Geographic cellular automata beyond land-use

Healthier school zones modelling

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Content

1. Introduction

- Similarities: all three projects presented are based on:
  - Cellular Automata (CA) modelling
  - Participatory process
  - NASZ
  - Metronamica software

- Differences:
  - Three settings: Spain, Colombia, Australia
  - Three scales: Regional, Metropolitan, Suburb
  - Scenario types: adaptation of EU millennium, narrow breath, normative
  - Timeframe: finished in 2015, 2017, underway

Why modelling?

Epstein's 16 reasons to justify modelling (2008)

1. Explain (very distinct from predict)
2. Guide data collection
3. Illuminate core dynamics
4. Suggest dynamical analogies
5. Discover new questions
6. Promote a scientific habit of mind
7. Bound (bracket) outcomes to plausible ranges
8. Illuminate core uncertainties
9. Offer crisis options in near-real time
10. Demonstrate tradeoffs / suggest efficiencies
11. Challenge the robustness of prevailing theory through perturbations
12. Expose prevailing wisdom as incompatible with available data
13. Train practitioners
14. Discipline the policy dialogue
15. Educate the general public
16 Reveal the apparently simple (complex) to be complex (simple)

none of these imply "prediction"

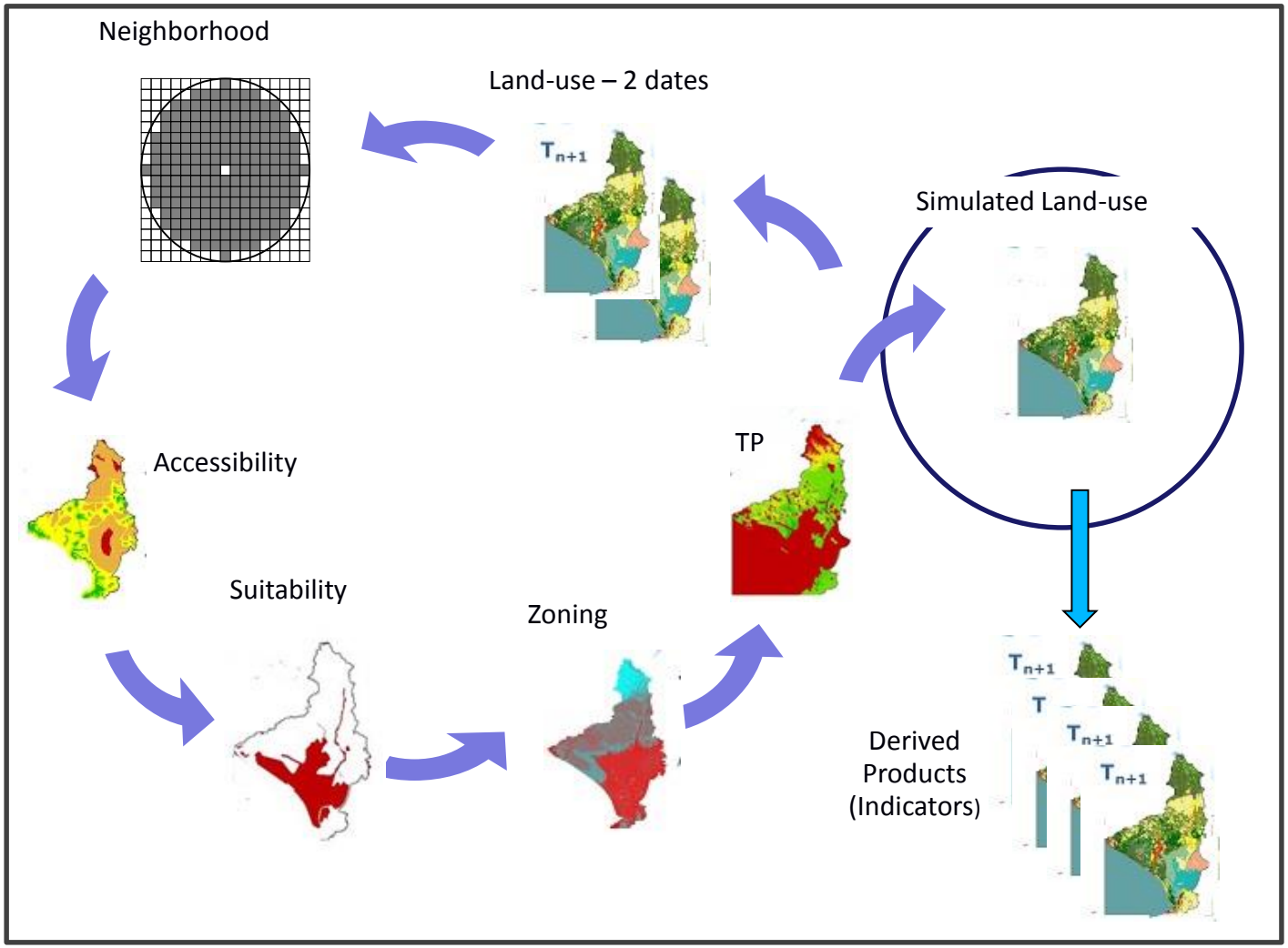
Cellular automata modelling

Among its many definitions:

