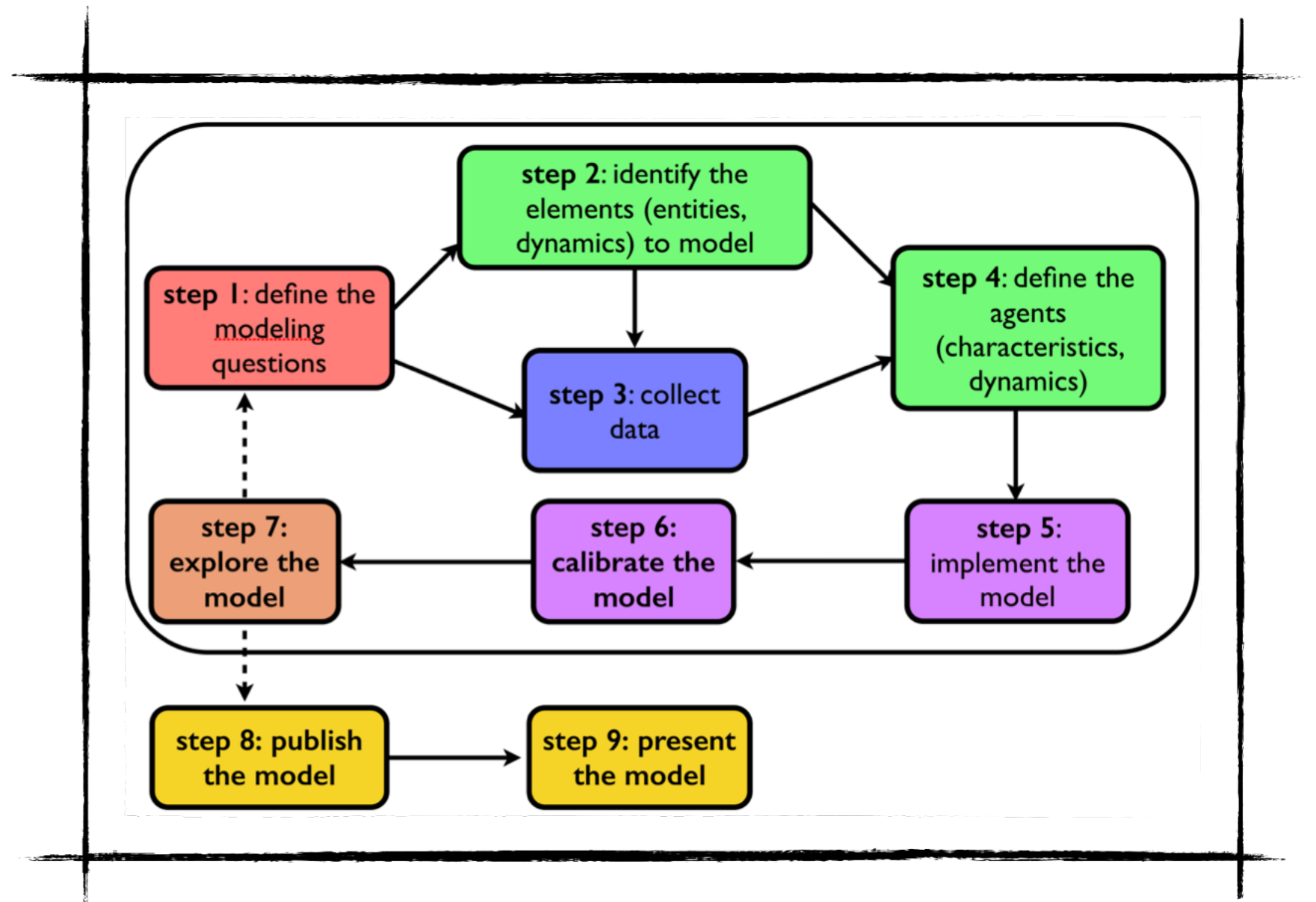
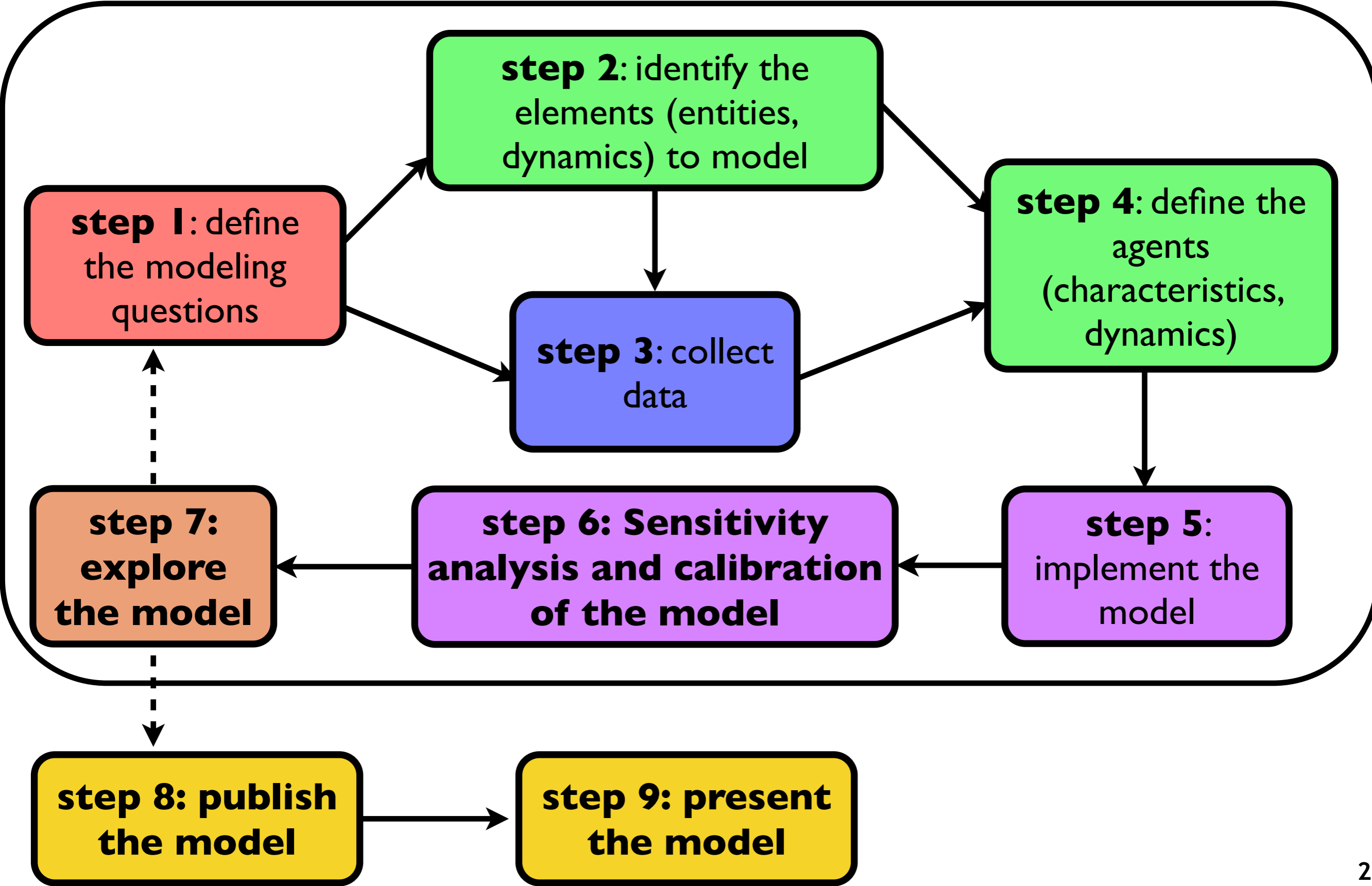


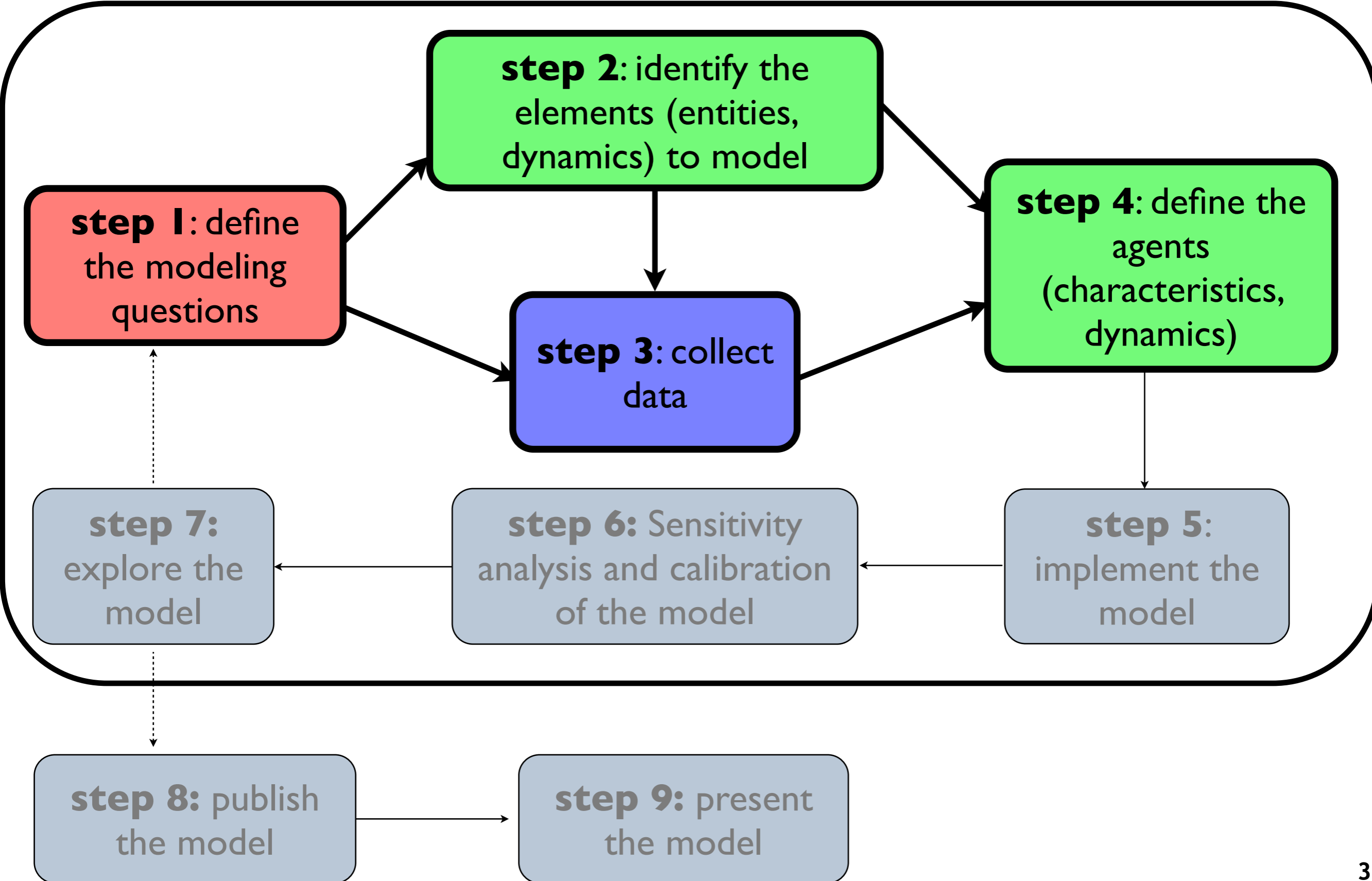
Modelling is a multi-step cycle.



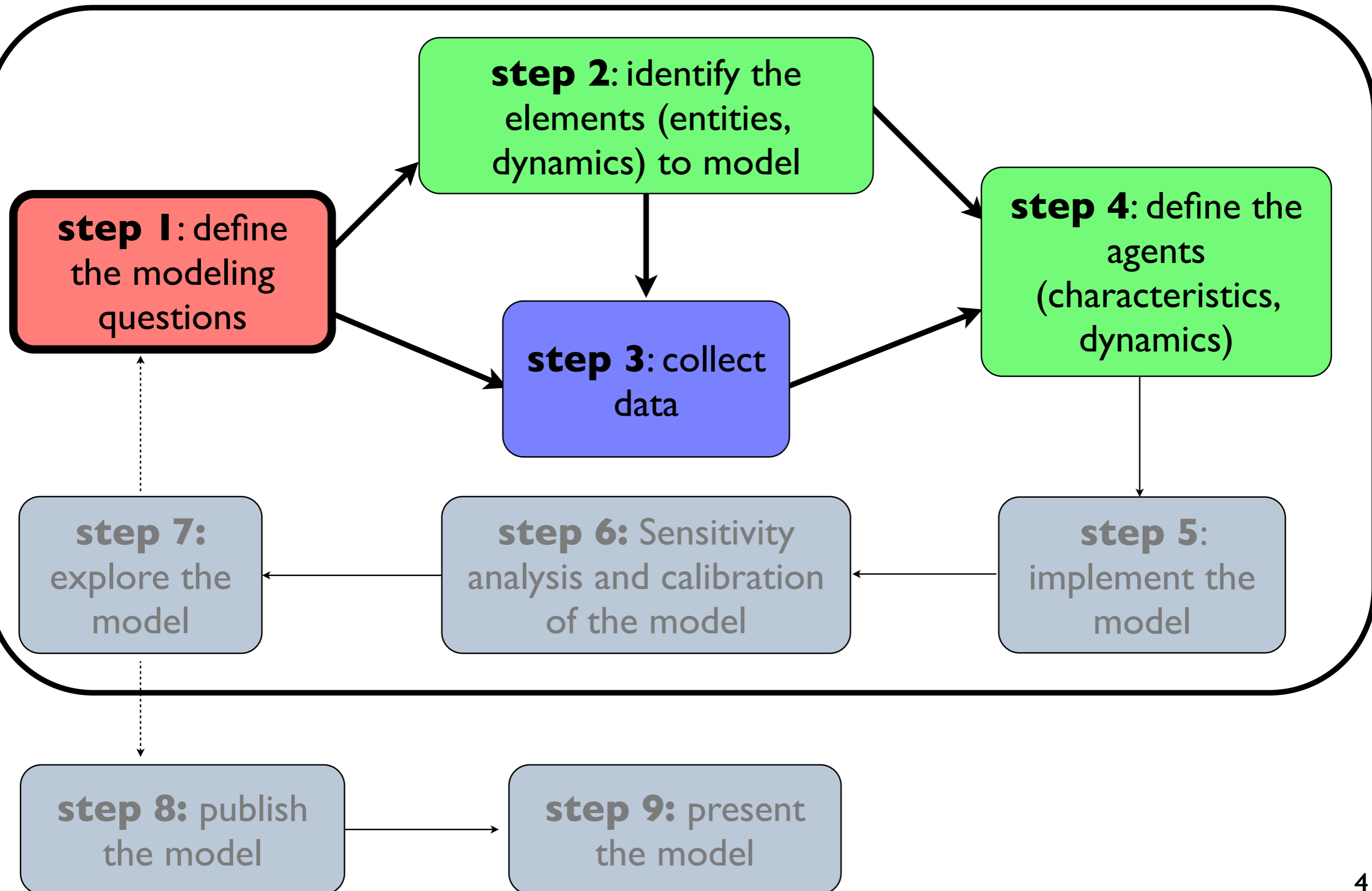
Modelling is a multi-step cycle.



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.

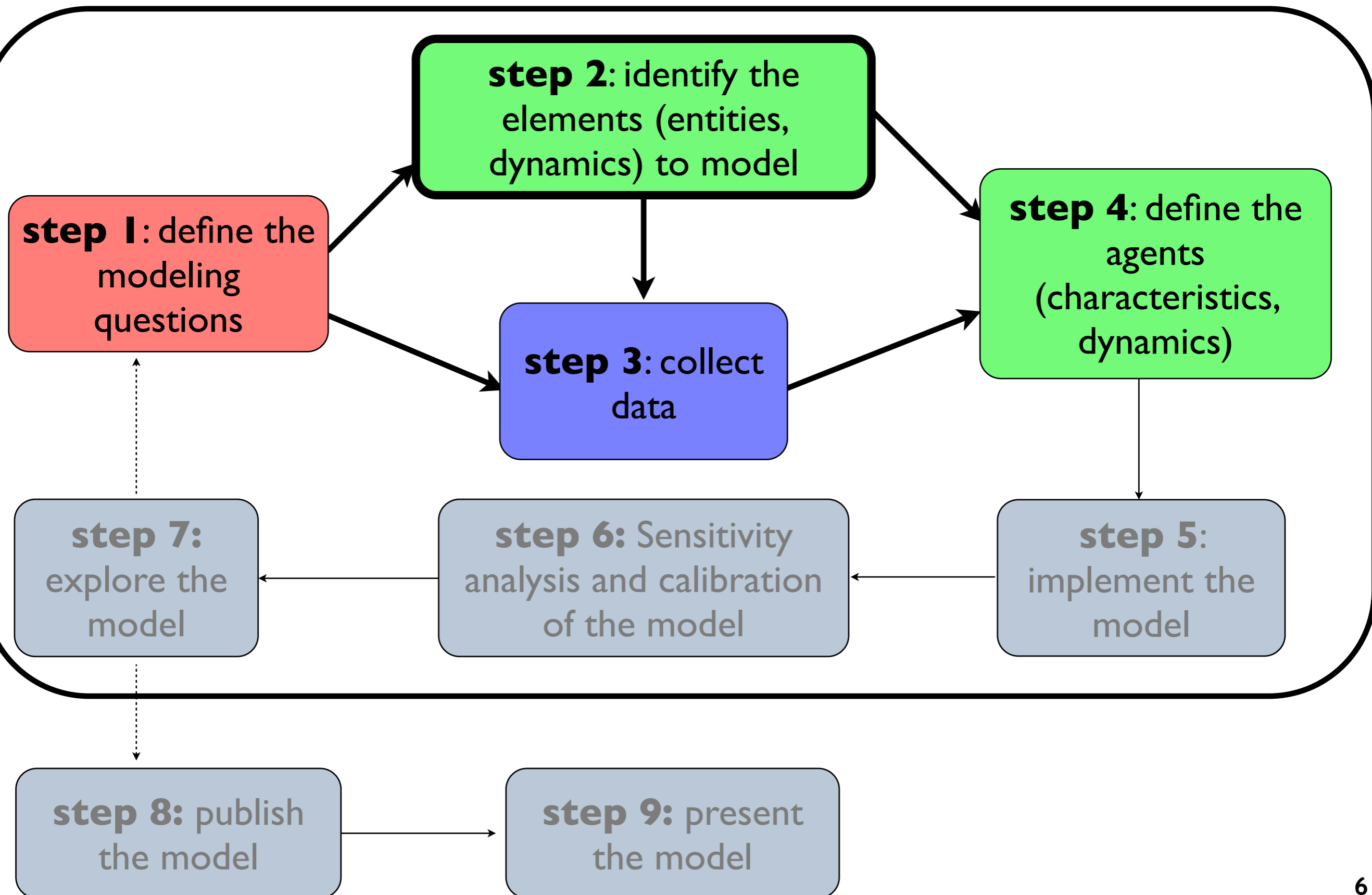
► **Understanding models:** that try to understand processes that generate phenomena. They are focused on the processes and try to get the phenomenon by simulation.

---> 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.

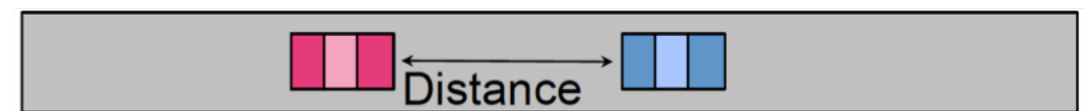


There is a huge number of languages to write a dynamic model.

- ▶ 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



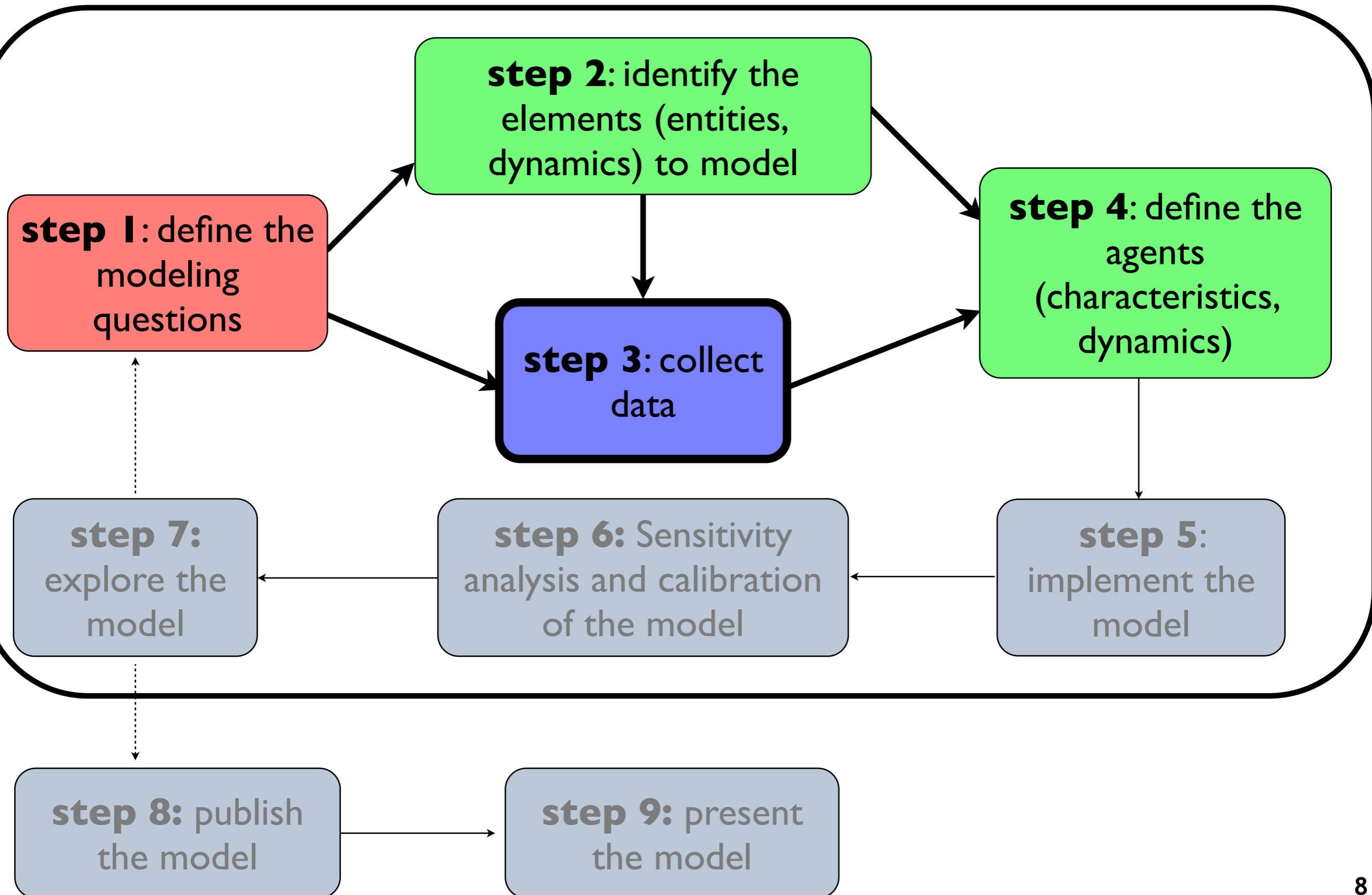
NaSch microscopic model



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

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!

