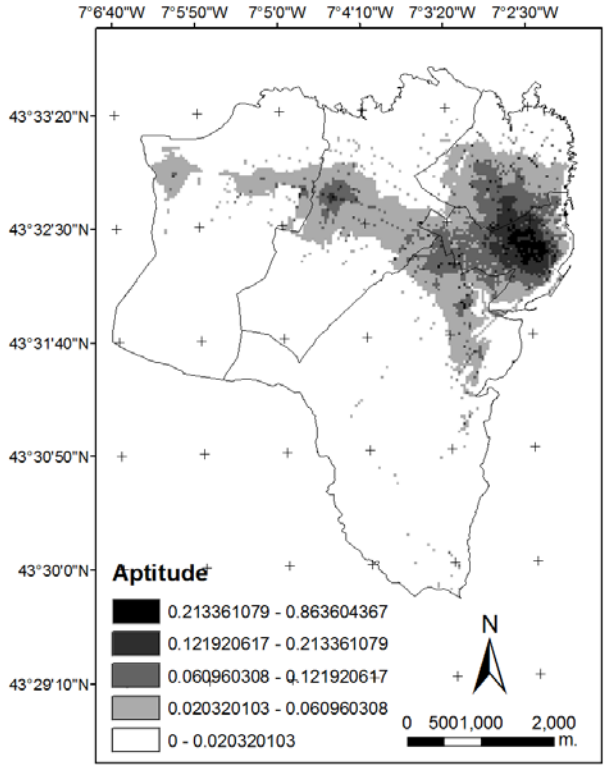
$$Ln(P/(1-P)) = b_0 + b_1 * x_1 + b_2 * x_2 + \ldots + b_k * x_k + error$$

Calculation of suitability (variables).

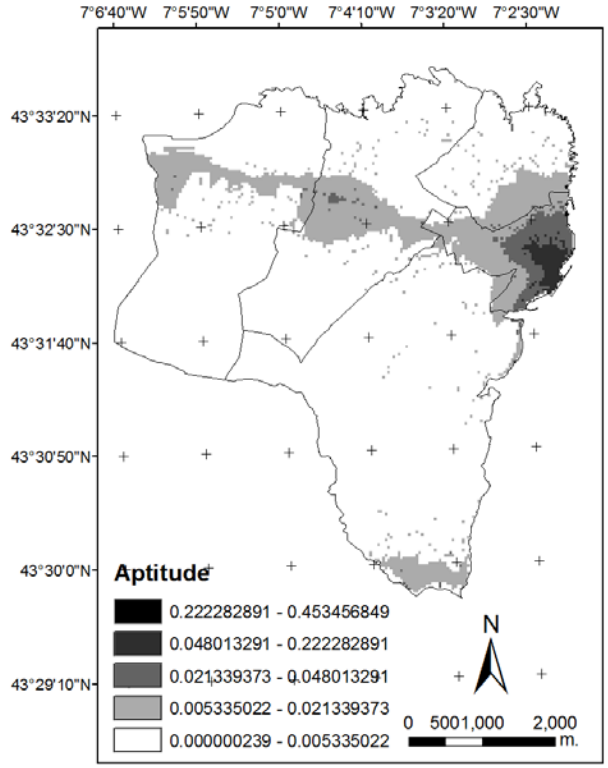
Variables	Commercial		Industrial		Residential	
	Pr(>|z|)		Pr(>|z|)		Pr(>|z|)	
Area of parcels	0.05		0.009	x	2.78E-12	x
Distance to water bodies.	0.0002	x	2.32E-09	x	7.27E-13	x
Distance to Ribadeo down town	0.7		0.04		7.21E-23	x
Distancia to municipal roads	0.02		0.1		1.26E-11	x
Distance to main roads	2.14E-07	x	3.19E-11	x	2.18E-18	x
Distance to secondary roads	0.4		1.33E-06	x	5.01E-18	x
Distance to railway tracks	0.04		0.0004	x	0.4	
Shape index of parcels	0.09		0.0009	x	8.65E-11	x
Slopes	0.7		0.7		1.28E-05	x

Calculation of suitability (results).