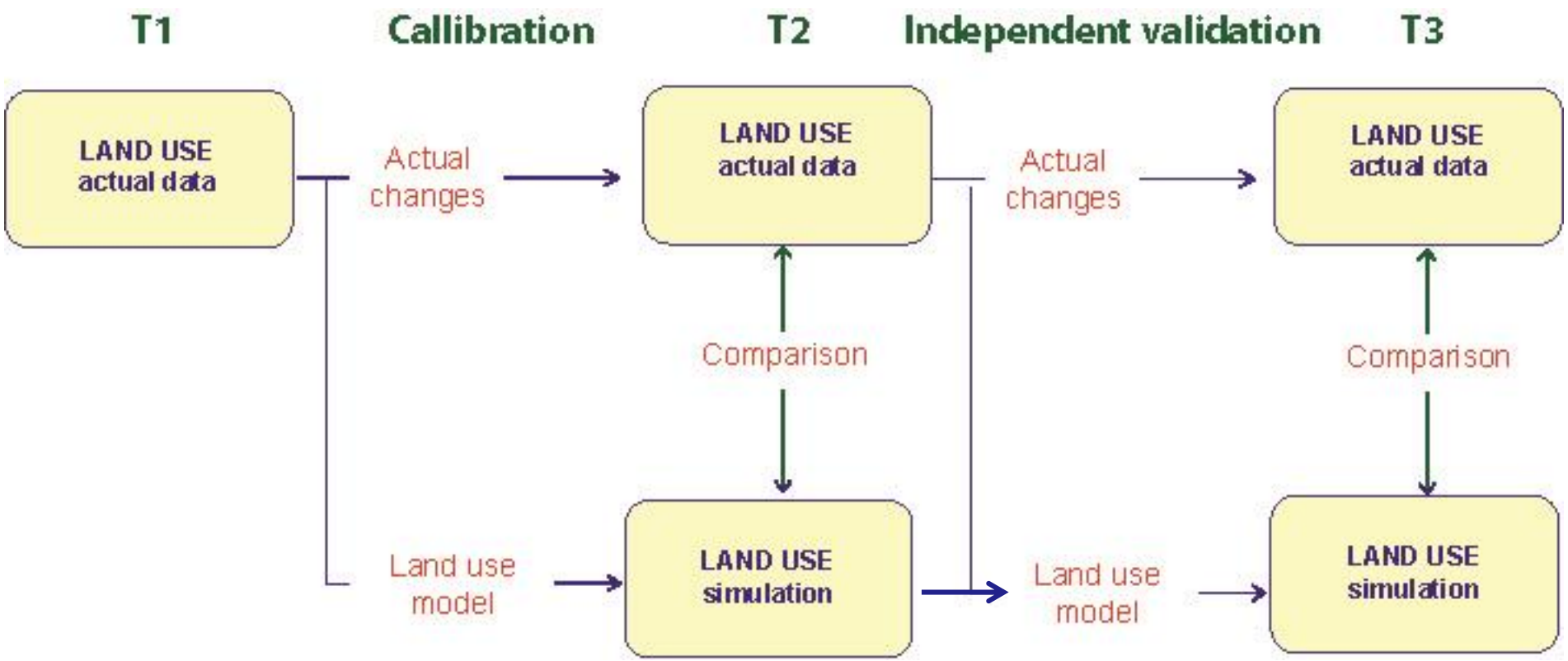
- Models allowing for the simulation of geographic space evolution
- Powerful models for understanding spatial phenomena and processes

