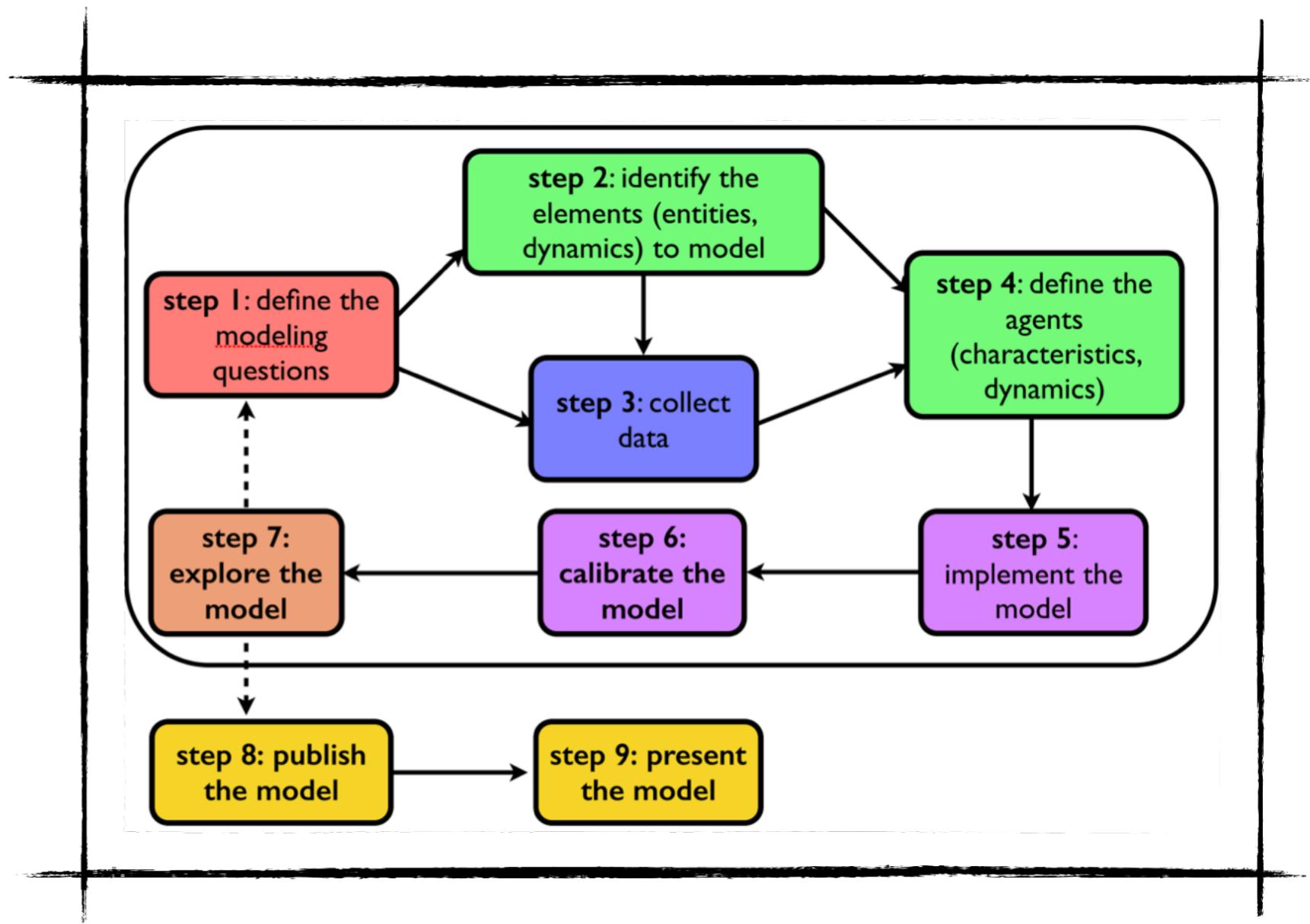
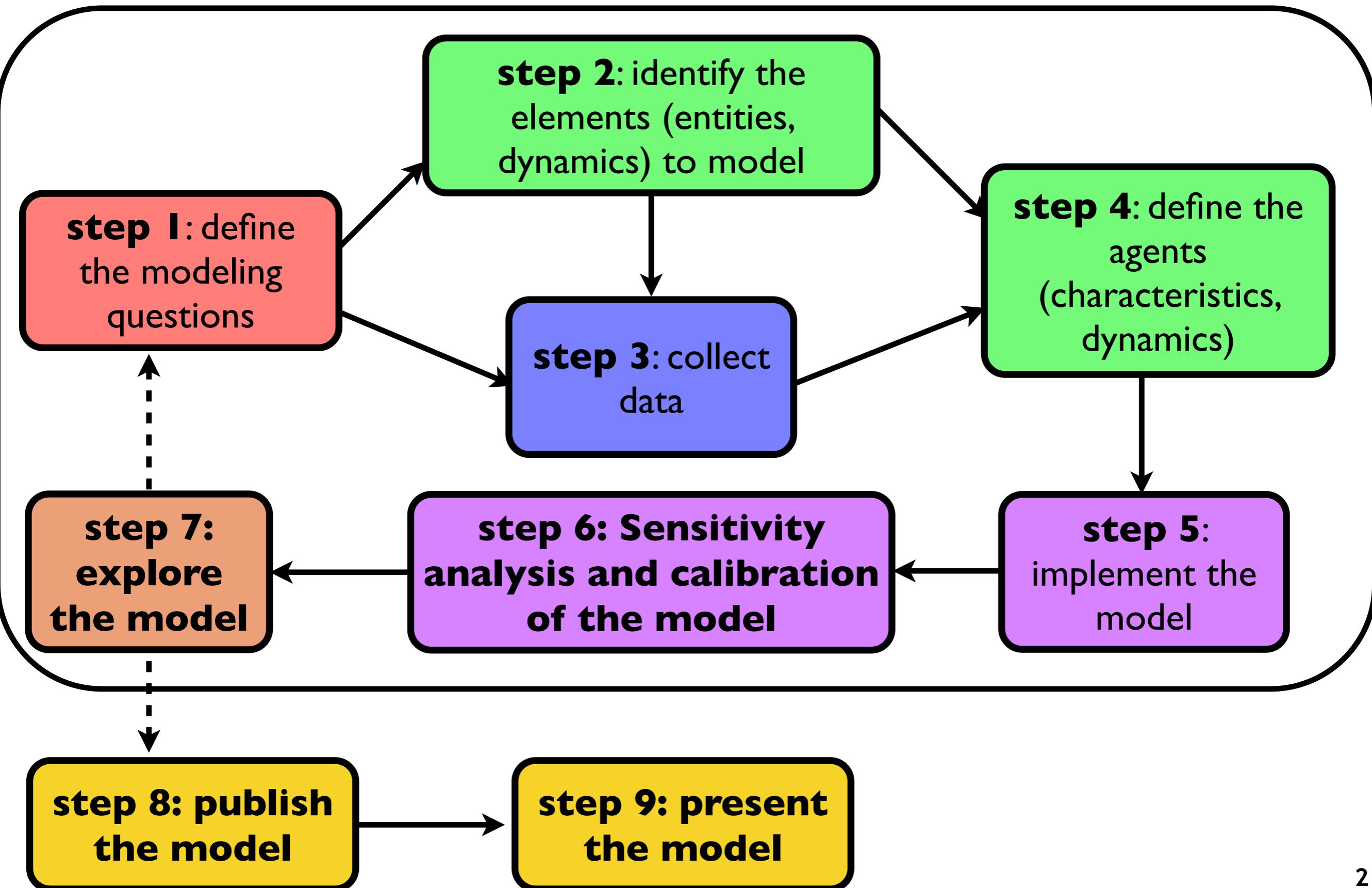


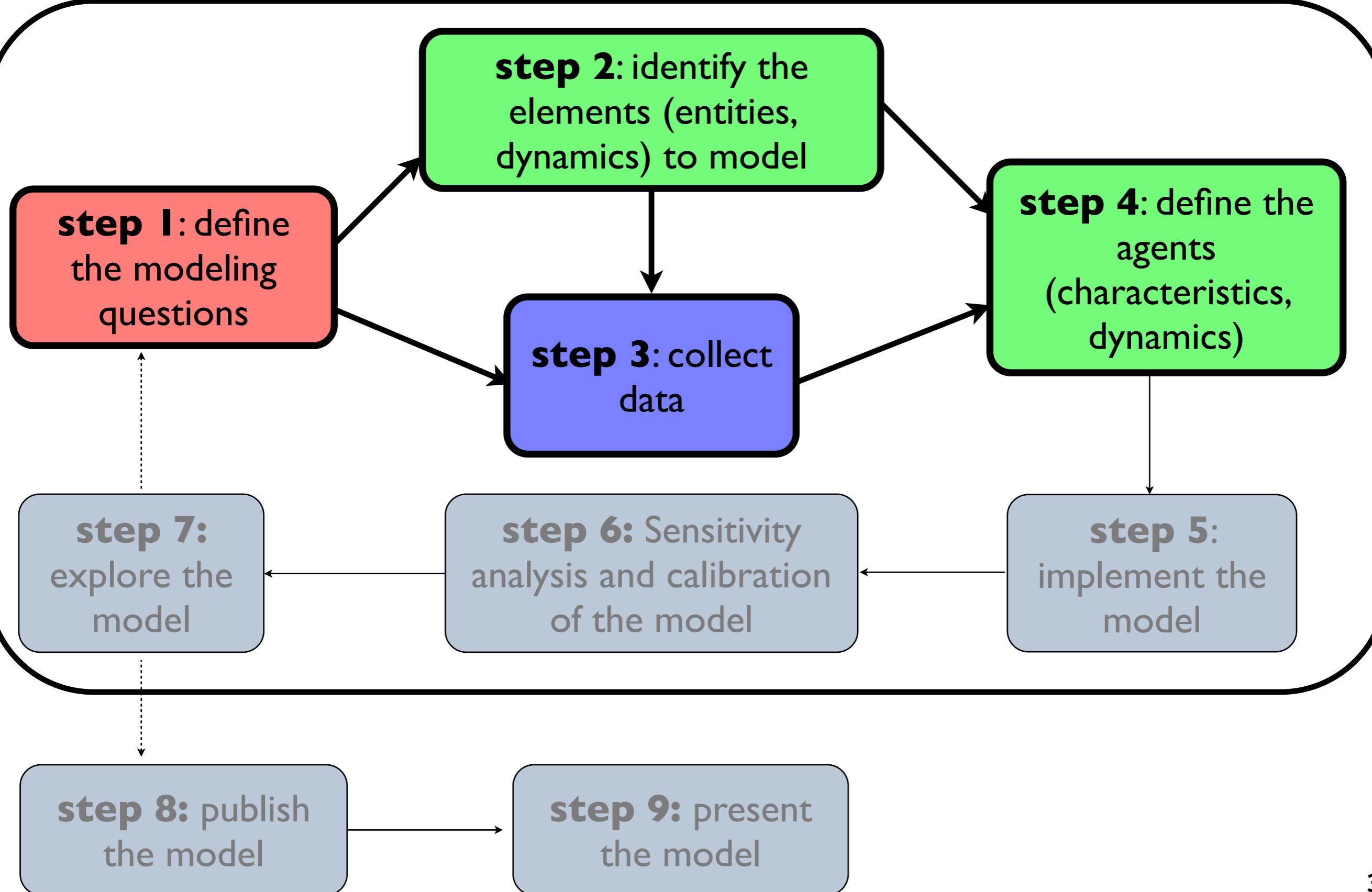
# Modelling is a multi-step cycle.



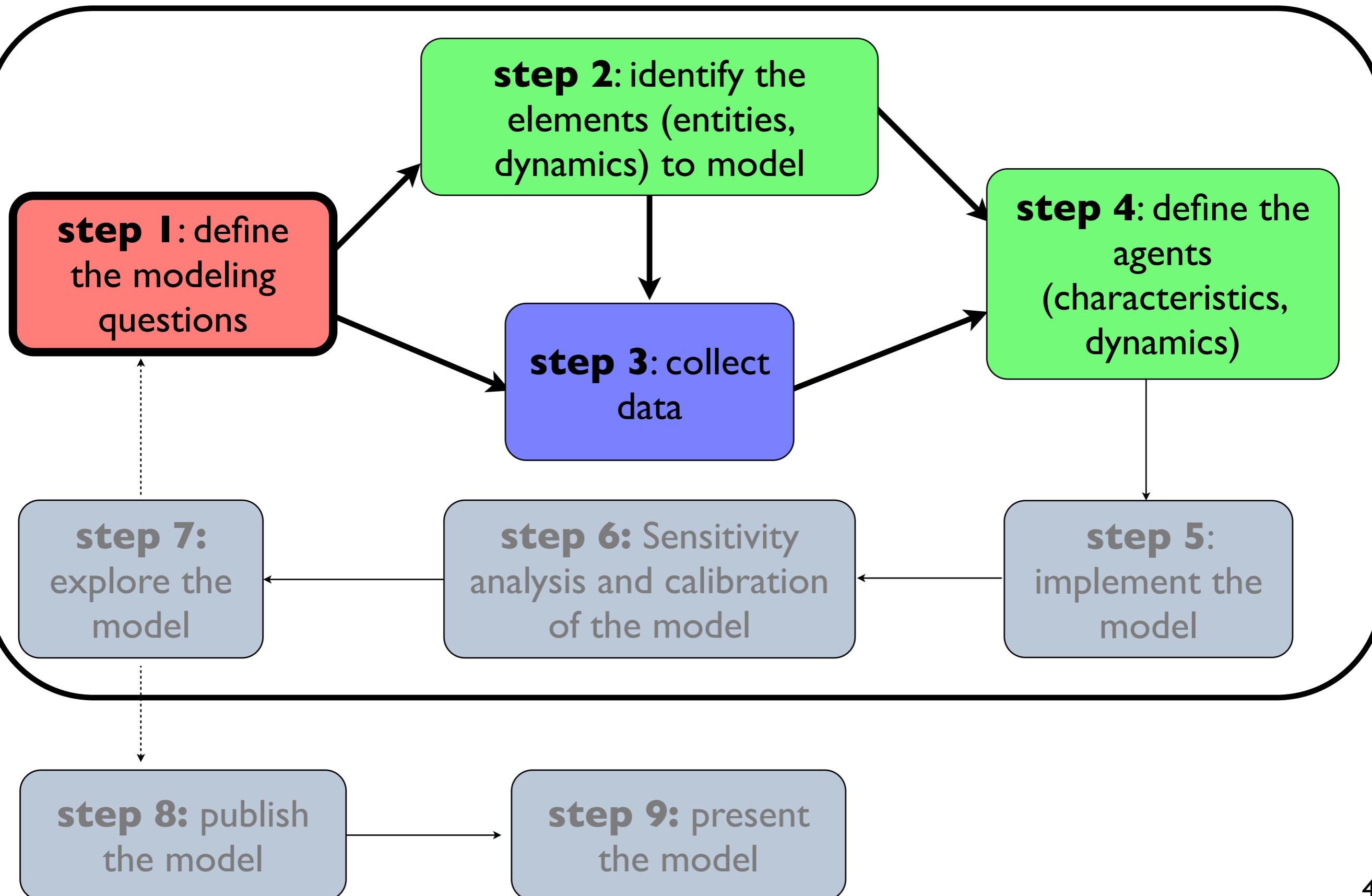
# Modelling is a multi-step cycle.



# Modelling is a multi-step cycle.



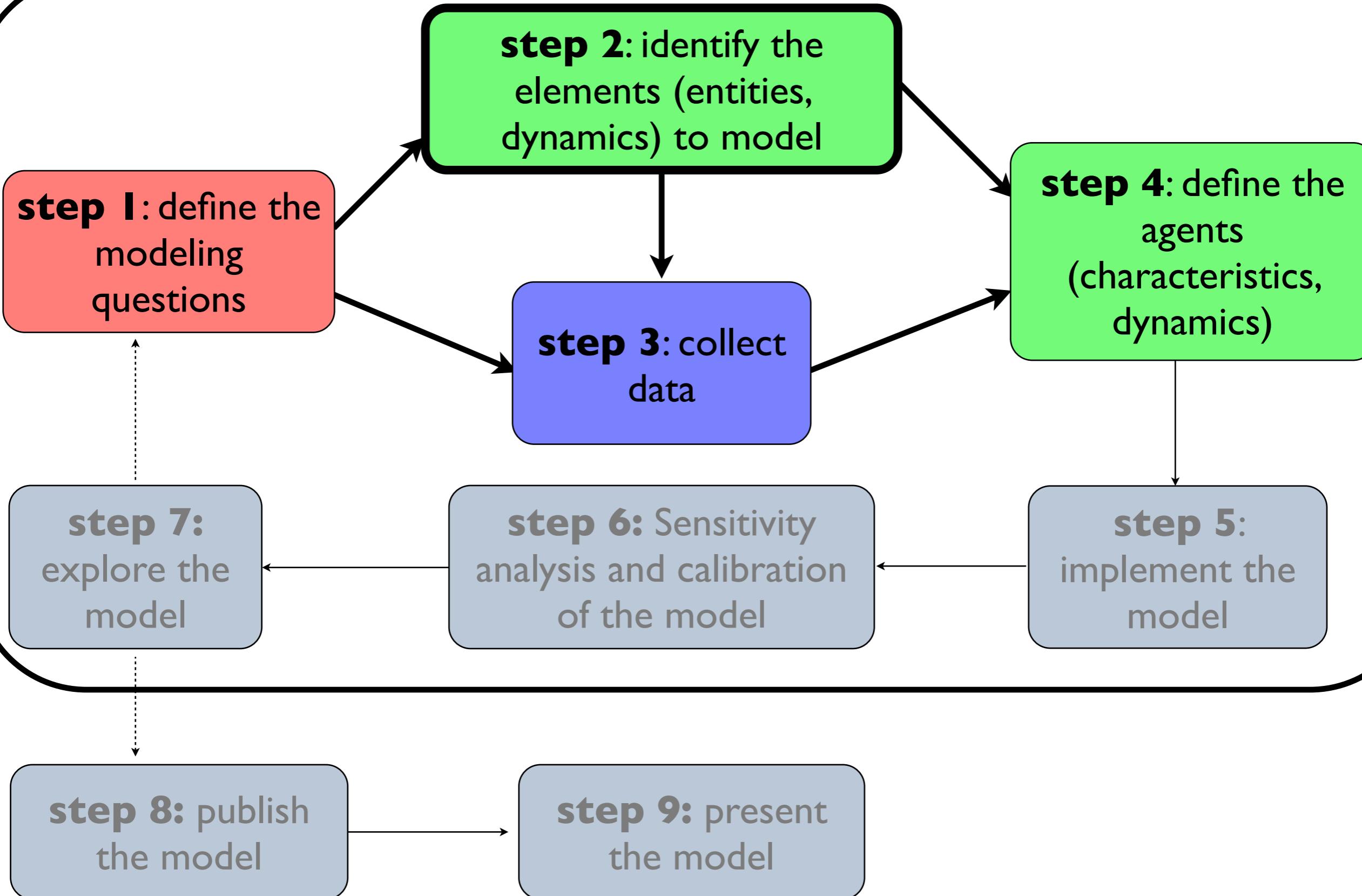
«Every model has to start from a clear question, problem, or hypothesis.» [Grimm, et al. 2010]



## Which questions for which models ?

- ▶ Among dynamic models we can distinguish:
  - ▶ **Reproduction models:** that try, given data, to reproduce as precisely as possible these data by simulation.  
---> we cannot understand the way the phenomenon is generated.  
But it could «**predict the future**», e.g. weather forecast.
  - ▶ **Understanding models:** that try to understand processes that generate phenomena. They are focused on the processes and try to get the phenomenon by simulation.  
----> allow to understand, explain and generate the phenomenon.
- Consequence: we can « **ask questions to the model**» via What-If scenario.
- ▶ We cannot tackle the same questions with all kinds of models.

# Modelling is a multi-step cycle.

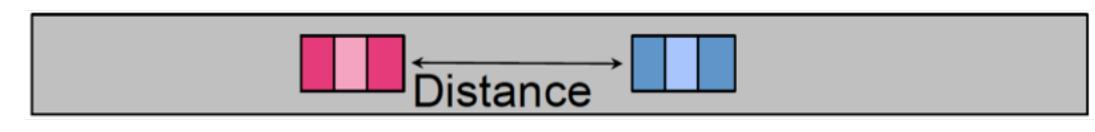


# There is a huge number of languages to write a dynamic model.

- ▶ Consider 2 main approaches:
  - ▶ **equation-based models:** describe the evolution at macroscopic level
  - ▶ **agent-based models:** describe microscopic entities, their behaviors and interactions between these entities and generate a macroscopic behavior
- ▶ Example: traffic
- ▶ We focus on **agent-based model** here.

$$\begin{cases} Q(\Delta x, \Delta t) = K(\Delta x, t)V(\Delta x, \Delta t) \\ V(\Delta x, \Delta t) = V_e(K(\Delta x, t)) \\ \frac{\partial Q(\Delta x, \Delta t)}{\partial x} + \frac{\partial K(\Delta x, t)}{\partial t} = 0 \end{cases}$$

LWR macroscopic model



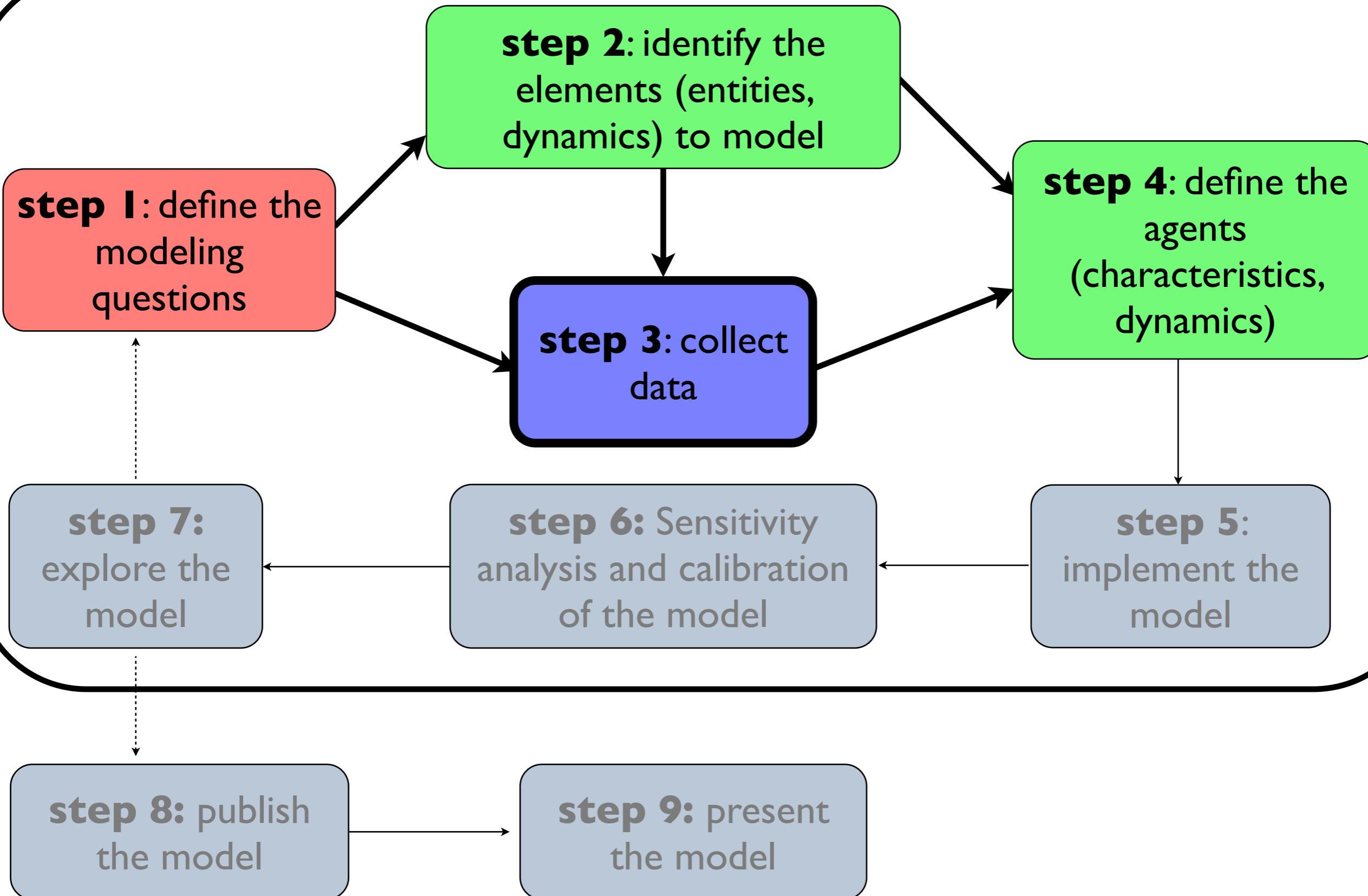
NaSch microscopic model



$$\begin{cases} \frac{dS}{dt} = -\beta IS \\ \frac{dI}{dt} = \beta IS - \alpha I \\ \frac{dR}{dt} = \alpha I \end{cases}$$

Example of epidemic equation-based model 7

# Modelling is a multi-step cycle.



# Data collection, cleaning and management are a huge and hard work in a modelling and simulation project!

## ► First: Get data

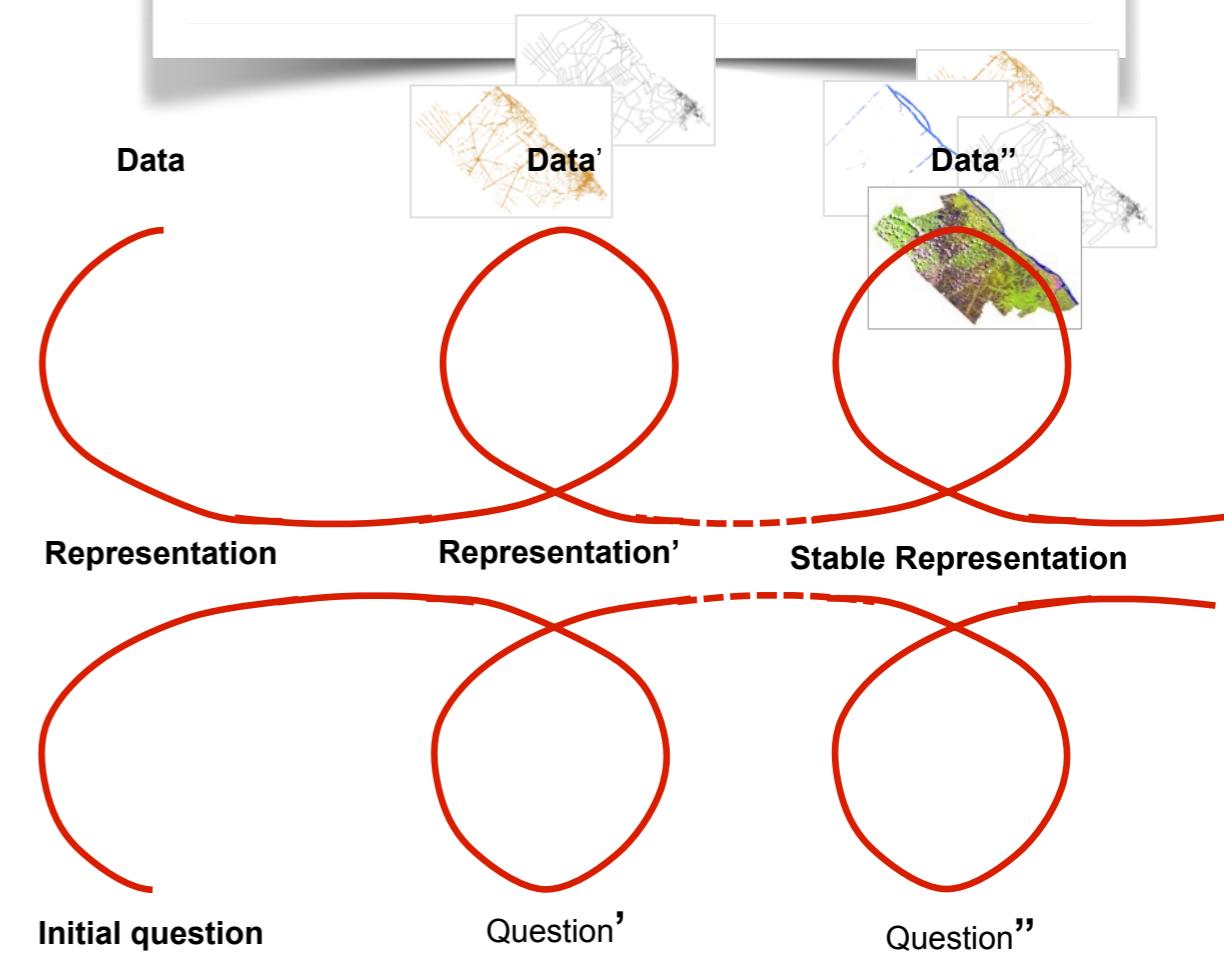
- ▶ collect yourself,
- ▶ ask/buy from government agency,
- ▶ get open source data (Open Data), e.g.  
OpenStreetMap, IGN (France)  
-> unequal quality

► E.g. : to get data from Can Tho, we need to ask the Department for Natural Ressources and Environment (*Sở tài nguyên môi trường Cần Thơ*)

► E.g. : in France, IGN, INSEE, Water Agency...