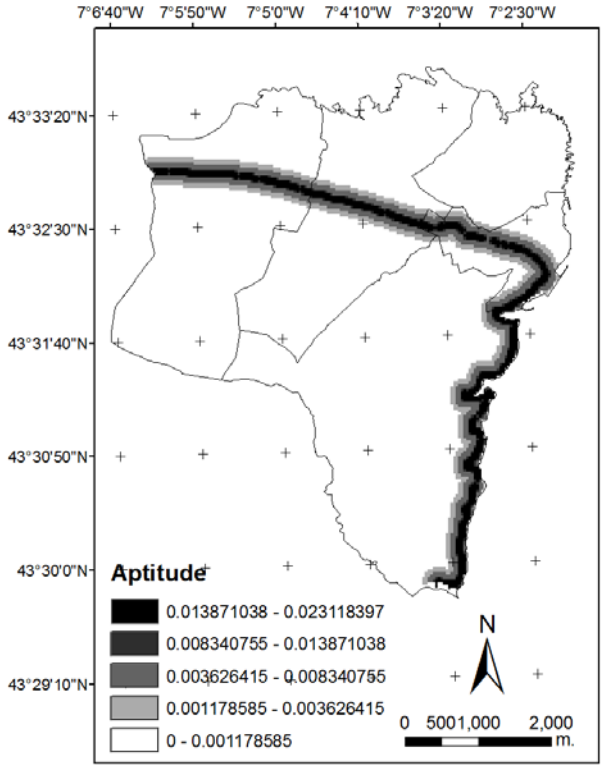
Residential



Industrial

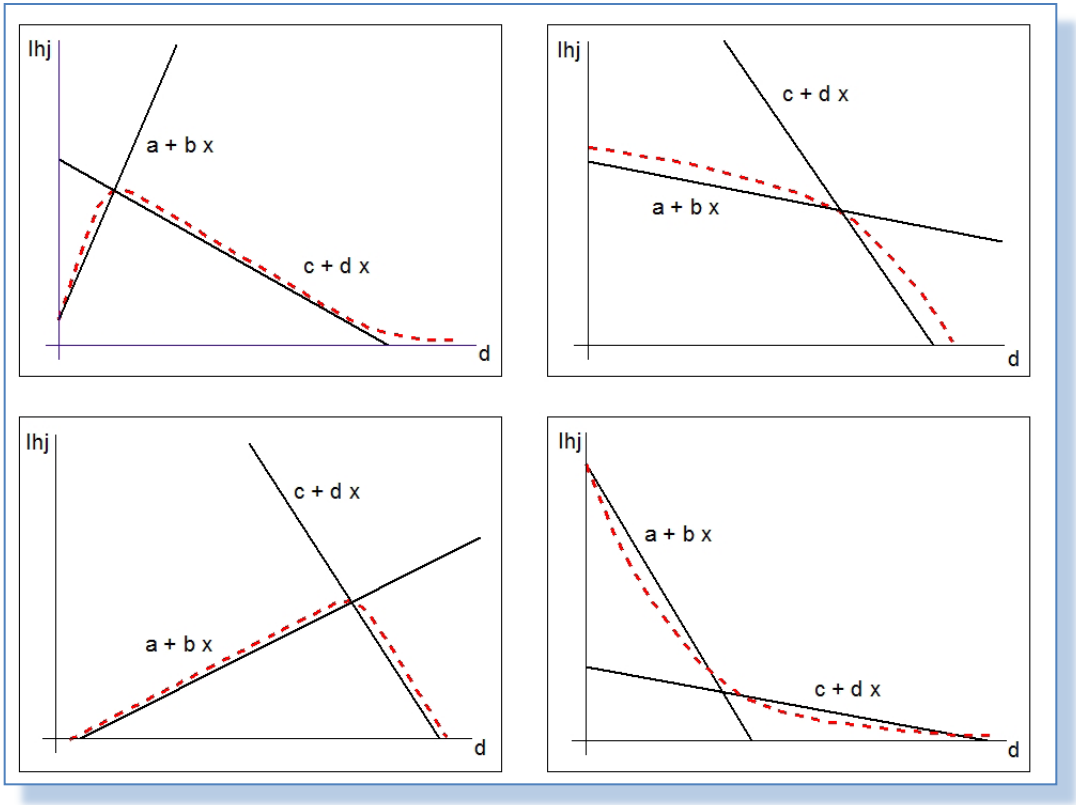


Commercial



Calculation of the neighbourhood.

To calculate the coefficients of the neighbourhood, lines which represent the distance decay effect were used.



Calibration

- Calibration using a Genetic Algorithm.
  - Creation of the initial population(700 individuals)
  - Evaluation of the population (Pontius index (2002), NP, AREA_MN, FRAC_AM)
  - Parents selection (Tournament).
  - Cross breeding(recombination with 2 cut point) and creation of next population.
  - Application of the mutation tax (0.008%) to the next generation.
  - The best parent survives.