New GIS generation

NASZ – neighbourhood, accessibility, suitability, zoning



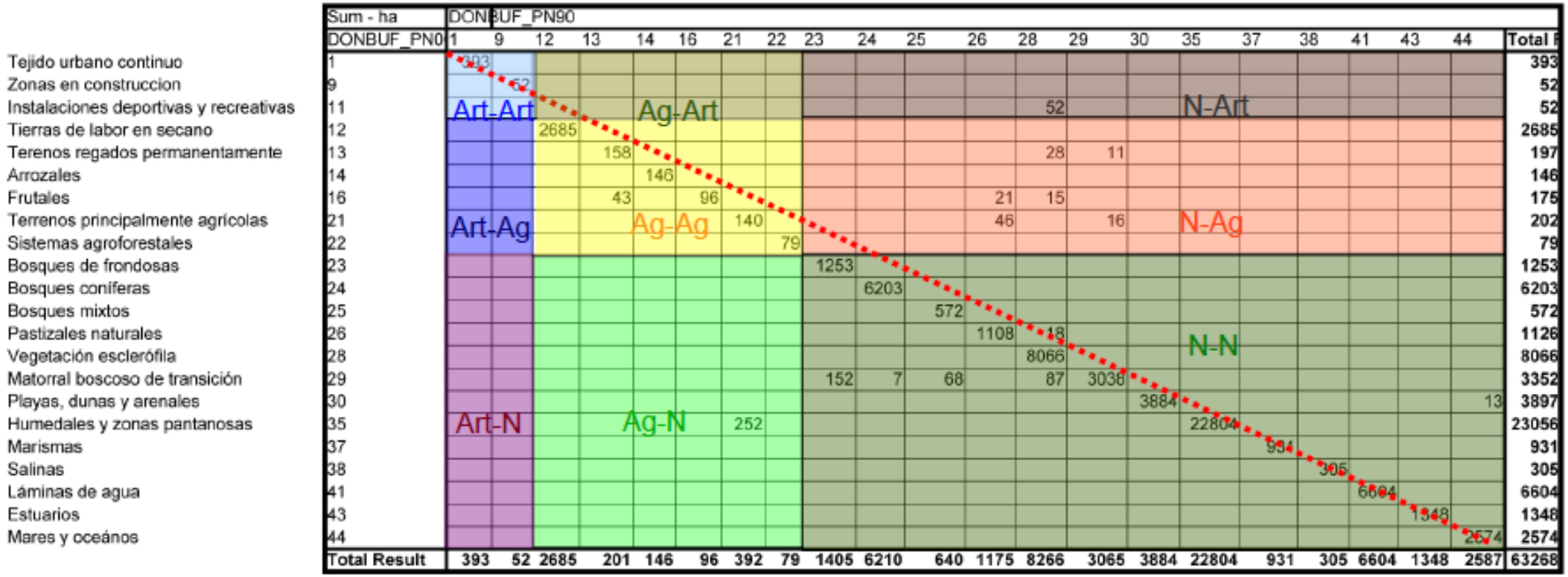
Model calibration and validation



2. Modelling land use dynamics in Doñana National Park and its hinterland (DUSPANAC)

www.geogra.uah.es/duspanac

Why Doñana?