► Then: process and clean them.

co-evolution in the MAELIA Project between question/  
data/representation

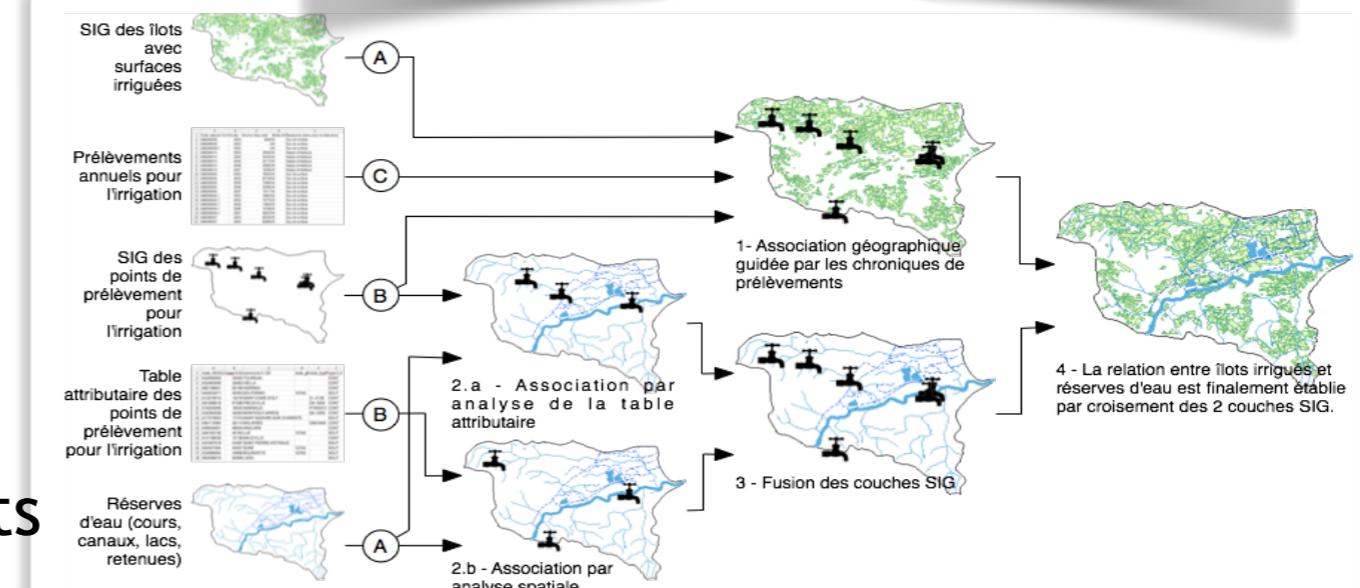


# Data need to be cleaned and processed, depending on the aim and need of the model.

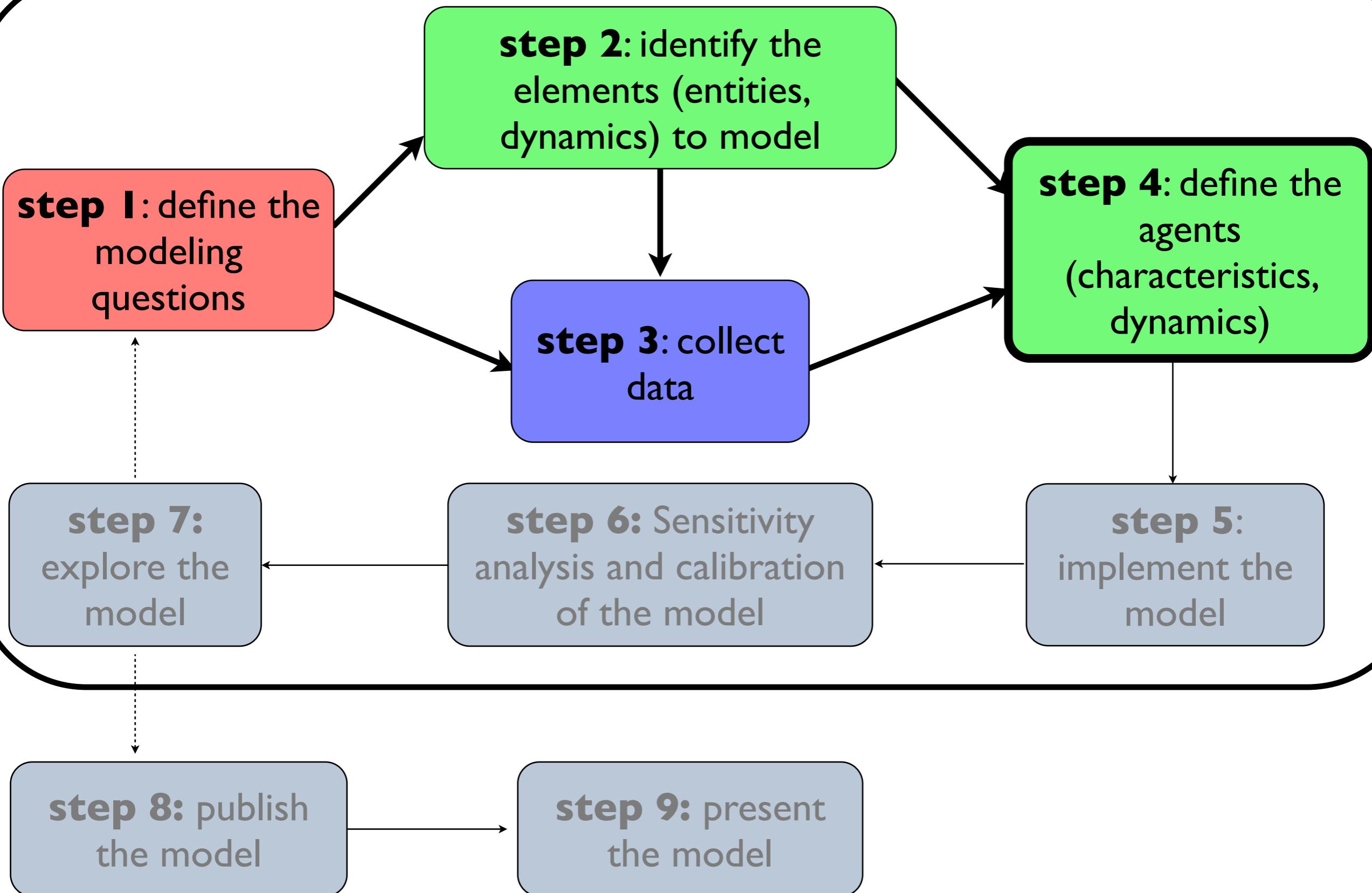
- ▶ Aim: building of a common GIS merging data from all the various sources.

- ▶ Example of issues to tackle:
  - ▶ convert all the data formats in a common one
  - ▶ clean data (e.g. correct invalid polygons, overlapping or disjoint polygons...)
  - ▶ transform data to be used in the model (e.g. , switch from polygons to polylines for roads...)
  - ▶ correct/create attribute table for each geographic objects
  - ▶ integrate / cross various data sources

Example on the MAELIA project of data integration.



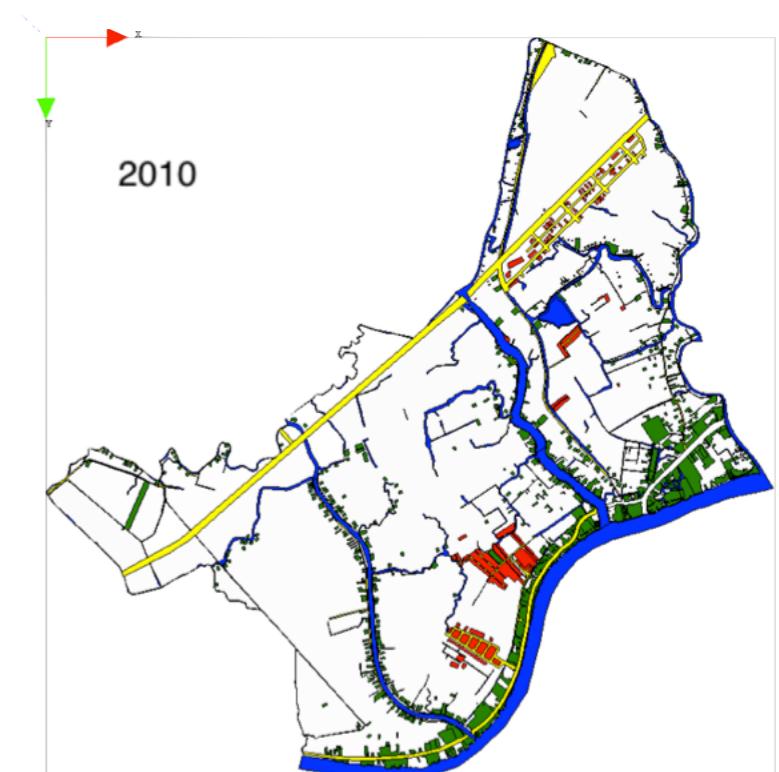
# Modelling is a multi-step cycle.



**Given the chosen entities and the data collected, we have to choose what will be an agent in our model (i.e. an entity with a behaviour)**

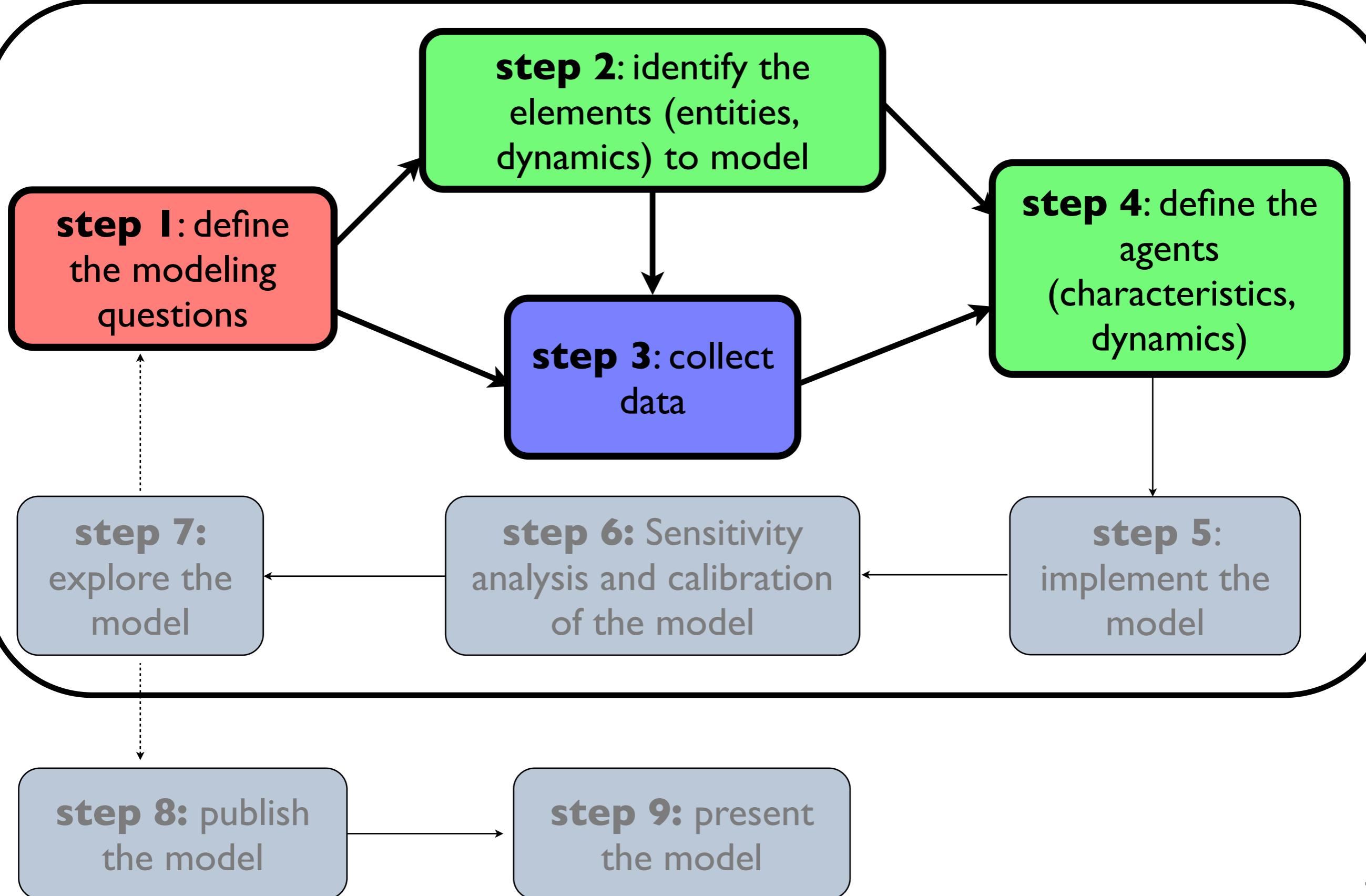
**What will be an agent depends mainly on the chosen scale (and data & question).**

- If we want to simulate a city, do we need to take into account each inhabitant, each household, each building ... ?



Can Tho - Ninh Kieu - 2010

# Example of modelling steps



**Current changes in worldwide urbanization patterns at all geographic scales are quite likely the most significant since the advent of humanity.**

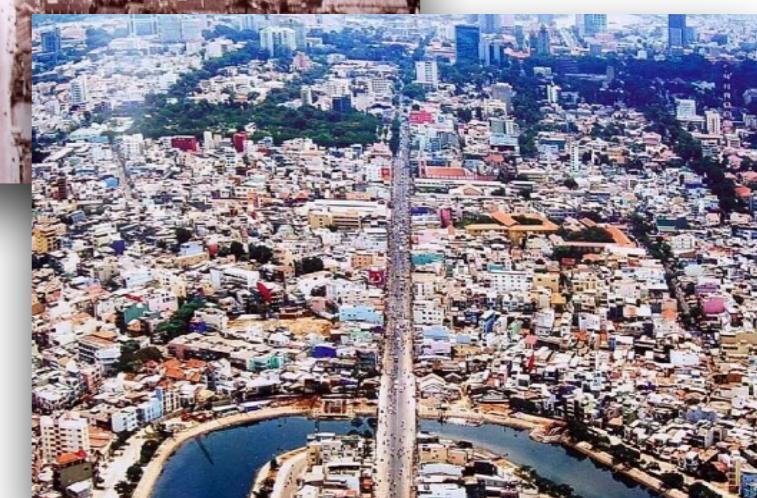
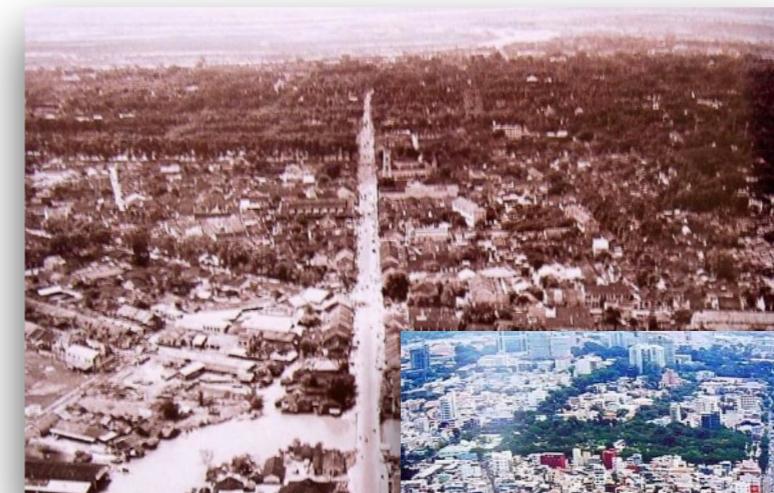
To address the challenges raised by these changes, there is a need for **tools and models that can support deciders** in:

**Providing knowledge on and understanding the dynamics of the urban system,**

**Anticipating and forecasting future changes or trends of development,**

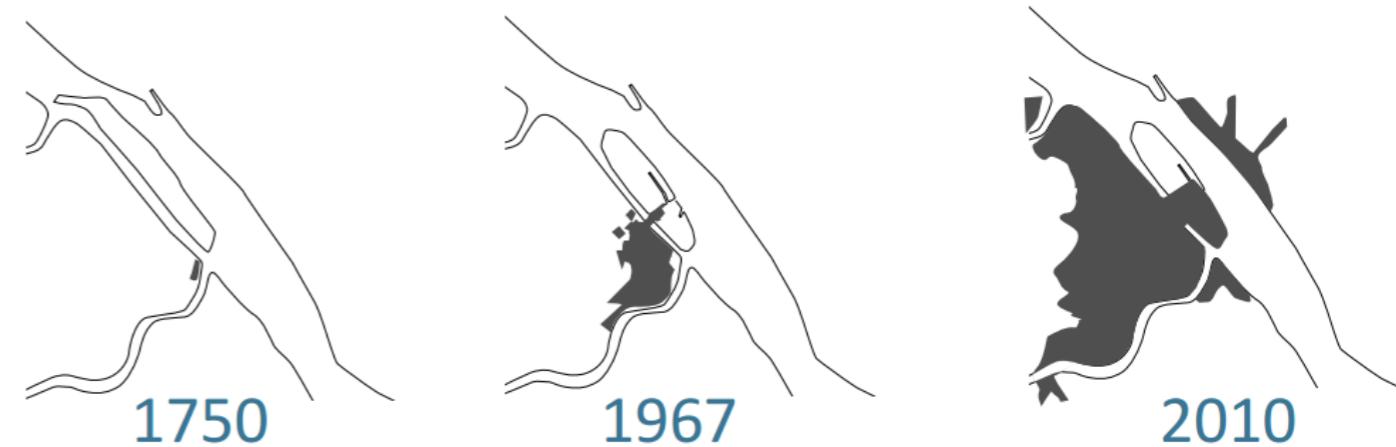
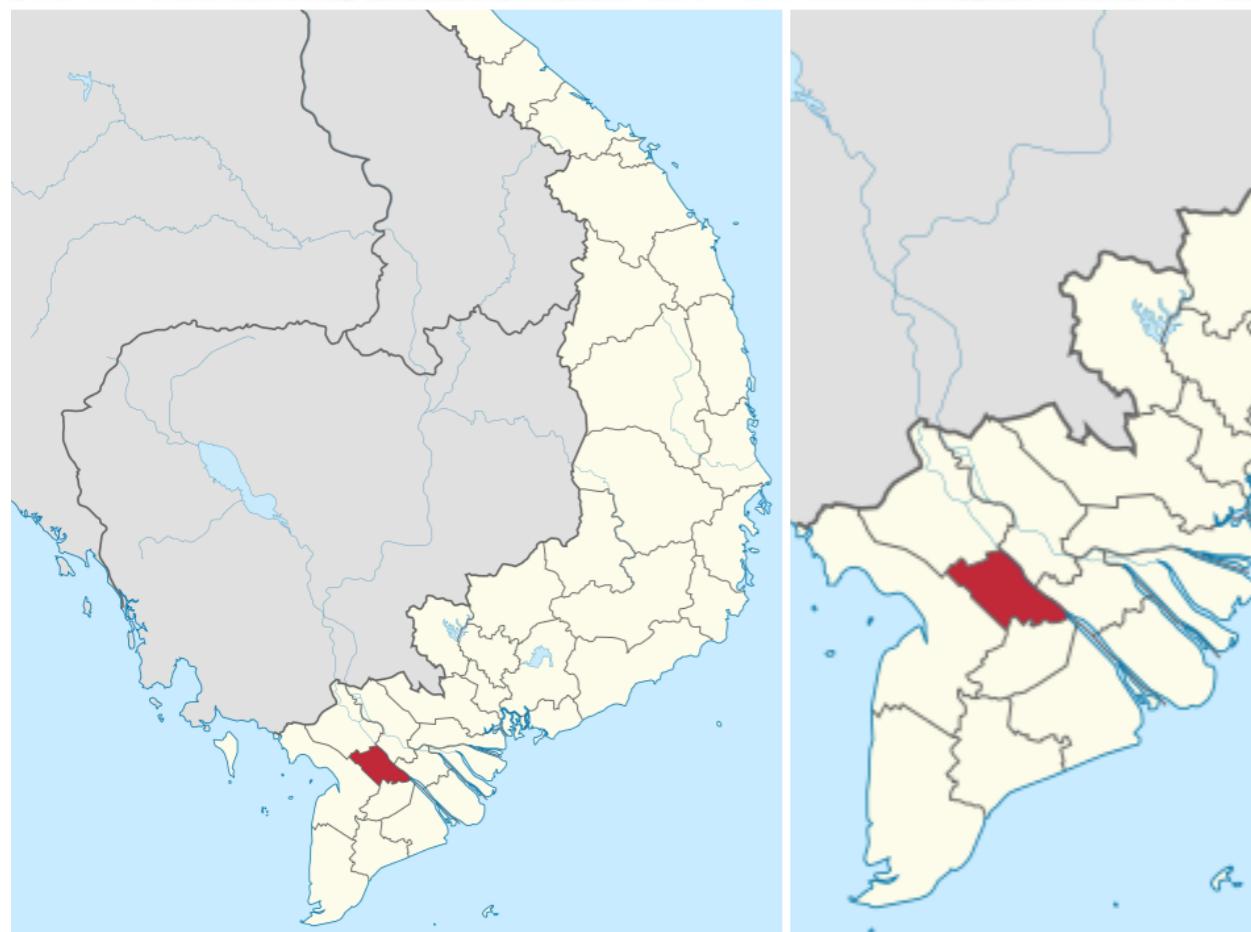
**Describing and assessing impacts of future development,**

**Exploring different policies and optimising planning and management of sustainable urban areas.**



The model is focus on designing and exploiting **urban morphogenesis (or growth) models**, i.e. models that represent the evolution(s) of the spatial inscription of the city.

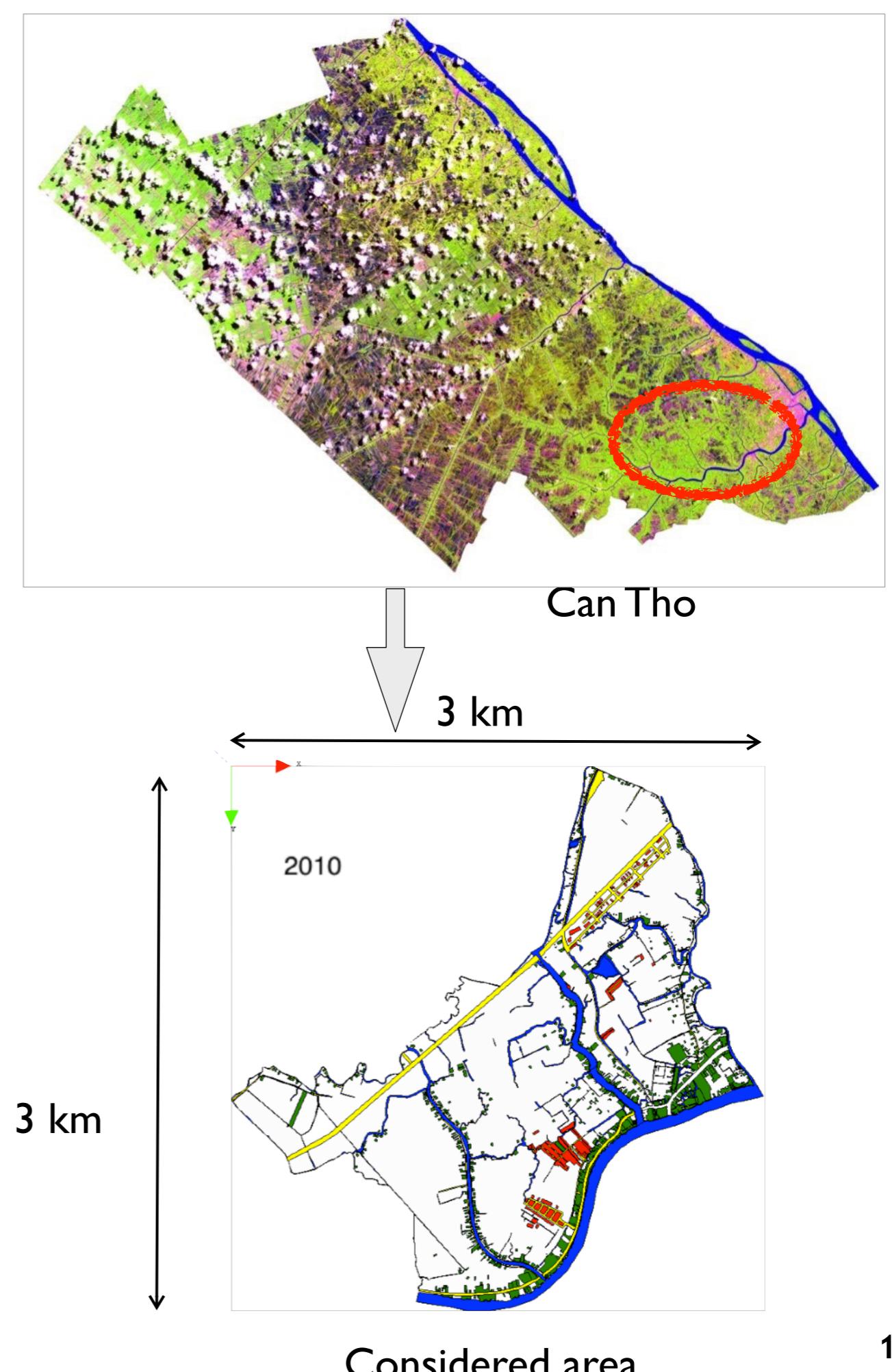
# Example 1: What are the mechanisms allowing a modeler to reproduce the urban growth in Can Tho ?