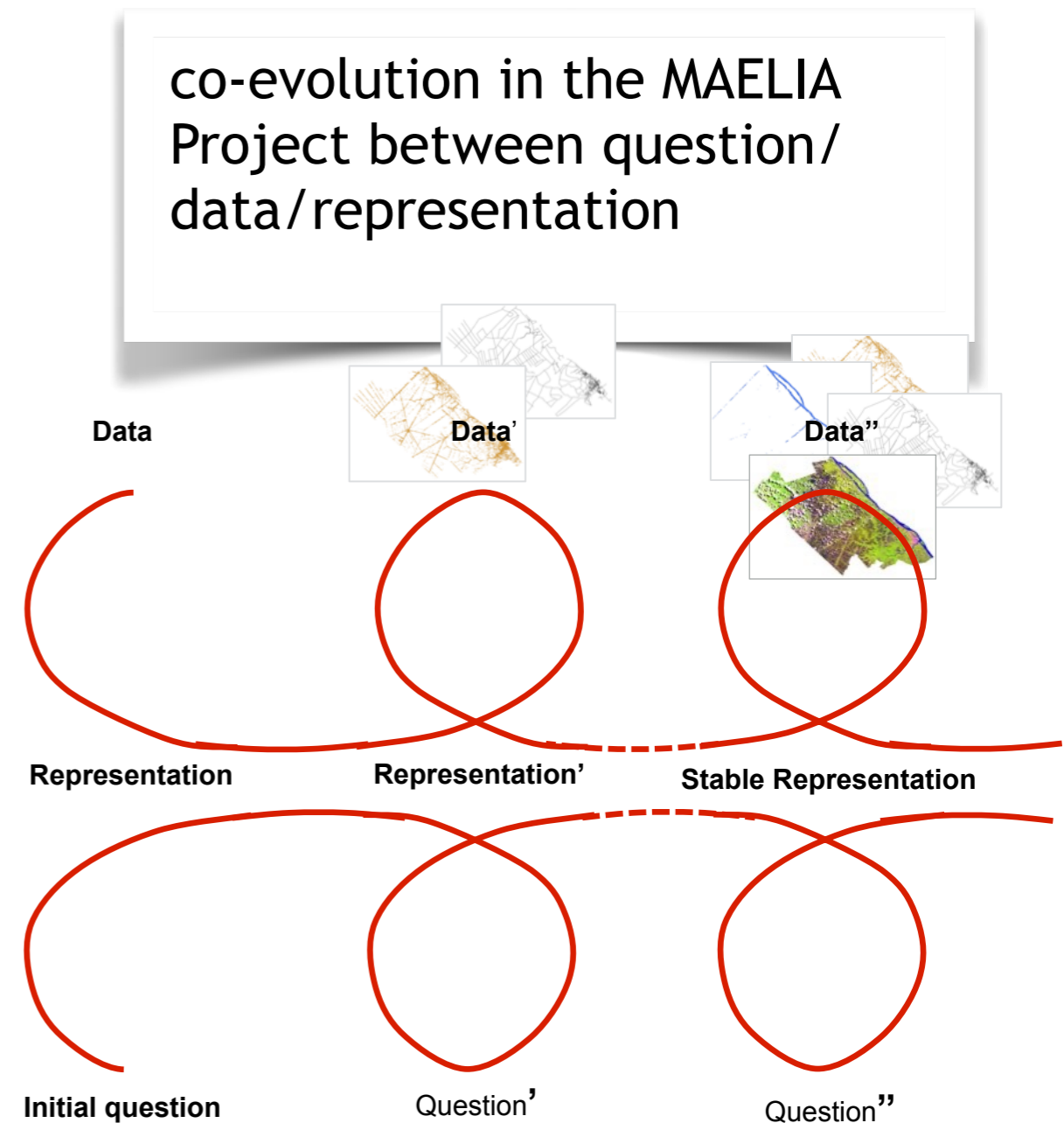
► First: Get data

- 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 Resources and Environment (*Sở tài nguyên môi trường Cần Thơ*)

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

► Then: process and clean them.



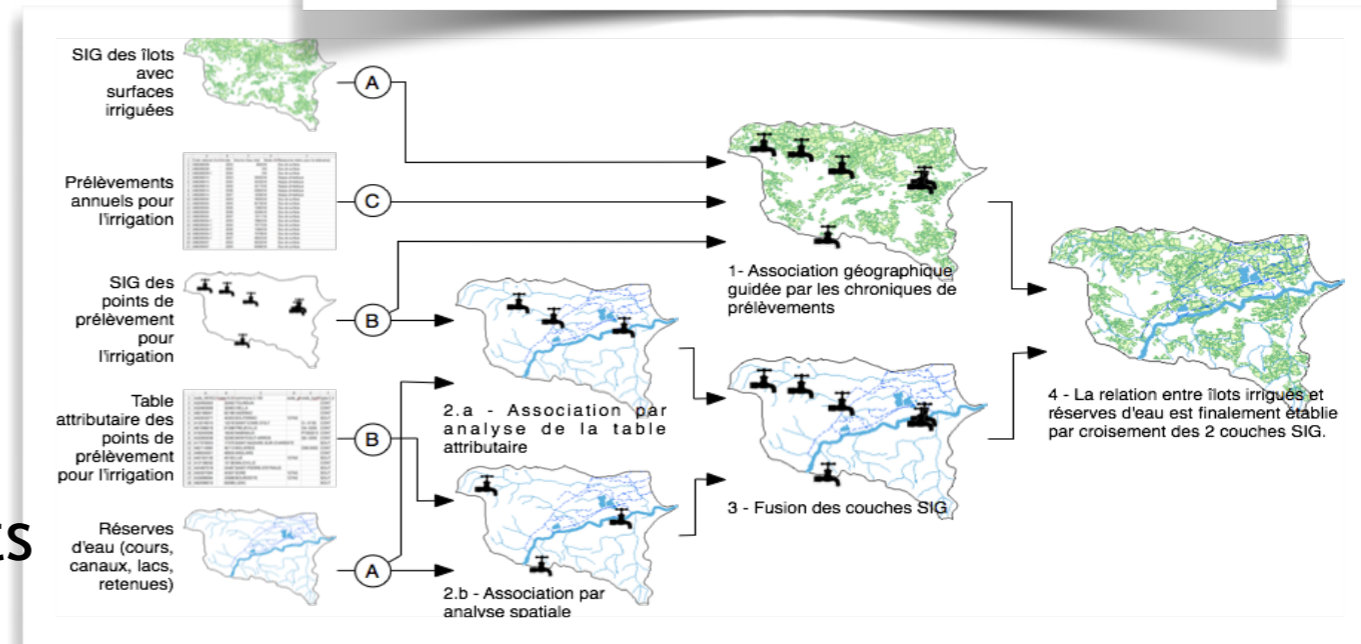
Data need to be cleaned and processed, depending on the aim and need of the model.

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

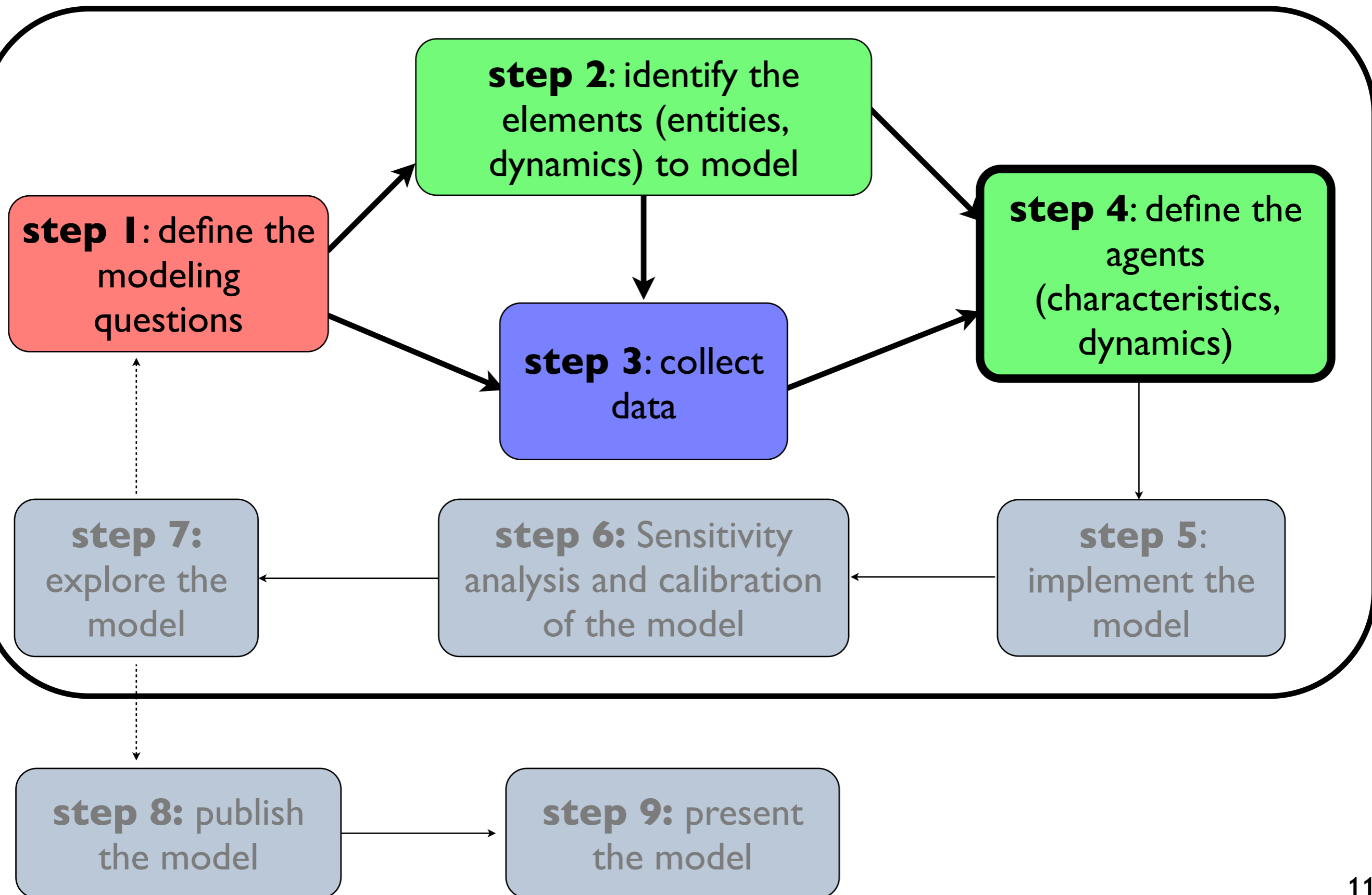
▶ Example of issues to tackle:

- ▶ 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.



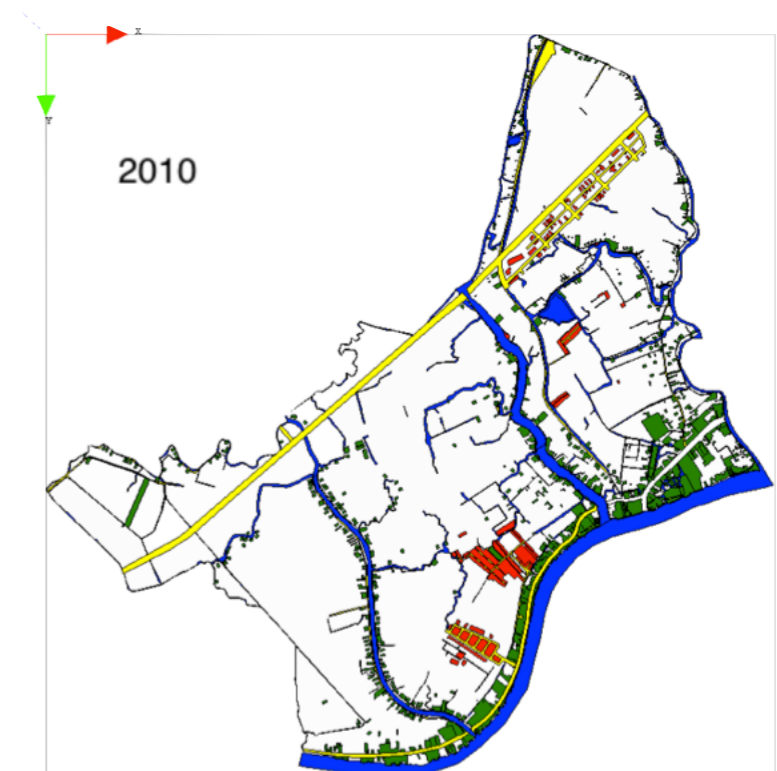
Modelling is a multi-step cycle.



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)

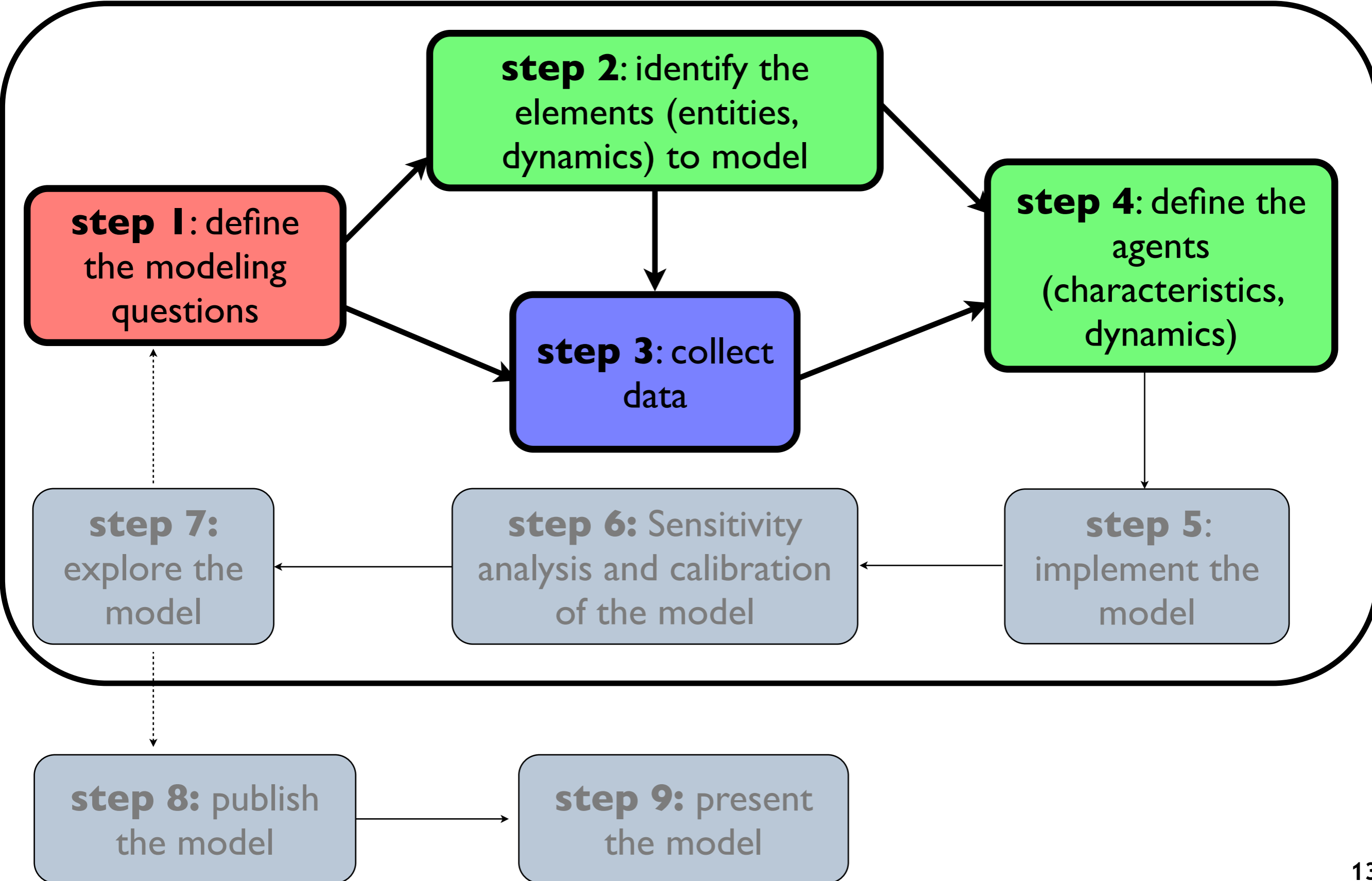
What will be an agent depends mainly on the chosen scale (and data & question).

- 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,

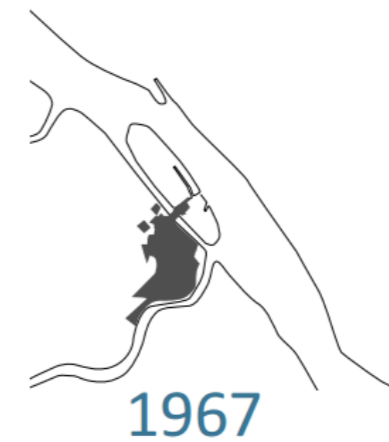
Describing and assessing impacts of future development,

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**

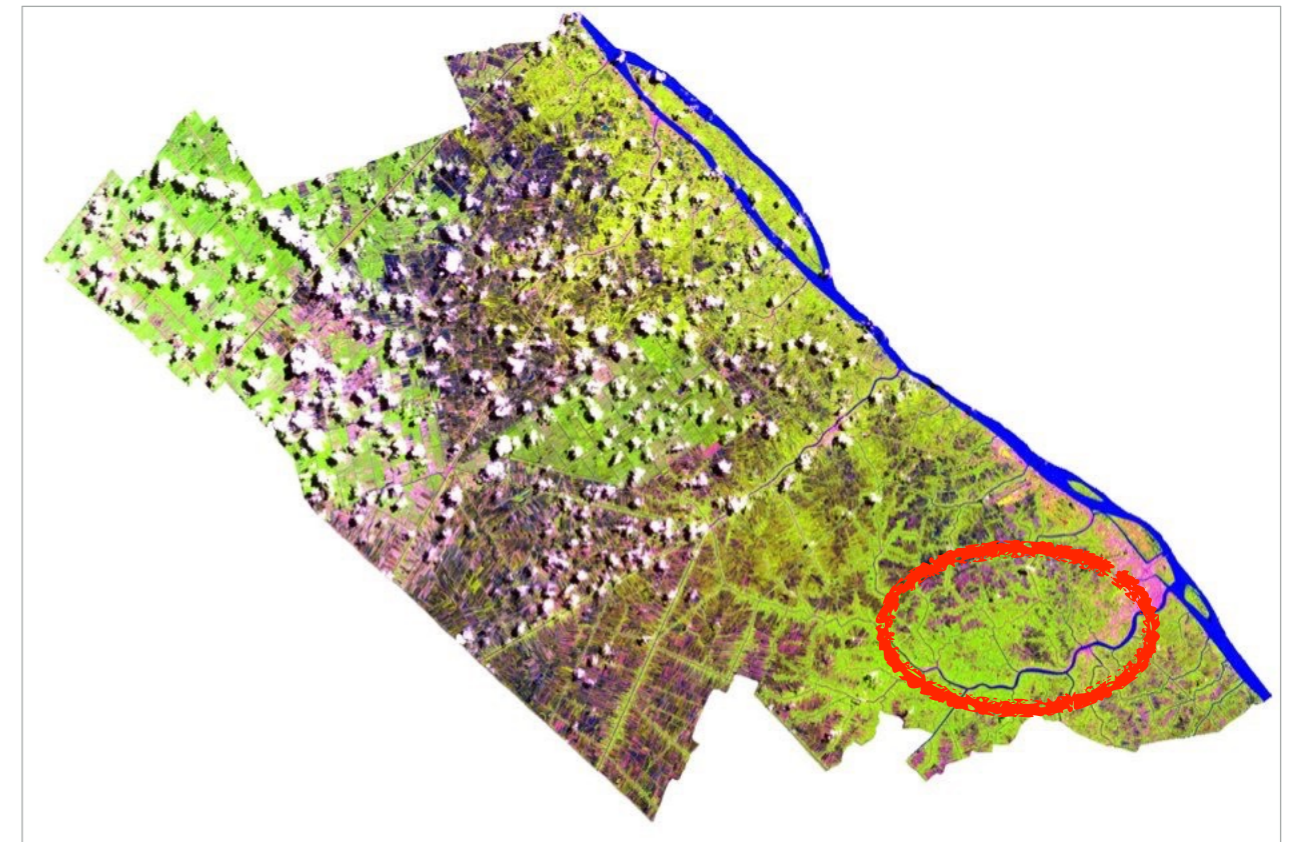
- Duration : 5 years from 2005 to 2010

- **Dynamic to take into account**

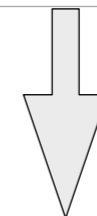
- The construction of buildings

- **Entities to take into account**

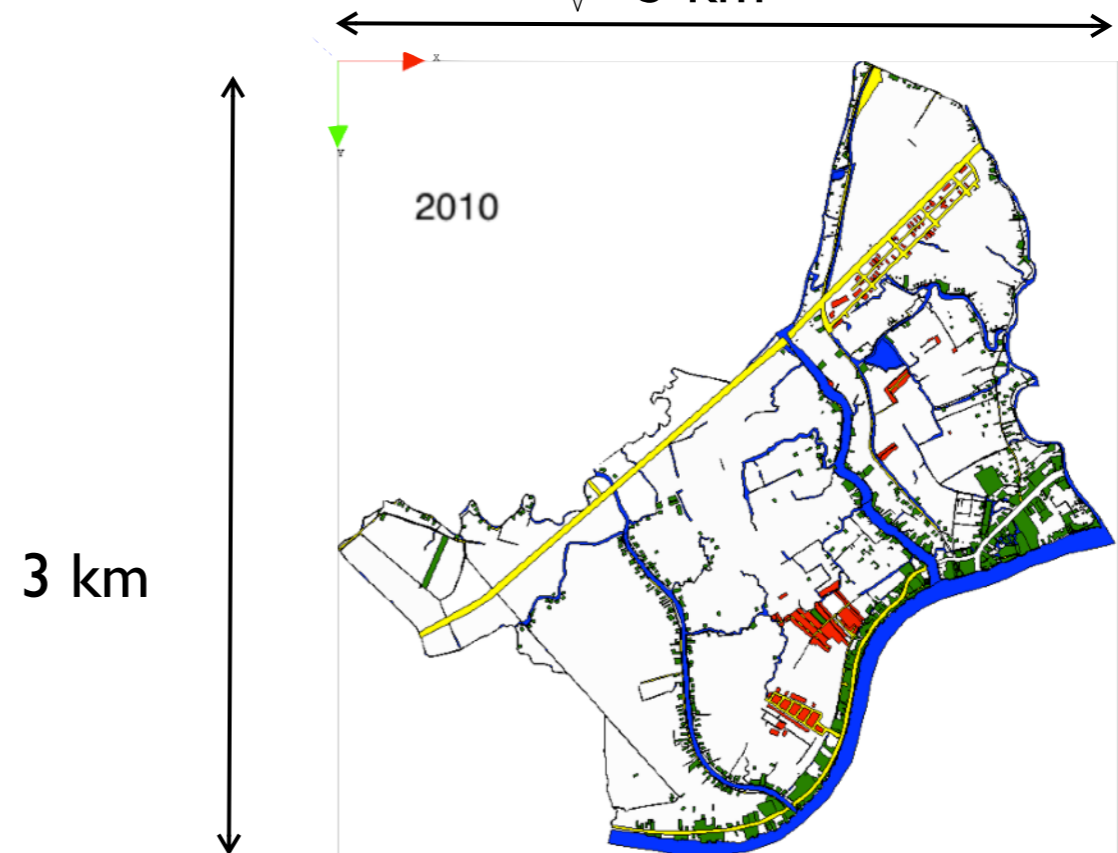
- Buildings
 - Roads
 - Rivers



Can Tho



3 km



2010

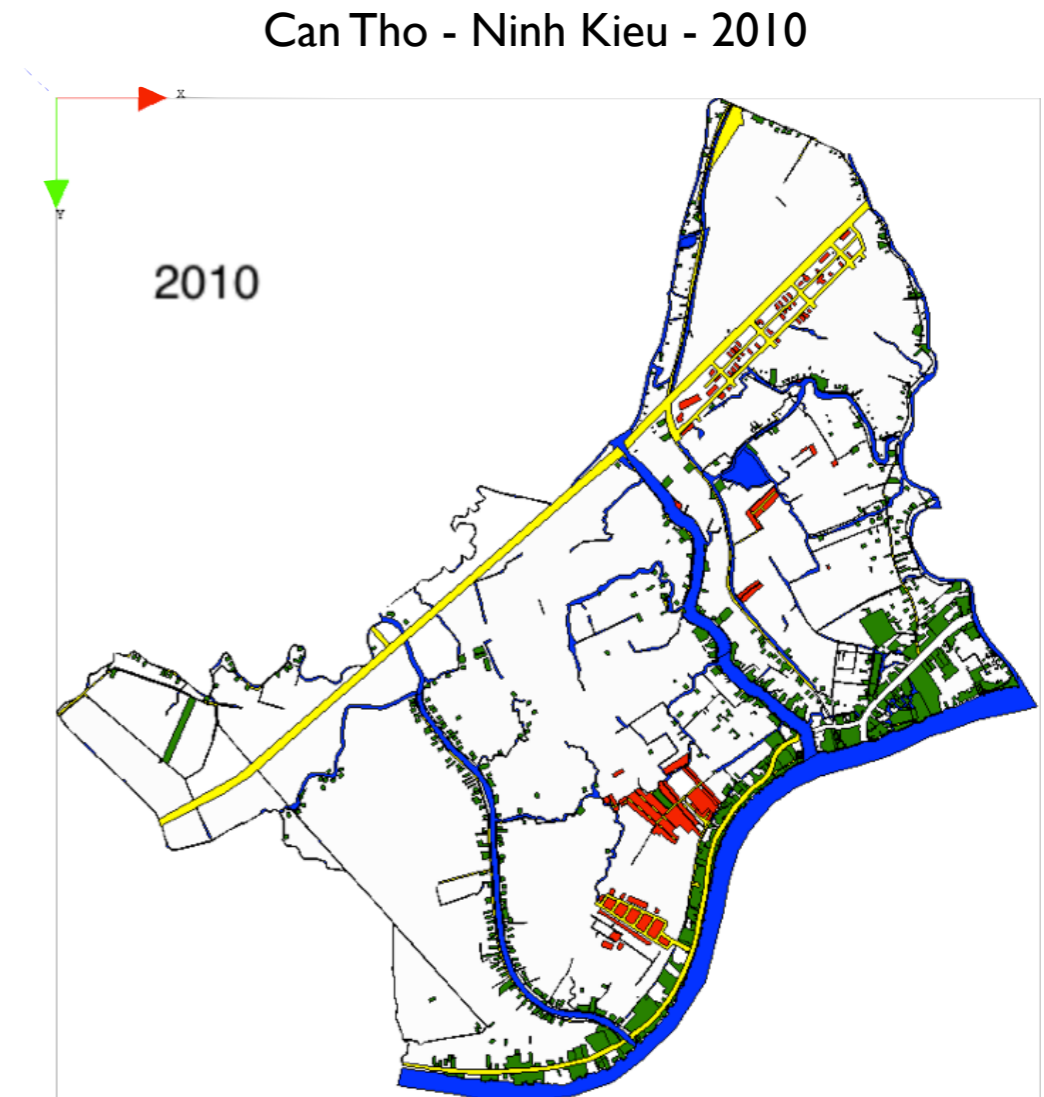
3 km

Considered area

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 choose 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