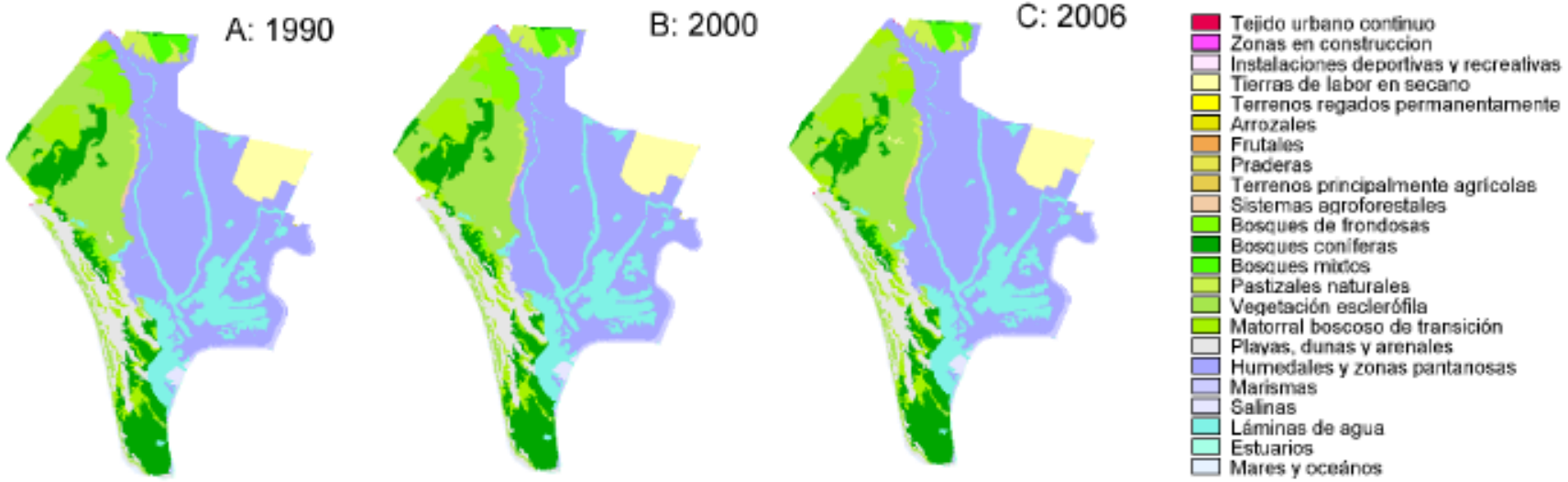


Sum - ha	DONBUF_PN90																							
DONBUF_PN0	1	9	12	13	14	16	21	22	23	24	25	26	28	29	30	35	37	38	41	43	44	Total F
Tejido urbano continuo	1	393																				393
Zonas en construccion	9		52																			52
Instalaciones deportivas y recreativas	11												52									52
Tierras de labor en secano	12			2685																		2685
Terenos regados permanentamente	13				158								28	11								197
Arrozales	14					146																146
Frutales	16				43		96					21	15									175
Terrenos principalmente agrícolas	21					Ag-Ag		140				46		16		N-Ag						202
Sistemas agroforestales	22								79													79
Bosques de frondosas	23									1253												1253
Bosques coníferas	24										6203											6203
Bosques mixtos	25											572										572
Pastizales naturales	26												1108	18								1126
Vegetación esclerófila	28												8066			N-N						8066
Matorral boscoso de transición	29									152	7	68		87	3038							3352
Playas, dunas y arenales	30														3884						13	3897
Humedales y zonas pantanosas	35							252								22804						23056
Marismas	37																931					931
Salinas	38																	305				305
Láminas de agua	41																		6604			6604
Estuarios	43																			1348		1348
Mares y oceános	44																				2574	2574
Total Result		393	52	2685	201	146	96	392	79	1405	6210	640	1175	8266	3065	3884	22804	931	305	6604	1348	2587	63268

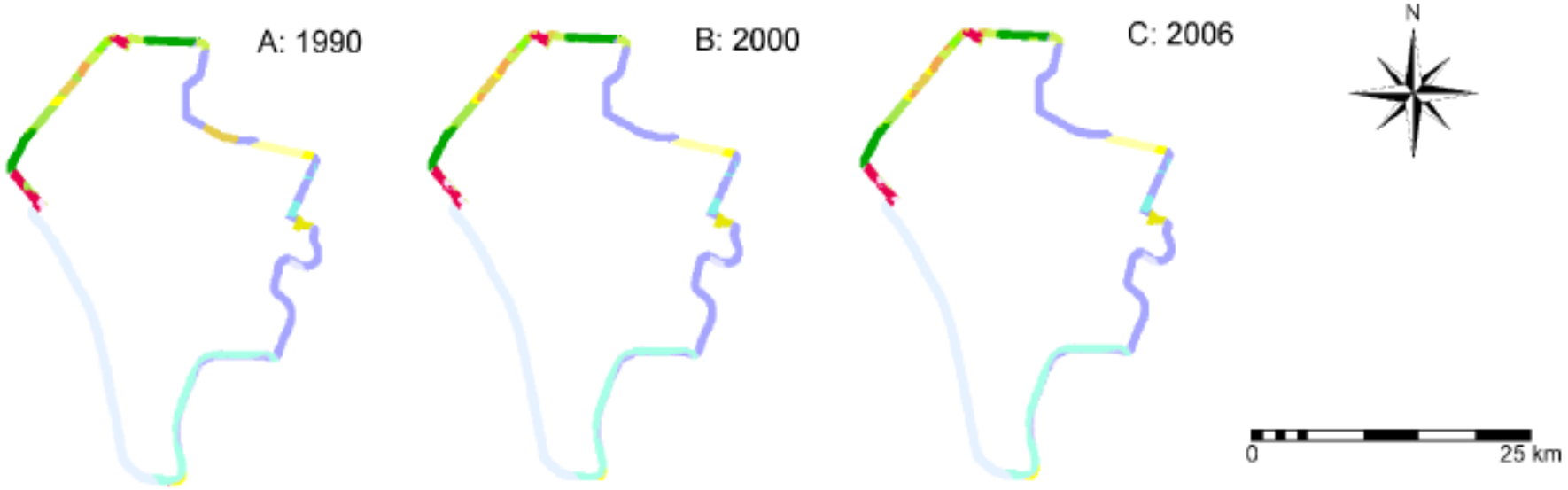
- Threats
- Data availability
- Relevance
- Variety of land use classes

Doñana – land use changes 1990 – 2000 - 2006

Doñana, ocupación de suelo, parque interior.