► Application: urban planning

# Model 1: entities, dynamic and scales

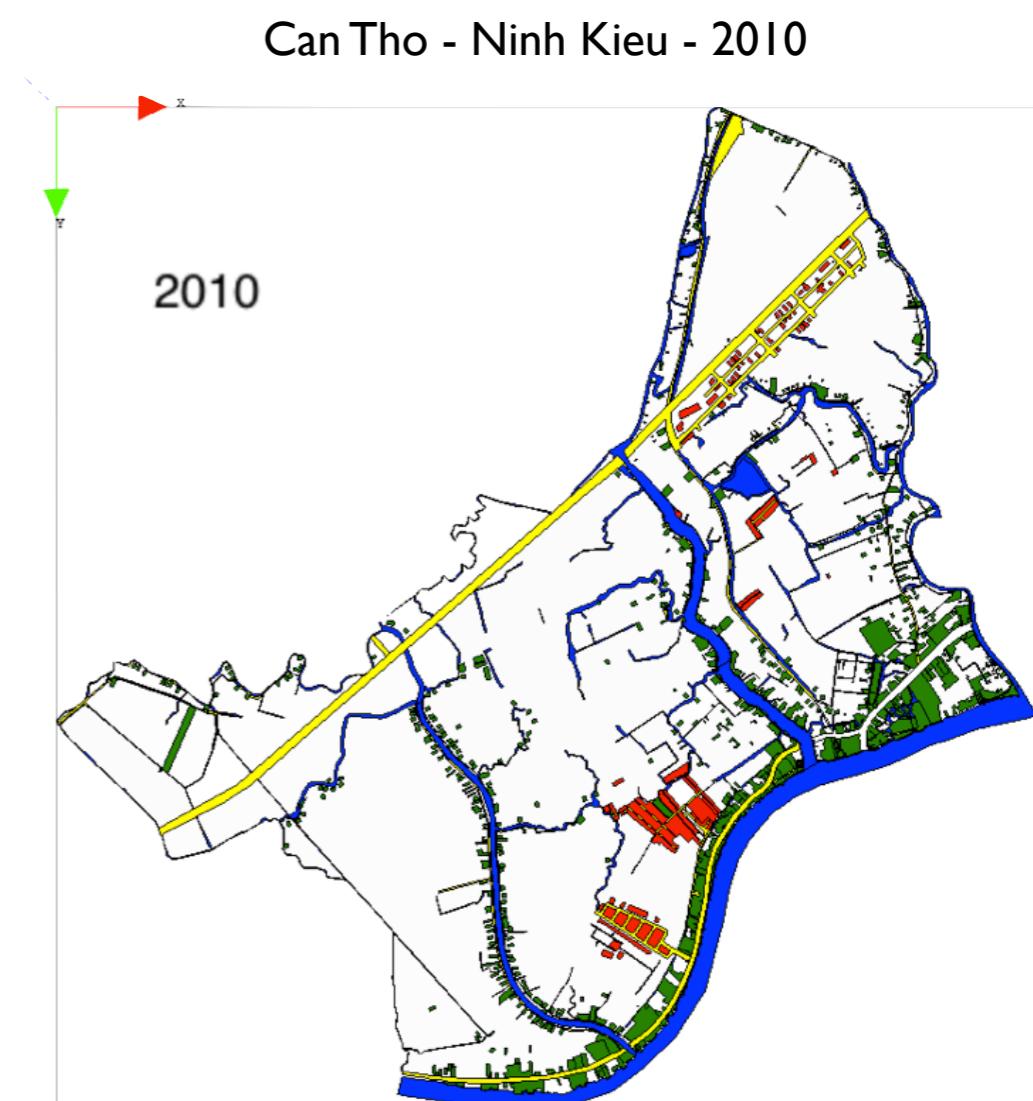
- **Spatial scale**
  - The An Binh ward of Can Tho
- **Time scale**
  - Duration : 5 years from 2005 to 2010
- **Dynamic to take into account**
  - The construction of buildings
- **Entities to take into account**
  - Buildings
  - Roads
  - Rivers



# Given the chosen entities and the data collected, we have to choose what will be an agent in our model

## ▶ First attempt

- ▶ as we are interested in the new buildings, we can chose to make buildings as agents.
- ▶ They have a shape, location and type as attributes.
- ▶ We have *concrete agents*:  
1 agent = 1 physical entity  
(building, road)
- ▶ Dynamics should then be described at the level of the building.

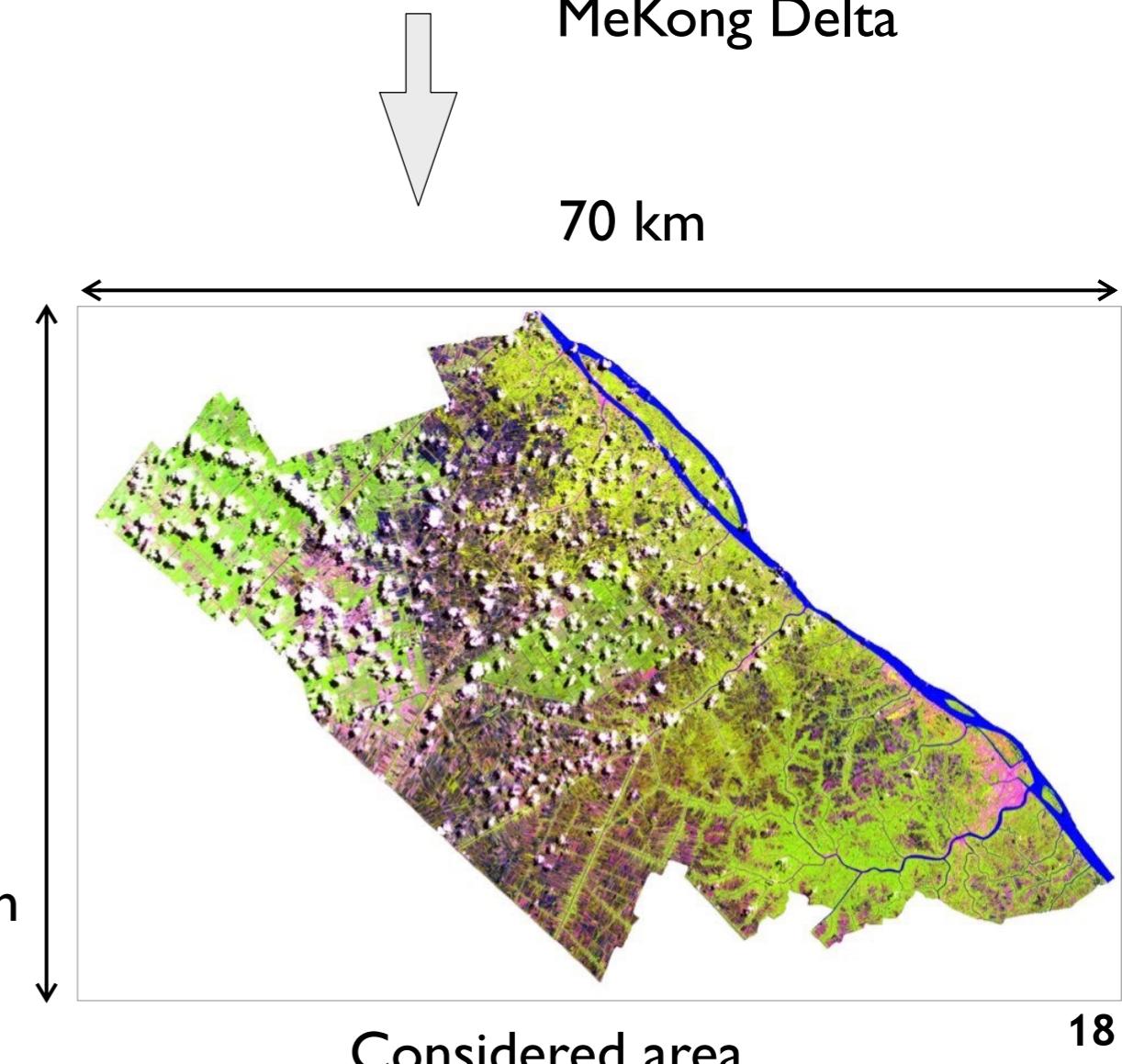


# Model 2: entities, dynamic and scales

- ▶ **Spatial scale**
  - ▶ Area that covers Can Tho city and the nearby suburbs
- ▶ **Time scale**
  - ▶ Duration : 15 years from 1999 to 2014
- ▶ **Dynamic to take into account**
  - ▶ The construction of buildings
- ▶ **Entities to take into account**
  - ▶ Buildings
  - ▶ Roads
  - ▶ Rivers



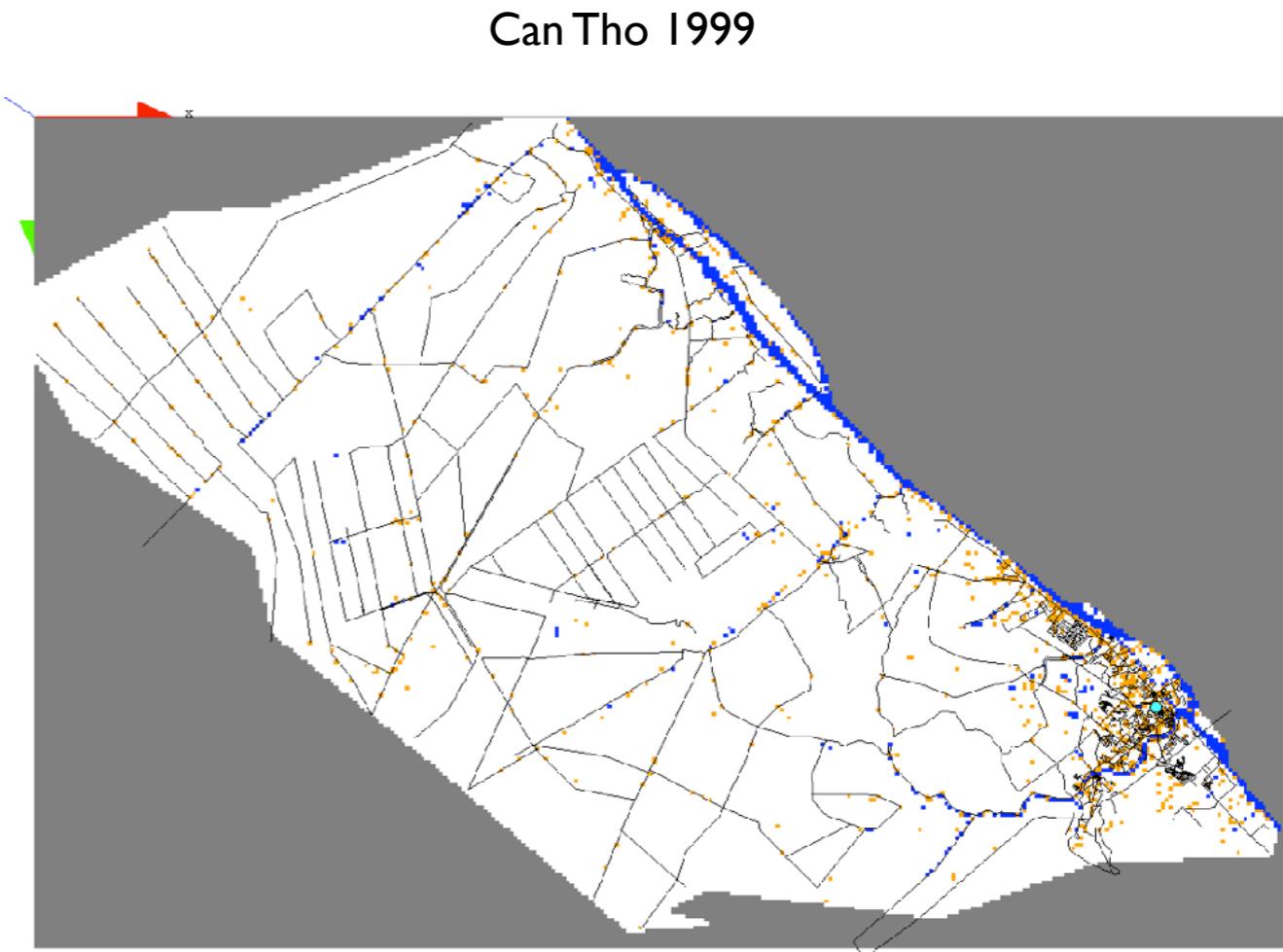
MeKong Delta



Considered area

# Given the chosen entities and the data collected, we have to choose what will be an agent in our model

- ▶ To deal with the whole city, we have to switch to something else...
- ▶ **Second attempt**
  - ▶ we choose to discretise the whole space on a regular grid. Agents will be the cells.
  - ▶ they are characterised by a rate of building on the cell area.

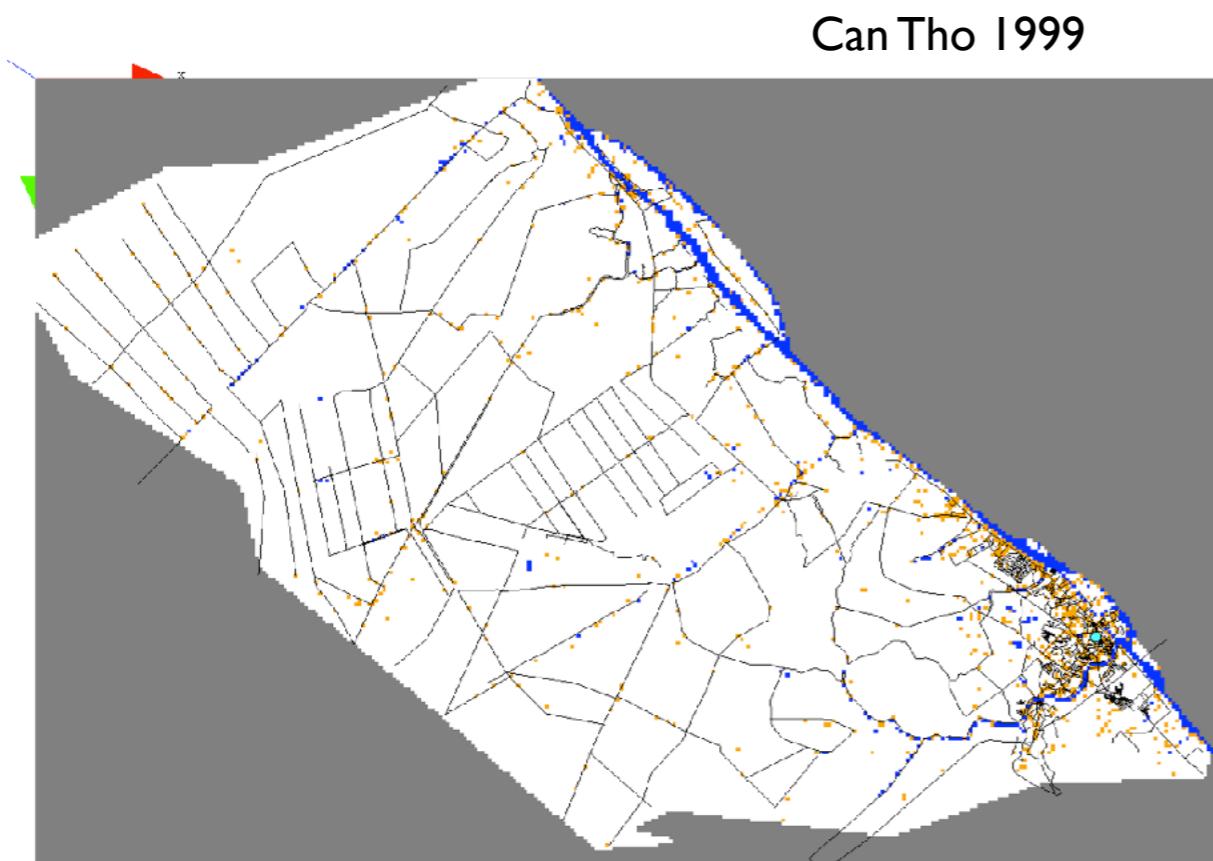


- ▶ We have *abstract agents*:
  - 1 agent = 1 entity aggregating buildings.
- ▶ We can choose the number of cells, so the discretisation rate, and so the precision.

## Can Tho Case study

- Objective: reproduce the urban growth of the agglomeration of Can Tho from 1999 to 2014

- Empty space
- Water space
- Built space
- Road
- City center

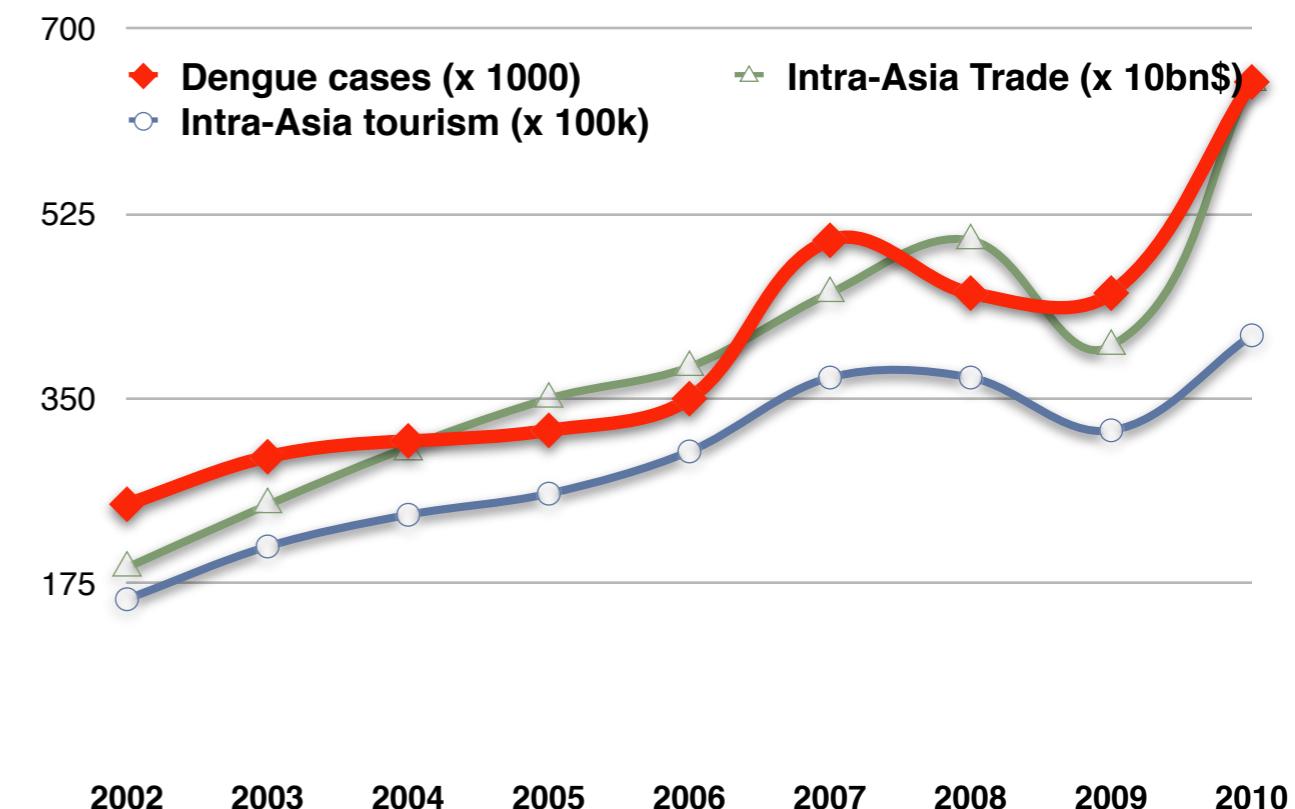


For each free cell (empty space): evaluation of their constructability value based on 3 criteria:

- density (C1)
- distance to road (C2)
- distance to city center (C3)

The decision is made using multi-criteria (**weighted mean**) decision-making process, with 3 weights ( $w_1, w_2, w_3$ ) associated to each criteria.

# Example 2: What incidence do the economic exchanges between ASEAN countries have on the dengue spread?



► Impact of country control policies ?

# Model: entities, dynamic and scales

## ► Spatial scale

- Area that covers the ASEAN corridor from Myanmar to Vietnam (200 000km<sup>2</sup>)



## ► Time scale

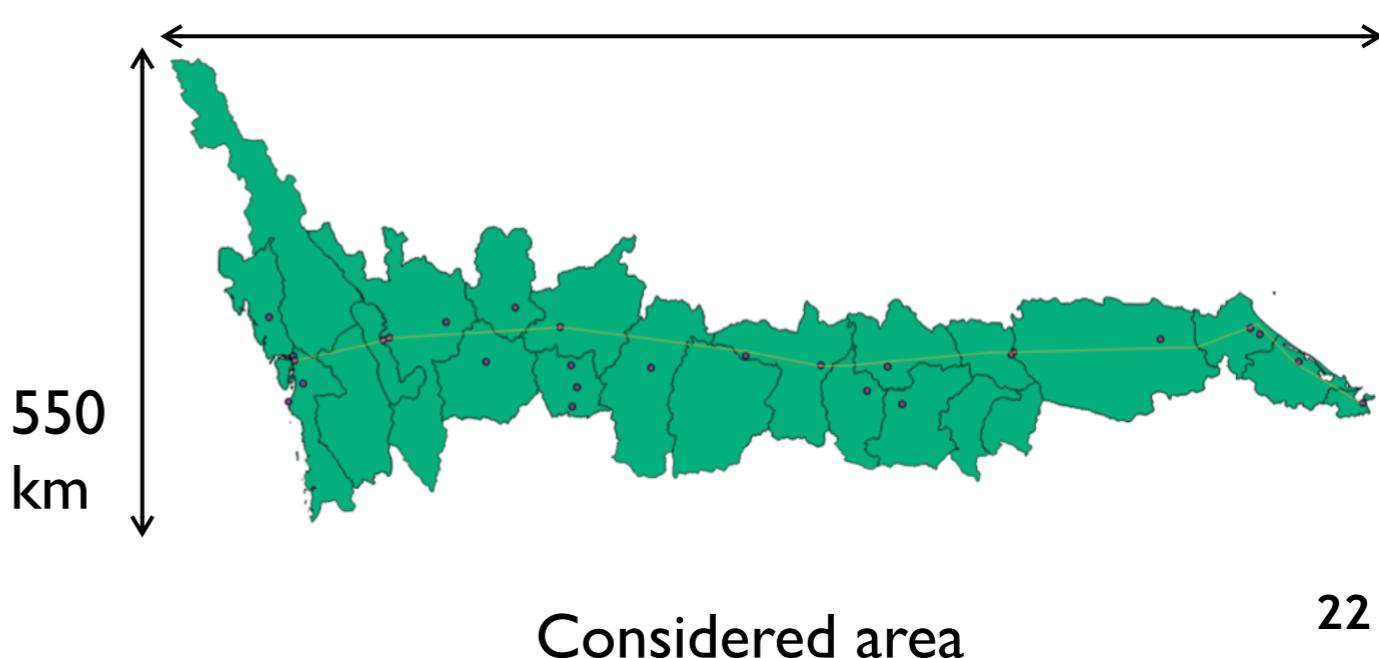
- Duration : from 2004
- Time step = 12 hours

## ► Dynamic to take into account

- Epidemic spread
- Weather
- Mobility

## ► Entities which may be taken into account

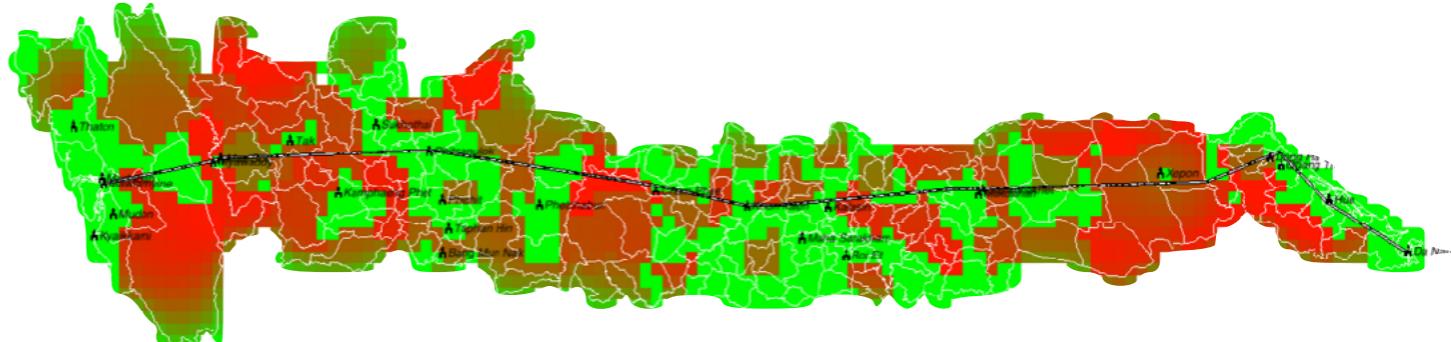
- Mosquitoes, humans
- Meteo Station
- trucks, roads, cities



# What will be the agents in this case ?

## ► Issue:

- #humans = 15 000 000,
- #mosquitos = unknown (a lot !)  
=> We cannot simulate each individual.