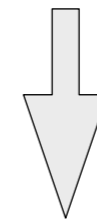
- ▶ The construction of buildings

▶ Entities to take into account

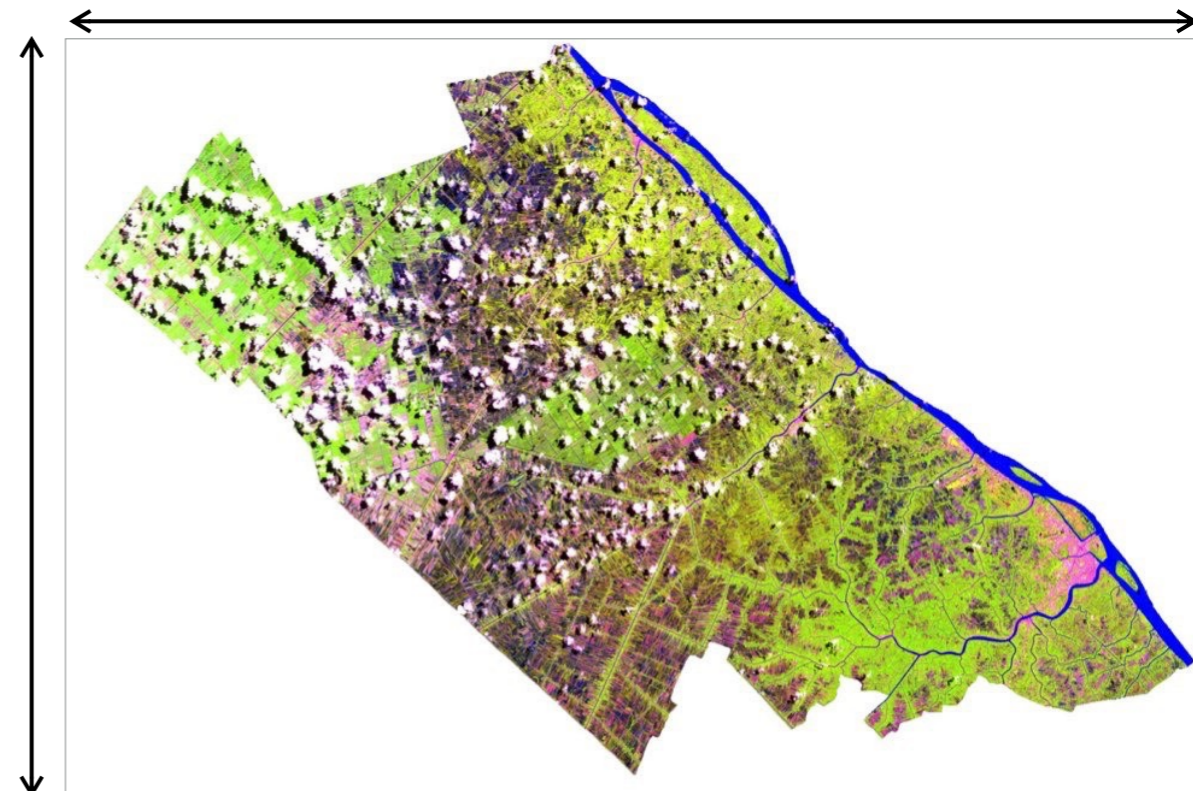
- ▶ Buildings
- ▶ Roads
- ▶ Rivers



Mekong Delta



70 km



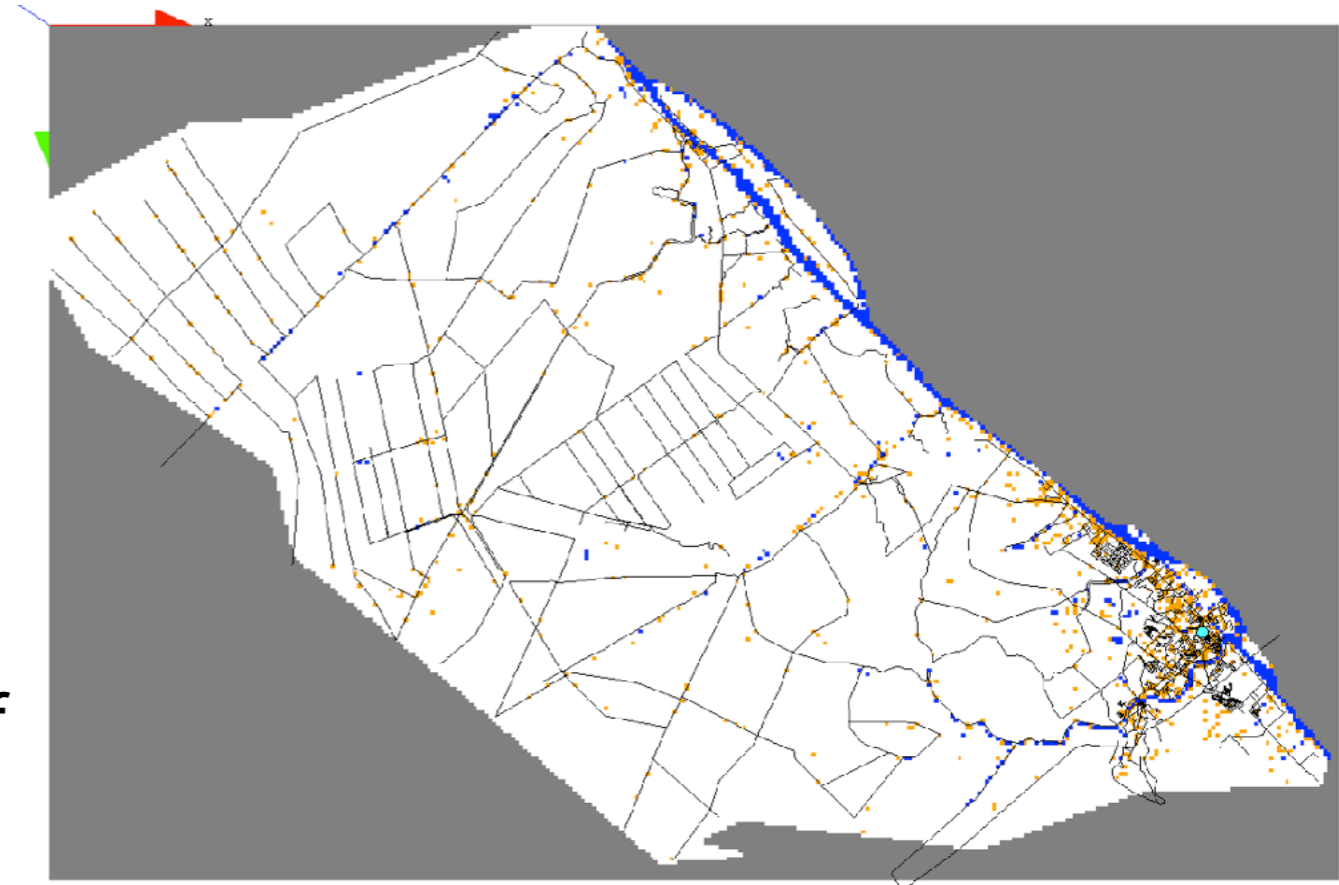
45 km

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 to whole space on a regular grid. Agents will be the cells.
 - ▶ they are characterised by a rate of building on the cell area.

Can Tho 1999



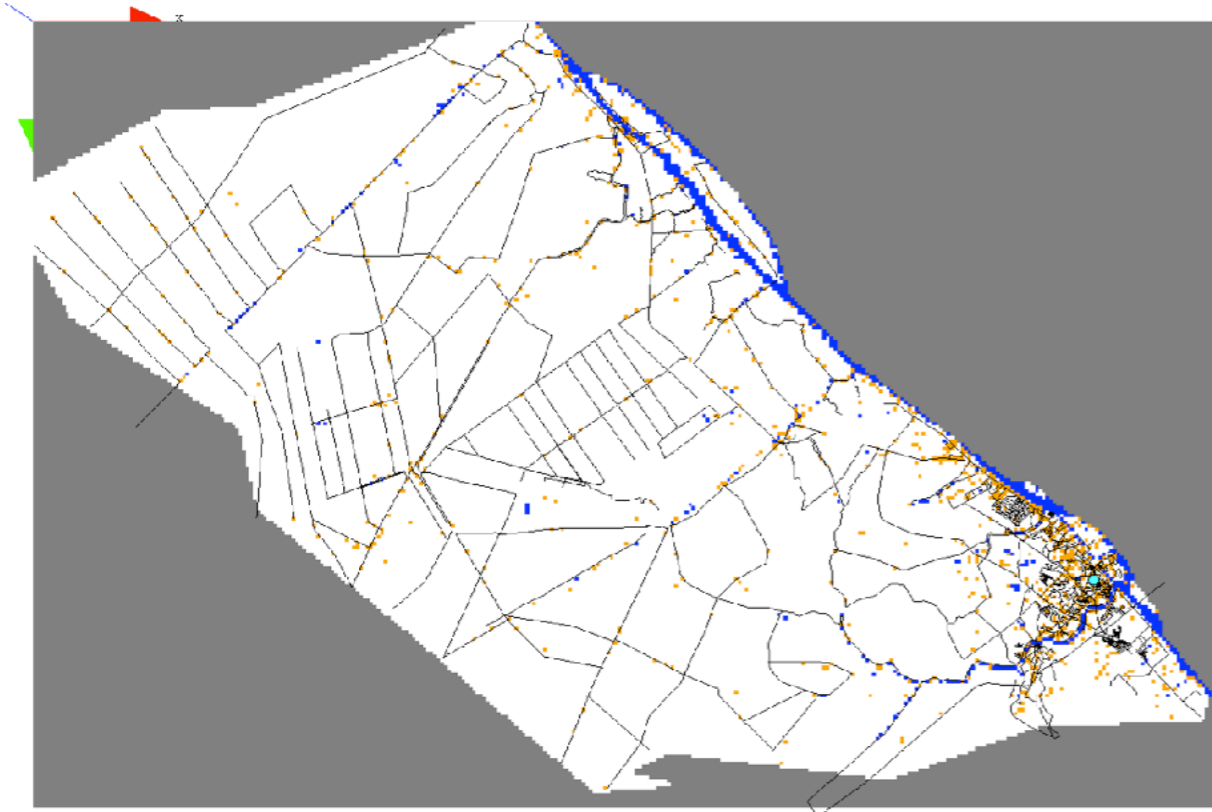
- ▶ We have *abstract agents*:
 - 1 agent = 1 entity aggregating buildings.
- ▶ We can choose the number of cells, so the discretisation rate, and so the precision.

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

Can Tho 1999



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.

Model: entities, dynamic and scales

▶ Spatial scale

- ▶ Area that covers the ASEAN corridor from Myanmar to Vietnam (200 000km²)

▶ Time scale

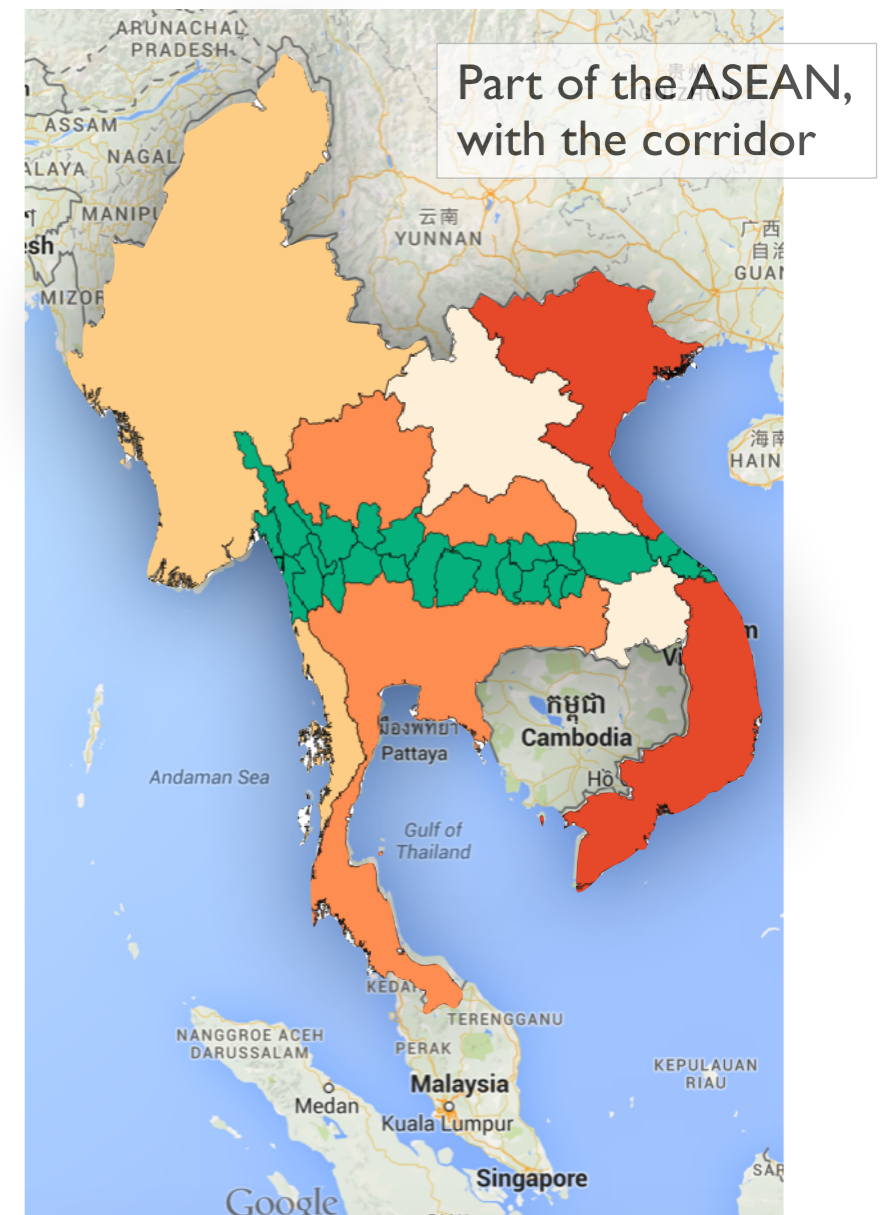
- ▶ Duration : from 2004
- ▶ Time step = 12 hours

▶ Dynamic to take into account

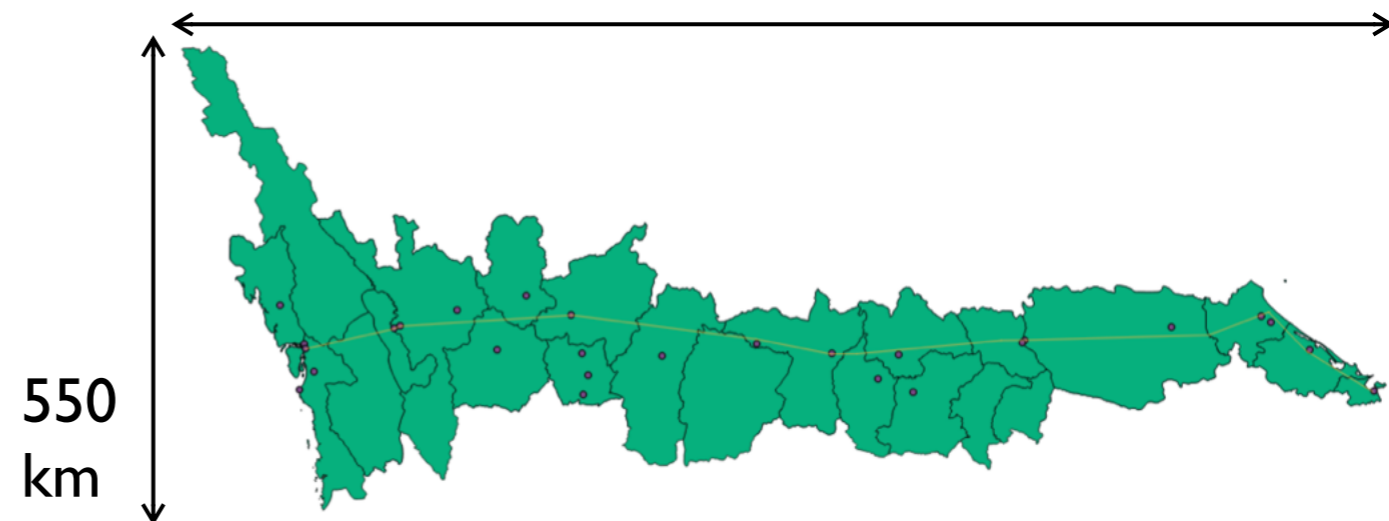
- ▶ Epidemic spread
- ▶ Weather
- ▶ Mobility

▶ Entities which may be taken into account

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



1300 km

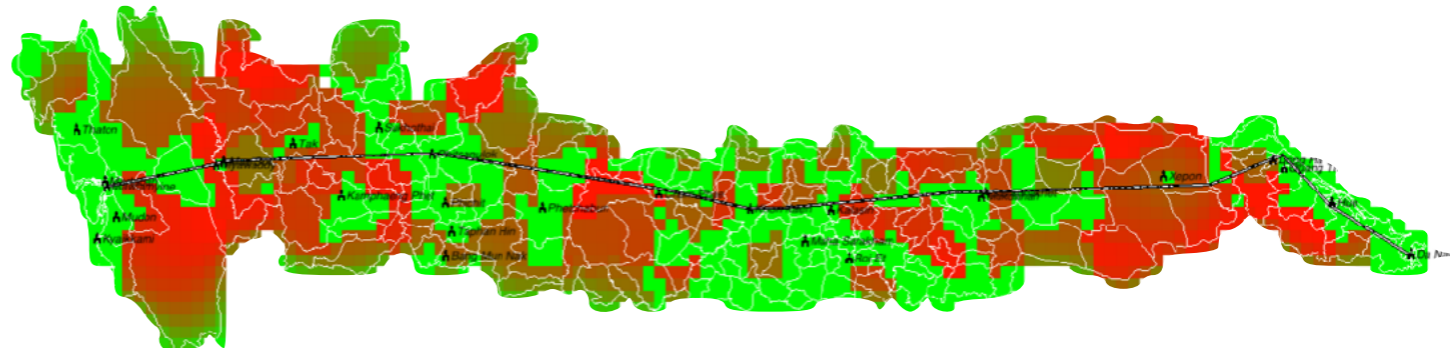


Considered area

What will be the agents in this case ?

► Issue:

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

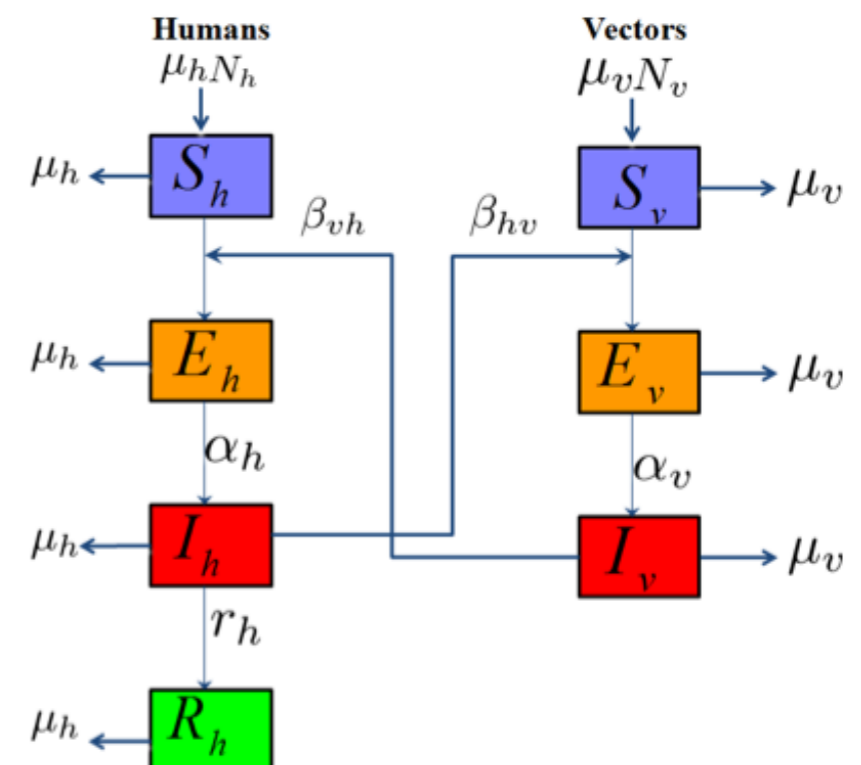


► Hypothesis & Choice:

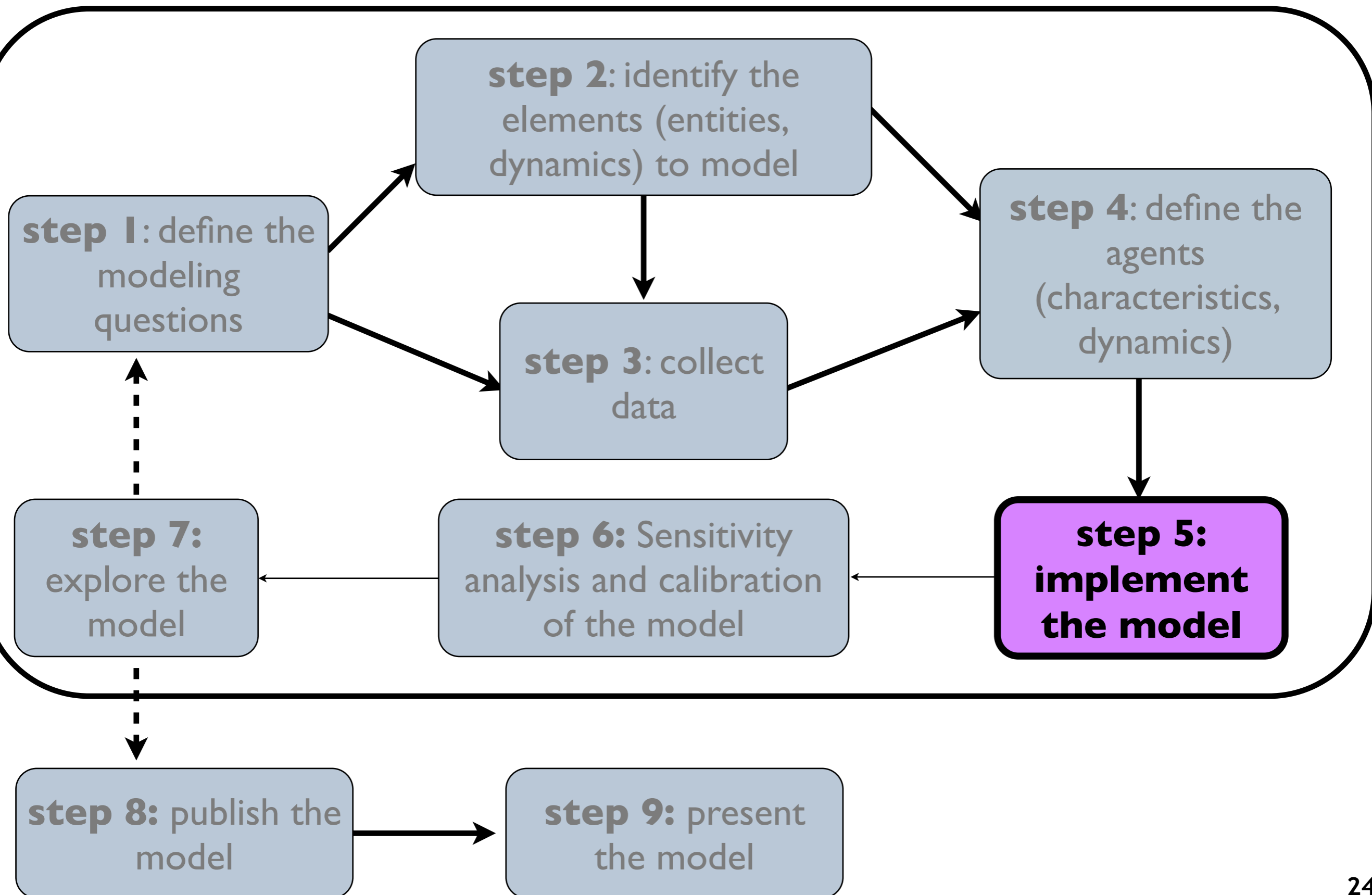
- we choose to discretise to whole space on a regular grid. Agents will be the cells.
- they are characterised by populations of mosquitos and human beings in each epidemic state.