Calibration (fitness function)

- Index of Pontius.

$$Pg = \frac{\sum_{n=1}^{Ng}\left[Wn\sum_{j}^{J} MIN(Rn, j, Sn, j)\right]}{\sum_{n=1}^{Ng} Wn}$$

$$P = \frac{\sum_{g}^{G} \exp^{b\times g} \times Pg}{\sum_{g}^{G} \exp^{b\times g}}$$

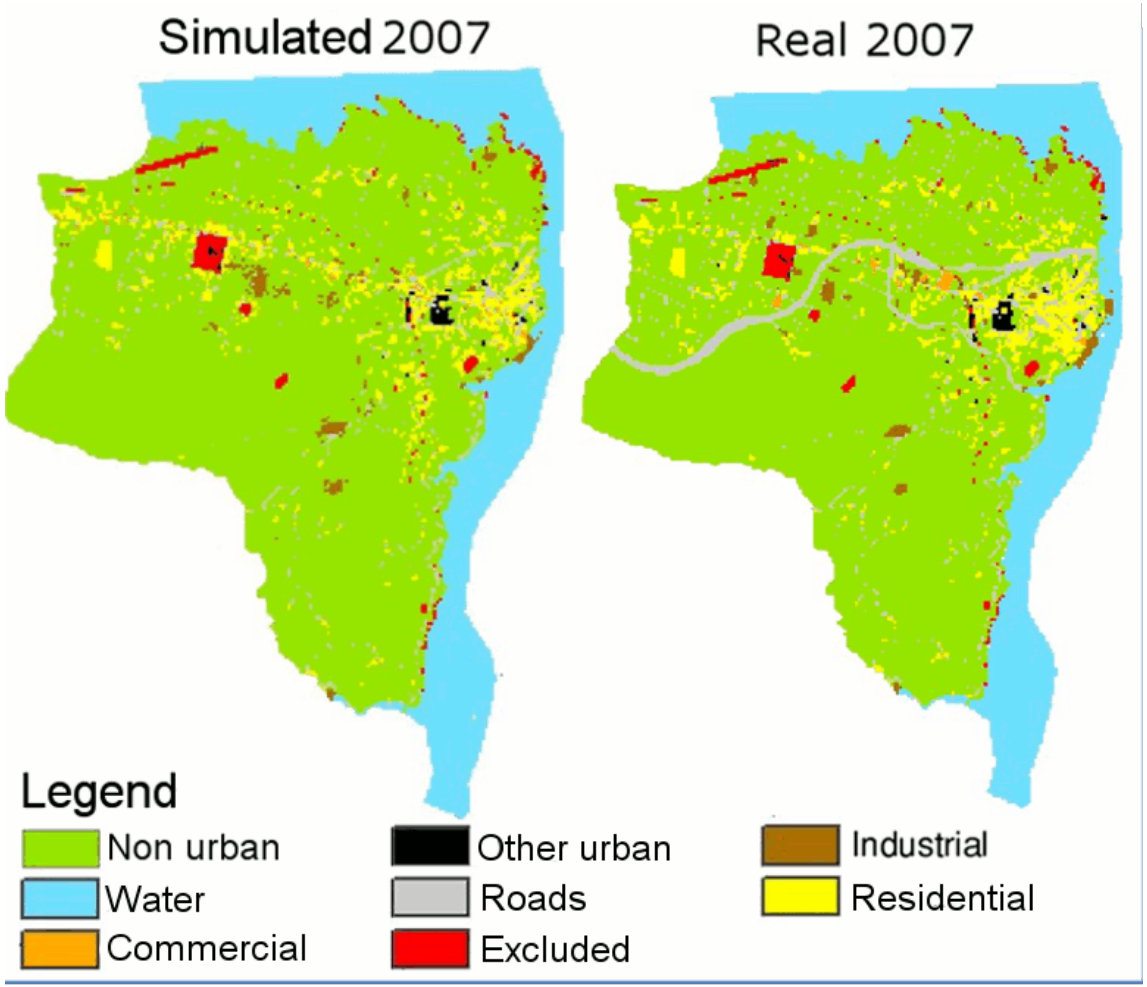
- Fitness function.

$$F = \left[\frac{\frac{normalized\ NP + normalized\ AREA\_AM + normalized\ ED}{3} + Normalized\ P}{2}\right]^{-1}$$

Comparison of simulated and real maps using spatial metrics.

	USO	NP	LPI	AREA_MN	FRAC_AM	ENN_AM
Sim. 2007	**Industrial**	56	0.11	0.63	1.1	148.23
Real 2007	**Industrial**	45	0.10	0.77	1.06	276.24
Sim. 2007	**Residential**	272	0.44	0.65	1.13	89.53
Real 2007	**Residential**	224	0.98	0.78	1.16	88.79
Sim. 2007	**Commercial**	61	0.01	0.16	1.02	106.89
Real 2007	**Commercial**	13	0.06	0.73	1.05	252.12

Visual comparison



Index of Pontius: 0.961

Conclusions

- Model has simulated **accurately** urban growth in the study area.
- **Model simplifications** kept its **power of analysis** and allowed using an **automatic calibration** method.
- **Genetic algorithms** are a good calibration method.
- Future research should focus on **validation** methods.

Obrigado pela sua atenção

Thank you for your attention