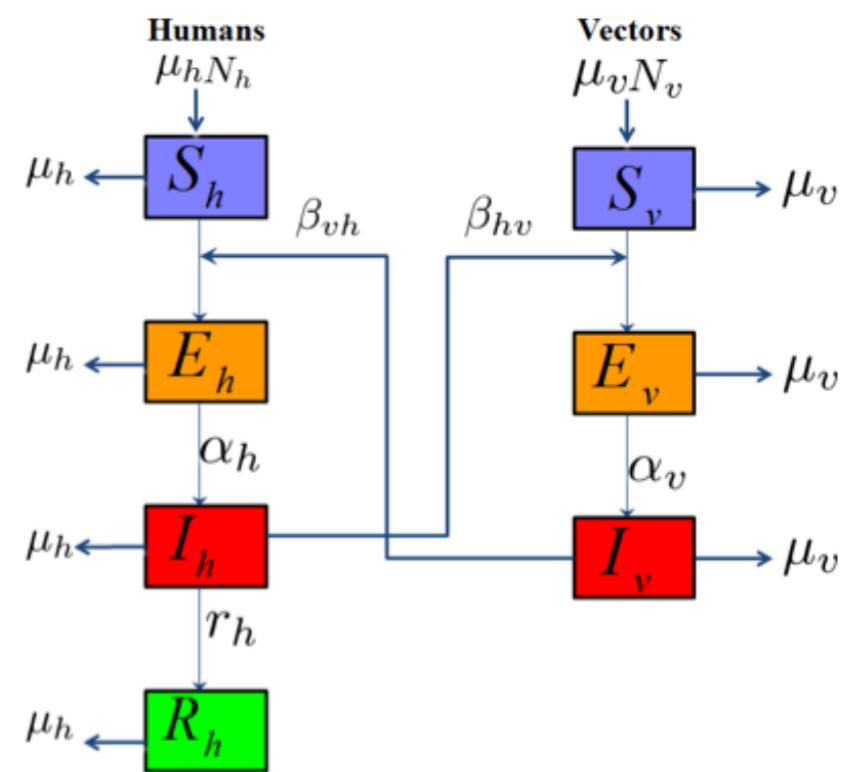


## ► Hypothesis & Choice:

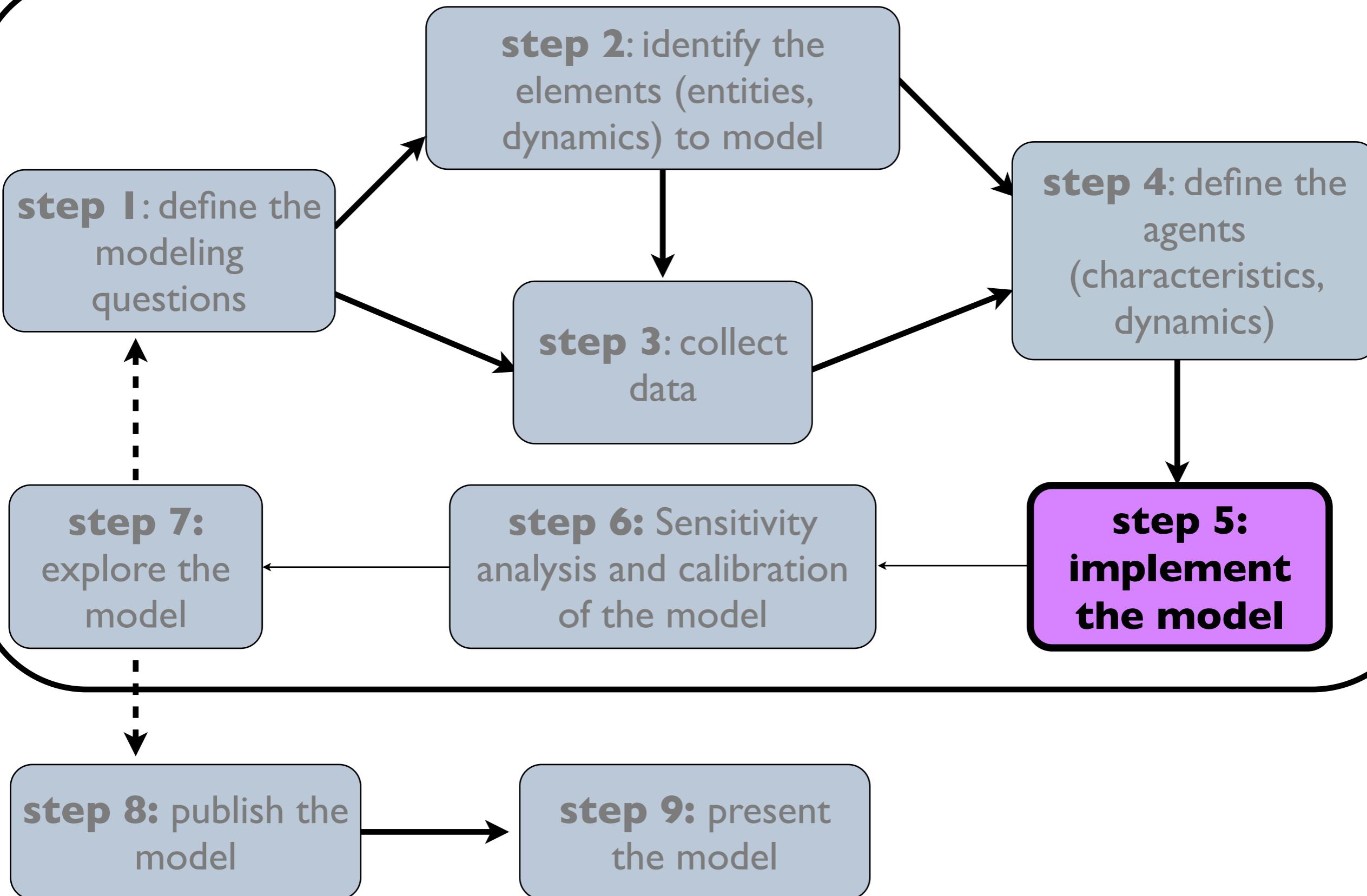
- we choose to discretise to whole space on a regular grid. Agents will be the cells.
- they are characterised by populations of mosquitos and human beings in each epidemic state.

## ► Dynamics:

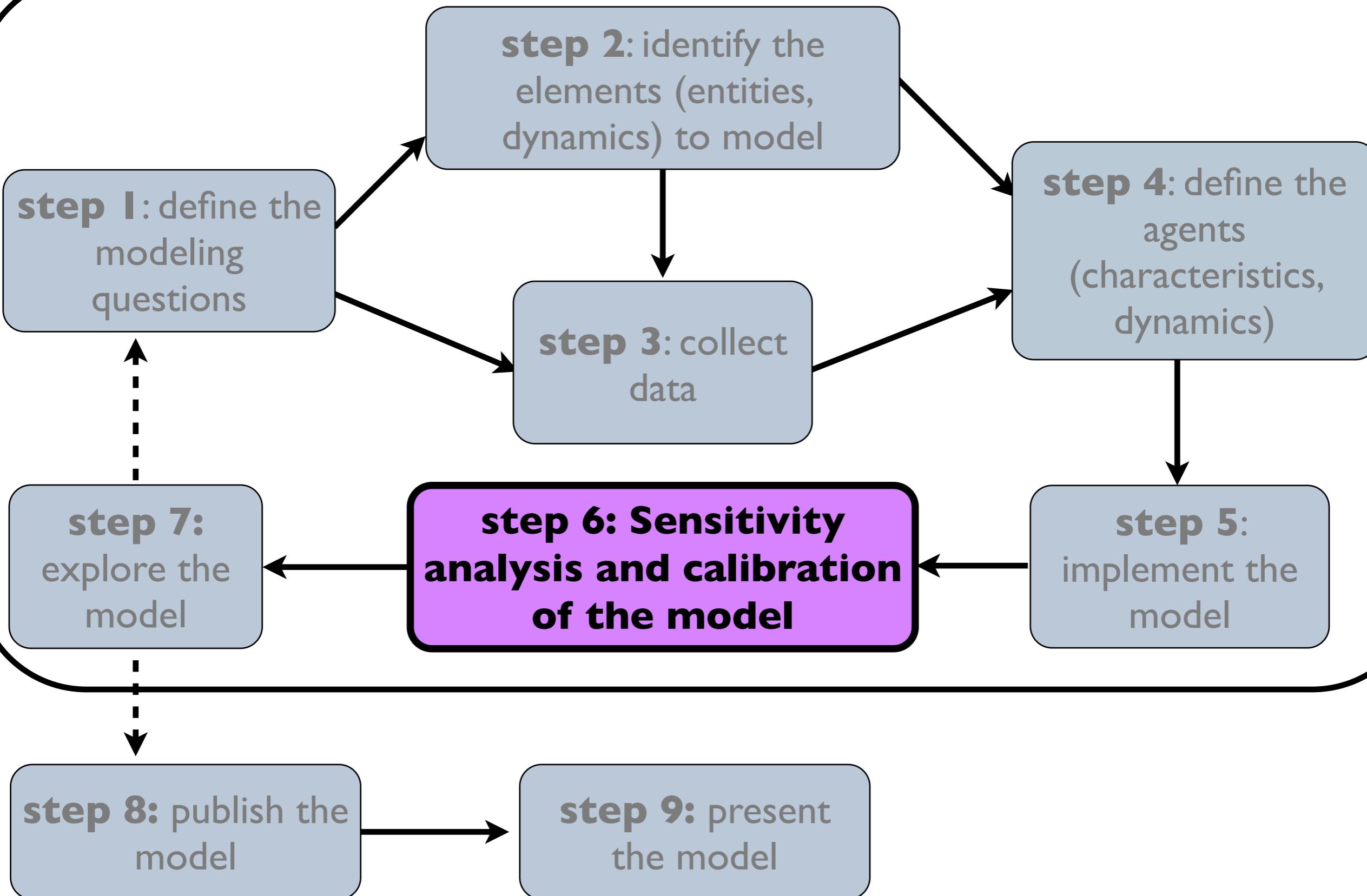
- disease spread : mathematical equation-based model (SEIRS + SEI model on each cell).



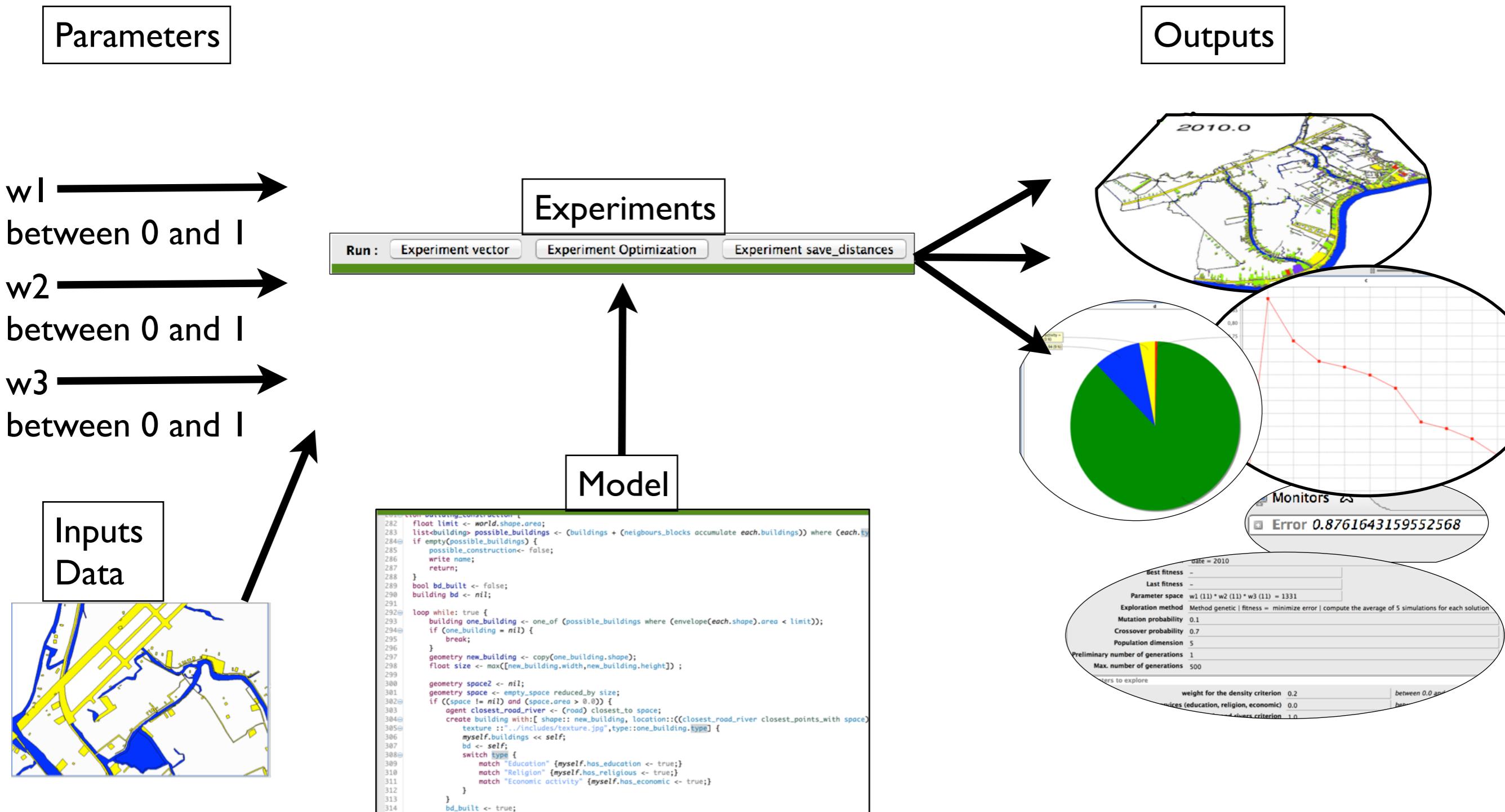
# Modelling is a multi-step cycle.



# Modelling is a multi-step cycle.



A model is an object that can be manipulated or explored via simulation and on which we can launch experiments.



**Often there are at least 2 ways to run simulations.**

**GUI experiment:**

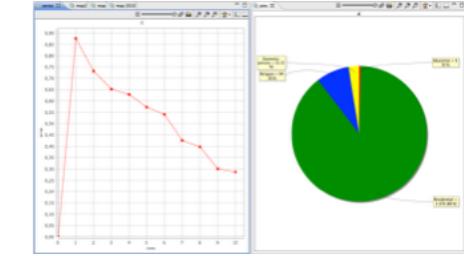
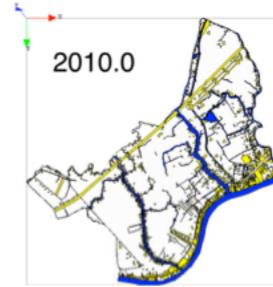
Gui experiments allow the modeler to observe indicators evolution during a simulation

**batch experiment:**

batch experiments allow model to observe the evolution of indicators of the simulation (computed at the end of the simulation) over the change of parameters.

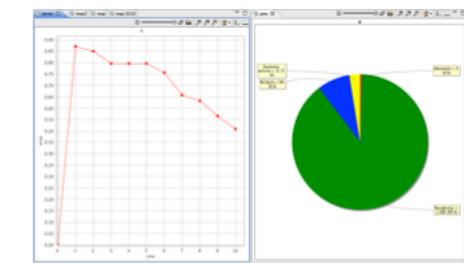
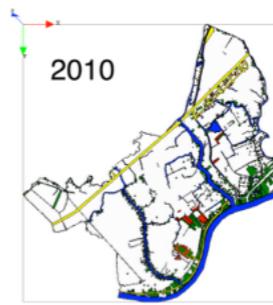
**GUI experiments allow to test various parameters values and observe the output.... which can be long and fastidious at hand ...**

$w1 = 0.2$   
 $w2 = 0.0$   
 $w3 = 1.0$



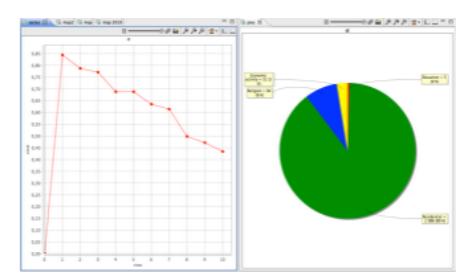
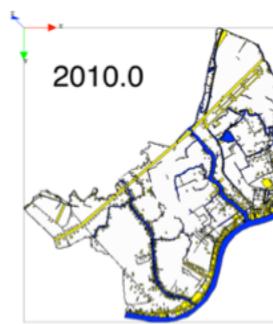
Error = 0.2869

$w1 = 0.7$   
 $w2 = 0.5$   
 $w3 = 0.2$



Error = 0.5093

$w1 = 0.5$   
 $w2 = 0.3$   
 $w3 = 0.8$

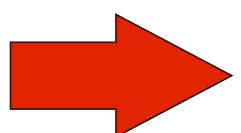


Error = 0.4344

.....

# The batch mode allows to automatically execute parameter space exploration.

- ▶ Exploring the parameters space of a model can be used to:
  - Correct the model,
  - Do sensibility analysis,
  - Calibrate it,
  - Discover emerging properties,
  - ...

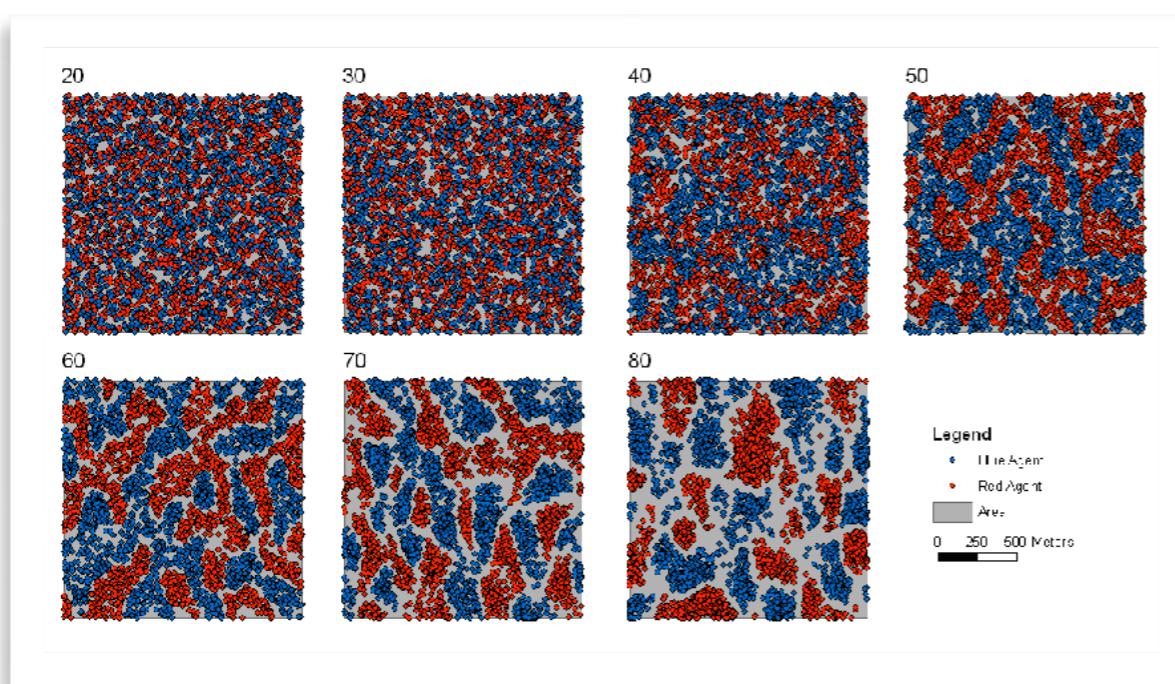


A necessary step!

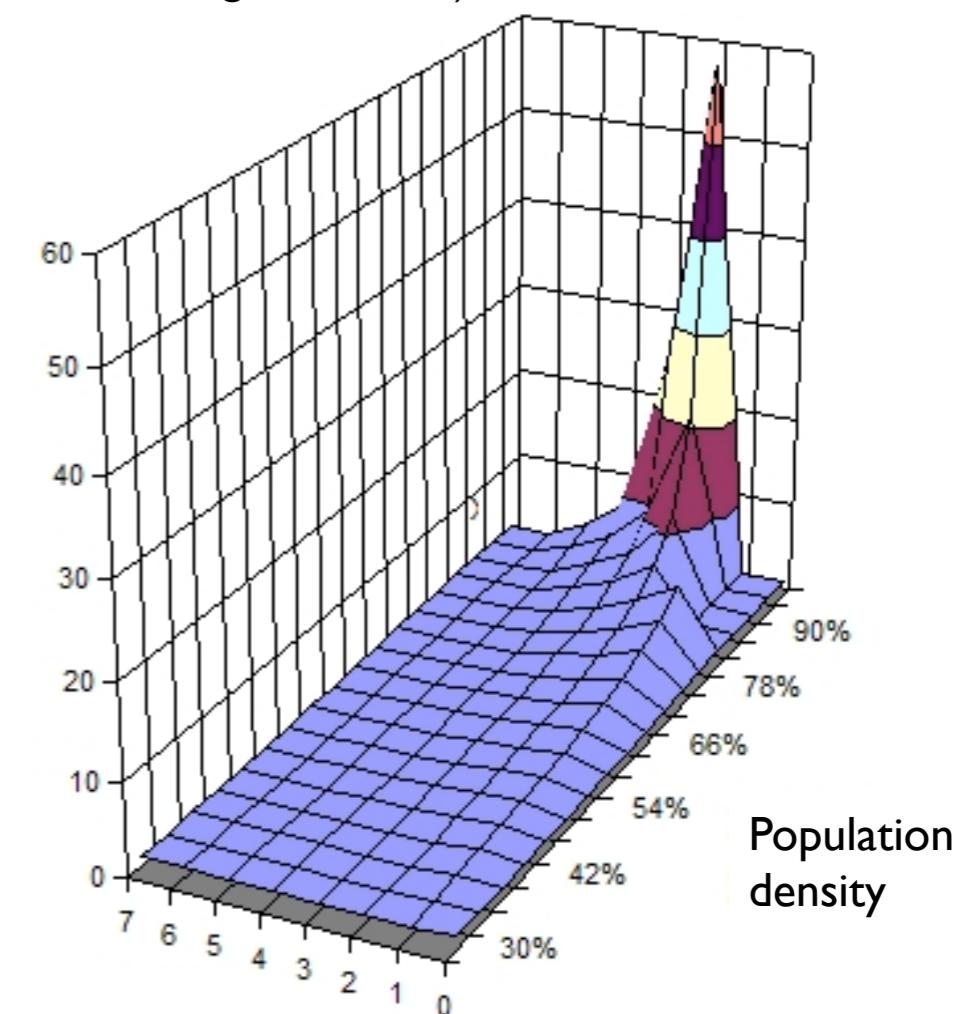
# Explore the model behaviour through the exploration of the parameters space.

**Aim:** to have a deep knowledge of the behaviour of the model (and in particular its **sensitivity to parameters variations**)

Example on the Schelling's model:



Mean size of aggregates depending on the 2 parameters:  
- number of different neighbours accepted  
- population density  
(Daudé E. & Langlois P. 2006)



Number of different  
neighbours that can be  
accepted by an agent

«Exhaustive» exploration  
of the Schelling's model

The calibration allows to find parameters values making the simulation results fitting to real data.

## Objective:

What are the values of parameters:

- that allow to obtain a «realist» model ?
- that minimise the difference between real and simulated data ?



Real data (at the time of the simulation end)

w1 = ??  
w2 = ??  
w3 = ??



Real data at initial time

error = difference  
between simulated  
data and real data



Simulated data at the end of the simulation

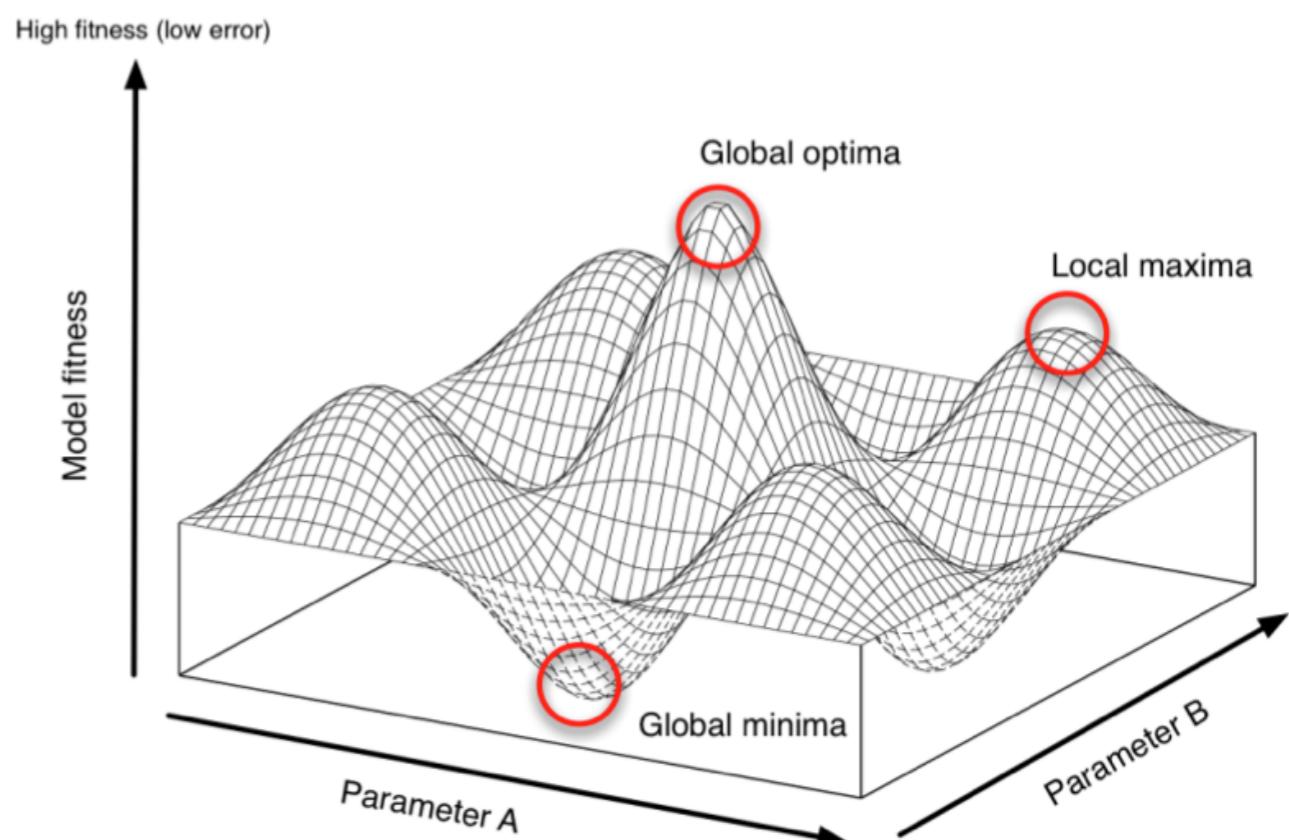
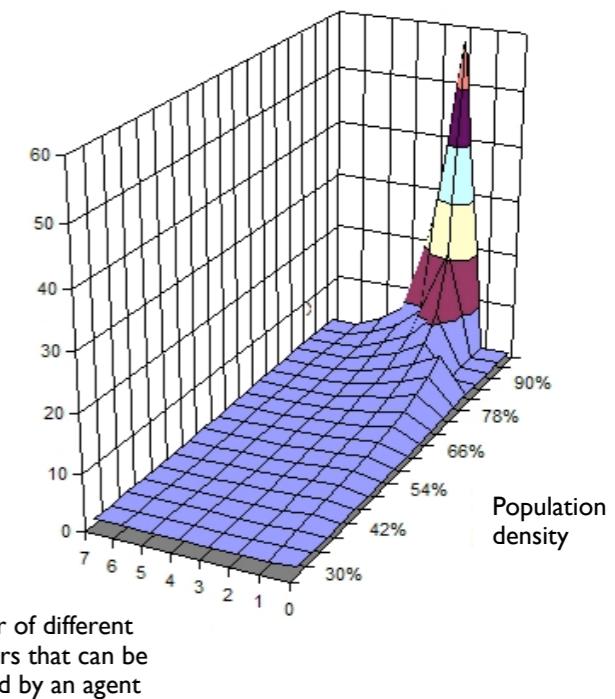
## Issues linked to the calibration.

Find a good **indicator** (often named fitness) to represent the fact that a **simulation is «good»** (e.g. the difference between real and simulated data):

- in the case of urban growth model, this indicator should represent the distance between real and simulated maps.