► Dynamics:

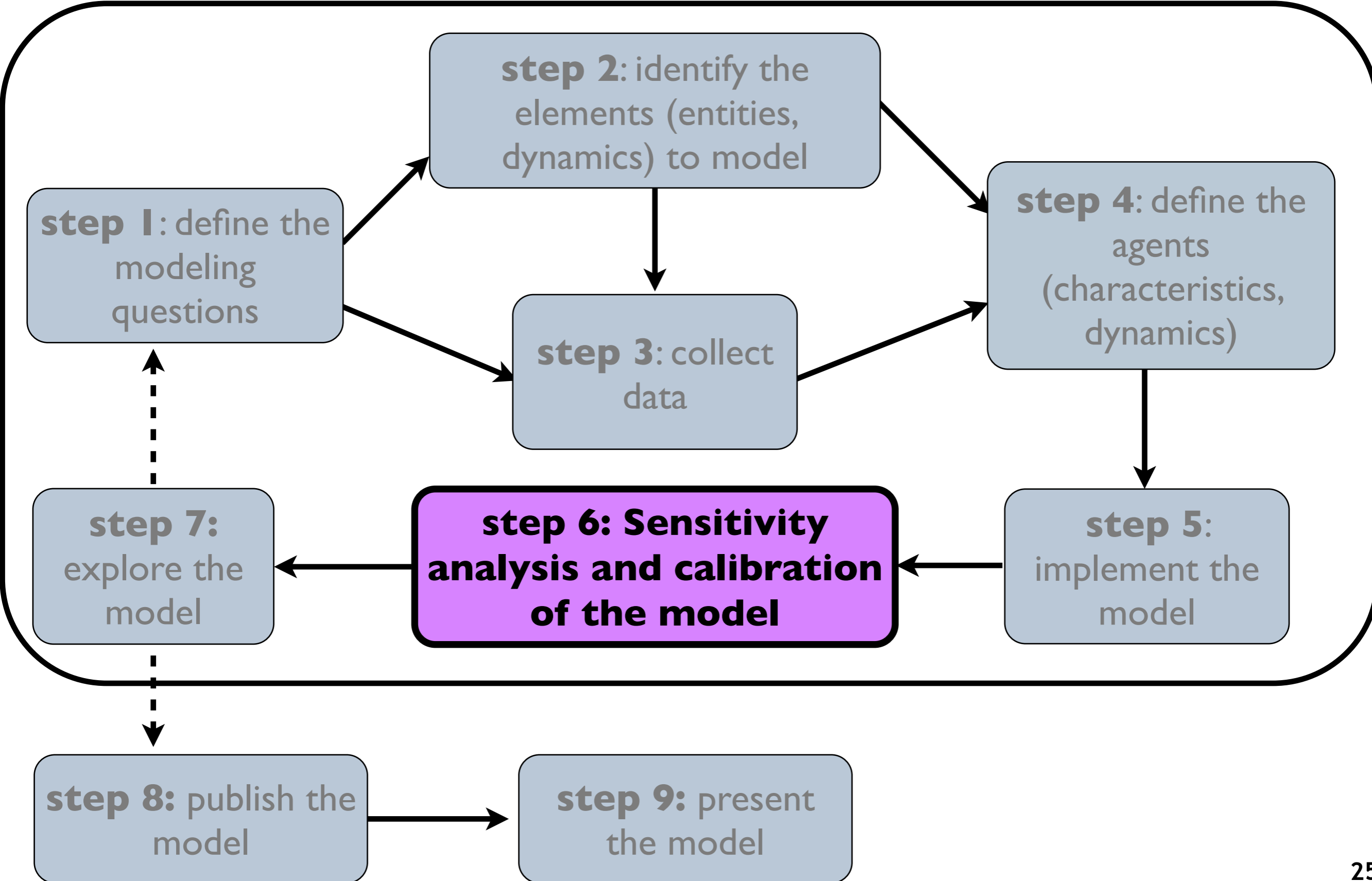
- disease spread : mathematical equation-based model (SEIRS + SEI model on each cell).



Modelling is a multi-step cycle.



Modelling is a multi-step cycle.

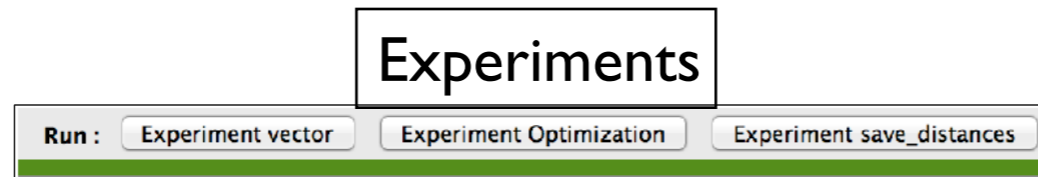


A model is an object that can be manipulated or explored via simulation and on which we can launch experiments.

Parameters

Outputs

w1 →
between 0 and 1
w2 →
between 0 and 1
w3 →
between 0 and 1

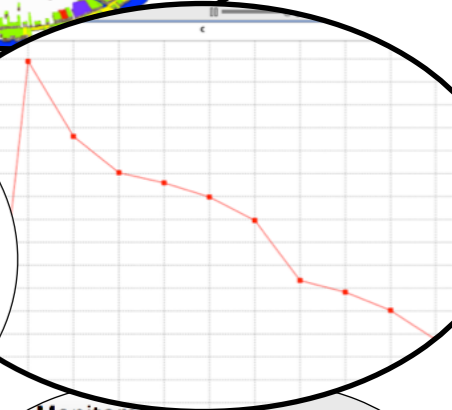
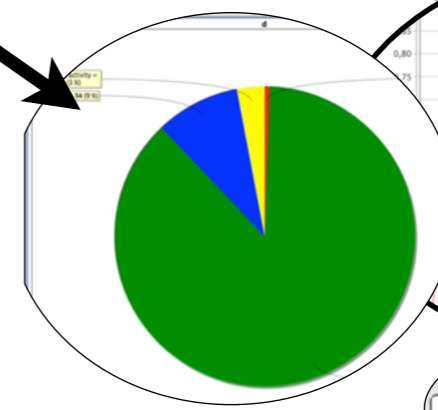
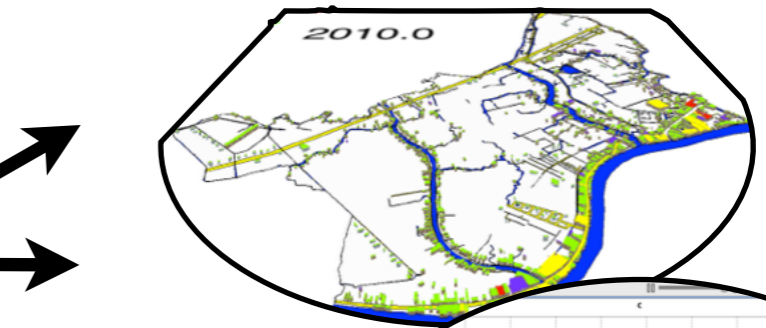


Model

Inputs
Data



```
282 float limit <- world.shape.area;  
283 list-building possible_buildings <- (buildings + (neighbours_blocks accumulate each.buildings)) where (each.  
284 if empty(possible_buildings) {  
285 possible_construction <- false;  
286 write name;  
287 return;  
288 }  
289 bool bd_built <- false;  
290 building bd <- nil;  
291  
292 loop while: true {  
293 building one_building <- one_of (possible_buildings where (envelope(each.shape).area < limit));  
294 if (one_building = nil) {  
295 break;  
296 }  
297 geometry new_building <- copy(one_building.shape);  
298 float size <- max([new_building.width,new_building.height]) ;  
299  
300 geometry space2 <- nil;  
301 geometry space <- empty_space reduced_by size;  
302 if ((space != nil) and (space.area > 8.0)) {  
303 agent closest_road_river <- (road) closest_to space;  
304 create building with:[ shape:: new_building, location::((closest_road_river closest_points_with space)  
305 texture :: "/includes/texture.jpg",type::one_building.type] {  
306 myself.buildings << self;  
307 bd <- self;  
308 switch type {  
309 match "Education" {myself.has_education <- true;}  
310 match "Religion" {myself.has_religious <- true;}  
311 match "Economic activity" {myself.has_economic <- true;}  
312 }  
313 }  
314 bd_built <- true;
```



Monitors
Error 0.8761643159552568

Best fitness	-
Last fitness	-
Parameter space	w1 (11) * w2 (11) * w3 (11) = 1331
Exploration method	Method genetic fitness = minimize error compute the average of 5 simulations for each solution
Mutation probability	0.1
Crossover probability	0.7
Population dimension	5
Preliminary number of generations	1
Max. number of generations	500
weight for the density criterion	0.2
weights (education, religion, economic)	0.0
diversity criterion	1.0

Often there are at least 2 ways to run simulations.

GUI experiment:

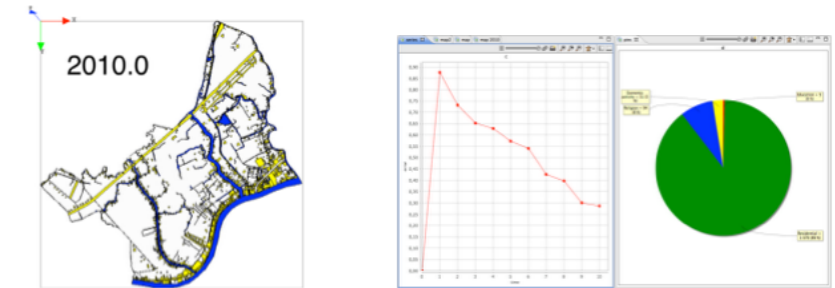
Gui experiments allow the modeler to observe indicators evolution during a simulation

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.

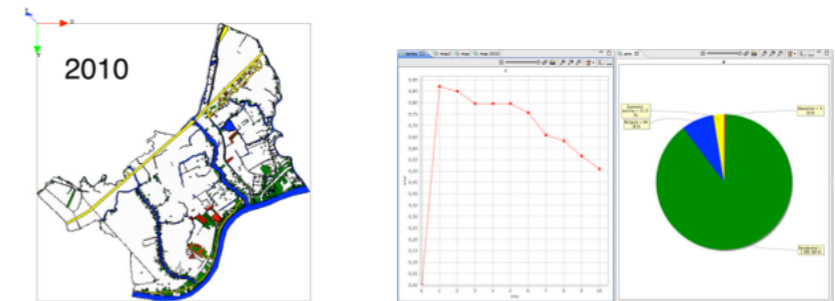
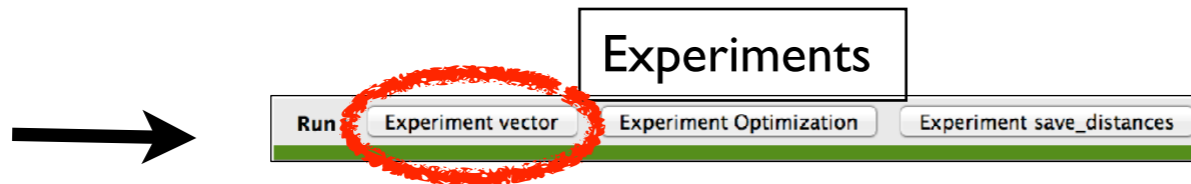
GUI experiments allow to test various parameters values and observe the output... which can be long and fastidious at hand ...

$w_1 = 0.2$
 $w_2 = 0.0$
 $w_3 = 1.0$



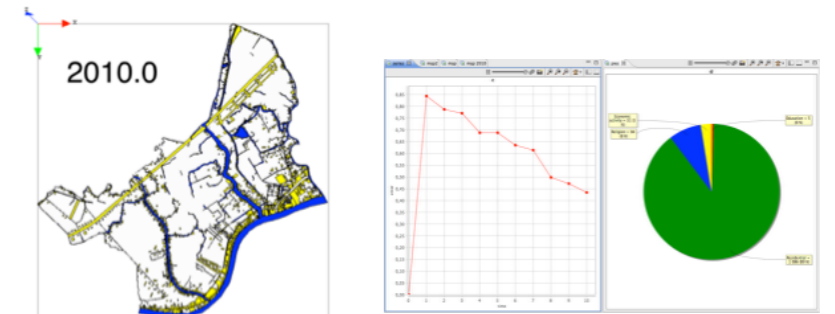
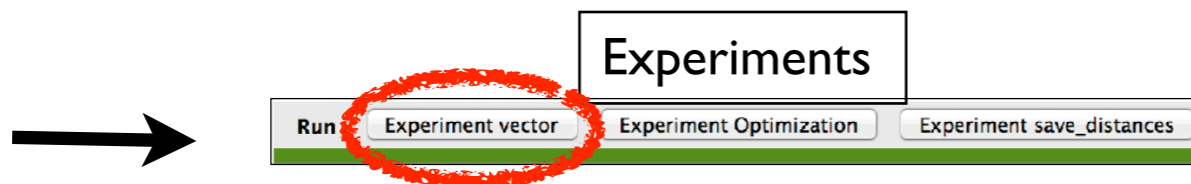
Error = 0.2869

$w_1 = 0.7$
 $w_2 = 0.5$
 $w_3 = 0.2$



Error = 0.5093

$w_1 = 0.5$
 $w_2 = 0.3$
 $w_3 = 0.8$

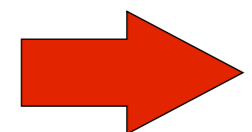


Error = 0.4344

.....

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,
 - ...



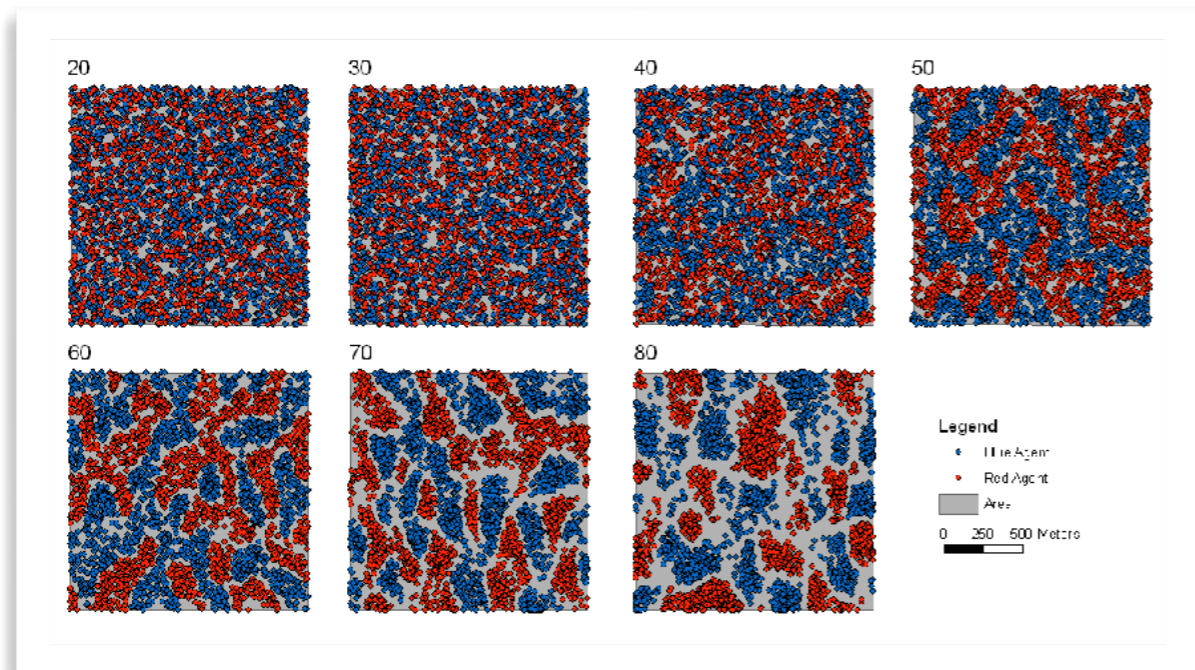
A necessary step!

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

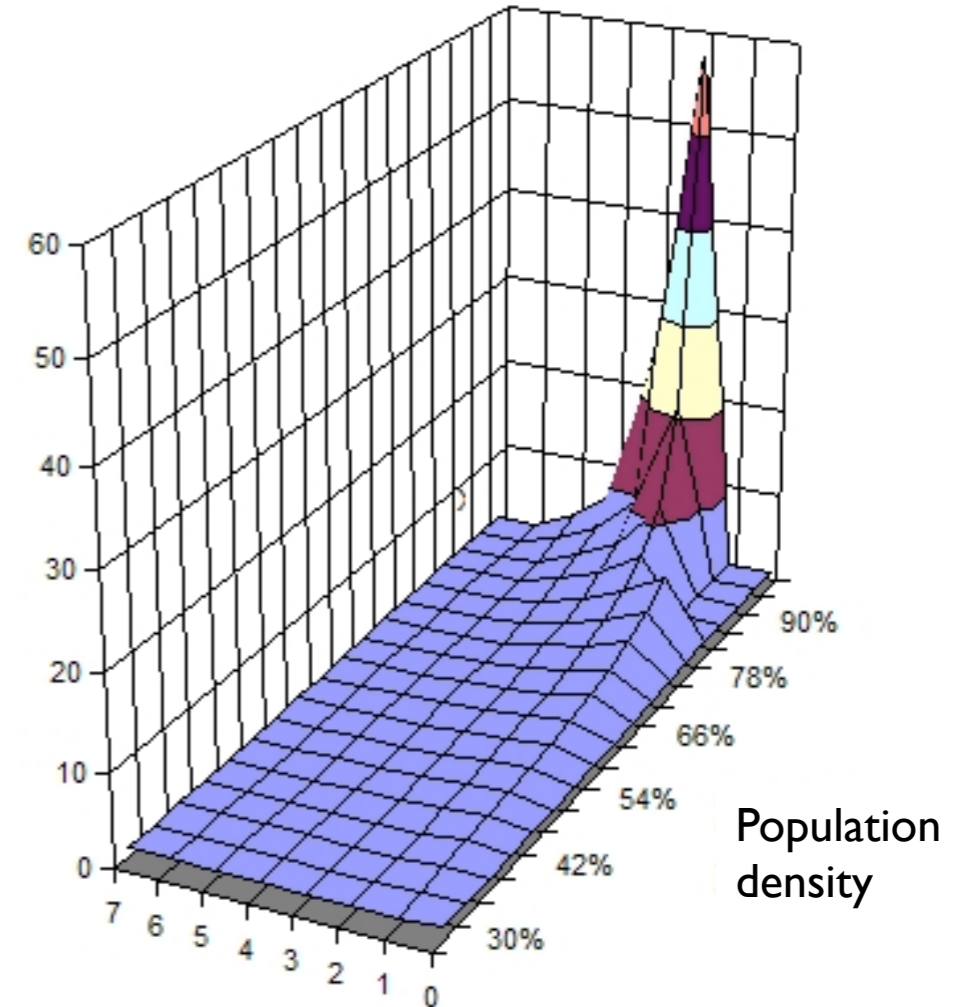
Aim: to have a deep knowledge of the behaviour of the model (and in particular its **sensitivity to parameters variations**)

==> the range of values to which the simulation is very sensitive -> discretisation need (step= 1, 0.1 or 0.0001 ...)

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 ?



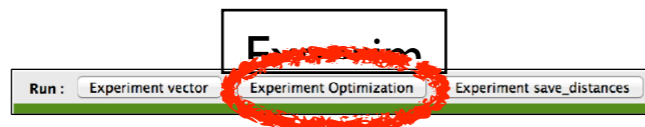
Real data (at the time of the simulation end)

error = difference between simulated data and real data



Simulated data at the end of the simulation

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



Real data at initial time

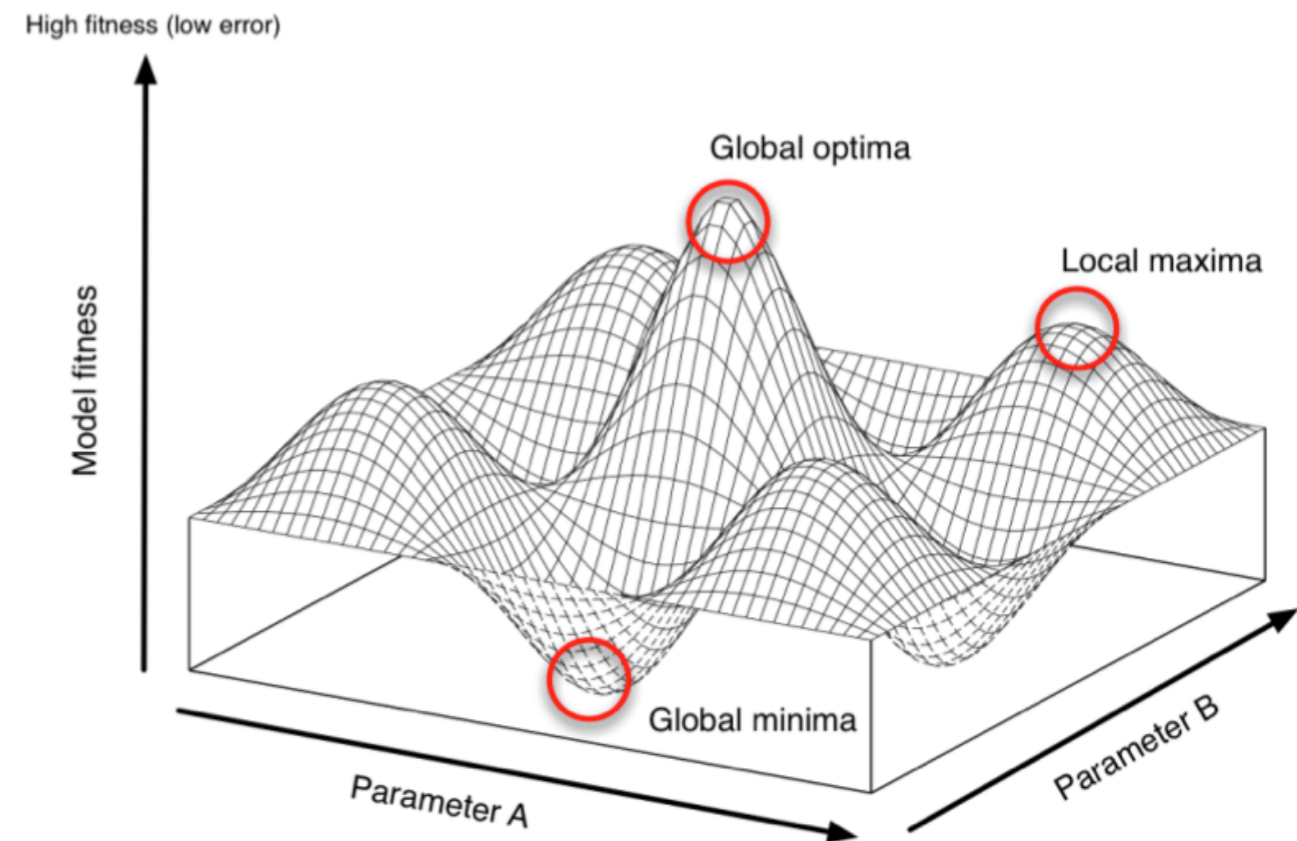
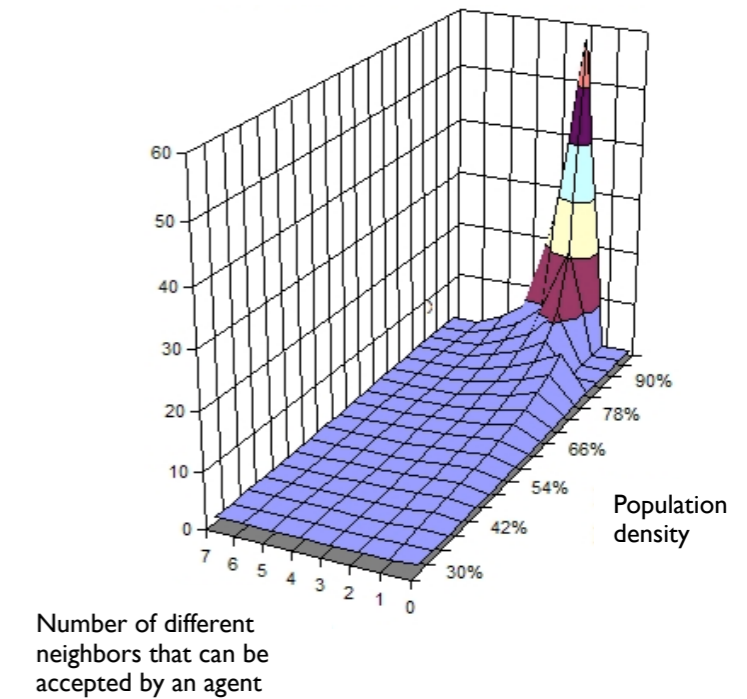
Issues linked to the calibration.

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, ...)



Steps in an experiment design.