Doñana, ocupación de suelo, buffer 800m



Doñana National Park

– Challenges:

- National Park since 1969 and UNESCO World Heritage since 1994
- Long calibration period – data needs
- Profound conflicting interests


NATIONAL PARKS NETWORK
Picos de Europa (PIC)
Marítimo-terrestre de las Islas Atlánticas de Galicia (ISA)
Ordesa y Monte Perdido (OMP)
Aigüestortes i Estany de Sant Maurici (AIG)
Sierra de Guadarrama (GUA)
Monfragüe (MON)
Cabañeros (CBN)
Tablas de Daimiel (TDA)
Archipiélago de Cabrera (CBR)
Doñana
Doñana (DON)
Sierra Nevada (SNV)
Caldera de Taburiente (CLT)
Teide (TEI)
Timanfaya (TIM)
Garajonay (GAR)
National parks
800 m buffer
Autonomous regions
0 50 100 200 km
0 50 100 200 km

Doñana

- National Park area: > 50,000 ha
- Modelling area: > 300,000 ha
- Natural values:
  - Diverse ecosystems (marshes, coastal dunes, Mediterranean forest, riparian formations)
  - Biodiversity
  - Emblematic species – Iberian Lynx, Imperial Iberian Eagle
- Cultural values


Tienda Rociera
La Romería de El Rocío
HUELVA

Values… and issues

- Intensive agriculture
- Erosion
- Urbanization

The model attempts at answering questions like…

- What if…? – *Story lines / scenarios*
- On land use changes:
  - Increase or reduction of some uses
  - Change patterns
  - Inter-relations among land use classes

What future we want? Scenario development

Scenario 1 – “Shared knowledge”
Main driver: Technology

Scenario 3 – “Dry Doñana”
Main driver: Climate change

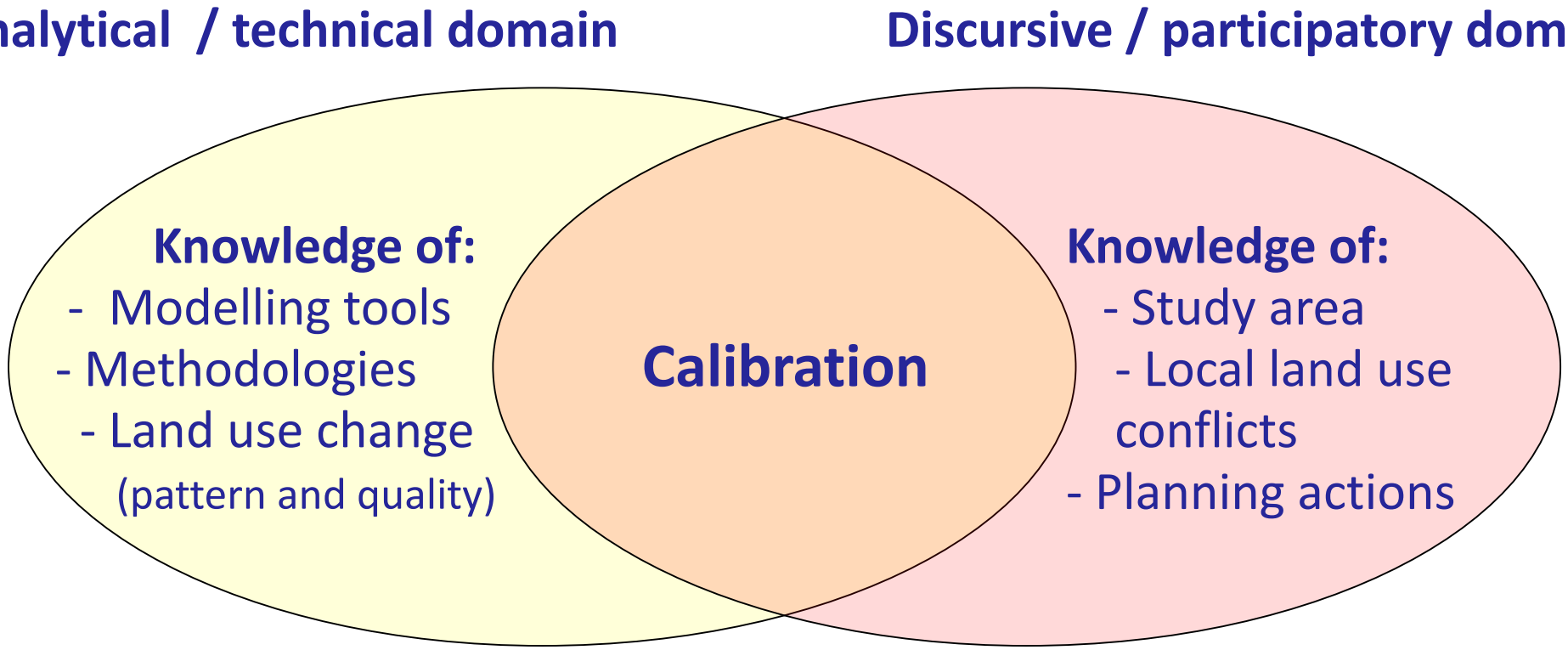
Scenario 2 – “Doñana trade mark”
Main driver: Globalisation

Scenario 4 – “Adaptive Doñana”
Main driver: Awareness

Participatory approach
Stakeholders' *vs* scientists' role

- Different interests
  - Research
  - Policy making and management
- Different capacities
  - Know how
  - Know what
- Cooperation is a must if the model is to be used

Why participatory modelling?