To find the parameters is closed to an optimisation problem (minimise a value):

- lot of methods exist (exhaustive, Genetic algorithms, ... )



[http://nickmalleson.co.uk/wp-content/uploads/2013/04/parameter\\_space.png](http://nickmalleson.co.uk/wp-content/uploads/2013/04/parameter_space.png)

# Steps in an experiment design.



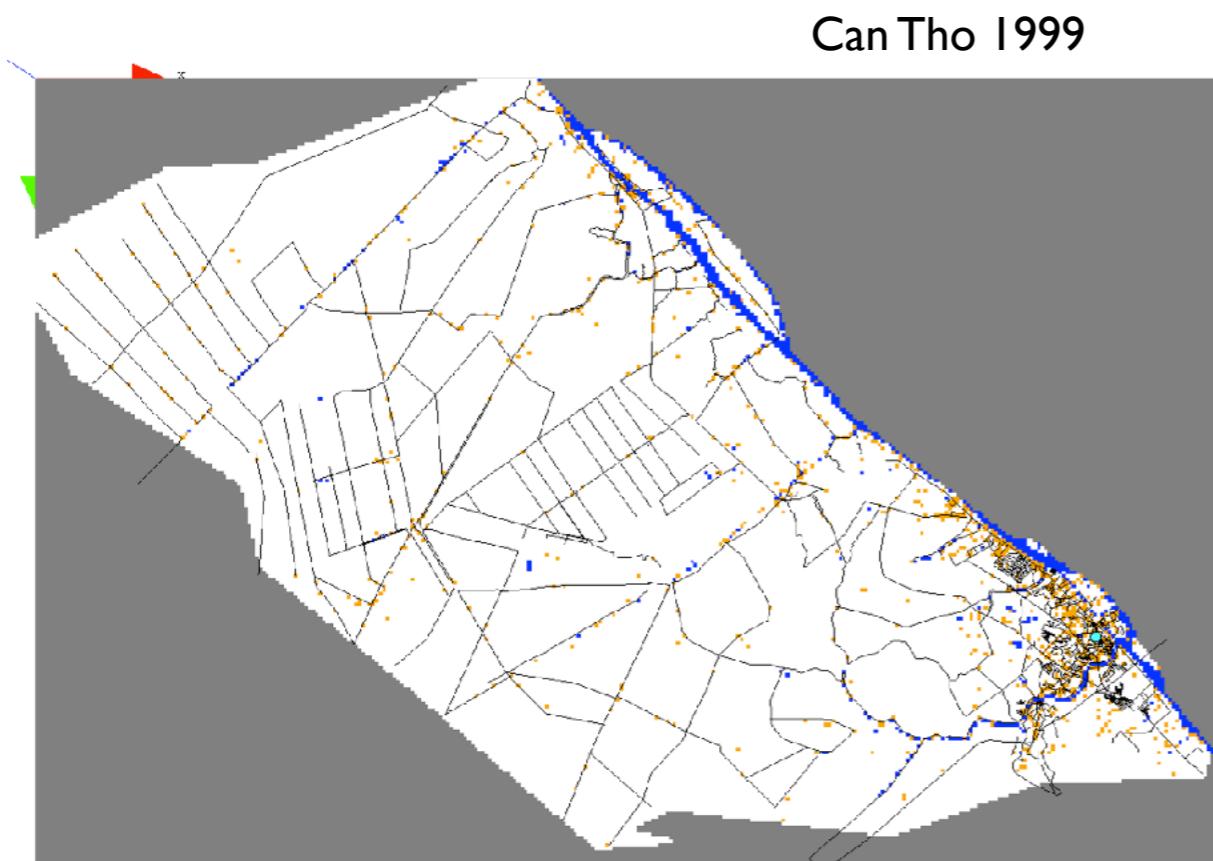
## General method :

- Define an **initial situation** and a **stop criterion** (of 1 simulation)
- Select the **set of parameters** to explore and the **indicators**
- Define a **strategy of exploration**
- Execute, collect and save the data
- Analyze the collected data

## Can Tho Case study

- Objective: reproduce the urban growth of the agglomeration of Can Tho from 1999 to 2014

- Empty space
- Water space
- Built space
- Road
- City center

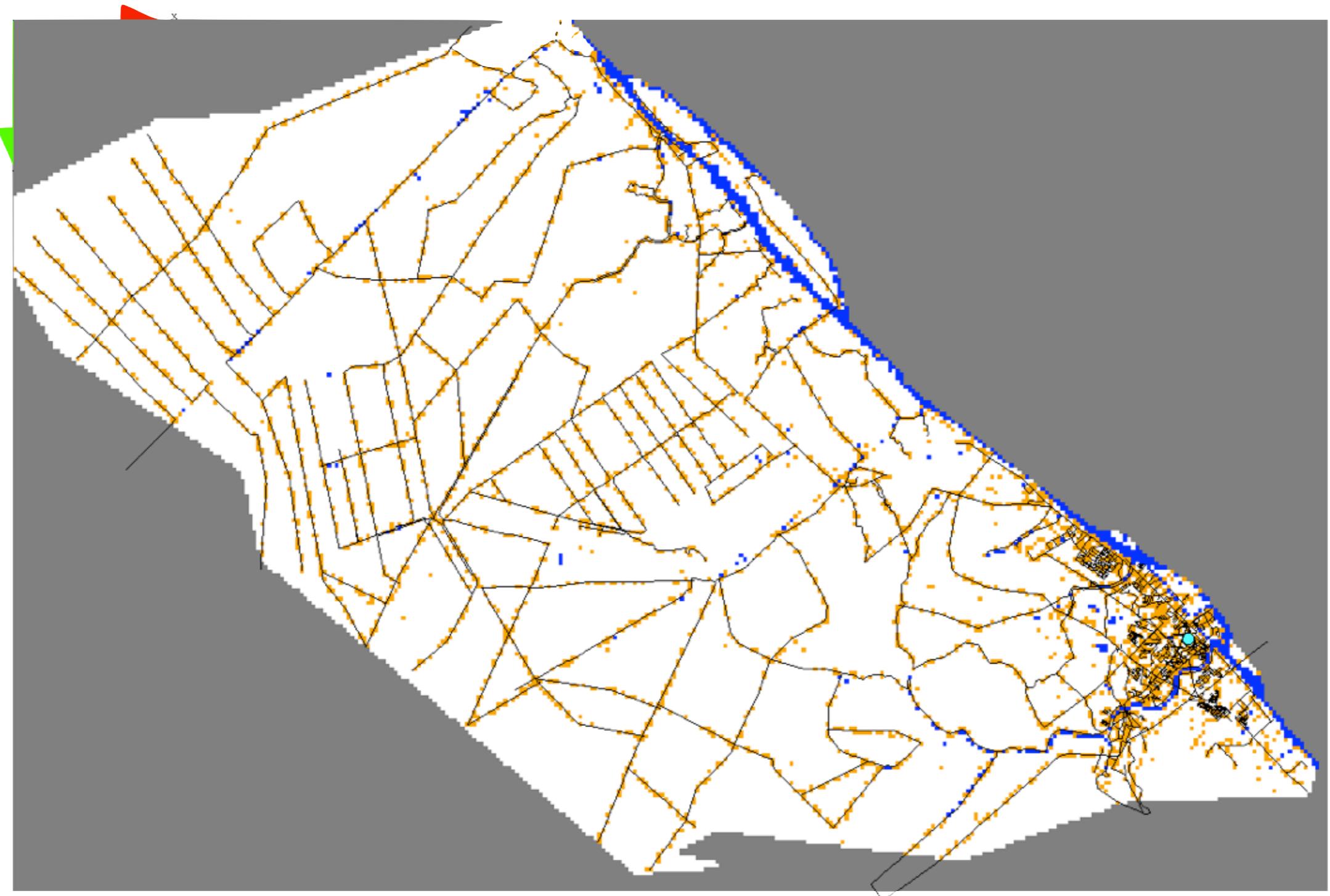


For each free cell (empty space): evaluation of their constructability value based on 3 criteria:

- density (C1)
- distance to road (C2)
- distance to city center (C3)

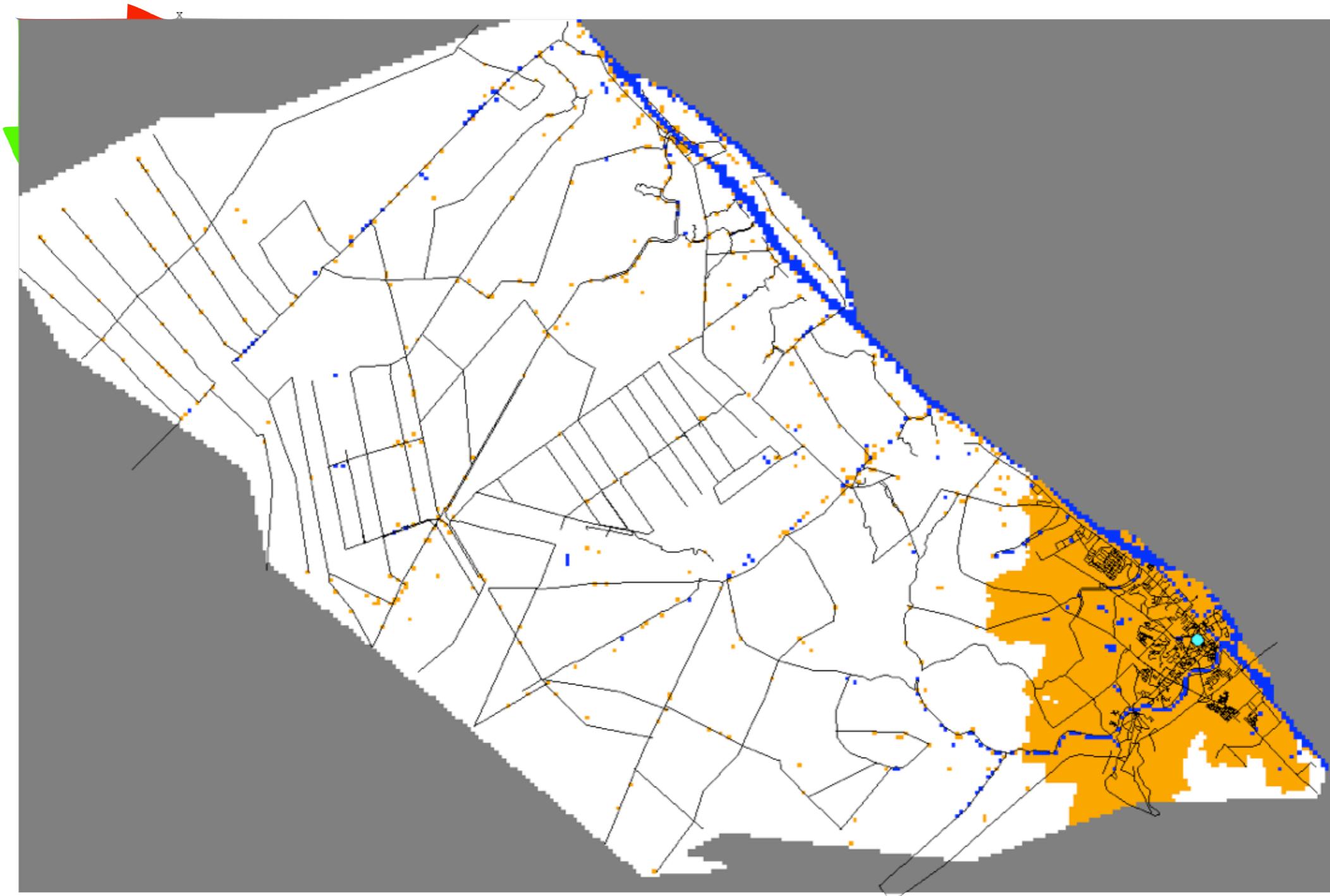
The decision is made using multi-criteria (**weighted mean**) decision-making process, with 3 weights ( $w_1, w_2, w_3$ ) associated to each criteria.

## Can Tho Case study: first simulation with only the distance to road criterion



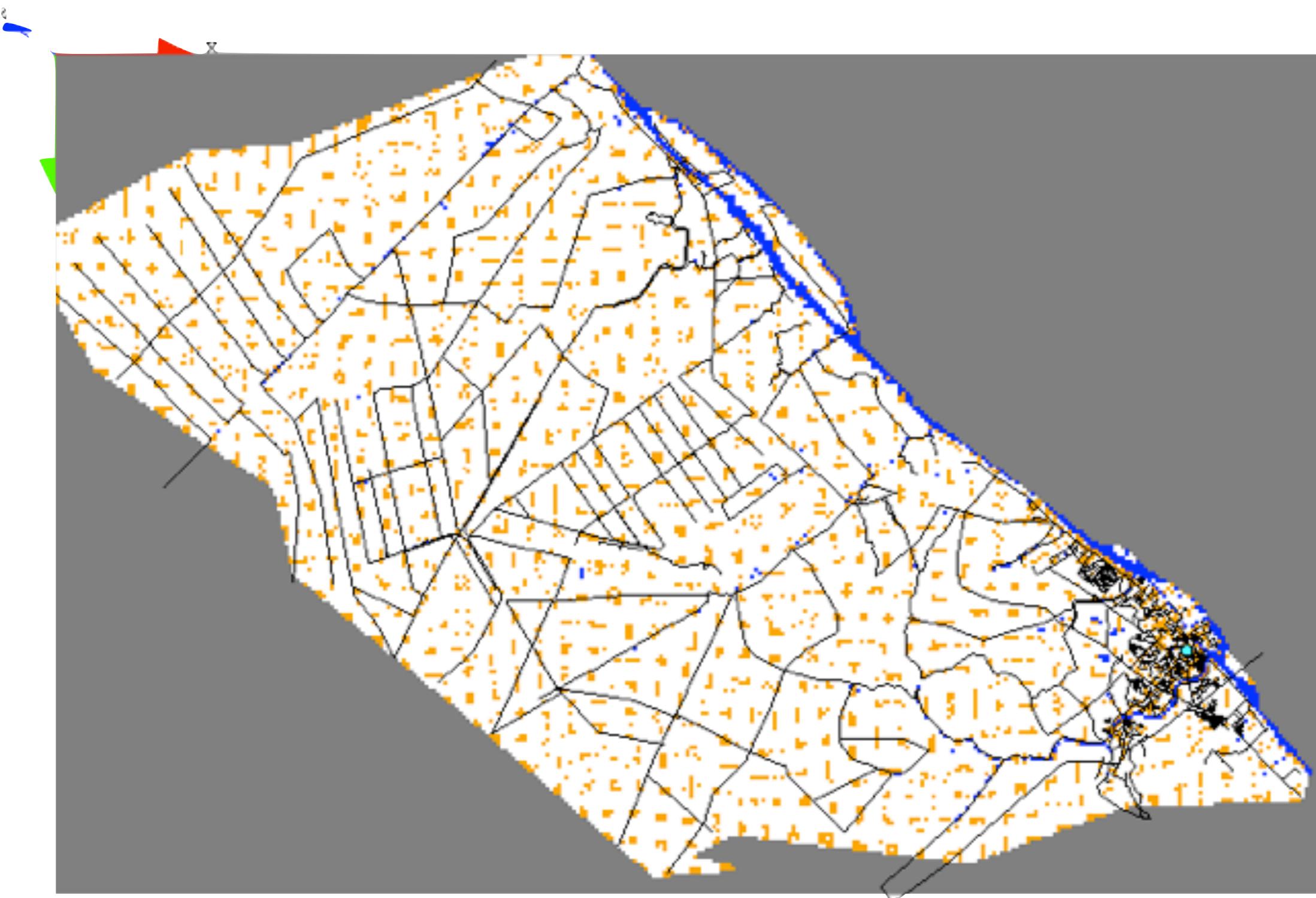
Construction along the roads

# Can Tho Case study: first simulation with only the distance to city center criterion



Expansion of the city center

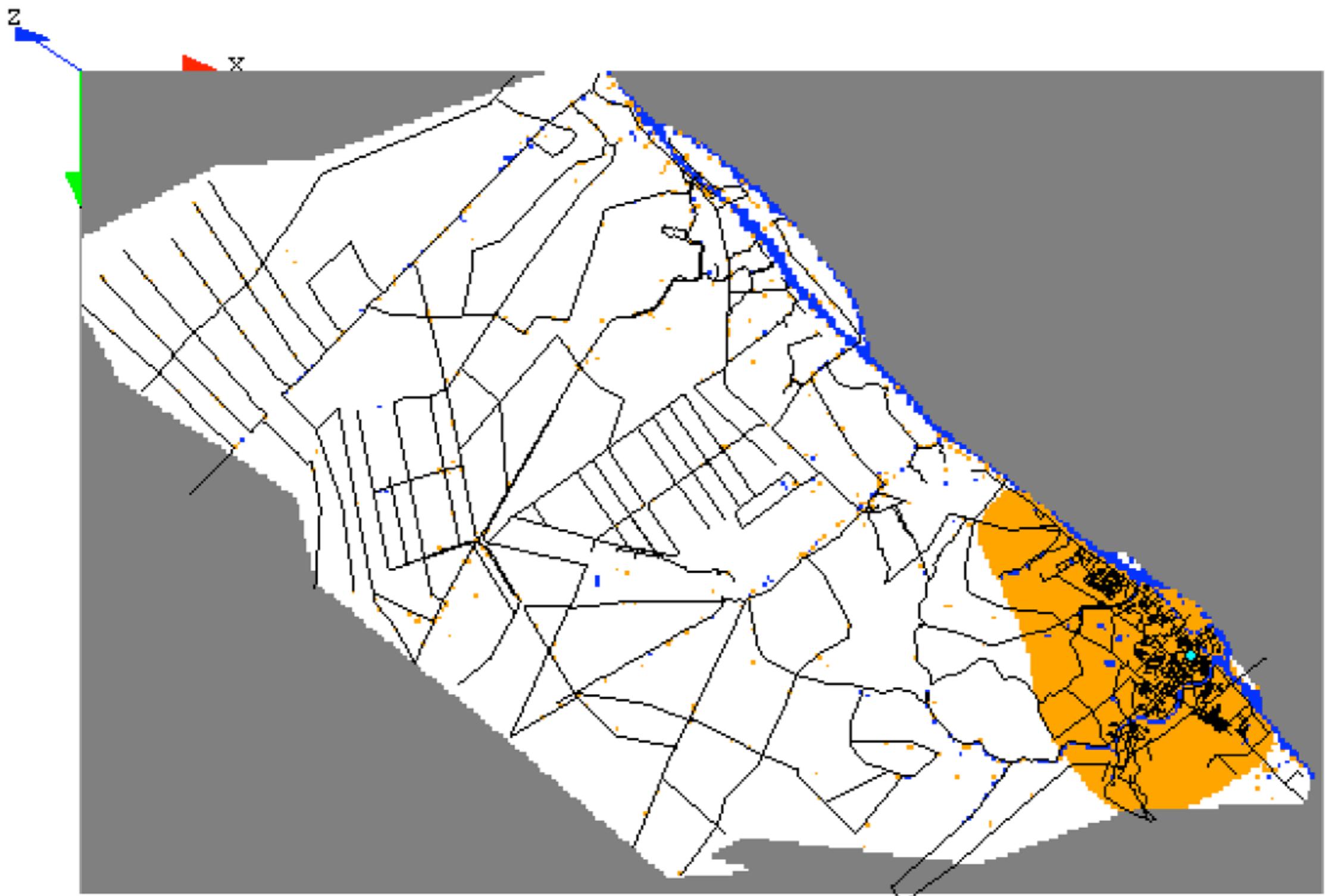
## Can Tho Case study: first simulation with only the (low) density criterion



Lot of small «building blocks» covering uniformly the space

w1 : density = 1 - (number of built neighbor cells / number of neighbor cells)

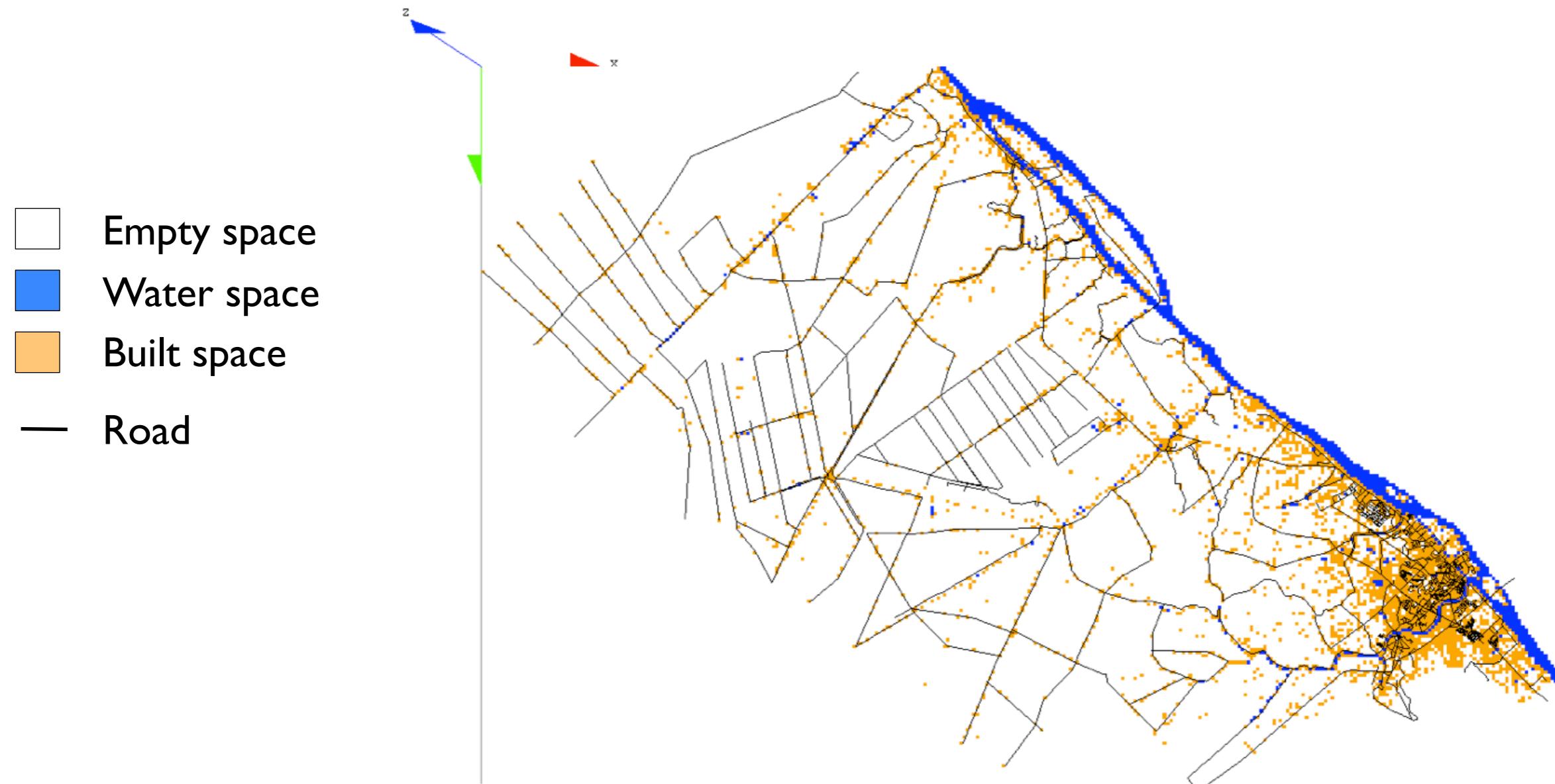
## Can Tho Case study: first simulation with only the (high) density criterion



Expansion from high density areas

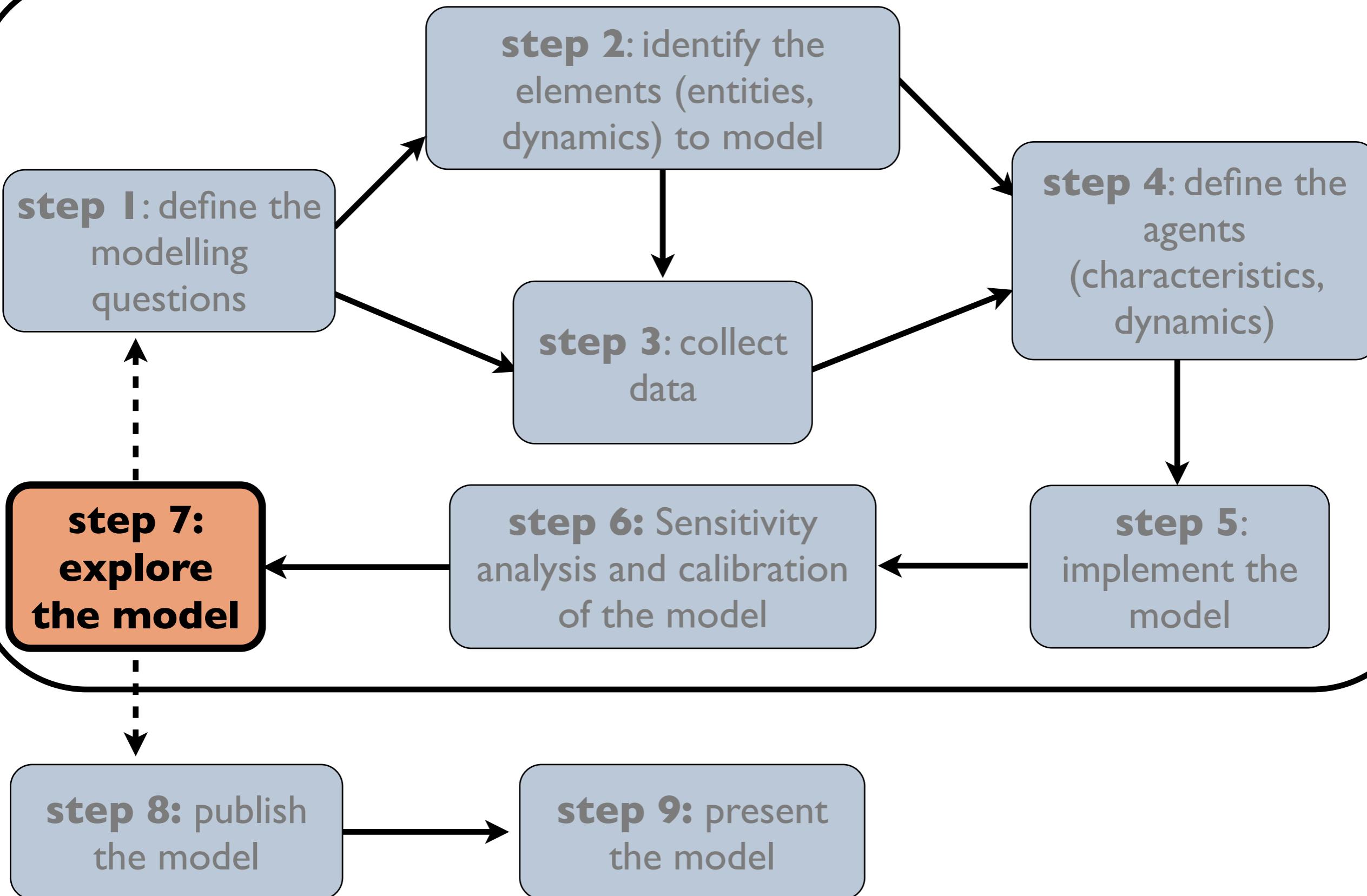
w1 : density = (number of built neighbor cells / number of neighbor cells)

# Can Tho Case study: calibration of the model to reproduce the real urban growth



How to evaluate the error between the simulation and the observed data?  
Use of the **Fuzzy Kappa Sim** indicator

# Modelling is a multi-step cycle.



# Once the model has been calibrated, we can explore the result of the simulation to various scenario.

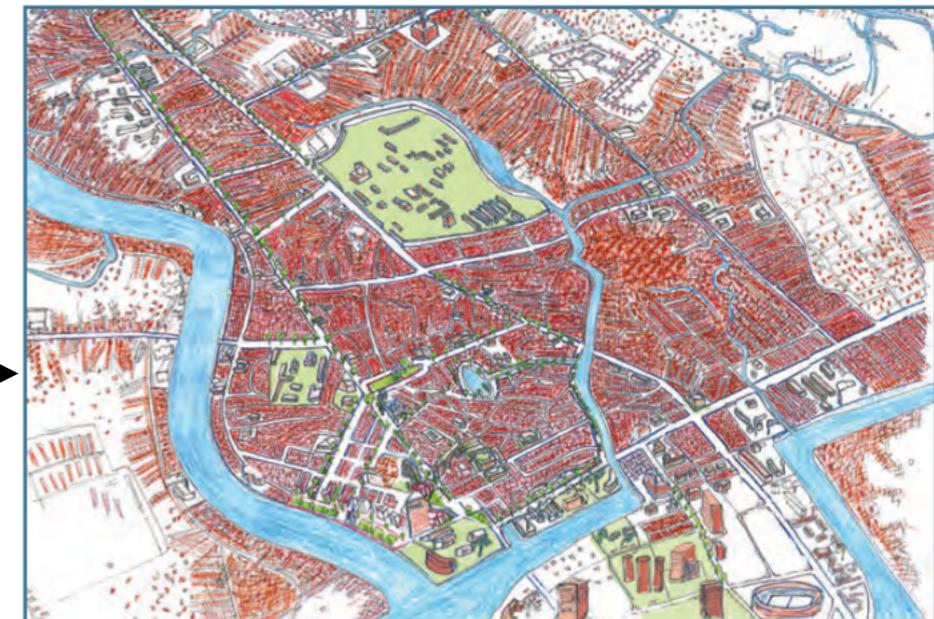
We can define scenario that we want to explore:

- building of a new road, of new houses, services...