▶ General method :

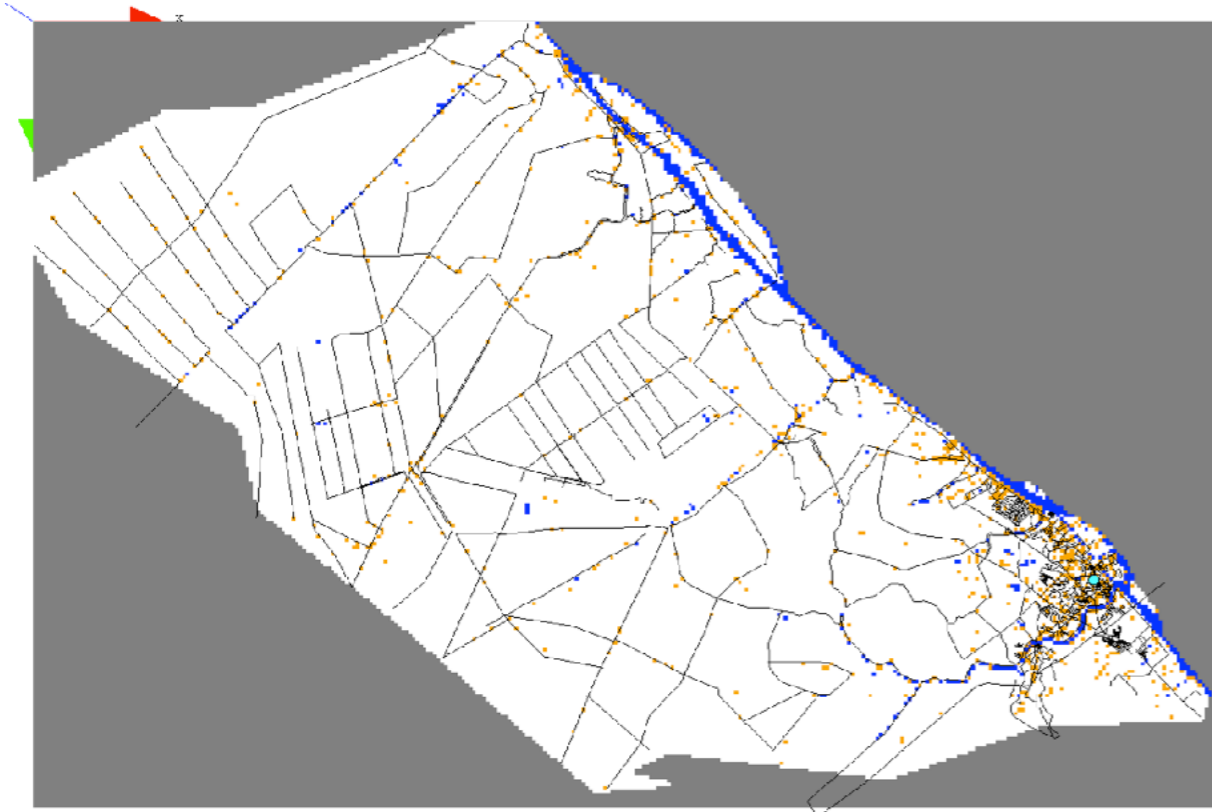
- Define an **initial situation** and a **stop criterion** (of 1 simulation)
- Select the **set of parameters** to explore and the **indicators**
- Define a **strategy of exploration**
- Execute, collect and save the data
- Analyze the collected data

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

Can Tho 1999

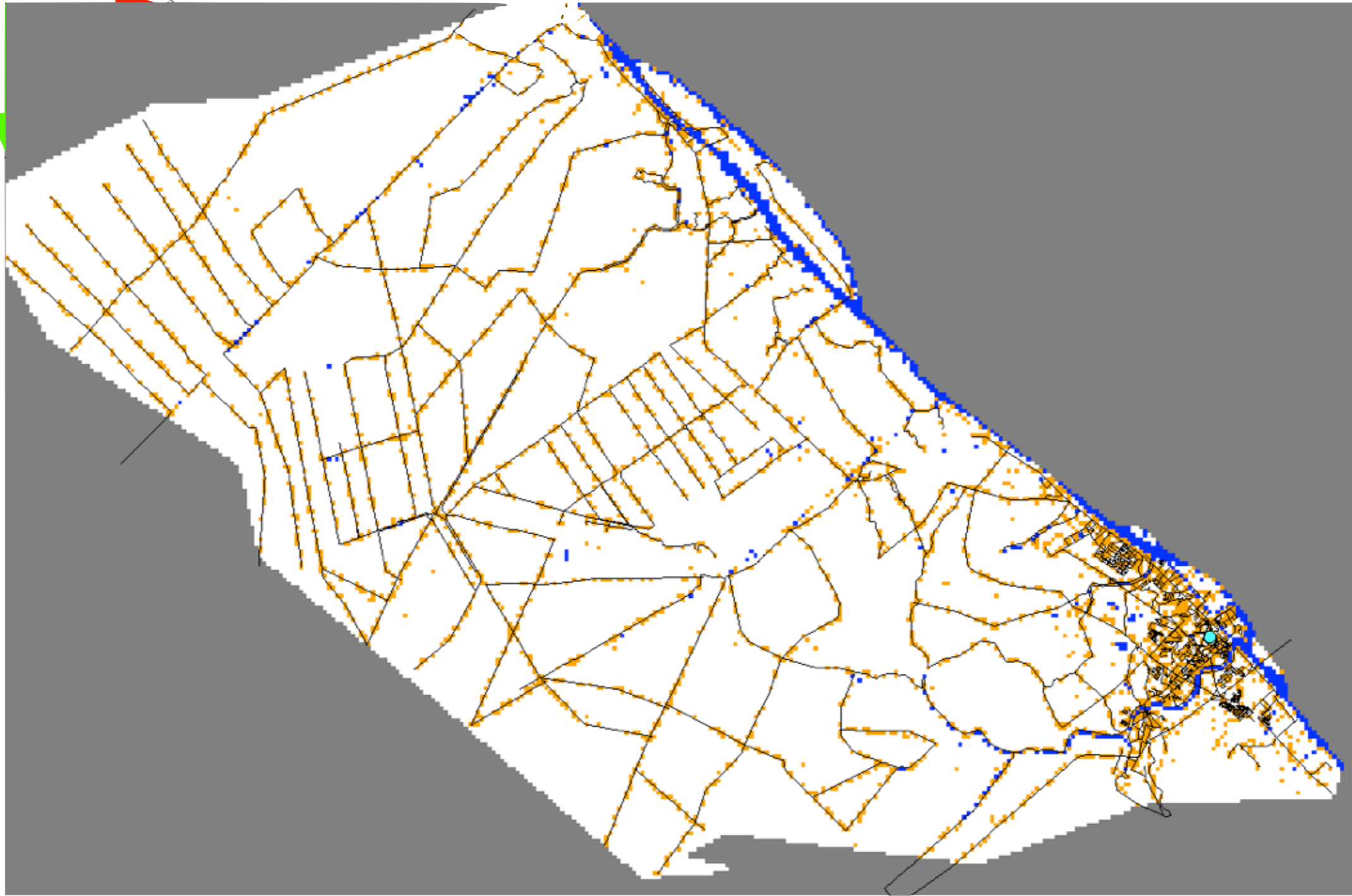


For each free cell (empty space): evaluation of their constructability value based on 3 criteria:

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

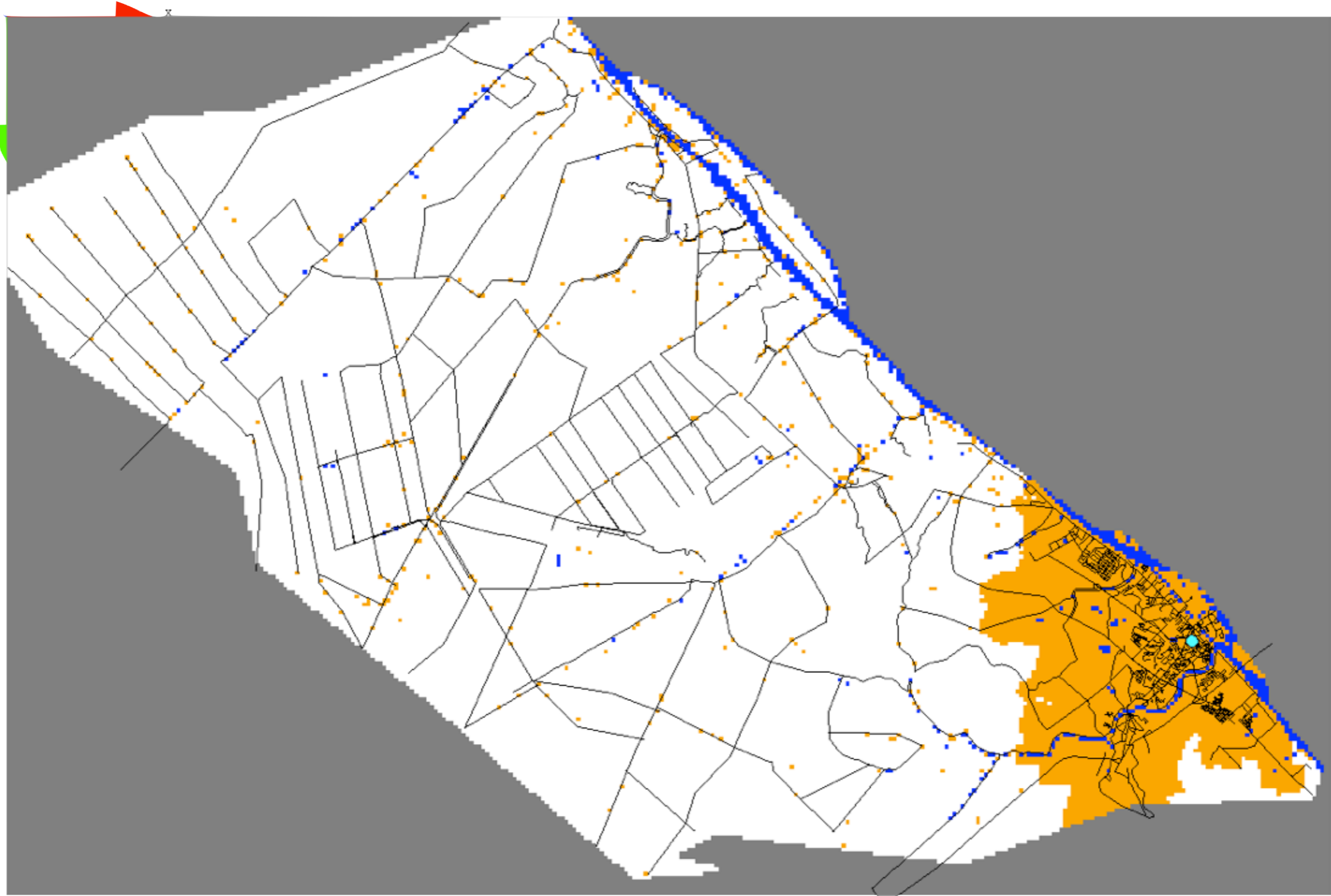
The decision is made using multi-criteria (weighted mean) decision-making process, with 3 weights (w_1 , w_2 , w_3) associated to each criteria.

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



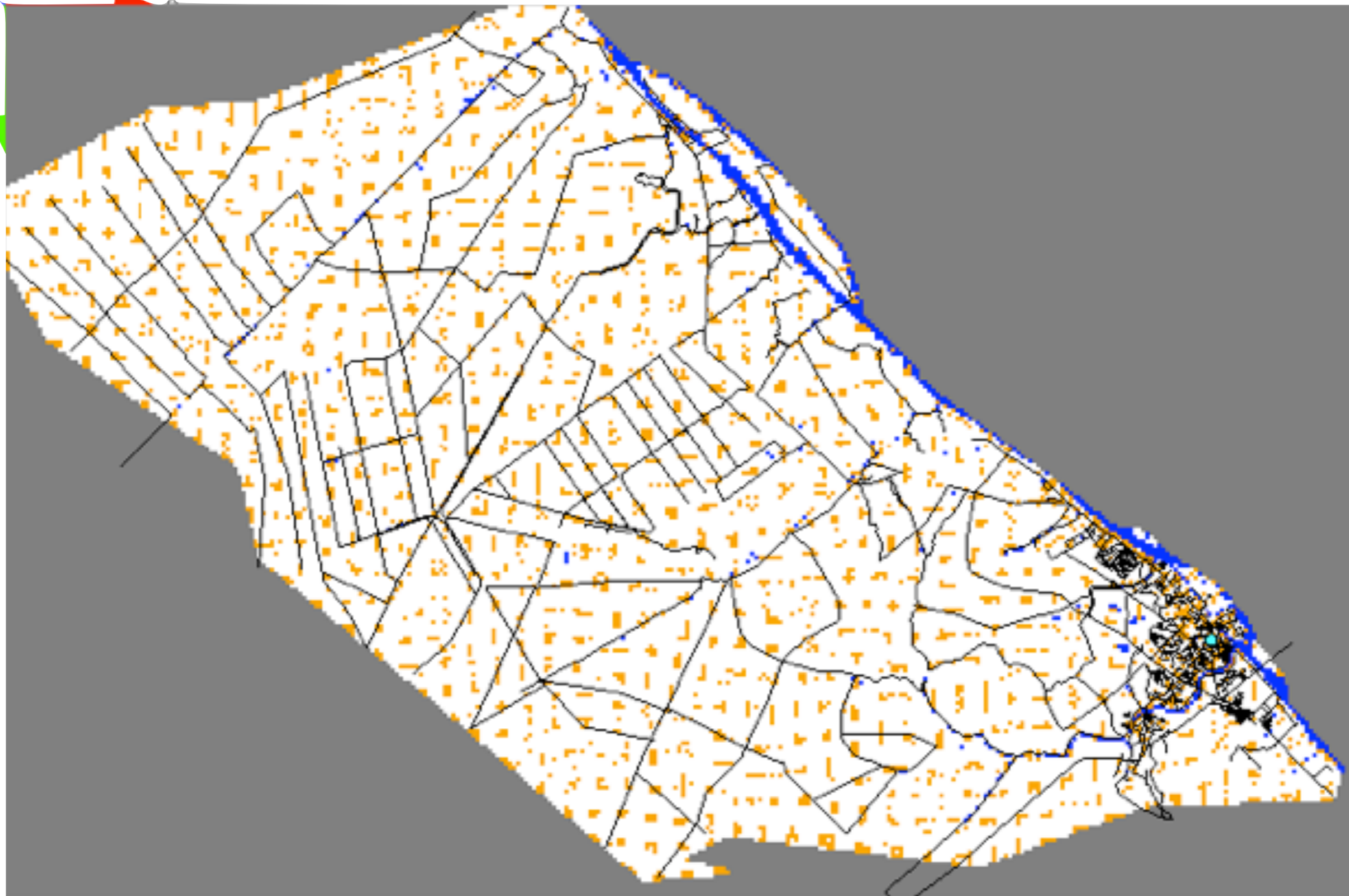
Construction along the roads

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



Expansion of the city center

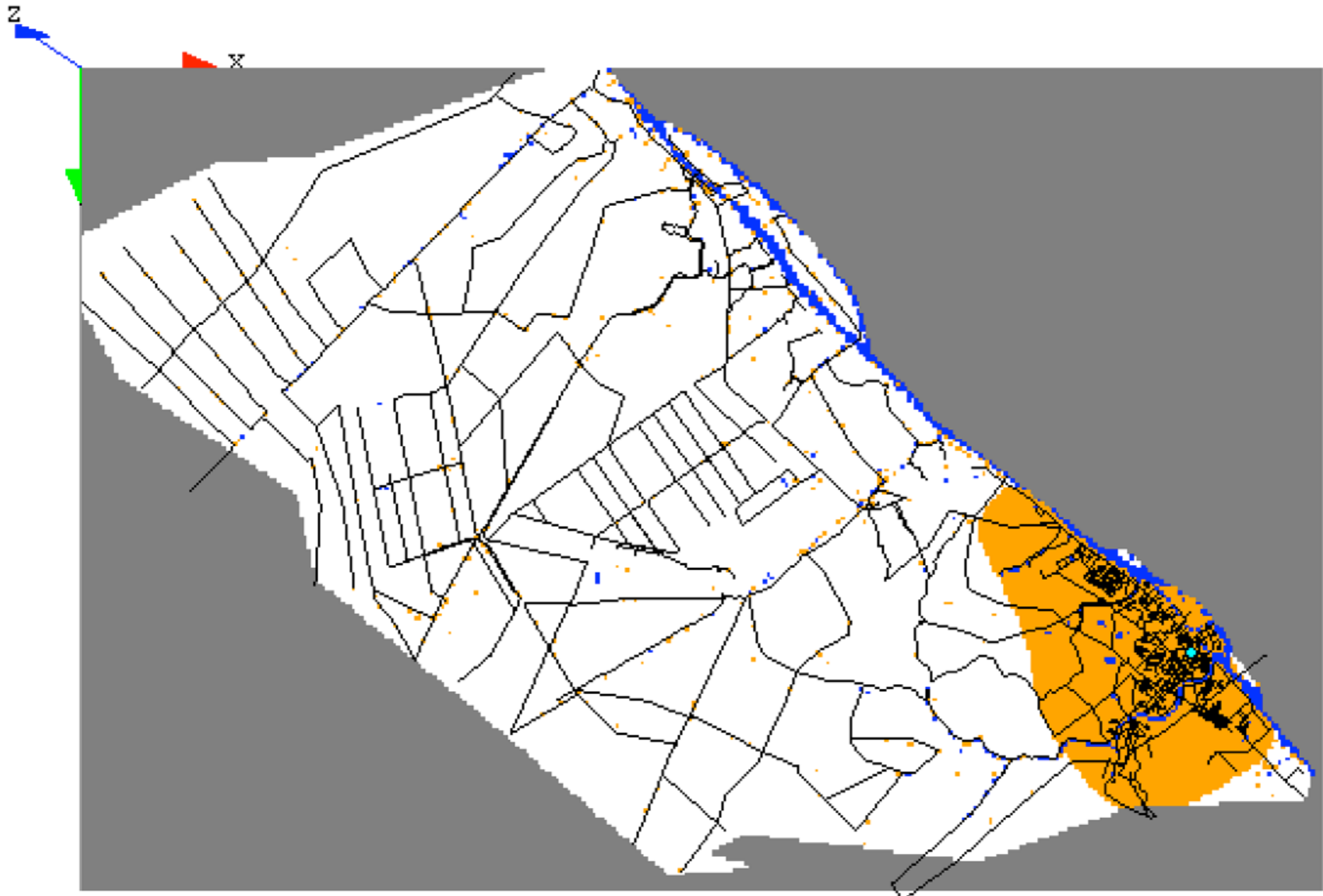
Can Tho Case study: first simulation with only the (low) density criterion



Lot of small «building blocks» covering uniformly the space

w_1 : density = $1 - (\text{number of built neighbor cells} / \text{number of neighbor cells})$

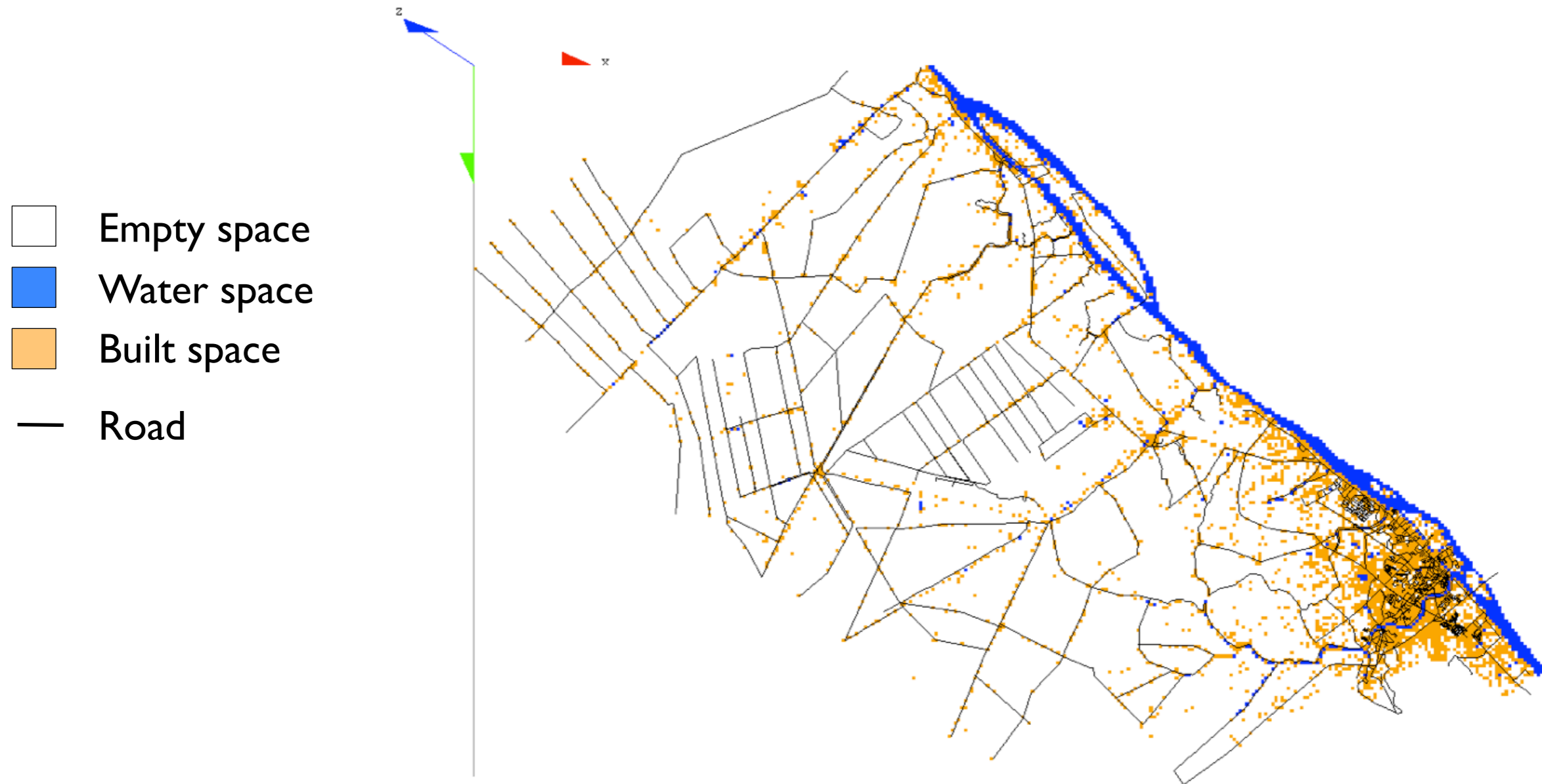
Can Tho Case study: first simulation with only the (high) density criterion



Expansion from high density areas

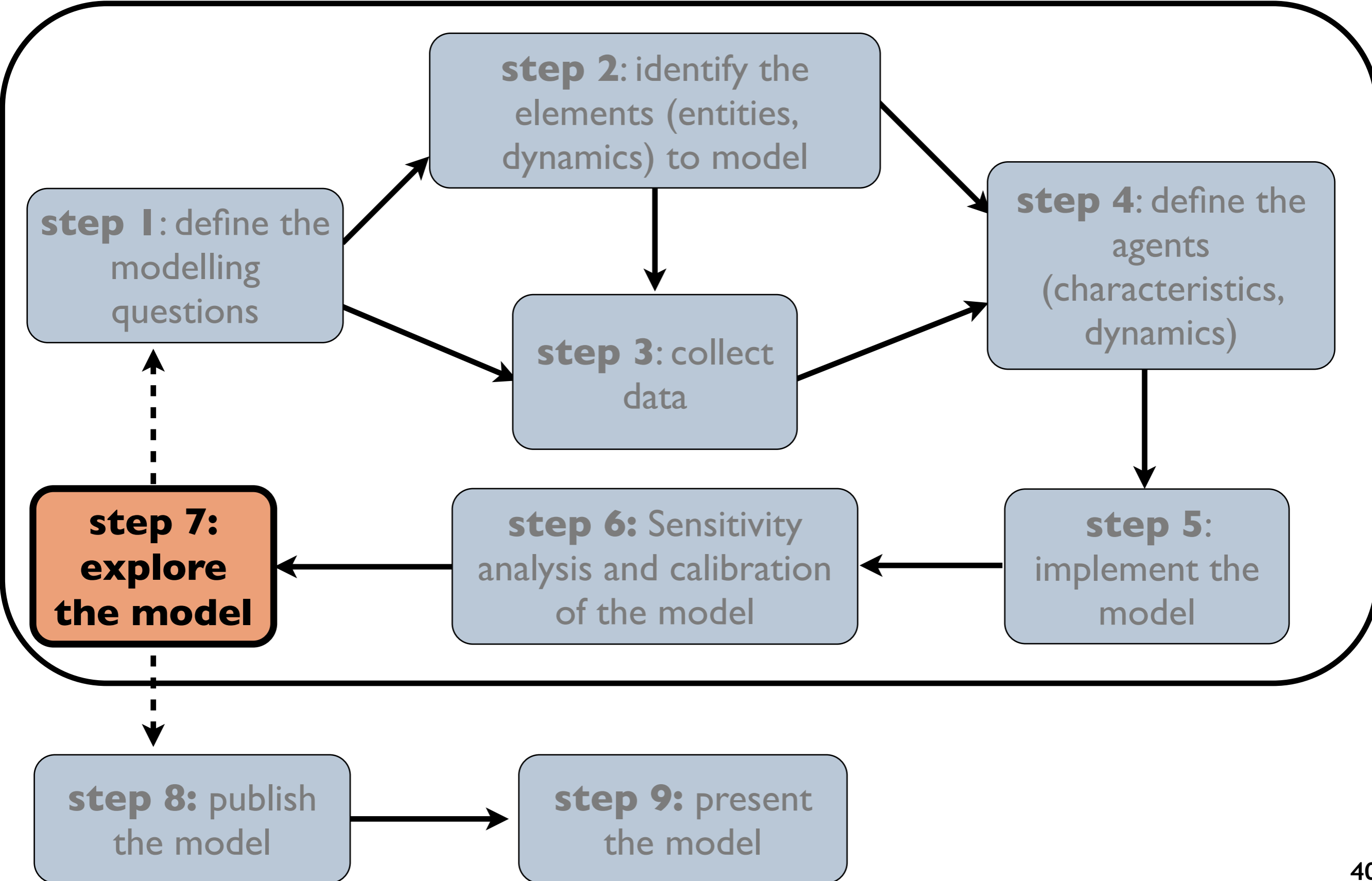
w_1 : density = (number of built neighbor cells / number of neighbor cells)

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 ?