Why participatory modelling?

Policy makers who are actively involved in model development are likely to find model outcomes, such as planning recommendations or environmental indicators derived from future land use scenarios difficult to reject (Voinov and Bousquet 2010)

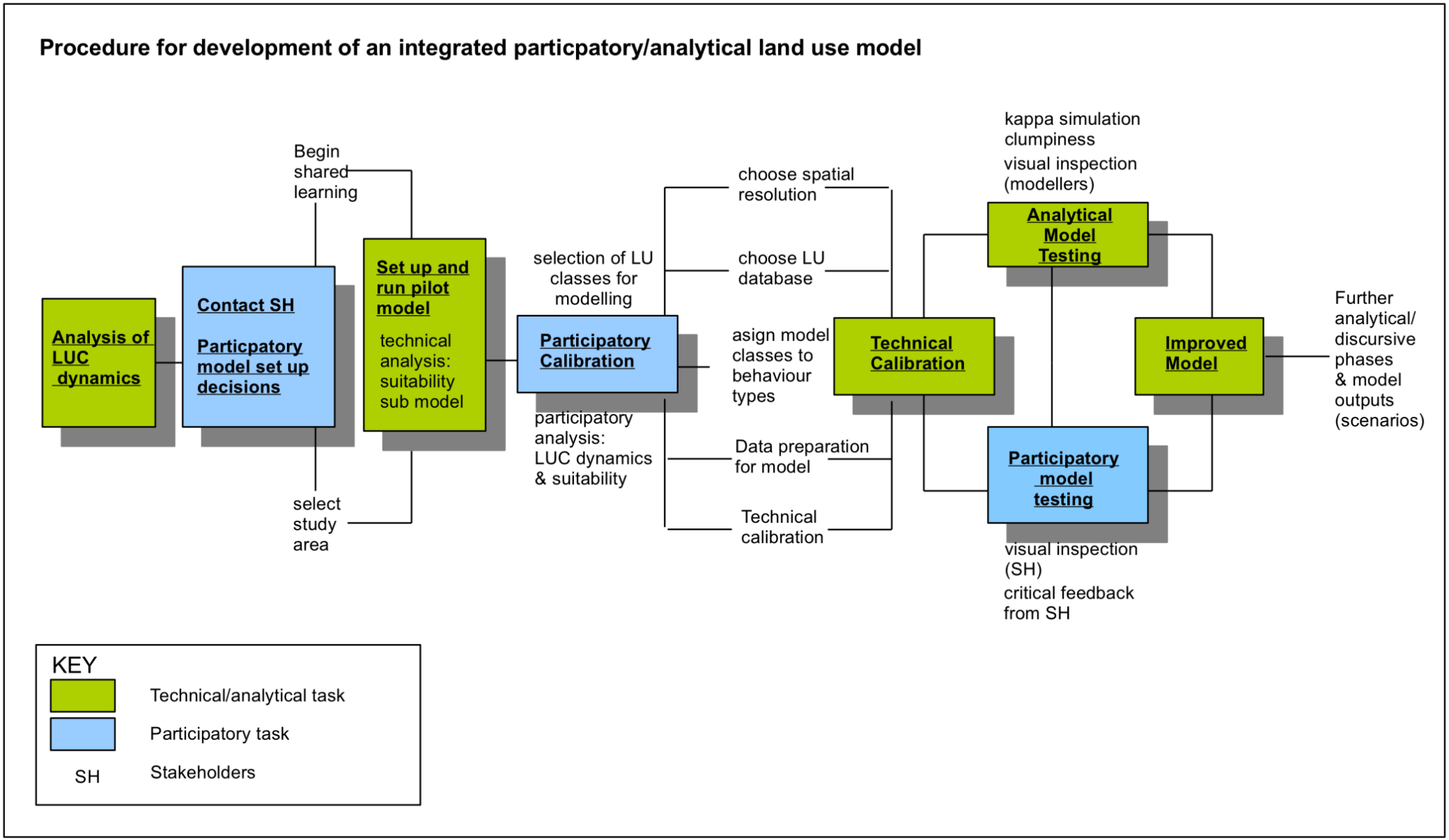
Workshops participants

- Managers
- Local councils
- Farmers
- Cattle ranchers
- Pilgrims associations
- Environmentalists
- Scientists
- Government officials