From an initial state

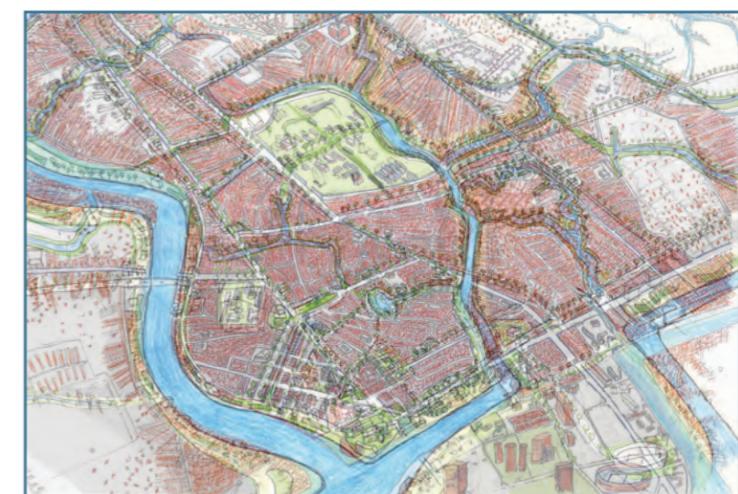


What-If no change is done  
in terms of urban planning ?



???????????

What-If water channels  
are improved ?



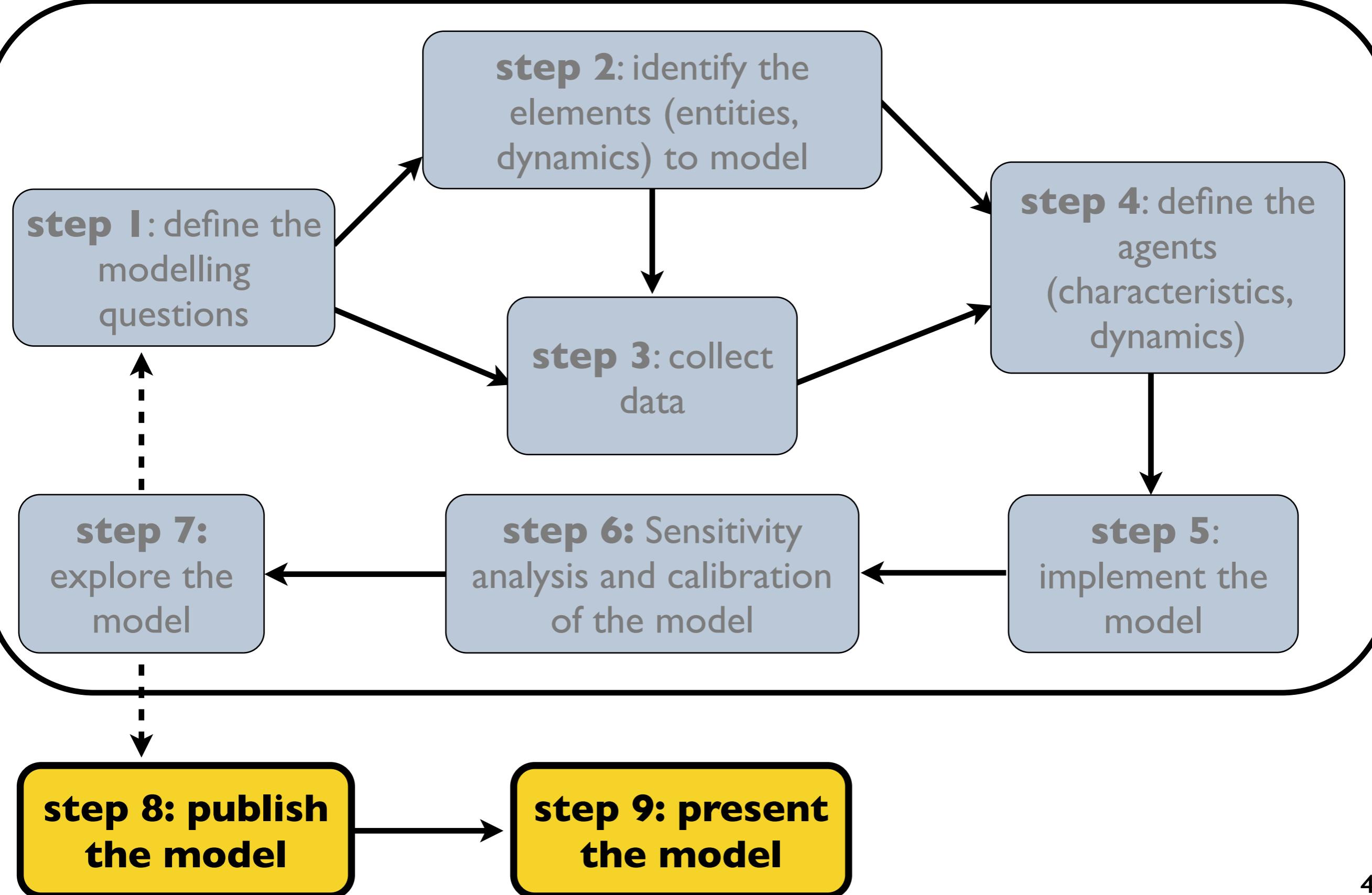
???????????

Modeling can be useful:

- to build Decision-Support Systems (DSS)
- > to help urban planning.



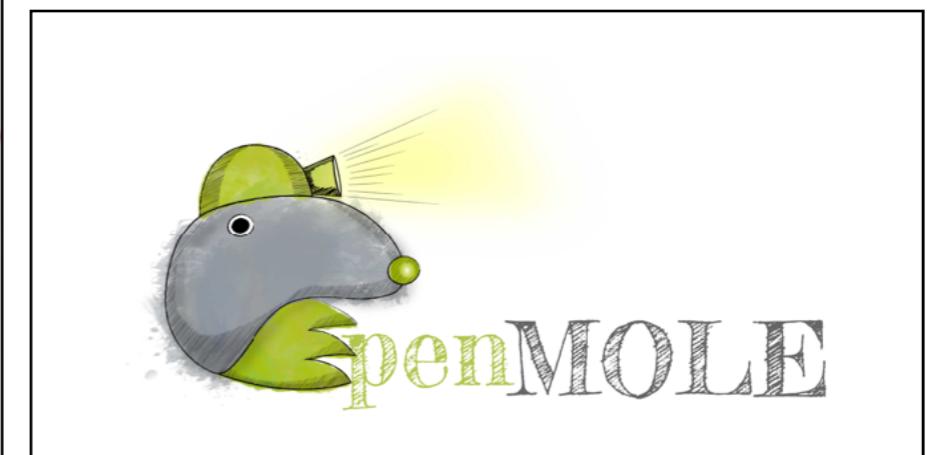
# Modelling is a multi-step cycle.



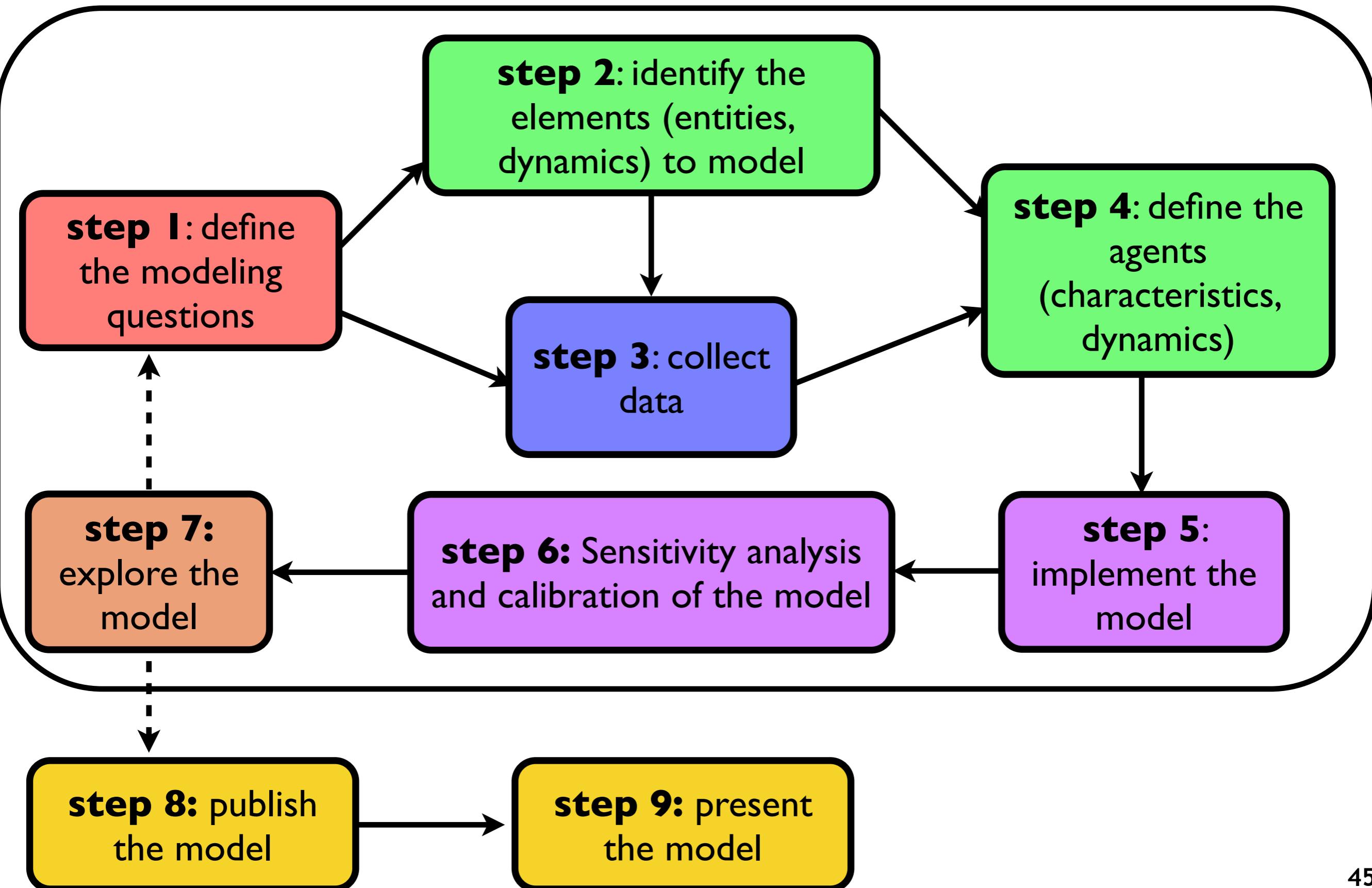
## Description and publication of ABM: Status in 2000's

- ▶ ABMs description very variable
  - ▶ UML descriptions not used/understood by everybody
  - ▶ Specially in ecology: lots of ABMs not considered as “real science” because not reproducible
- Need of a description protocol for reproducibility and reliability

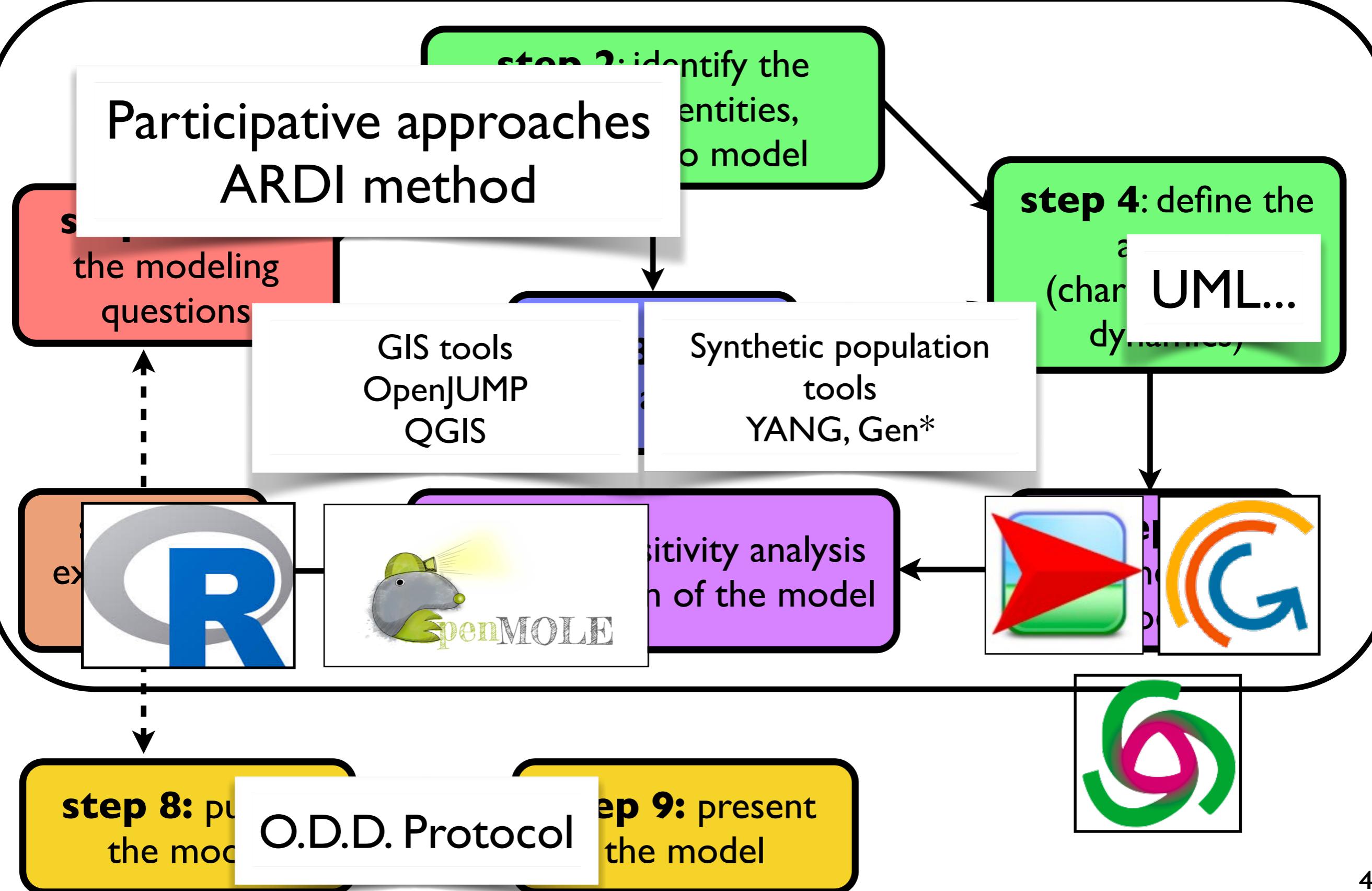
# Tools box for modeling and simulation



# Modelling is a multi-step cycle.



# Modelling is a multi-step cycle.

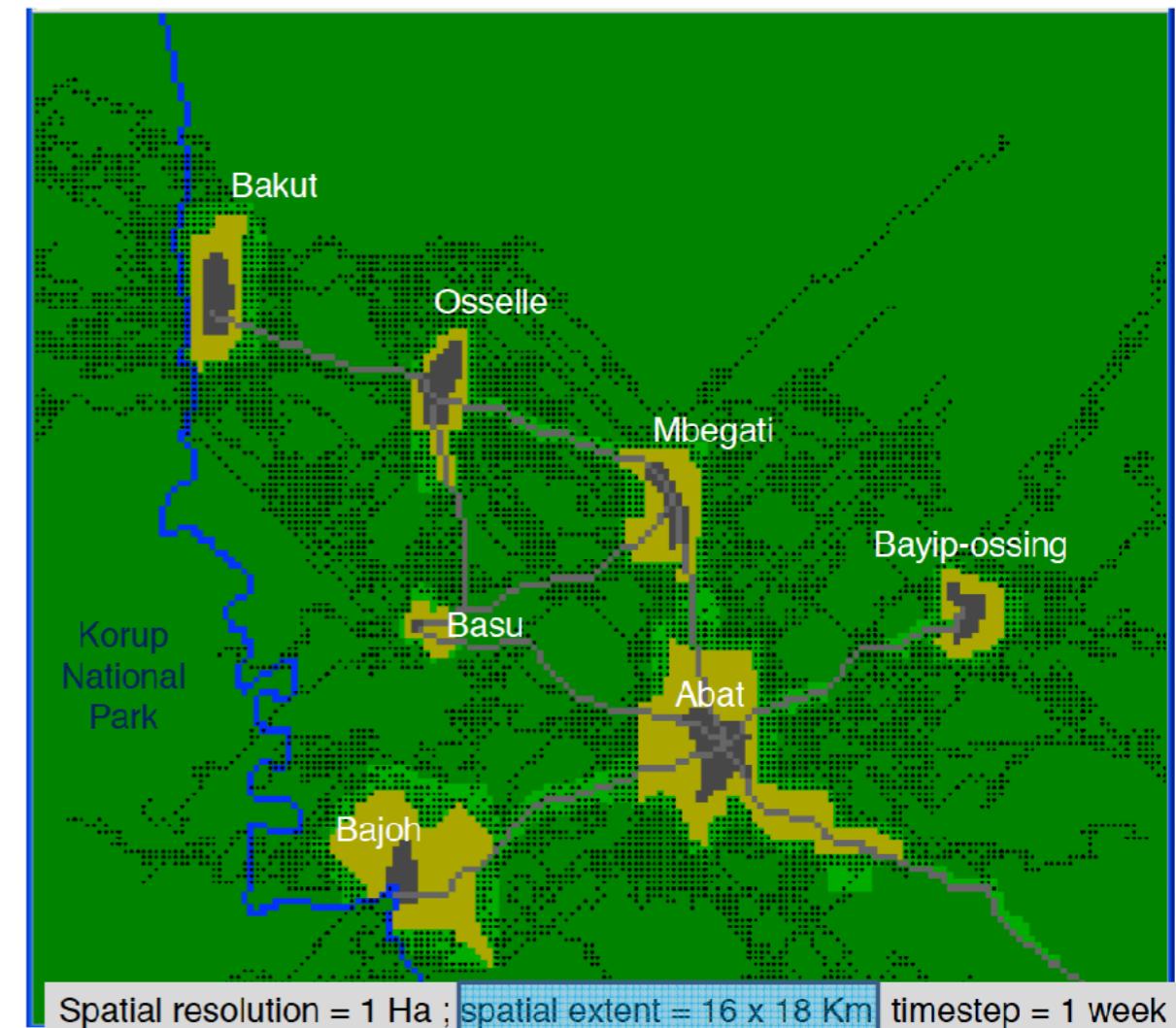


## Example of a participative modeling workshop



Serge Bobo Kadiri, Dschang University, Cameroon {bobokadiris@yahoo.com}  
Christophe Le Page, CIRAD Montpellier, France {le\_page@cirad.fr}

# Example of a participative modeling workshop

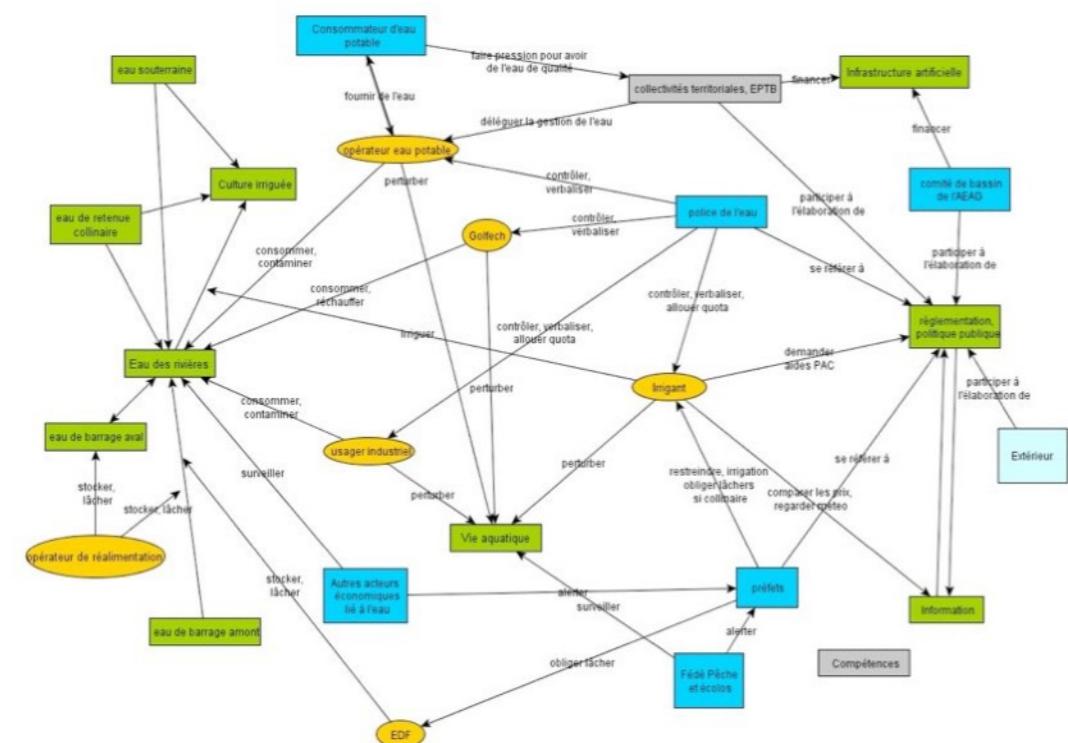


# The ARDI method

A methodology for co-design of a conceptual model of socio-environmental interactions in a socio-ecological system.

## Actors Resources Dynamics Interactions

From identification of a problem...  
... to a question



# Co-construction of a shared representation in 4 steps

A = Actors

R = Ressources

D = Dynamics/ processes

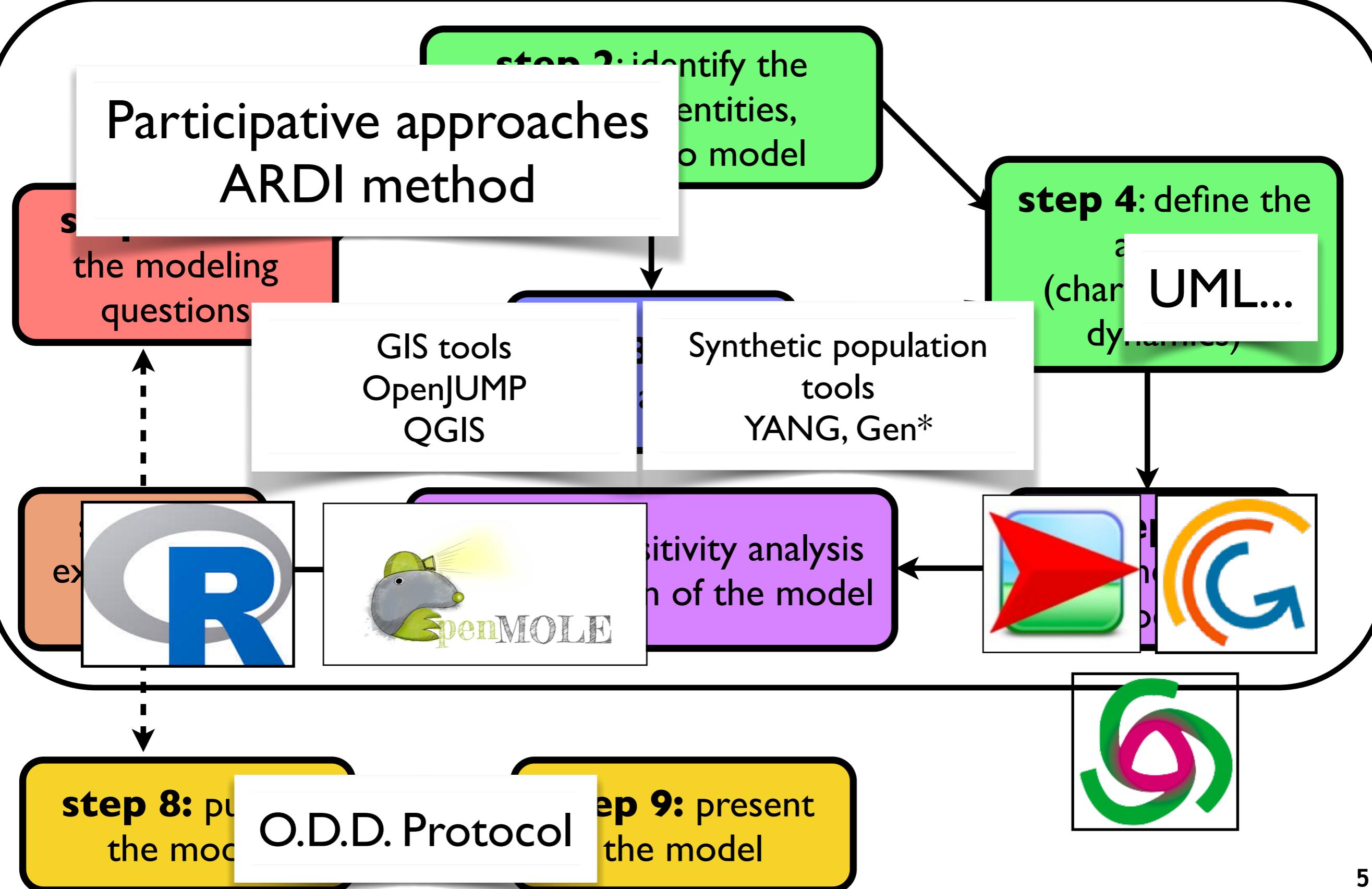
I = Interactions

Each step corresponds to a particular kind of question.