??????????

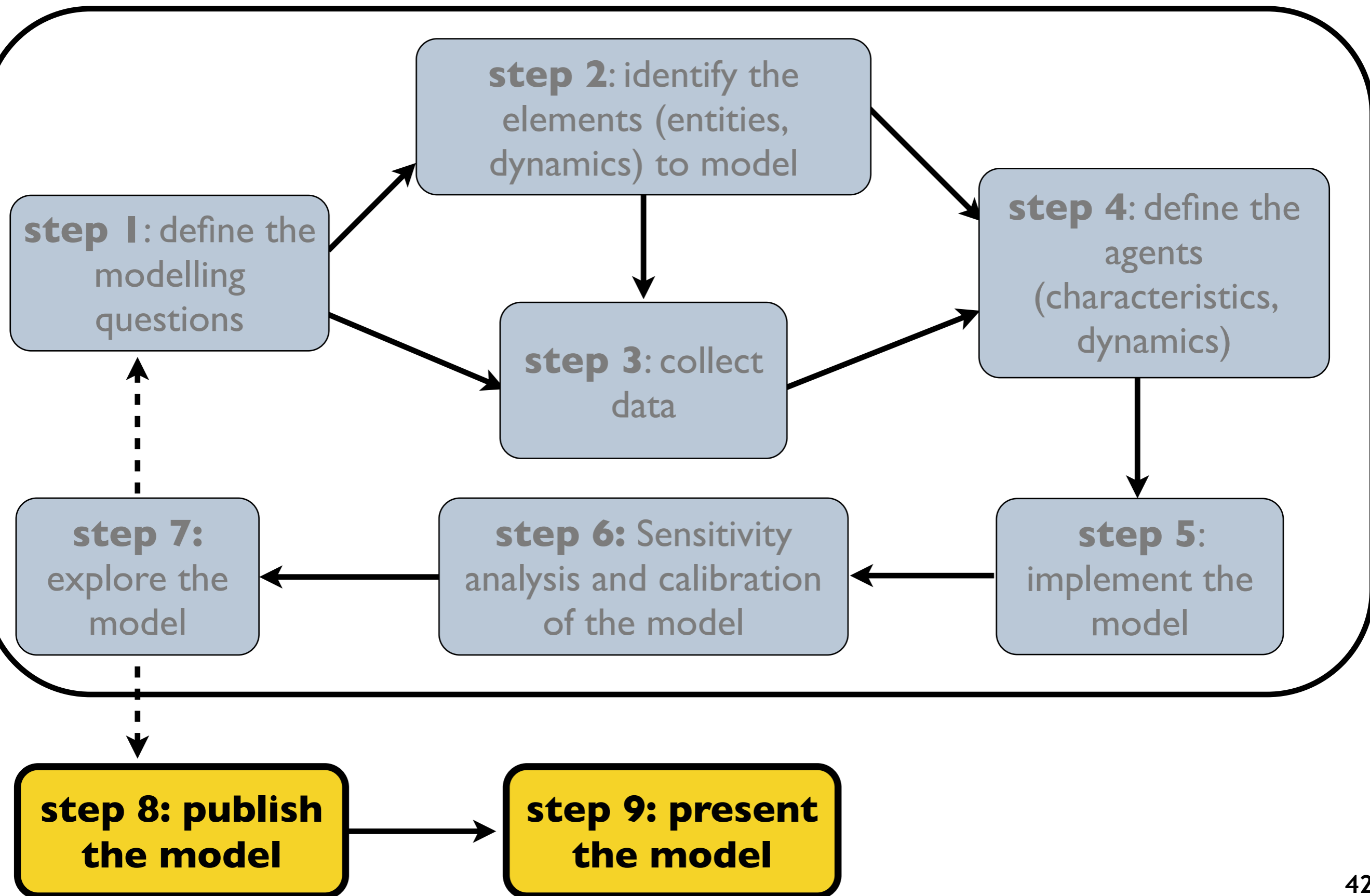
What-If water channels are improved ?



??????????

Modeling can be useful:
- to build Decision-Support Systems (DSS)
-> to help urban planning.

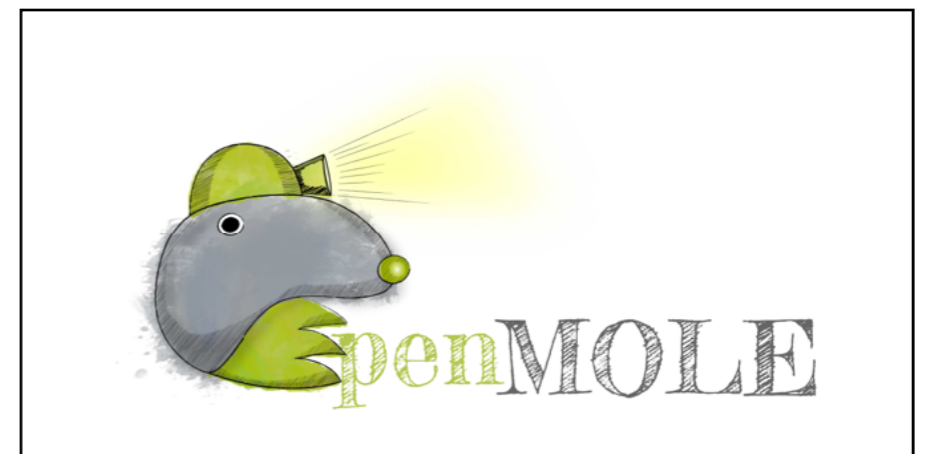
Modelling is a multi-step cycle.



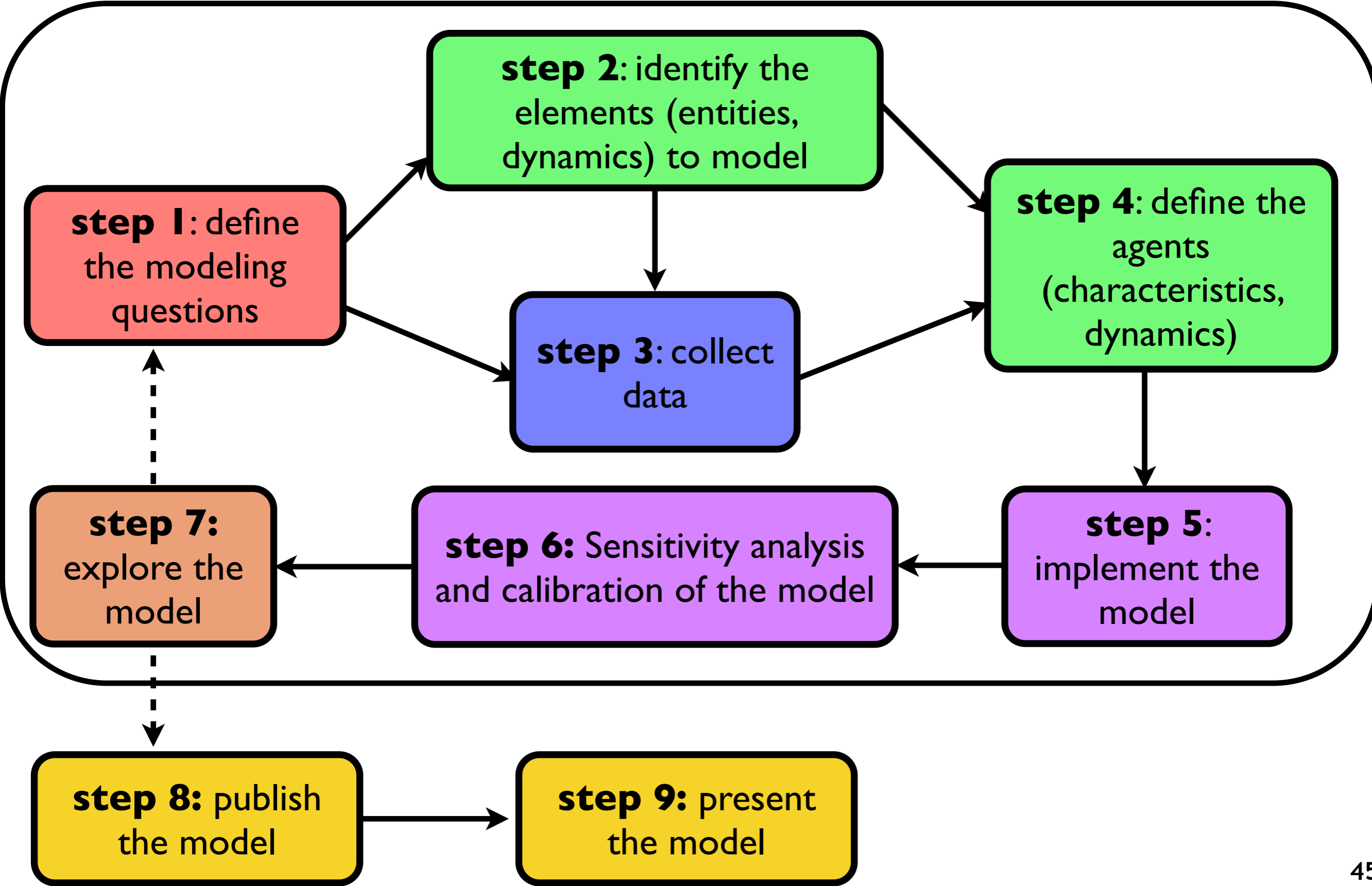
Description and publication of ABM: Status in 2000's

- ▶ 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

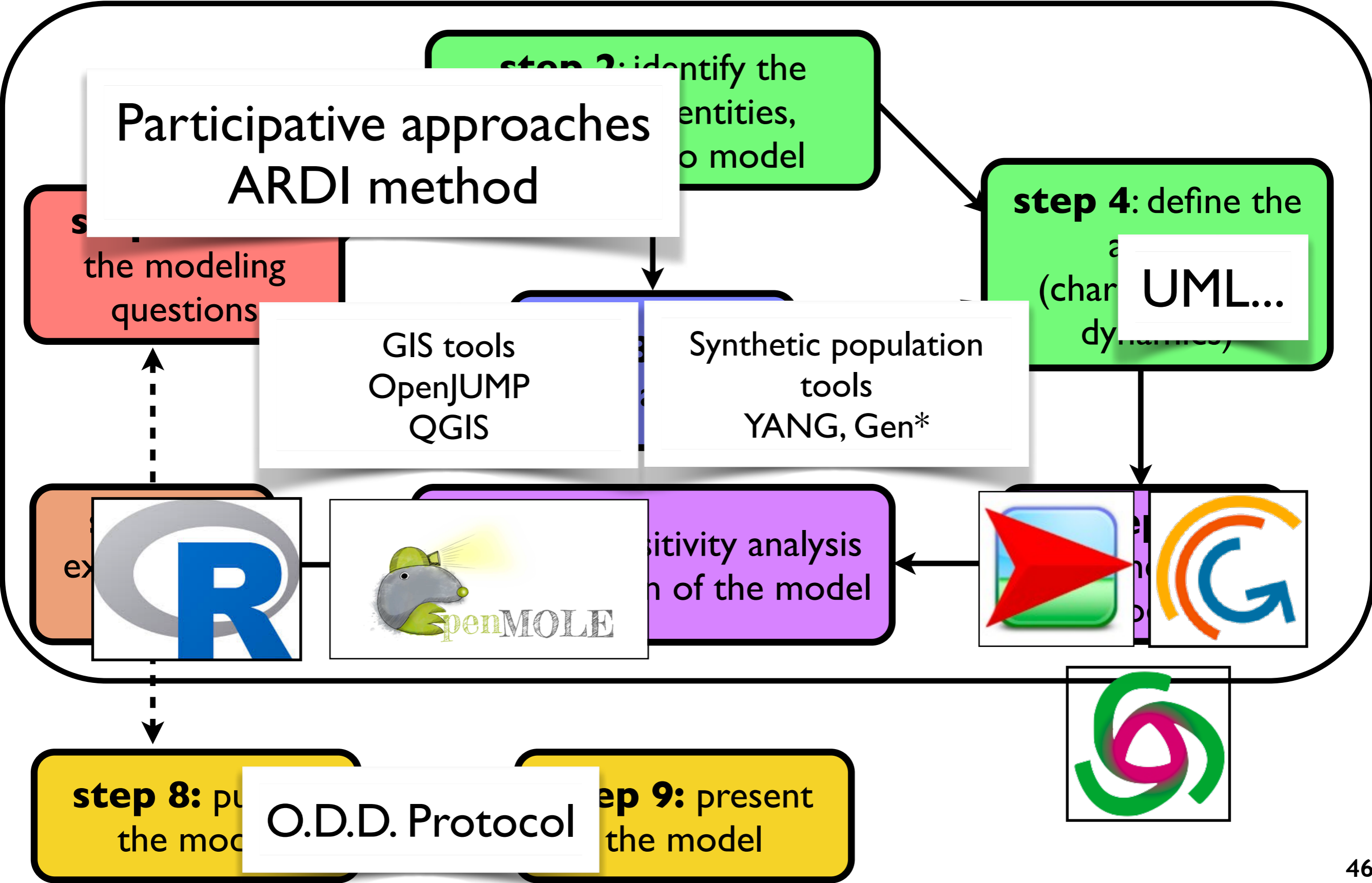
Tools box for modeling and simulation



Modelling is a multi-step cycle.



Modelling is a multi-step cycle.

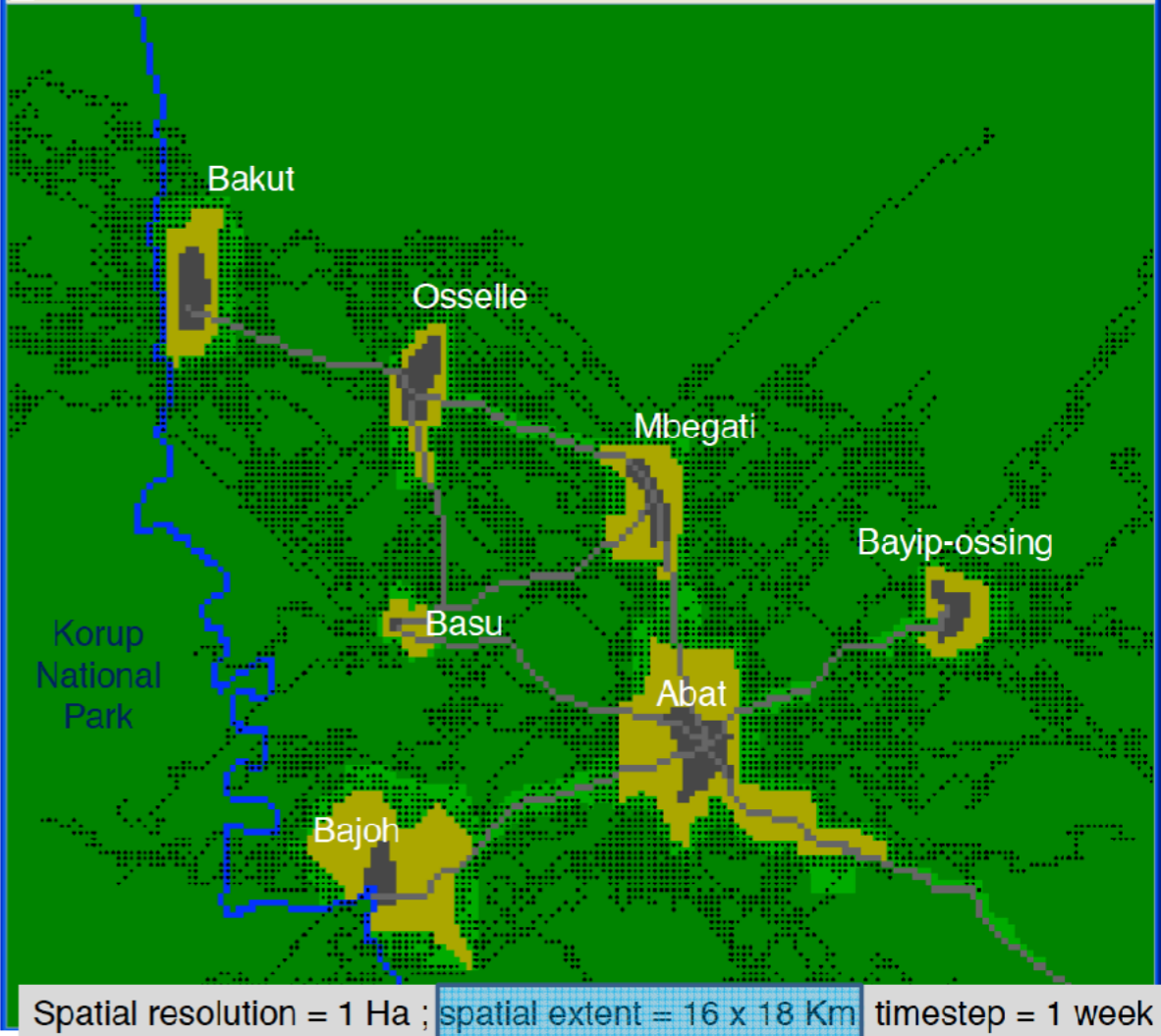


Example of a participative modeling workshop



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



Co-construction of a shared representation in 4 steps

A = Actors

R = Ressources

D = Dynamics/ processes

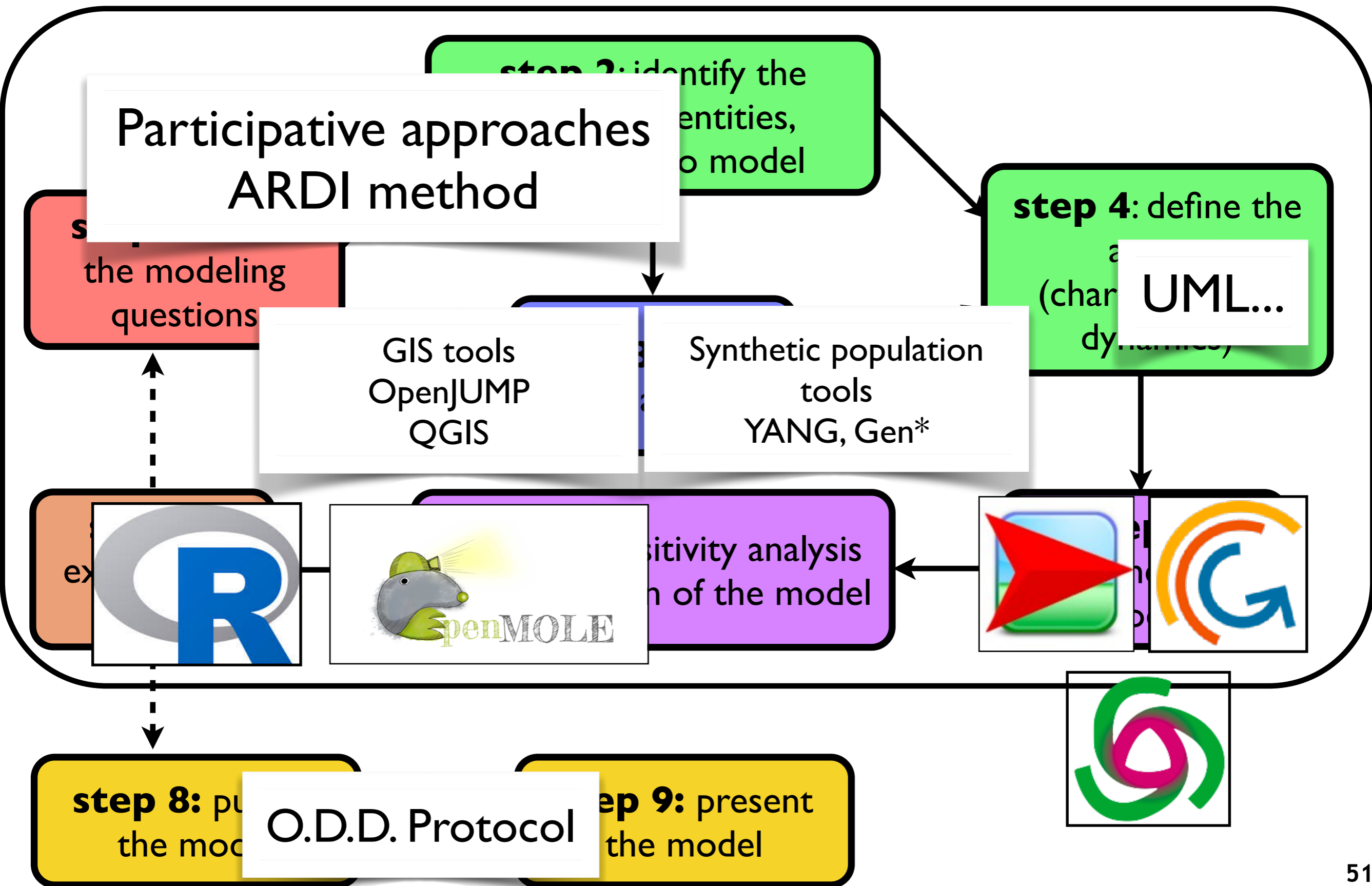
I = Interactions

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.

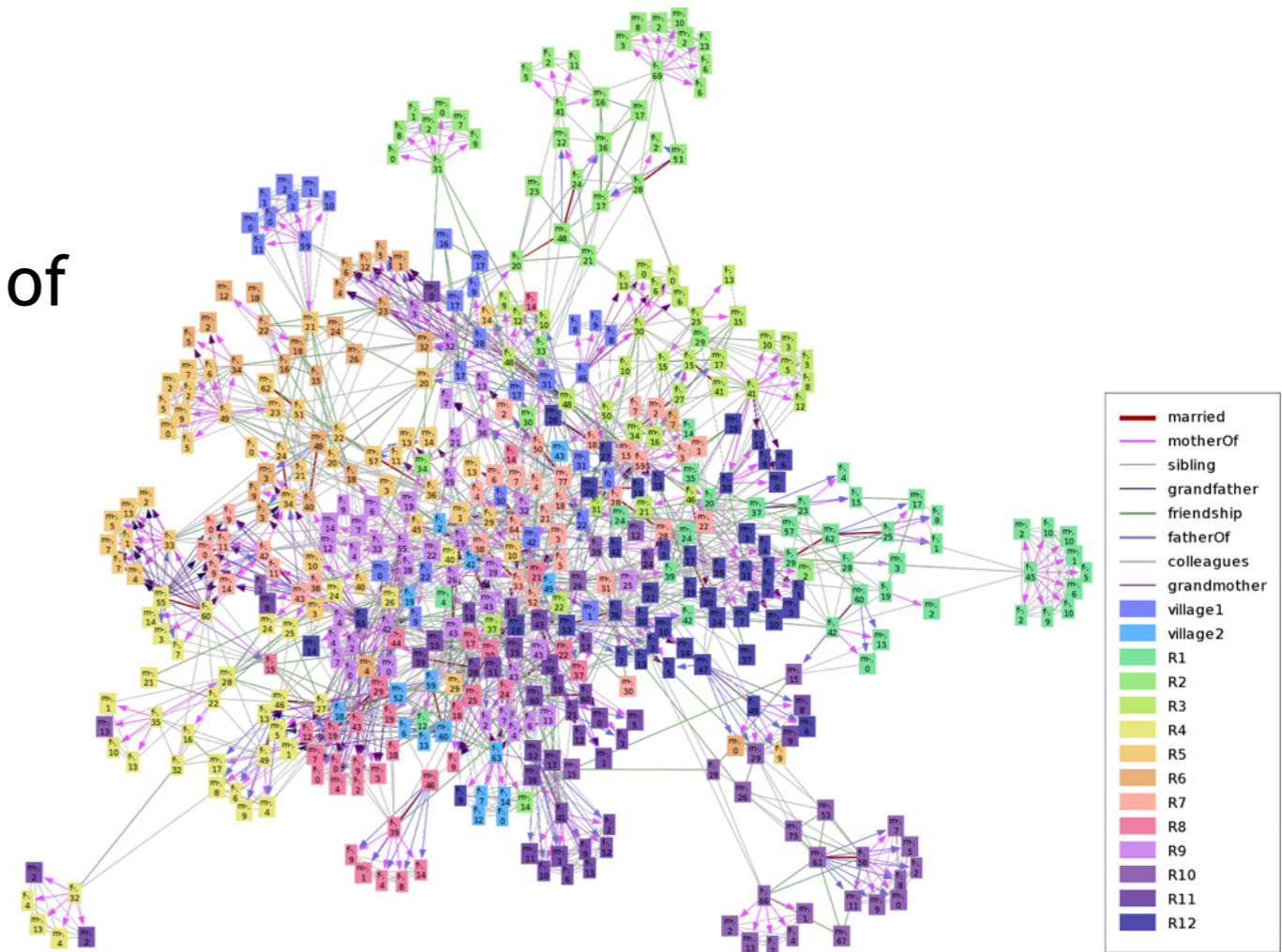


Yang : Yet Another Network Generator

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

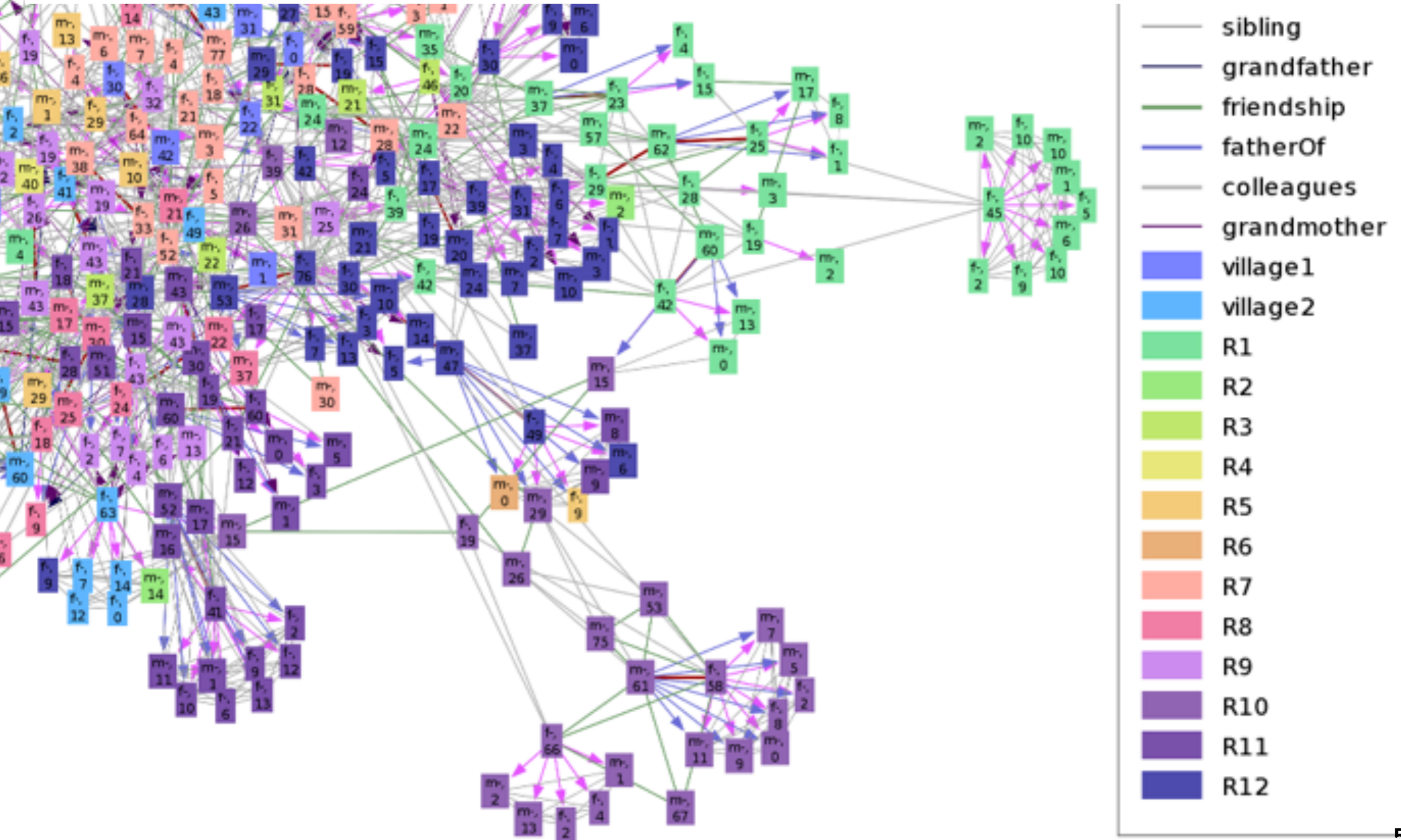
It has been applied to the generation of