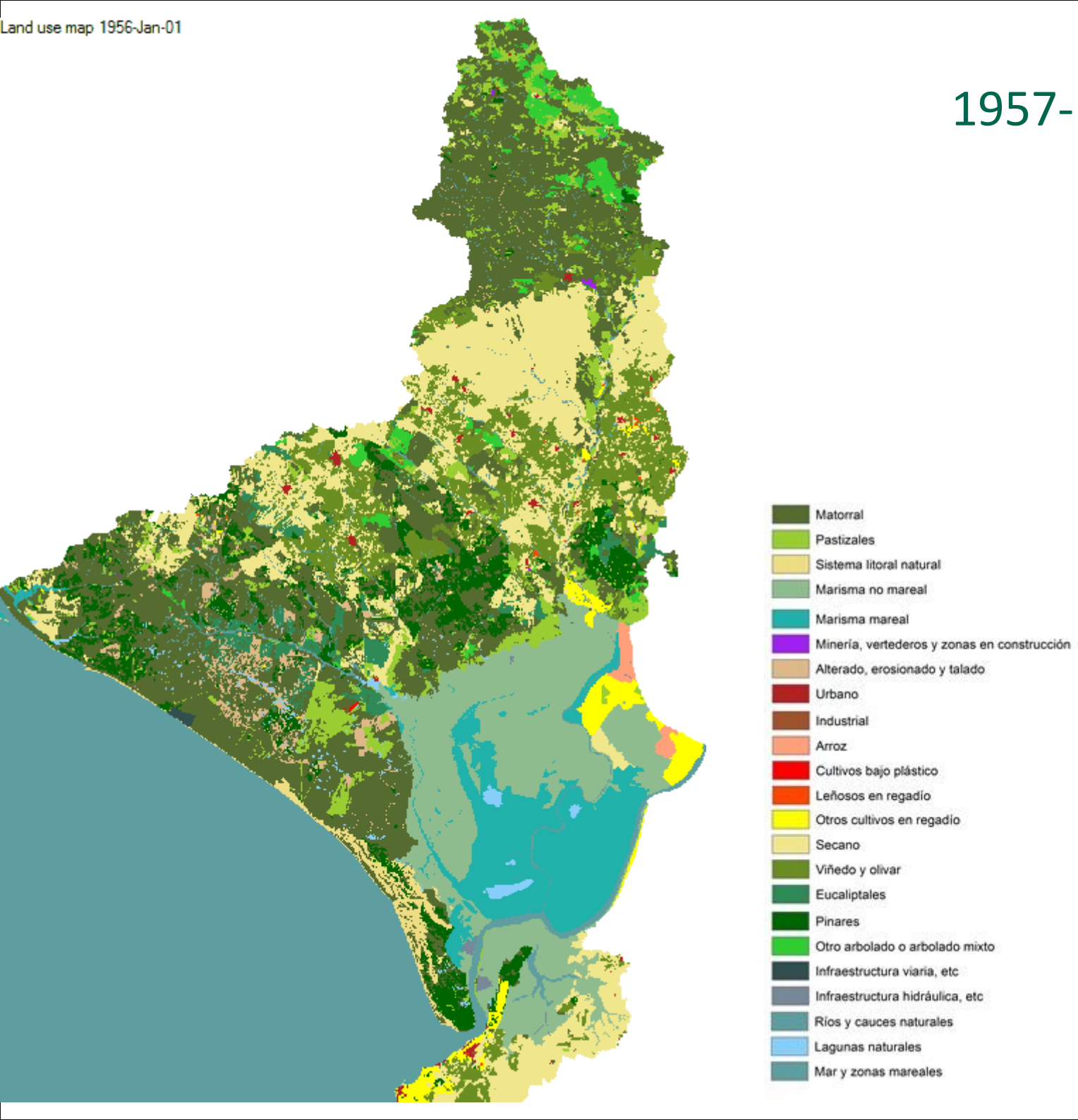
Participants' contribution

- Scenario development
- Defining study area – Guadiamar river basin
- Selecting data sets – Andalusia (from 1956 to 2007)
- Grouping land use classes
- Assisting on land use dynamics understanding
- Assisting on suitability composite maps
- Results and process evaluation