[Example on a case study of studying Adour-Garonne water basin]

1. Who are the main actors who interact with the river and its flow?
2. What are the resources in relation to the debit?
3. What are the main processes occurring in the Adour-Garonne basin and affecting the flow of water?
4. How each actor uses the resource

# Modelling is a multi-step cycle.

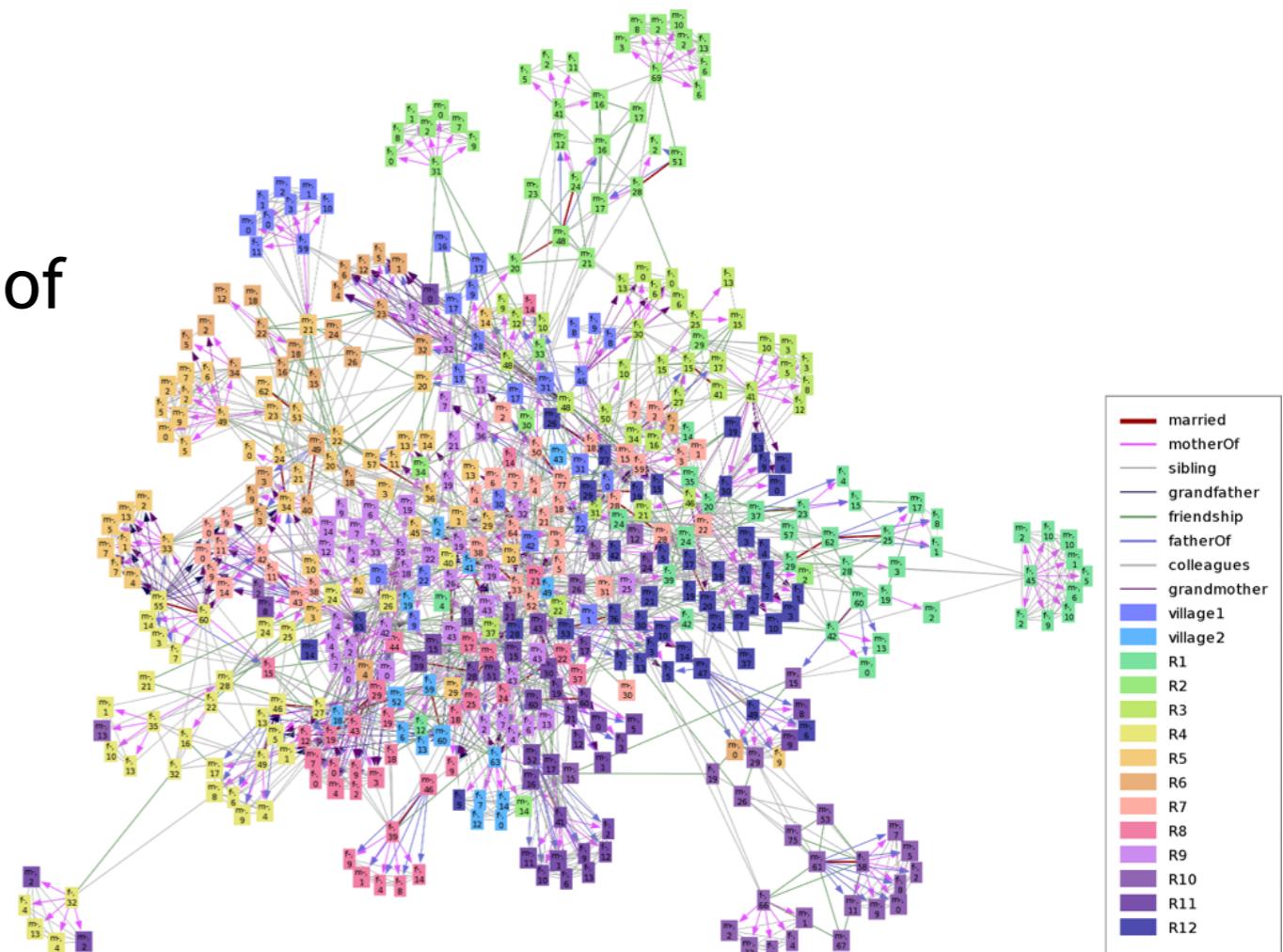


# Yang : Yet Another Network Generator

YANG (Yet Another Network Generator)  
is a tool dedicated to generate  
plausible synthetic networks from  
local rules.

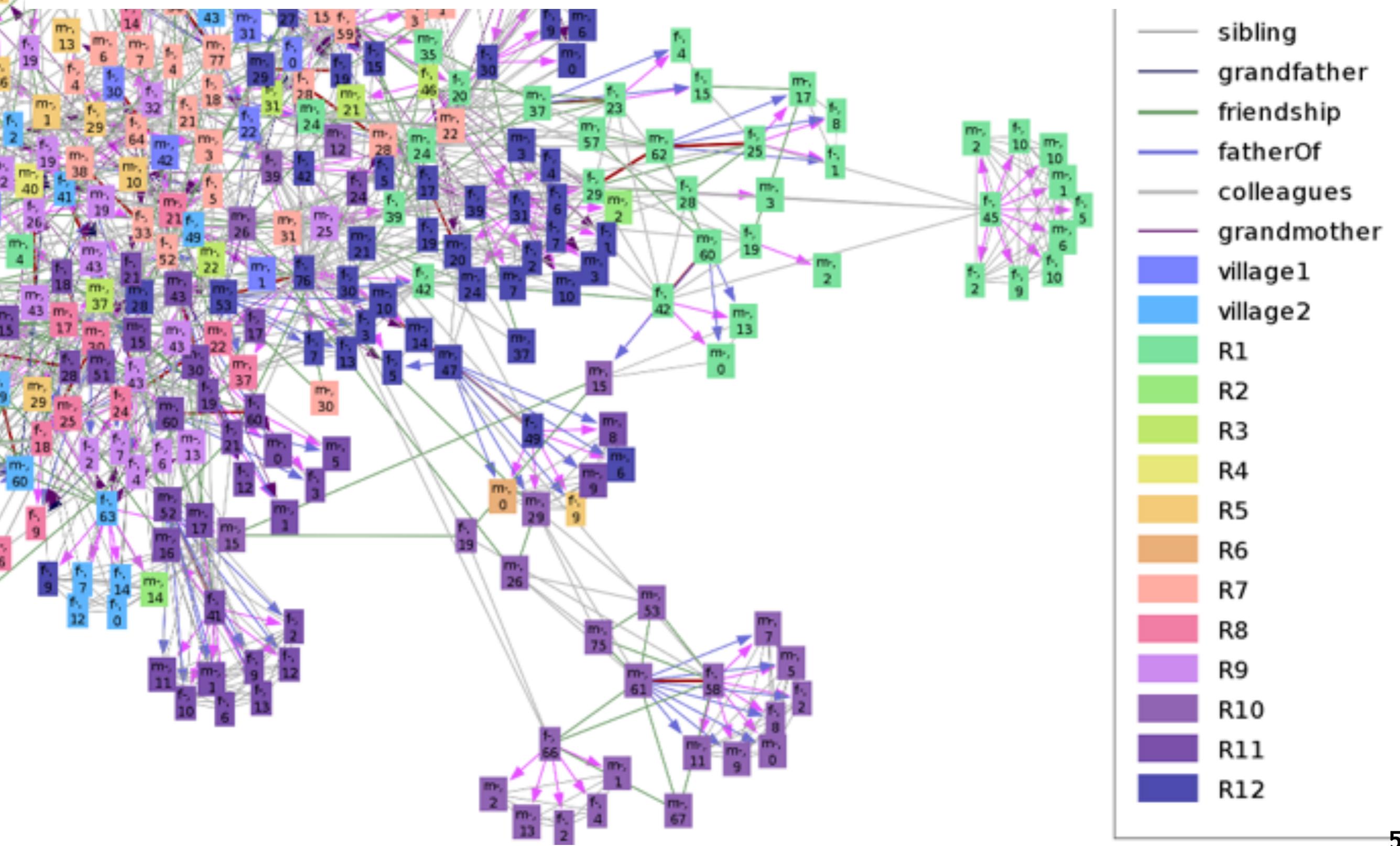
It has been applied to the generation of

- social networks in Kenya,
- social networks of economic solidarities on the island of Mayotte,
- a neural network from neuro-biological studies.



Yang : <http://sourceforge.net/projects/yang-j/>

# Yang : example of generated network on the case study of Kenya.

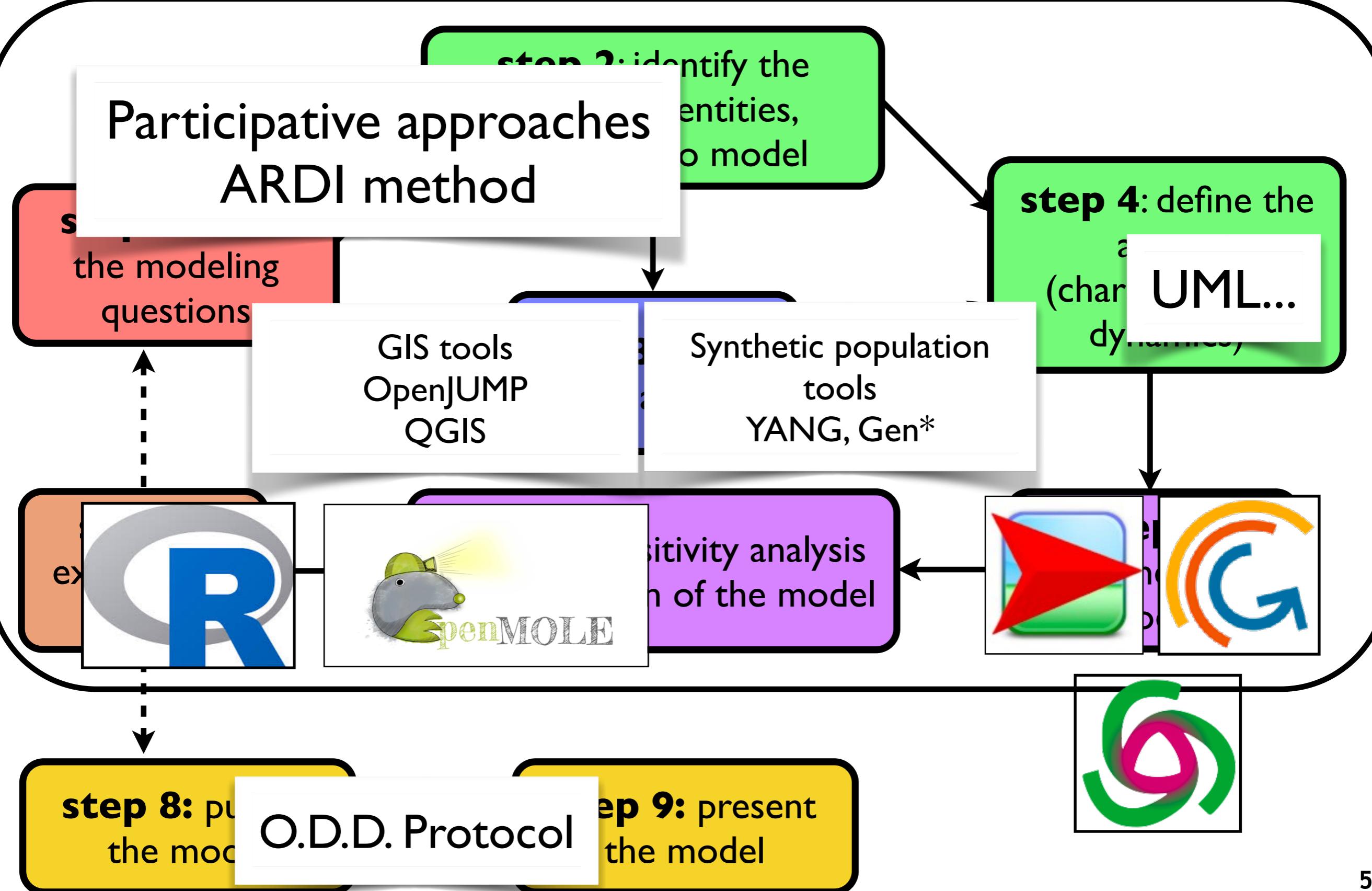


# Synthetic population generation: the GEN\* project

- ▶ Generation of synthetic population from aggregated data to feed agent-based simulations.
- ▶ individual characteristics
- ▶ localisation
- ▶ social structure



# Modelling is a multi-step cycle.

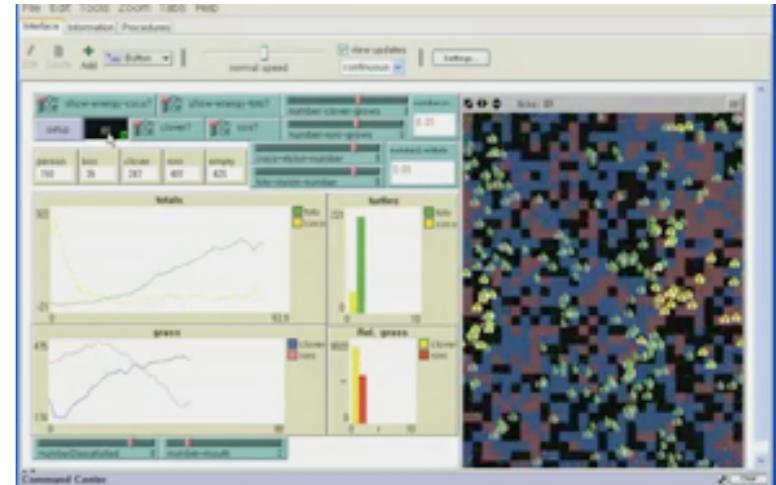


# Models can be implemented and simulated using any generic programming language, but also with some dedicated (open-source) platforms.

## NetLogo

<http://ccl.northwestern.edu/netlogo/>

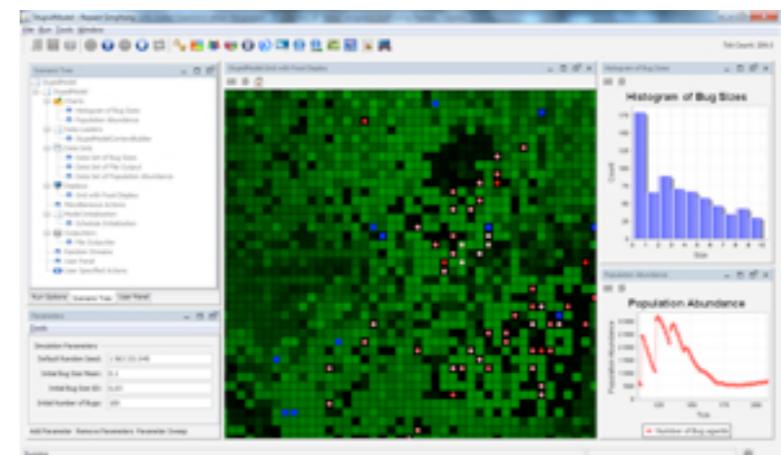
Pedagogical tool with a specific modeling language. Numerous examples in various domains. Ideal for beginners and prototypes, but somehow limited for large models.



## Repast Symphony

<http://repast.sourceforge.net/>

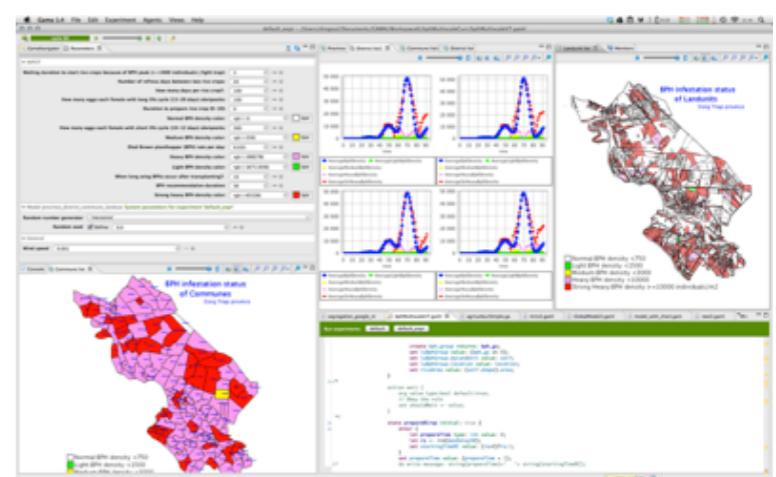
Toolbox for agent-based modeling in Java, numerous libraries of connected technologies (statistical analysis, GIS, 3D models, etc.). **Very powerful but requires very good programming skills.**



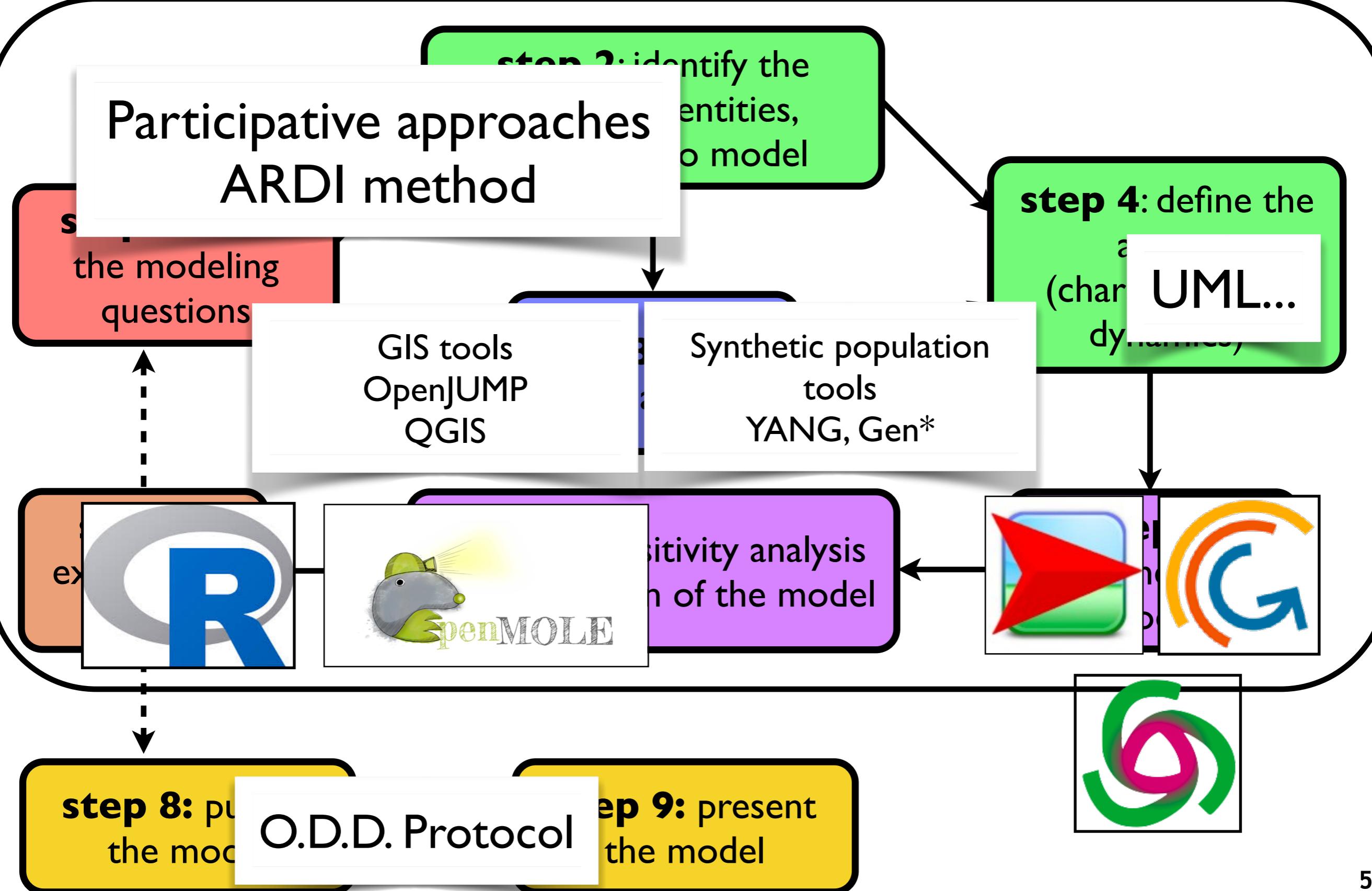
## GAMA

<http://gama-platform.org>

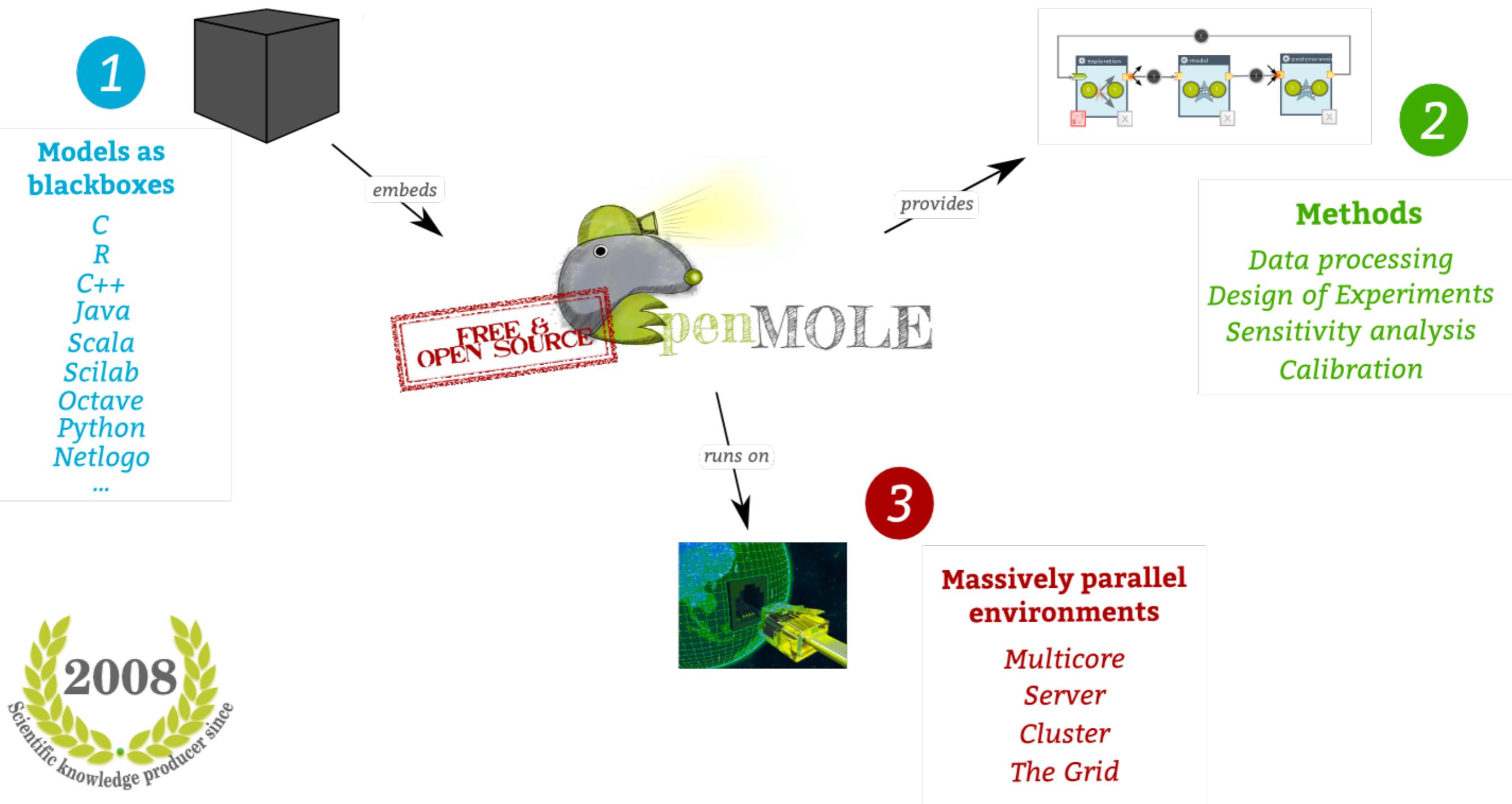
A compromise between the two platforms above. Using a dedicated modeling language, this platform pays a great deal of attention to the modeling of the environment and the use of GIS data, while staying open to new technologies through plug-ins.



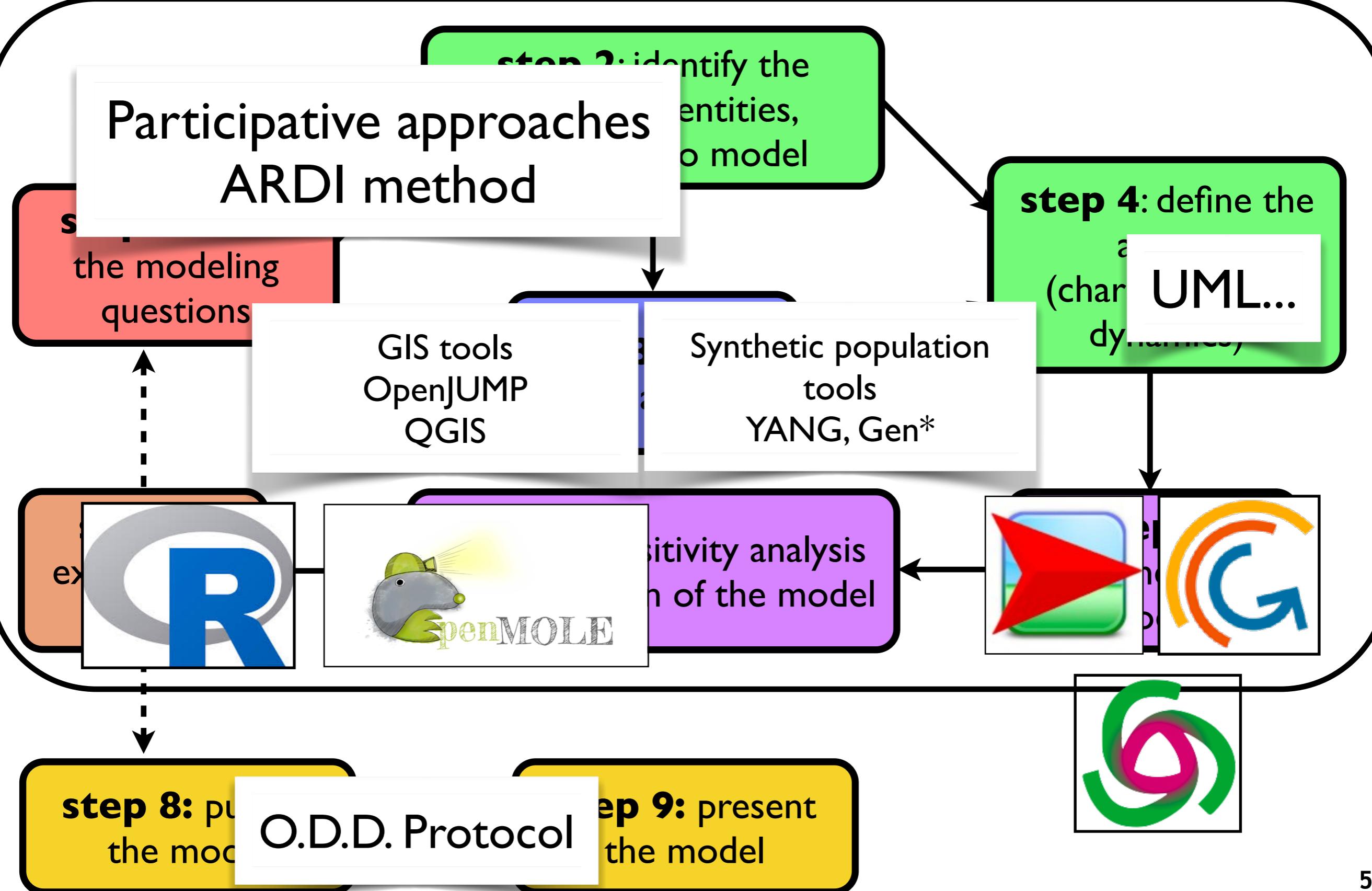
# Modelling is a multi-step cycle.