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



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

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

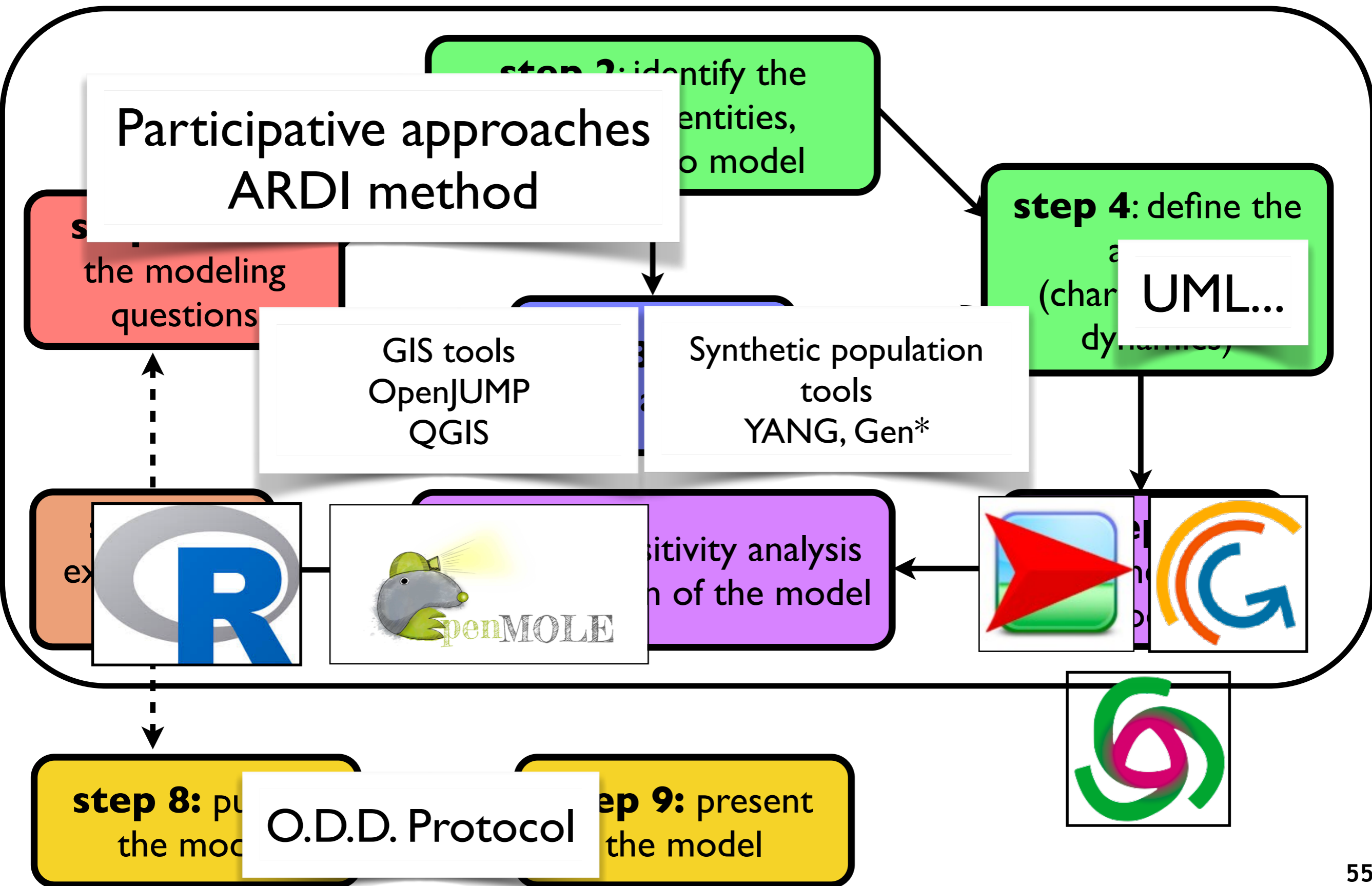


Synthetic population generation: the GEN* project

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



Modelling is a multi-step cycle.

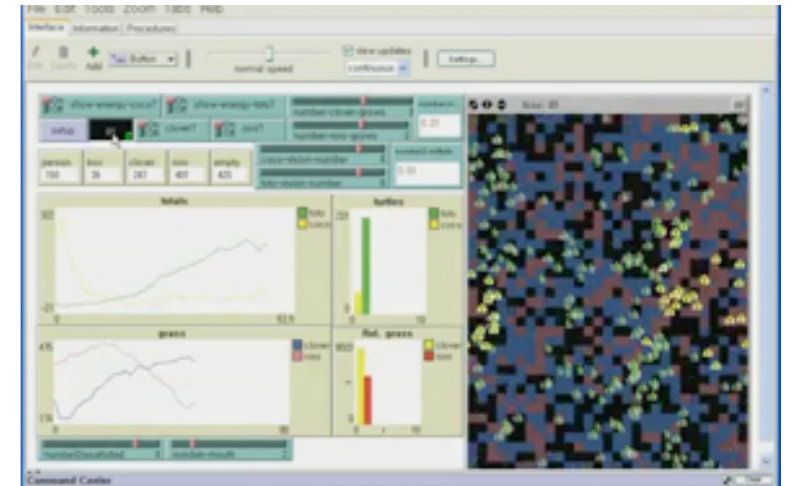


Models can be implemented and simulated using any generic programming language, but also with some dedicated (open-source) platforms.

NetLogo

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

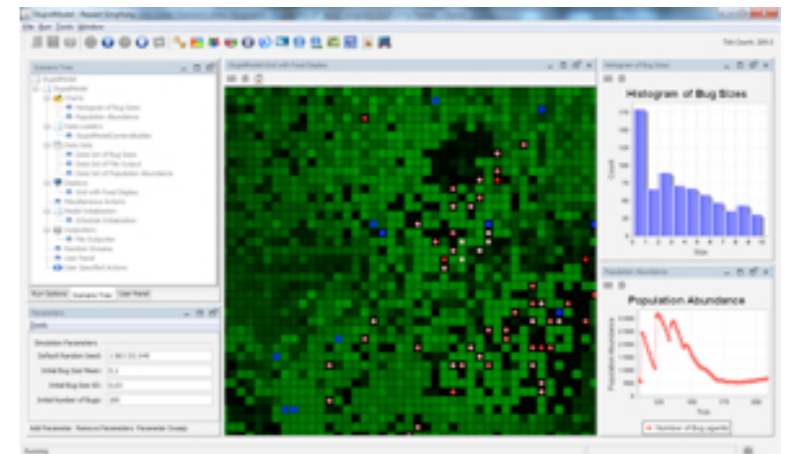
Pedagogical tool with a specific modeling language. Numerous examples in various domains. **Ideal for beginners and prototypes, but somehow limited for large models.**



Repast Symphony

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

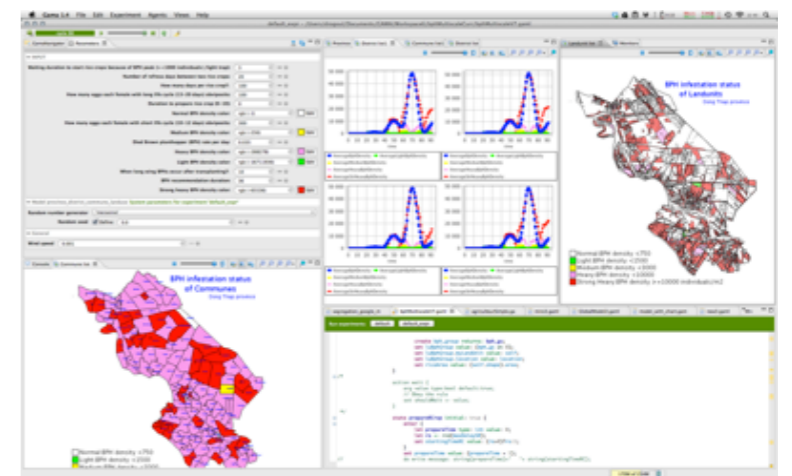
Toolbox for agent-based modeling in Java, numerous libraries of connected technologies (statistical analysis, GIS, 3D models, etc.). **Very powerful but requires very good programming skills.**



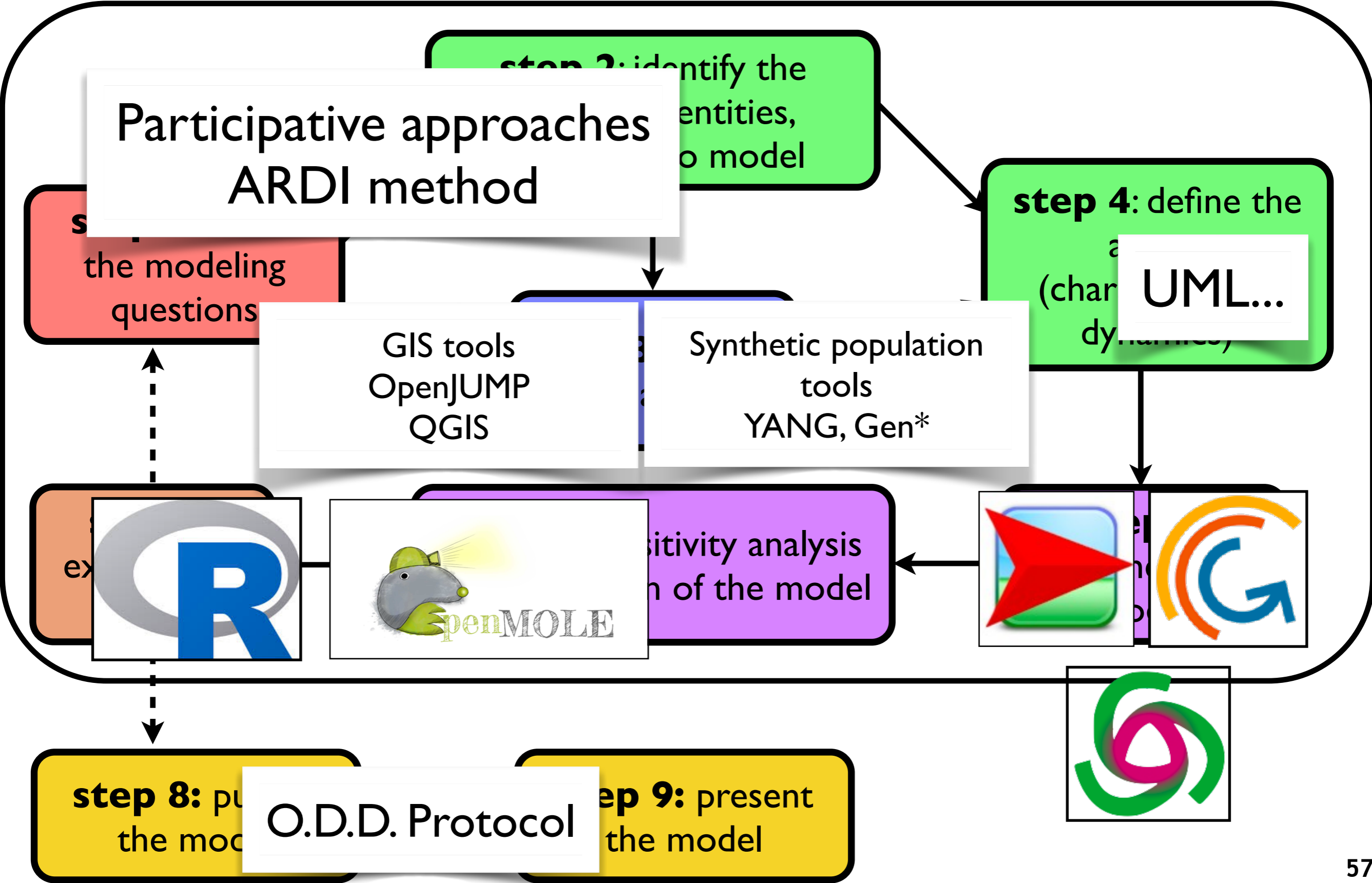
GAMA

<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.

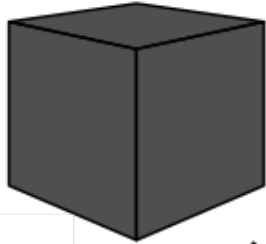


OpenMole: how to make exploration easy

1

Models as blackboxes

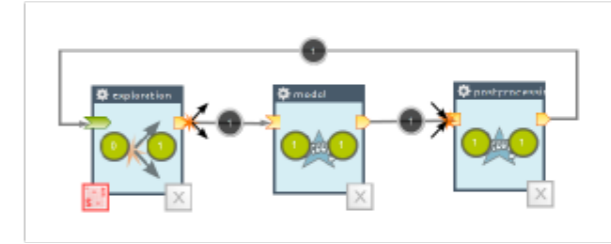
C
R
C++
Java
Scala
Scilab
Octave
Python
Netlogo
...



embeds



provides



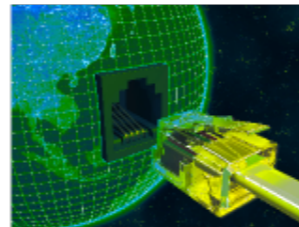
2

Methods

Data processing
Design of Experiments
Sensitivity analysis
Calibration

runs on

3

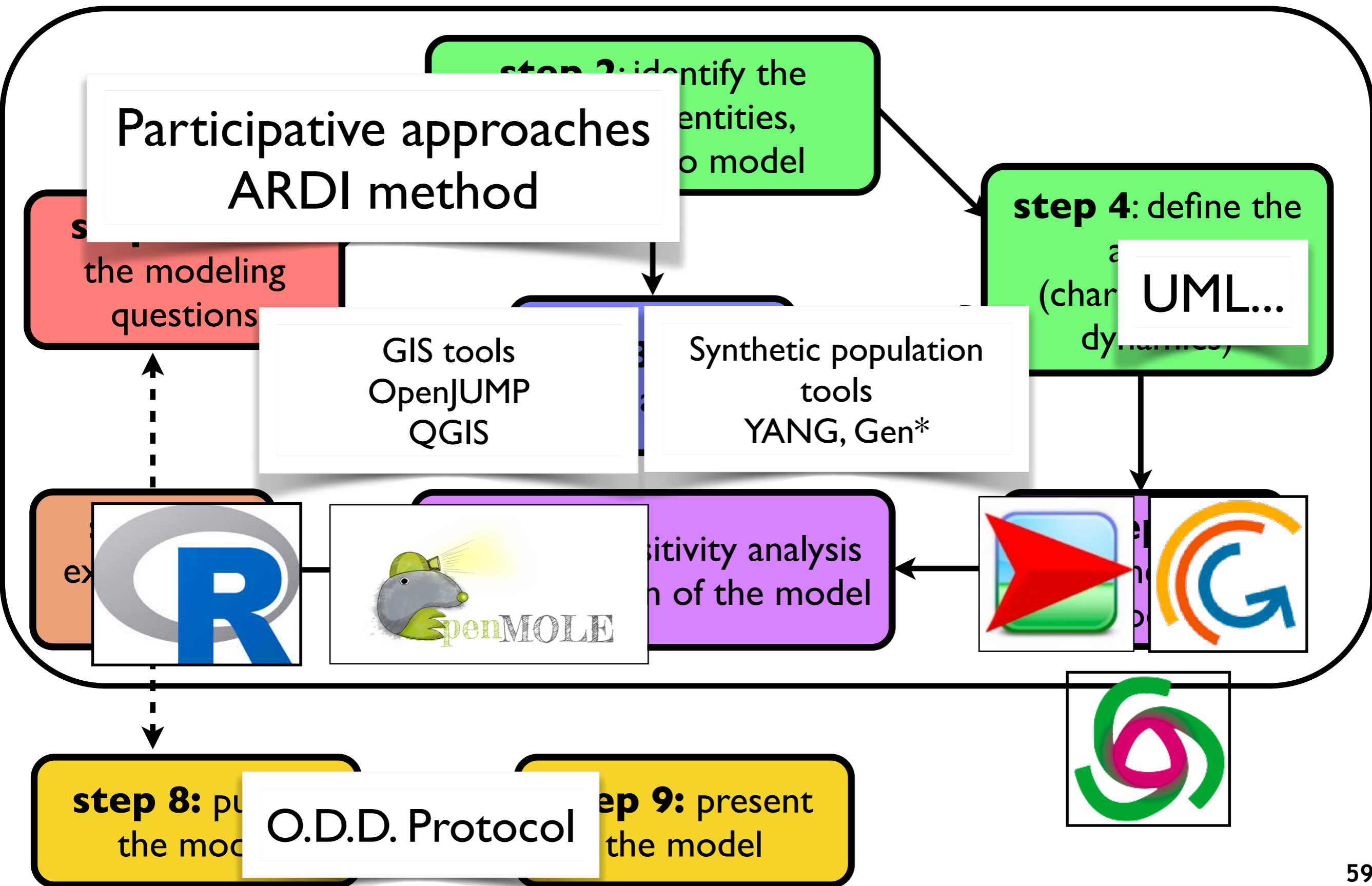


Massively parallel environments

Multicore
Server
Cluster
The Grid

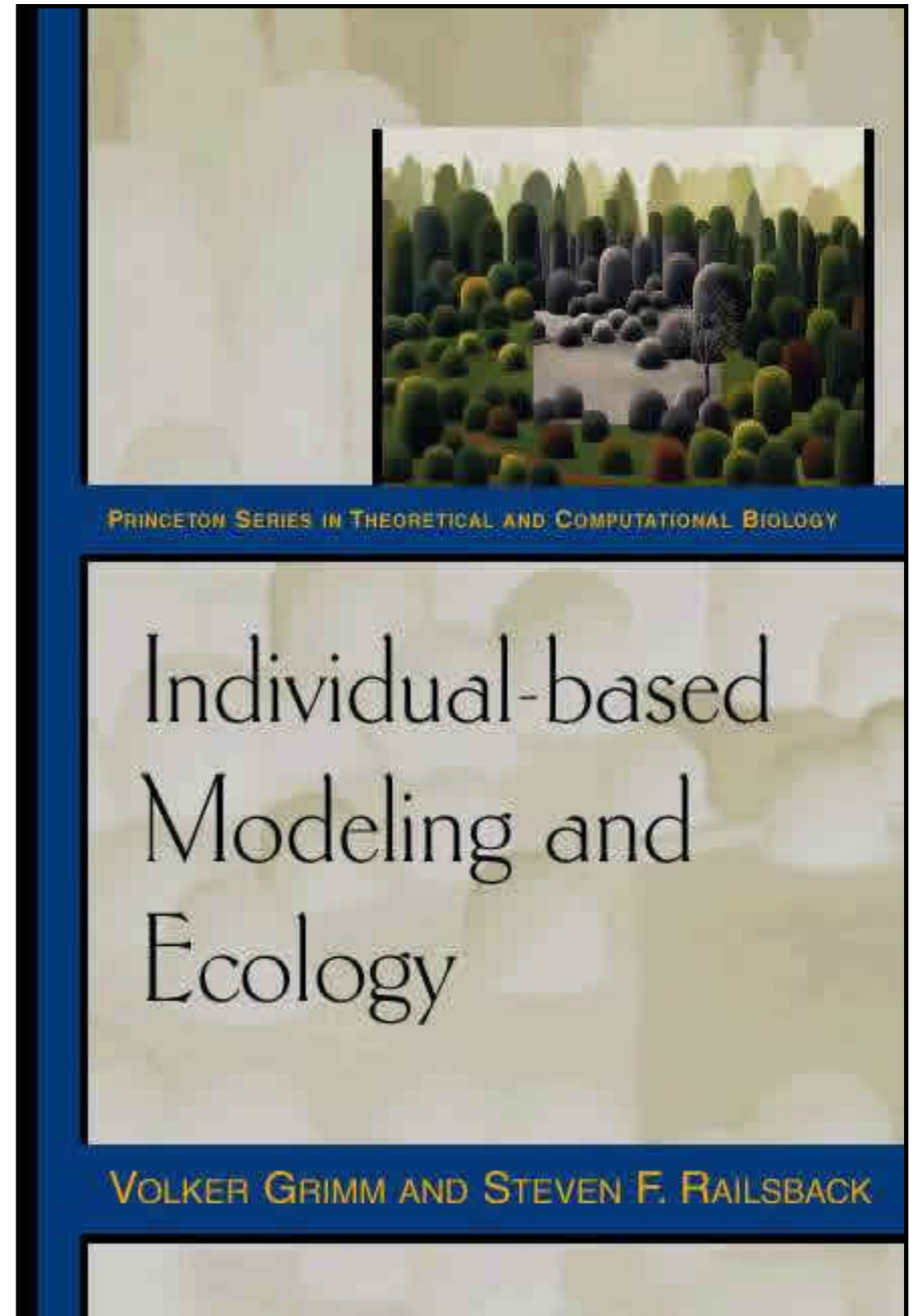


Modelling is a multi-step cycle.