# OpenMole: how to make exploration easy

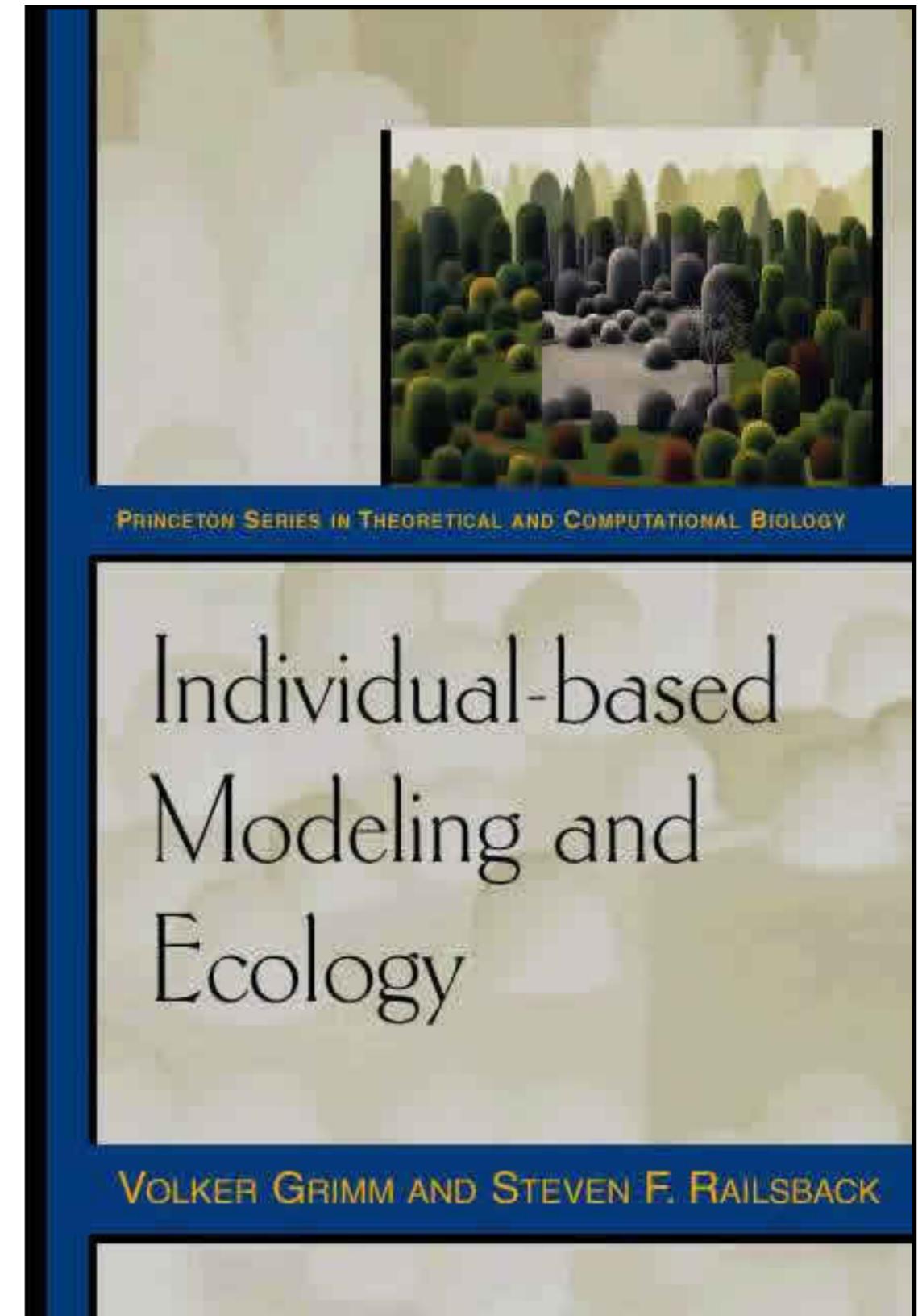


# Modelling is a multi-step cycle.



## First trial...

- ▶ 2005
- ▶ Chapter on formulating ABMs
- ▶ Chapter on communicating ABMs
- ▶ Ancestor of ODD protocol (PSPC+3)



# Workshop in Bergen, Norway, 2004

- ▶ a protocol for communicating ABMs
- ▶ “Take one of your ABM descriptions and re-write it according to the ODD protocol”
- ▶ 28 authors, 120 pages of model descriptions
  - ▶ A standard protocol for describing individual-based and agent-based models Online Appendix
- ▶ => ODD protocol, published in “Ecological Modelling”

One for the Ecologists on their green throne  
In the Ecological Modelling journal where Volker Grimm lies.  
One Protocol to describe them all, One Protocol to publish them all,  
One Protocol to bring them all and in the greenness bind them  
In the Ecological Modelling journal where Volker Grimm lies.

# ODD protocol 2006

ECOLOGICAL MODELLING 198 (2006) 115–126

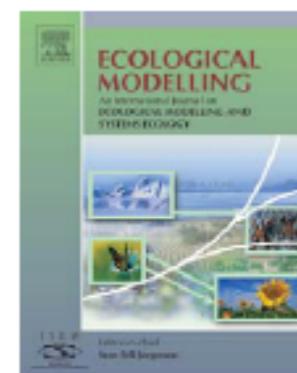


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available at [www.sciencedirect.com](http://www.sciencedirect.com)



journal homepage: [www.elsevier.com/locate/ecolmodel](http://www.elsevier.com/locate/ecolmodel)



## A standard protocol for describing individual-based and agent-based models

Volker Grimm<sup>a,\*</sup>, Uta Berger<sup>b</sup>, Finn Bastiansen<sup>a</sup>, Sigrunn Eliassen<sup>c</sup>, Vincent Ginot<sup>d</sup>,  
Jarl Giske<sup>c</sup>, John Goss-Custard<sup>e</sup>, Tamara Grand<sup>f</sup>, Simone K. Heinz<sup>c</sup>, Geir Huse<sup>g</sup>,  
Andreas Huth<sup>a</sup>, Jane U. Jepsen<sup>a</sup>, Christian Jørgensen<sup>c</sup>, Wolf M. Mooij<sup>h</sup>, Birgit Müller<sup>a</sup>,  
Guy Pe'er<sup>i</sup>, Cyril Piou<sup>b</sup>, Steven F. Railsback<sup>j</sup>, Andrew M. Robbins<sup>k</sup>, Martha M. Robbins<sup>k</sup>,  
Eva Rossmanith<sup>l</sup>, Nadja Rüger<sup>a</sup>, Espen Strand<sup>c</sup>, Sami Souissi<sup>m</sup>, Richard A. Stillman<sup>e</sup>,  
Rune Vabø<sup>g</sup>, Ute Visser<sup>a</sup>, Donald L. DeAngelis<sup>n</sup>

<sup>a</sup> UFZ Umweltforschungszentrum Leipzig-Halle GmbH, Department Ökologische Systemanalyse, Permoserstr. 15, 04318 Leipzig, Germany

<sup>b</sup> Zentrum für Marine Tropenökologie, Fahrenheitstr. 6, 28359 Bremen, Germany

<sup>c</sup> University of Bergen, Department of Biology, P.O. Box 7800, N-5020 Bergen, Norway

<sup>d</sup> INRA, Unité de Biométrie, Domaine St.-Paul, 84 814 Avignon Cedex 9, France

# ODD protocol 2006

		Elements of the original ODD protocol (Grimm et al. 2006)
	Overview	<b>1. Purpose</b>
		<b>2. State variables and scales</b>
		<b>3. Process overview and scheduling</b>
	Design concepts	<b>4. Design concepts</b> <ul style="list-style-type: none"><li>• Emergence</li><li>• Adaptation</li><li>• Fitness</li><li>• Prediction</li><li>• Sensing</li><li>• Interaction</li><li>• Stochasticity</li><li>• Collectives</li><li>• Observation</li></ul>
Details		<b>5. Initialization</b>
		<b>6. Input</b>
		<b>7. Submodels</b>

## References

- GAMA : <https://code.google.com/p/gama-platform/>
- Netlogo : <http://ccl.northwestern.edu/netlogo/>
- Cormas: <http://cormas.cirad.fr/>
- ARDI method: <http://cormas.cirad.fr/pdf/guideARDI.pdf>
- Yang : <http://sourceforge.net/projects/yang-j/>
- SIG: OpenJUMP : <http://www.openjump.org/>
- SIG : QGIS : <http://www.qgis.org/>
- Gephi : <http://gephi.org/>
- OpenMole : <http://www.openmole.org/>

## ARDI : references

Etienne M., 2009. Co-construction d'un modèle d'accompagnement selon la méthode ARDI : guide méthodologique. Cardère éditeur, Laudun, 71 p.

Etienne M., Du Toit D., Pollard S., 2011. ARDI: a co-construction method for participatory modelling in natural resources management. *Ecology and Society* 16(1): 44. [online] URL:  
<http://www.ecologyandsociety.org/vol16/iss1/art44/>

ARDI method:

<http://cormas.cirad.fr/pdf/guideARDI.pdf>

# References

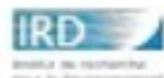


## MODÉLISATION ET SIMULATION À BASE D'AGENTS

Exemples commentés, outils informatiques  
et questions théoriques

*Préface de Paul Bourgine et Édith Perrier*

Jean-Pierre Traouït  
Alexis Dragout  
Jean-Daniel Zucker



## Recueil de fiches pédagogiques du réseau MAPS

*Modélisation multi-Agents appliquée  
aux Phénomènes Spatialisés*

2009 - 2014

Collectif MAPS

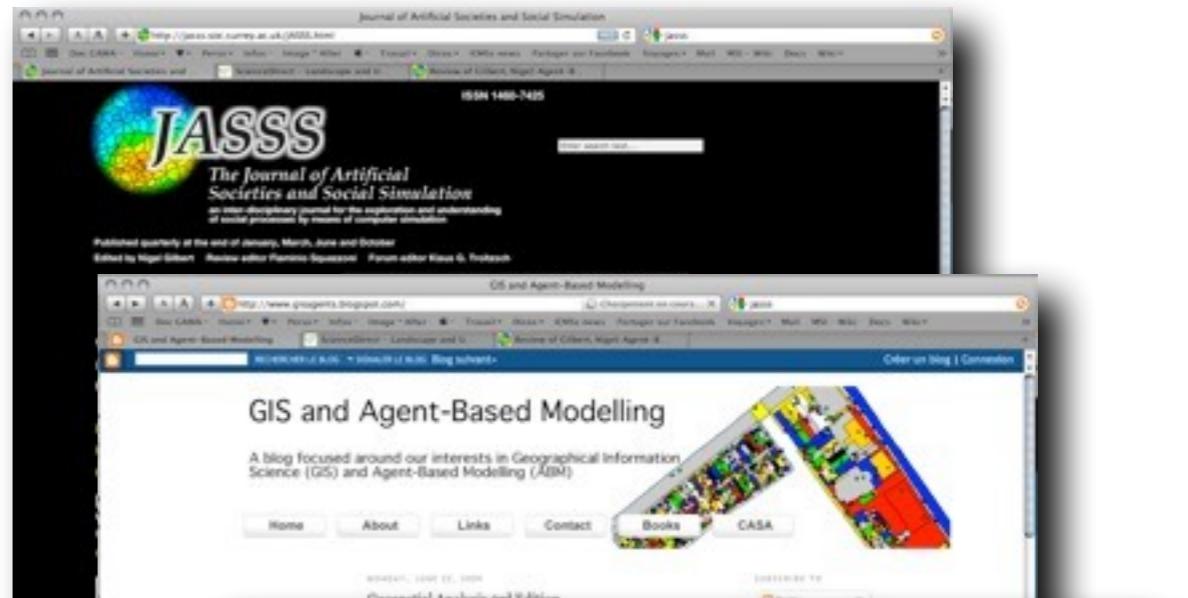
Juillet 2014



# A number of web references are available to go further

**JASSS : Journal of Artificial Societies and Social Simulation**

<http://jasss.soc.surrey.ac.uk/>



**GisAgents : GIS and Agent-Based Modelling**

<http://www.gisagents.blogspot.com/>



**OpenABM: Open Agent-Based Modeling Consortium**

<http://www.openabm.org/>

**Agent-based models: Methodology and philosophy**

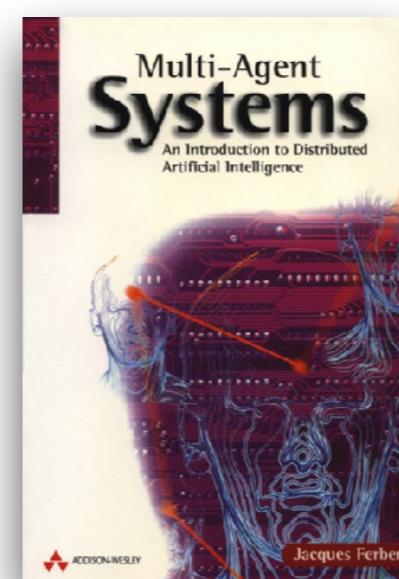
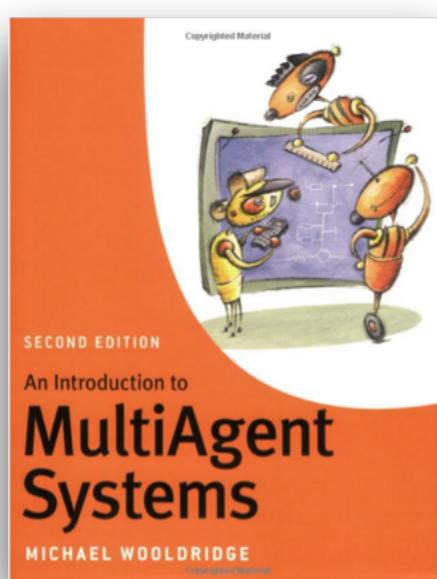
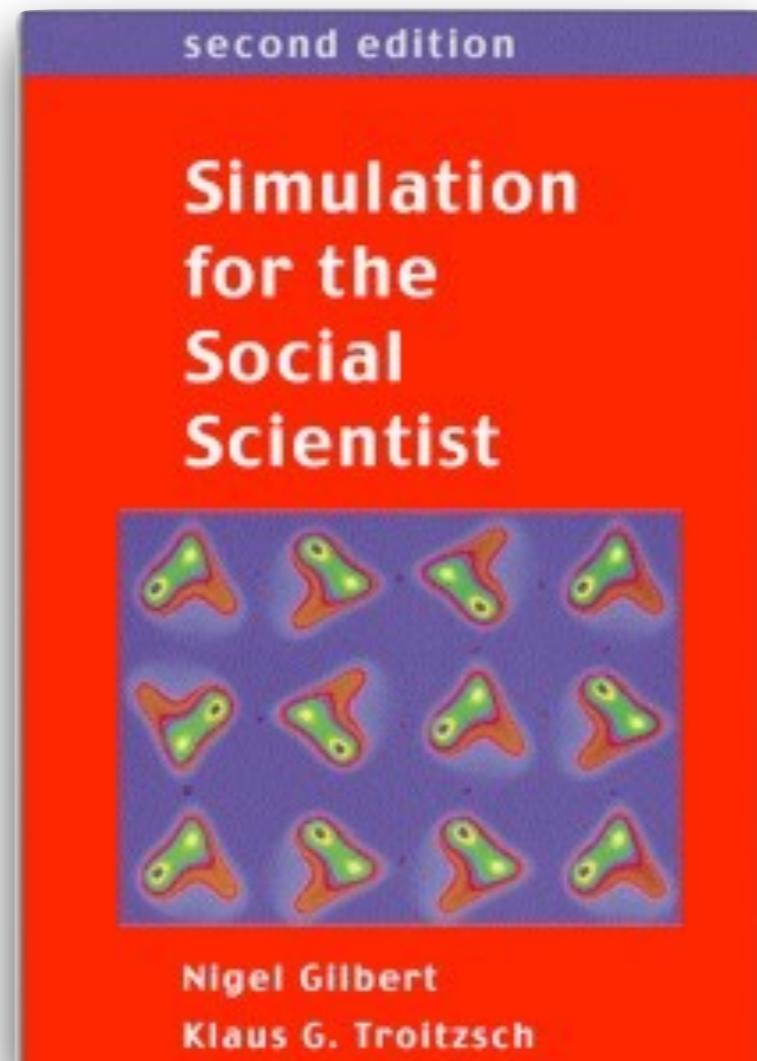
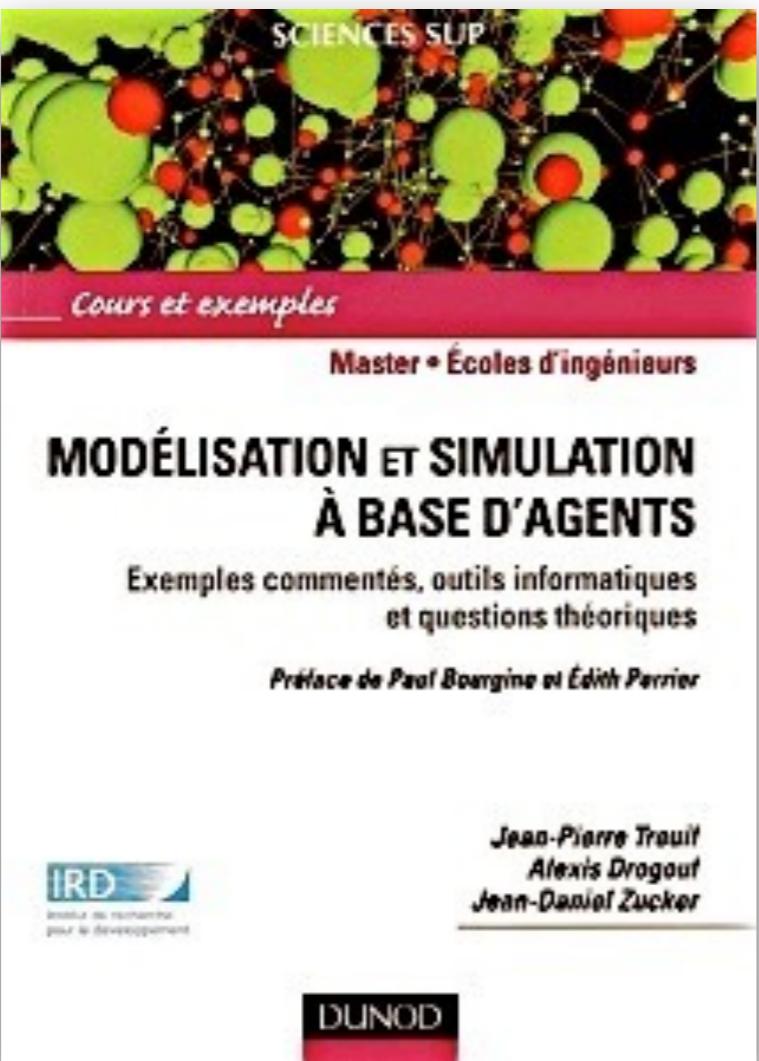
<http://www.agent-based-models.com/blog/>

**ACE : Agent-based Computational Economics**

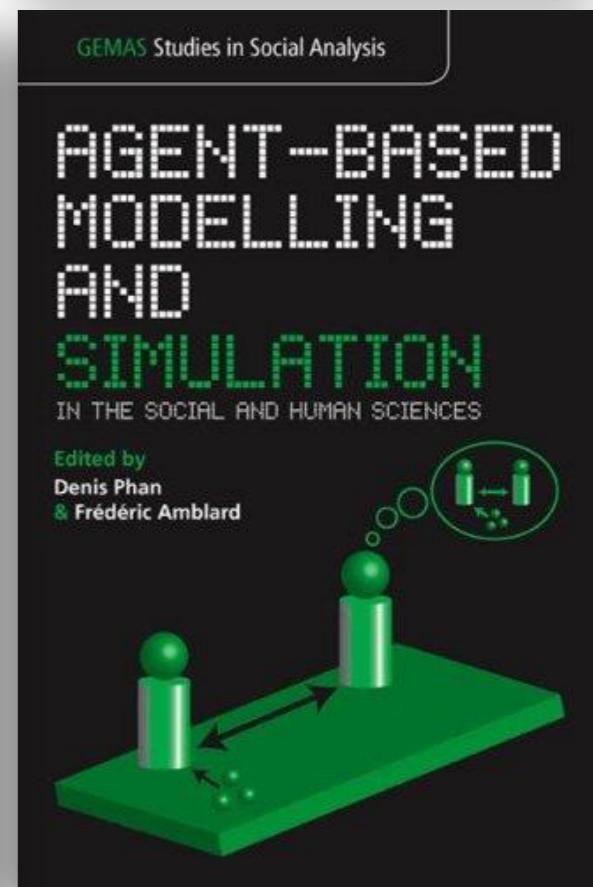
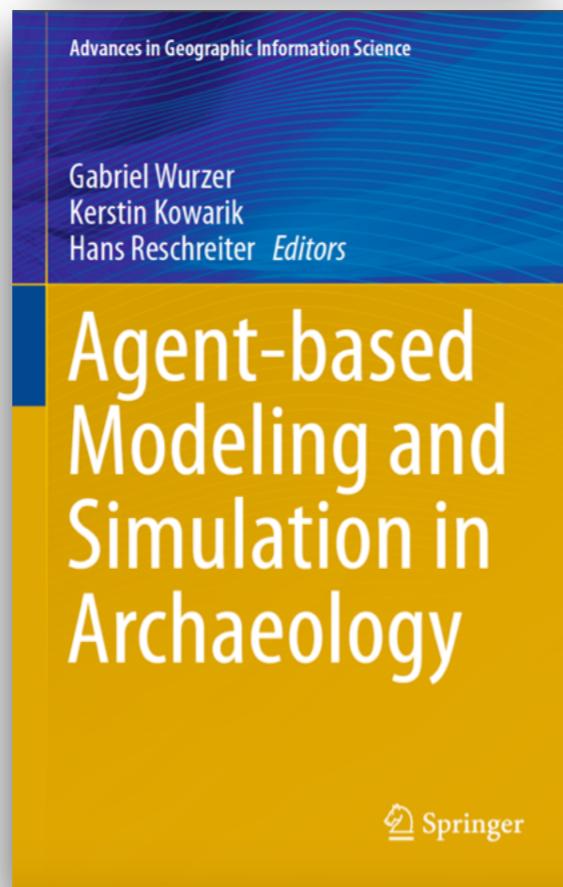
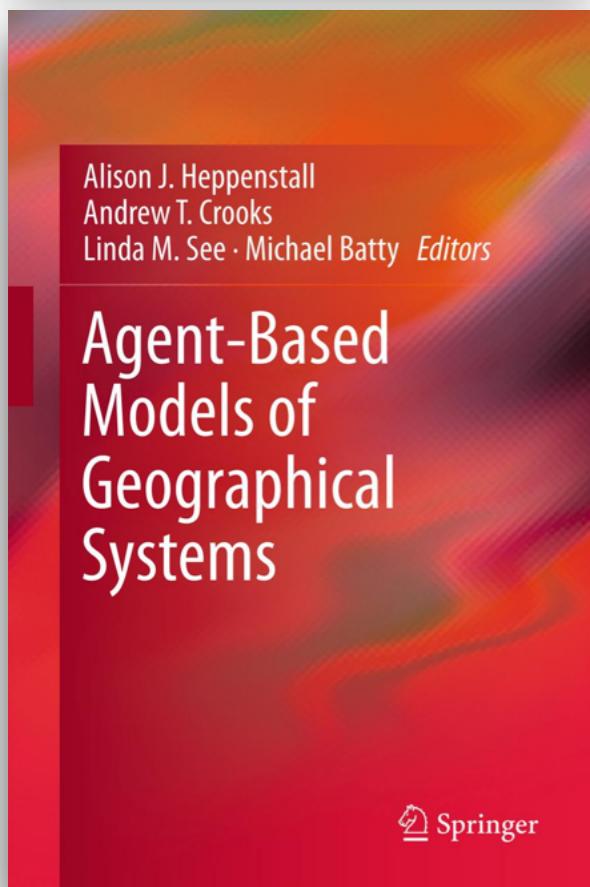
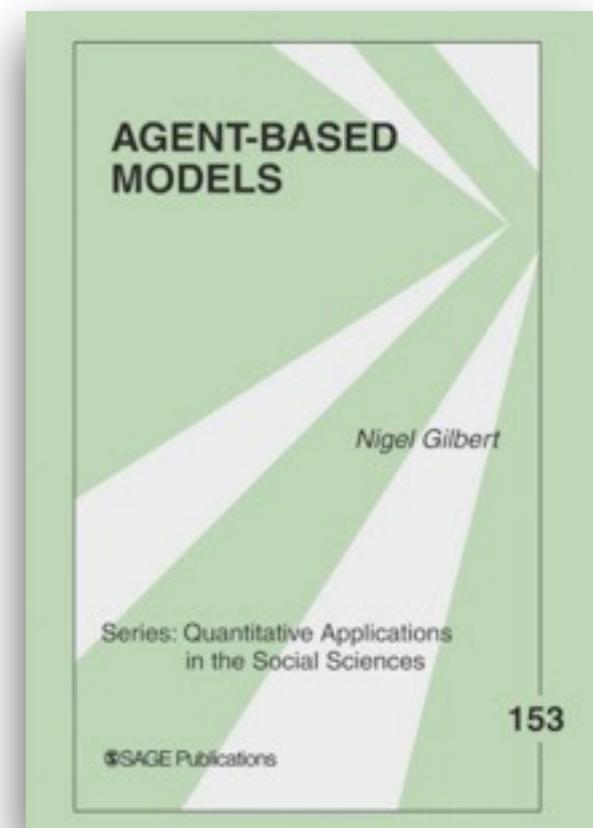
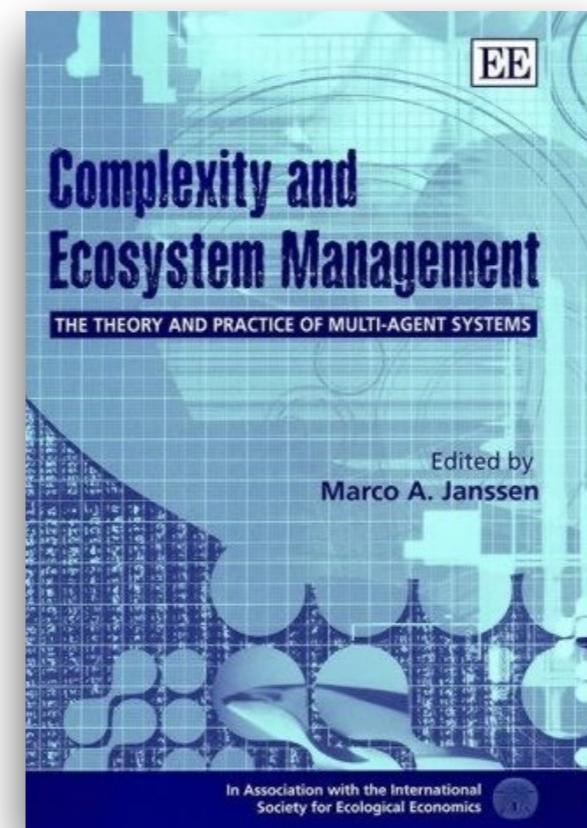
<http://www.econ.iastate.edu/tesfatsi/ace.htm>

**On-Line Guide for Newcomers to Agent-Based Modeling in the Social Sciences**

# References: some books



# References: some books



## Sources

- ▶ François Bousquet
- ▶ Alexis Drogoul
- ▶ Philippe Caillou

# References

- ▶ [Konings, 2012] Konings V., « Can Tho, how to grow? Flood proof expansion in rapidly urbanising delta cities in the Mekong delta: the case of Can Tho. », Master thesis, University of Delft, 2012.  
<http://repository.tudelft.nl/view/ir/uuid%3A84c58546-e387-44f7-b8ff-0958b018ae83/>
- ▶ [Grimm et al., 2010] Volker Grimm, Uta Berger, Donald L. DeAngelis, J. Gary Polhill, Jarl Giske, Steven F. Railsback. «The ODD protocol: A review and first update», Ecological Modelling 221, 2760-2768, 2010.