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”

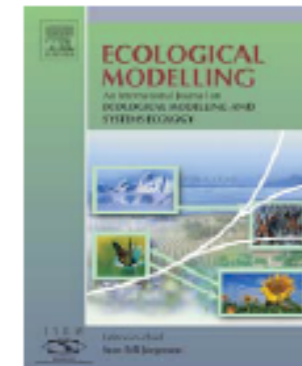
One for the Ecologists on their green throne
In the Ecological Modelling journal where Volker Grimm lies.
One Protocol to describe them all, One Protocol to publish them all,
One Protocol to bring them all and in the greenness bind them
In the Ecological Modelling journal where Volker Grimm lies.



available at www.sciencedirect.com



journal homepage: www.elsevier.com/locate/ecolmodel



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

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

^a UFZ Umweltforschungszentrum Leipzig-Halle GmbH, Department Ökologische Systemanalyse, Permoserstr. 15, 04318 Leipzig, Germany

^b Zentrum für Marine Tropenökologie, Fahrenheitstr. 6, 28359 Bremen, Germany

^c University of Bergen, Department of Biology, P.O. Box 7800, N-5020 Bergen, Norway

^d 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	1. Purpose
	2. State variables and scales
	3. Process overview and scheduling
Design concepts	4. Design concepts <ul style="list-style-type: none">• Emergence• Adaptation• Fitness• Prediction• Sensing• Interaction• Stochasticity• Collectives• Observation
Details	5. Initialization
	6. Input
	7. Submodels

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

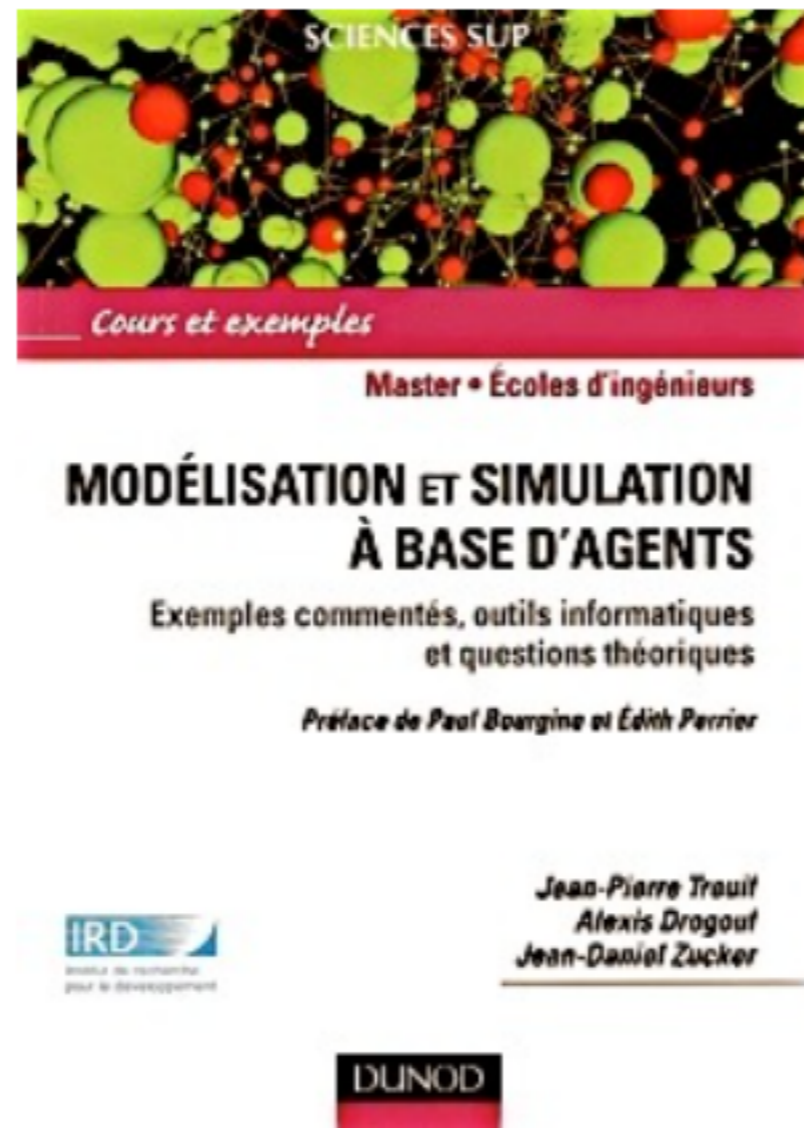
Etienne M., 2009. Co-construction d'un modèle d'accompagnement selon la méthode ARDI : guide méthodologique. Cardère éditeur, Laudun, 71 p.

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



A number of web references are available to go further

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<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/>

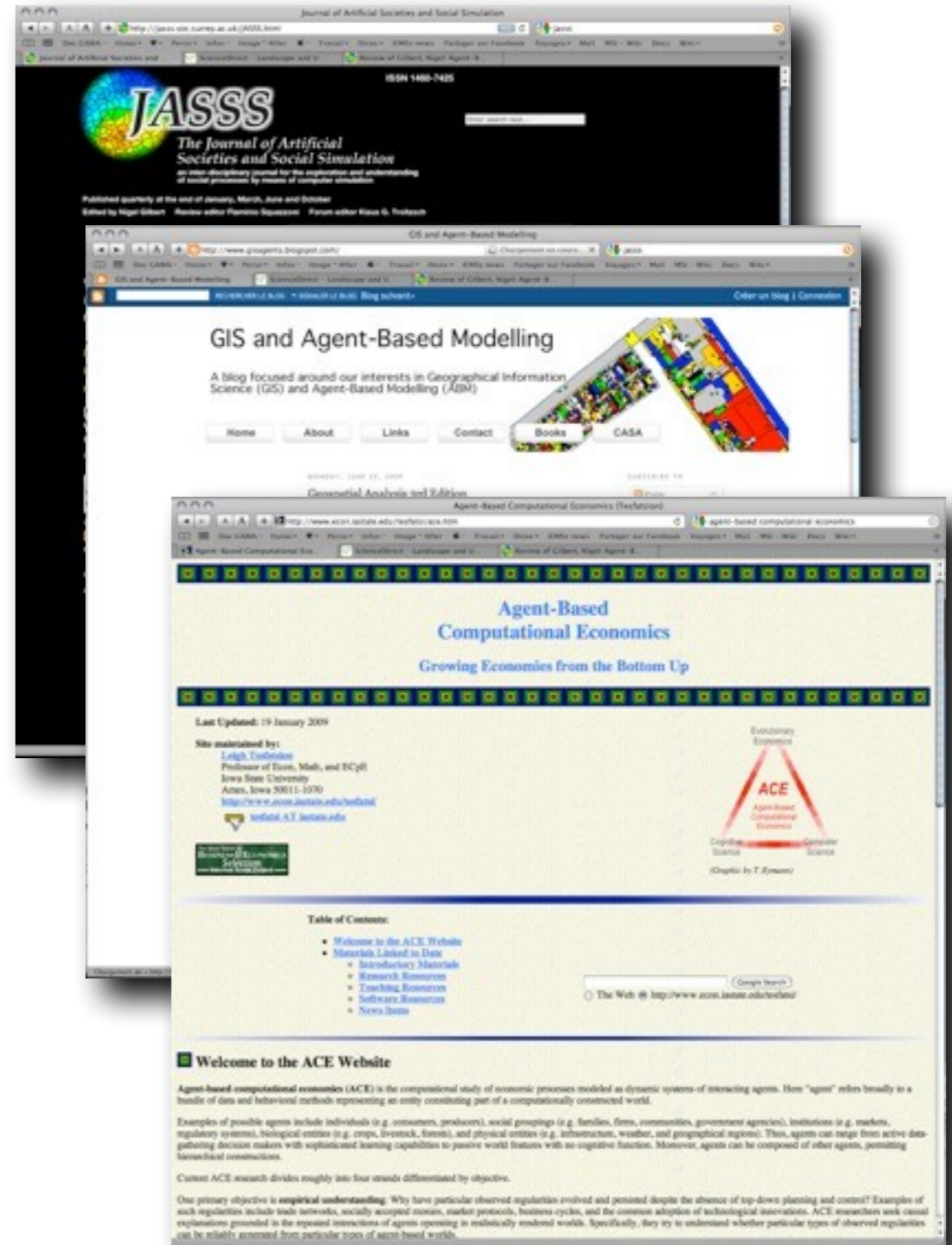
Agent-based models: Methodology and philosophy

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

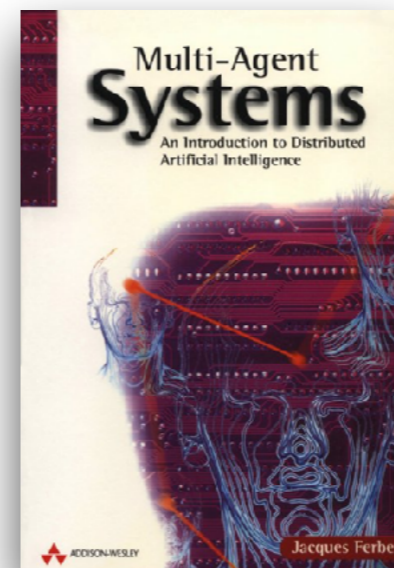
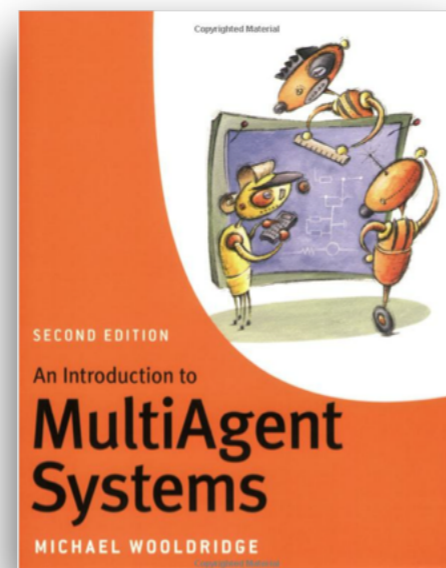
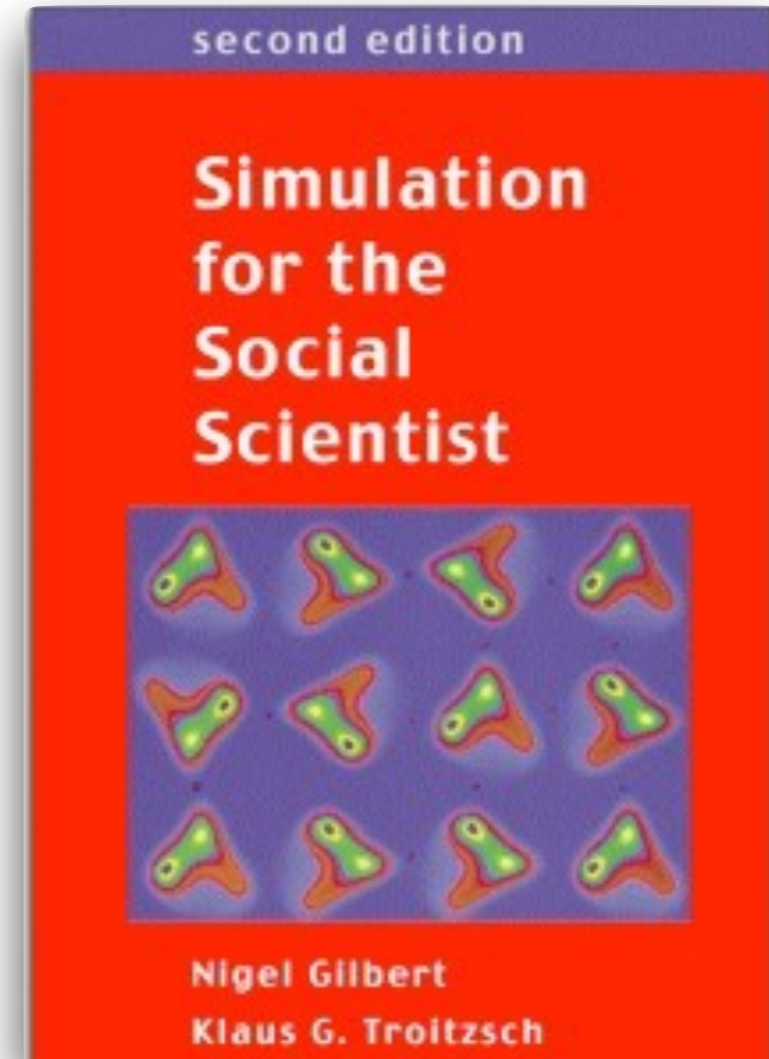
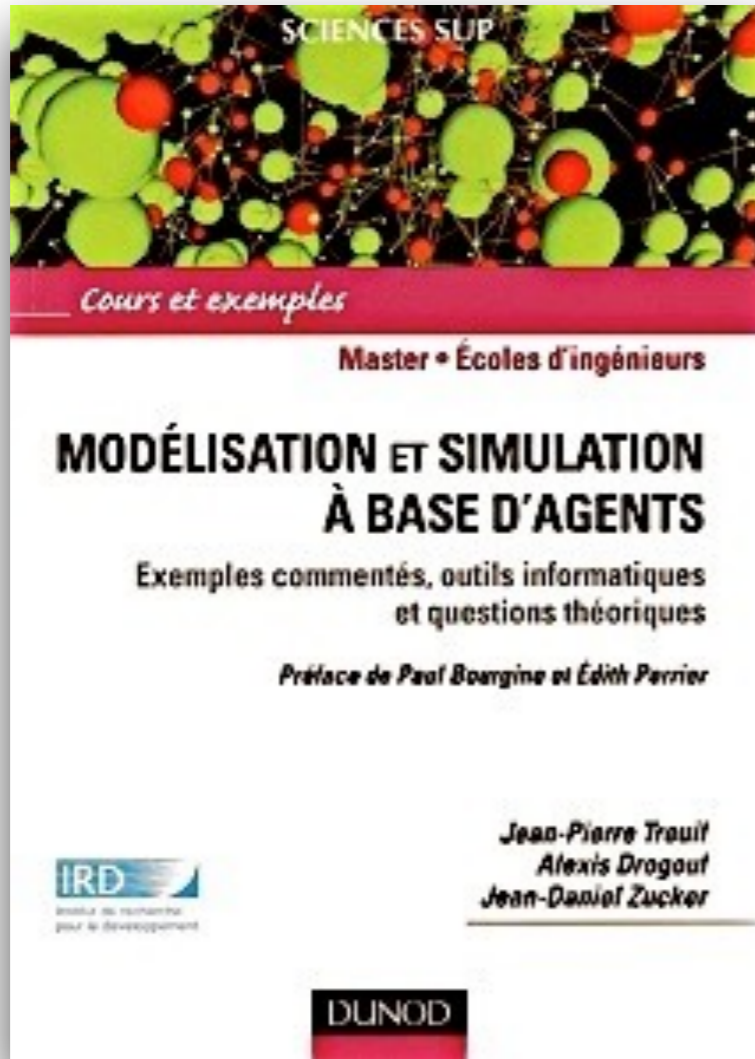
ACE : Agent-based Computational Economics

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

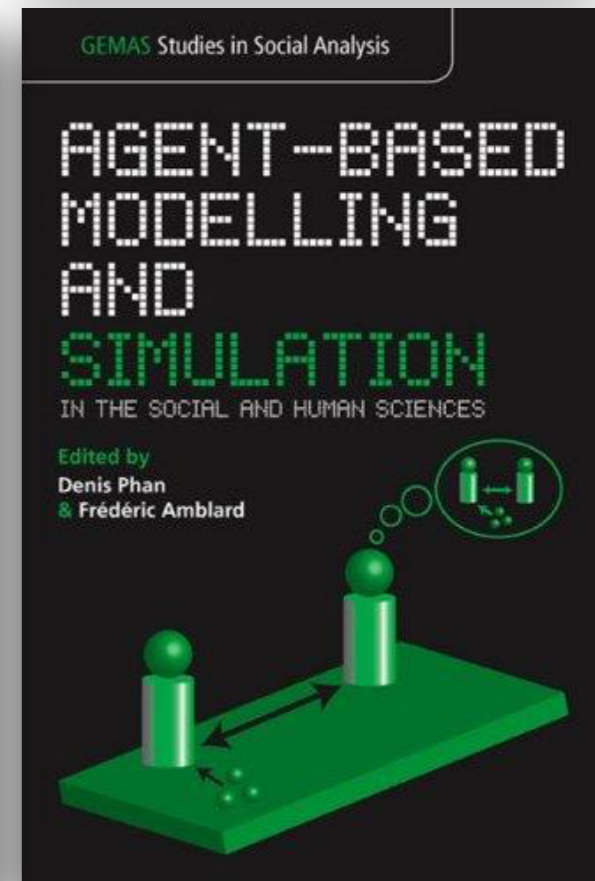
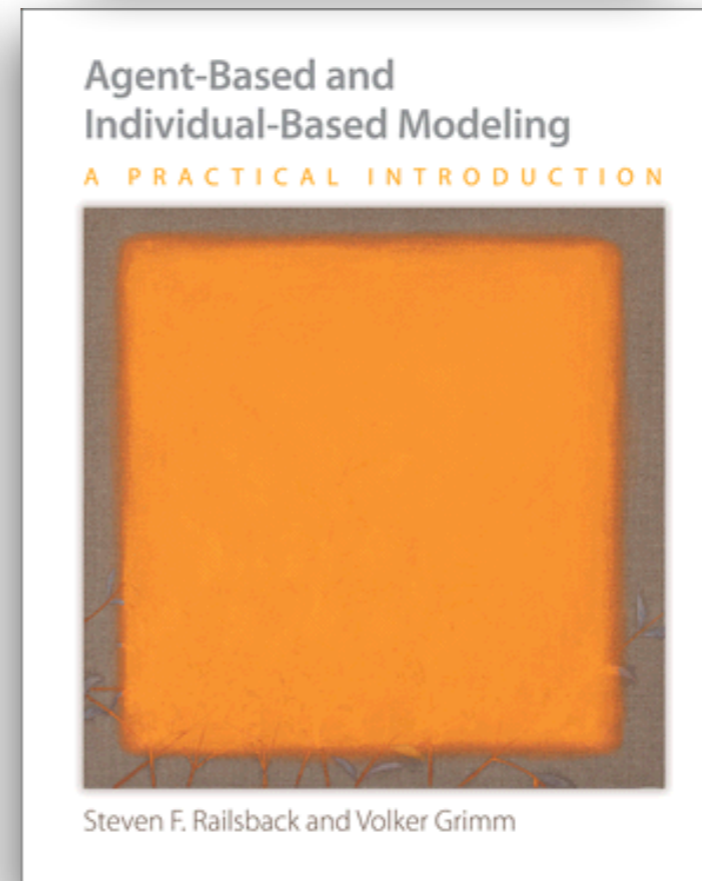
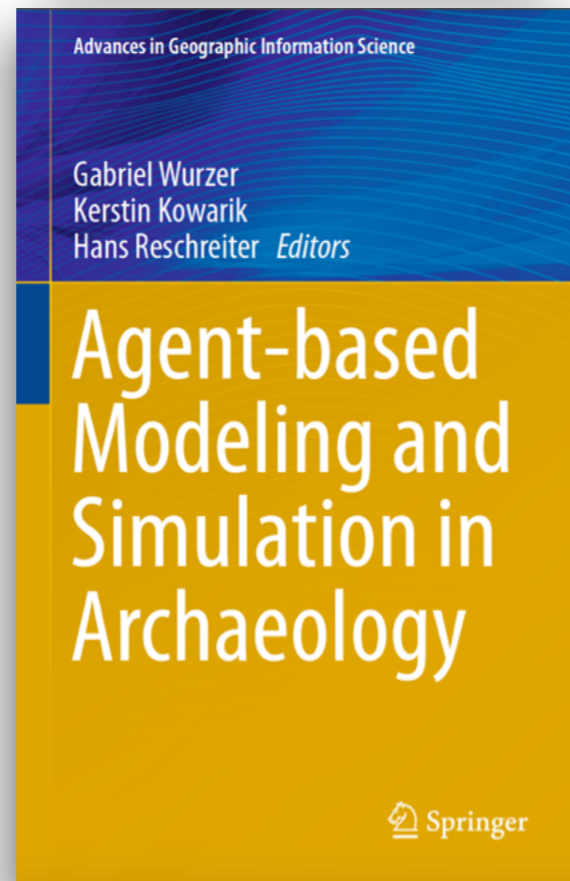
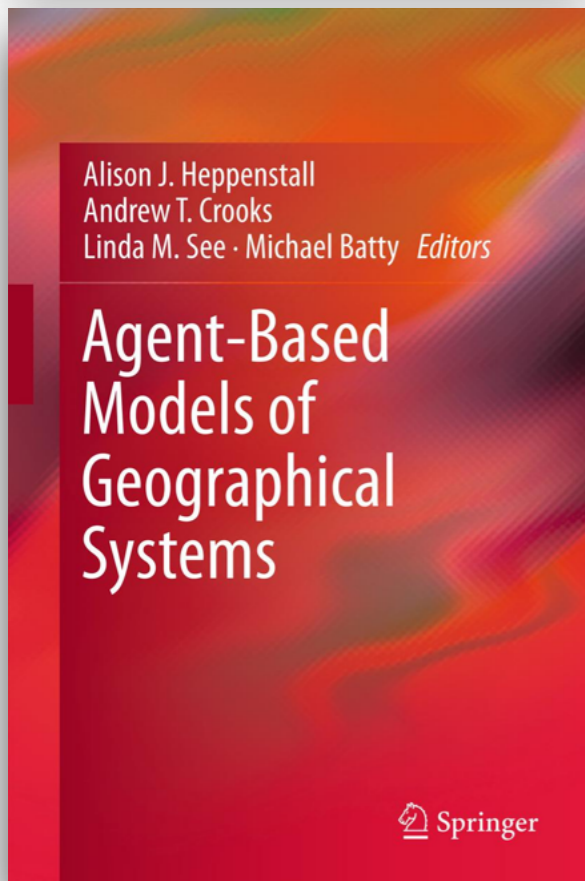
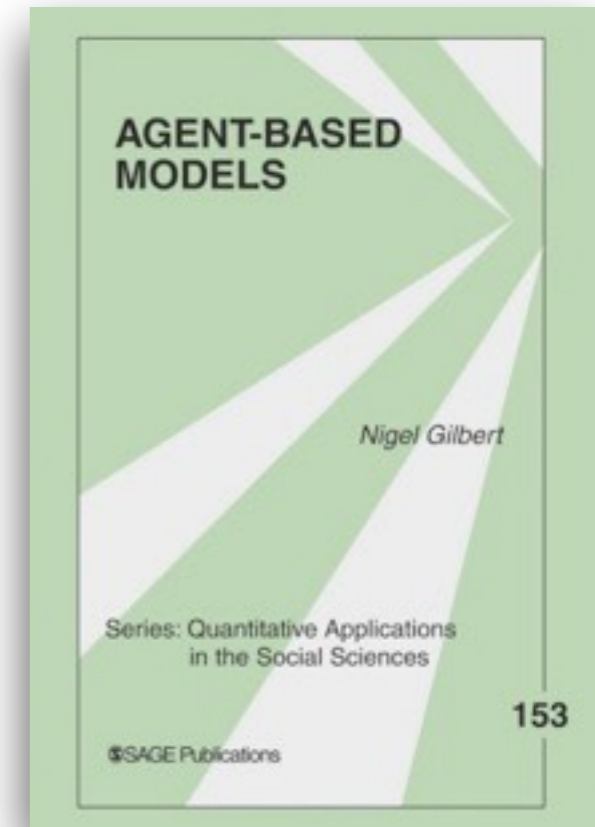
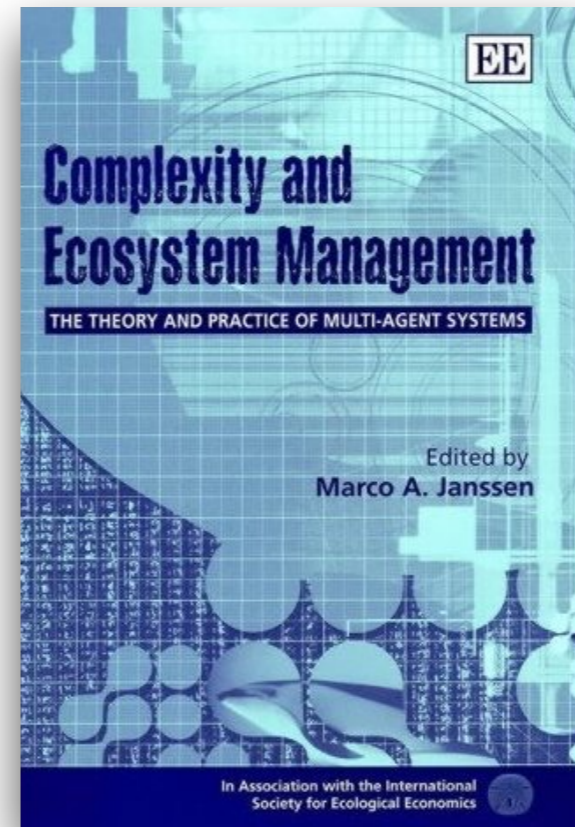
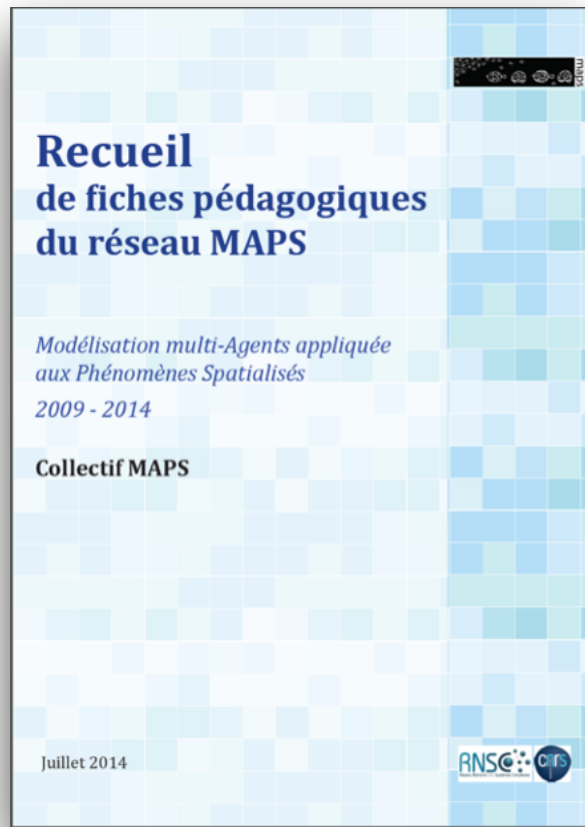
[On-Line Guide for Newcomers to Agent-Based Modeling in the Social Sciences](#)



References: some books



References: some books



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- ▶ [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.