Integrated tasks: stakeholders - scientists



Three workshops, nine activities at Doñana



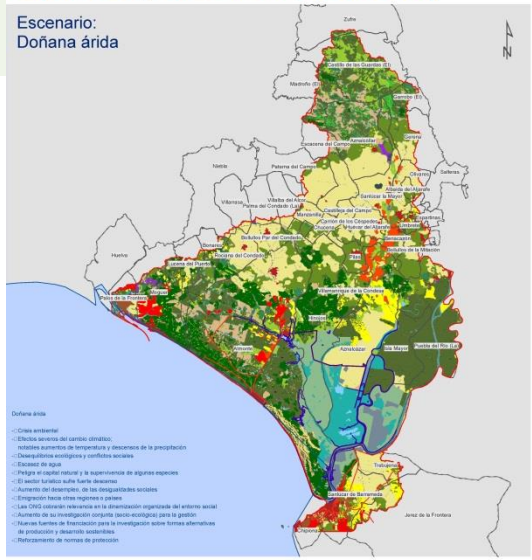
1957-1999 simulation

Results

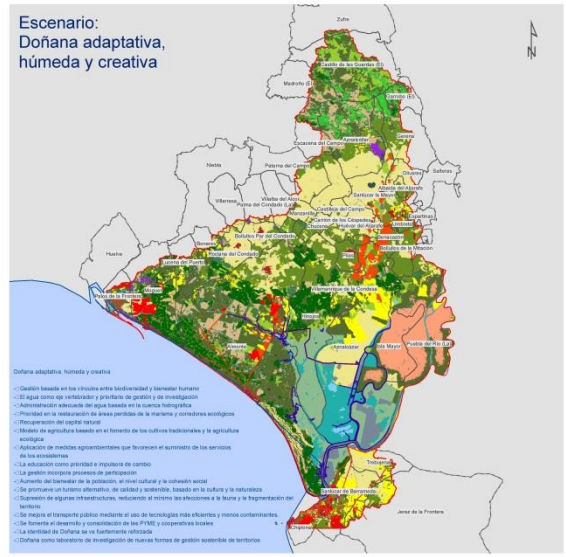
Escenarios de futuro en la ocupación del suelo de Doñana
Cuenca del río Guadiamar - horizonte 2035

Modelización de las dinámicas de usos del suelo en la red de parques nacionales españoles y su entorno (DUSPANAC)

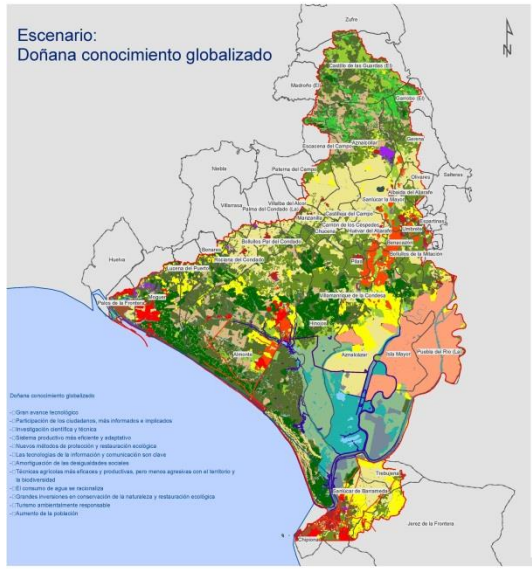
Escenario:
Doñana árida



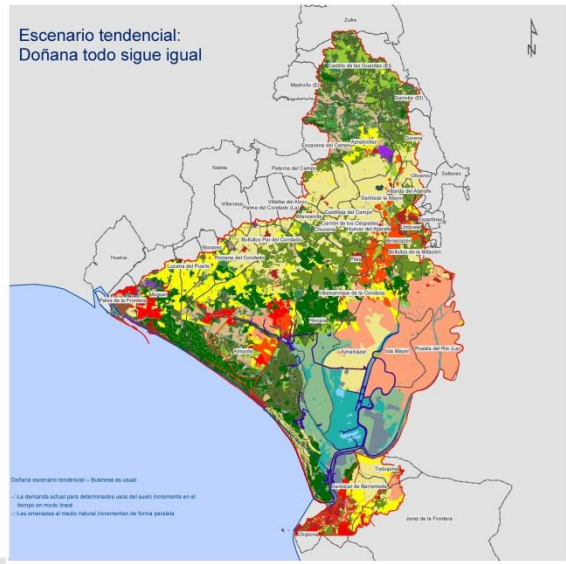
Escenario:
Doñana adaptativa, húmeda y creativa



Escenario:
Doñana conocimiento globalizado



Escenario tendencial:
Doñana todo sigue igual



Scenario 1 – “Shared knowledge”
Main driver: Technology

Scenario 3 – “Dry Doñana”
Main driver: Climate change

Scenario 2 – “Doñana trade mark”. Main driver: Globalisation

Scenario 4 – “Adaptive Doñana”. Main driver: Awareness

- Francisco Escobar, Dpto. de Geología, Geografía y Medio Ambiente, UAH
- Proyecto DUSPANAC (ref 118/2010), Organismo Autónomo de Parques Nacionales (Ministerio de Agricultura, Alimentación y Medio Ambiente)
- Fuentes: Junta de Andalucía, IGN
- Método: Metronamica (RIKS)
- Tratamiento: Equipo DUSPANAC

- Financiado por el Organismo Autónomo de Parques Nacionales Ministerio de Agricultura, Alimentación y Medio Ambiente (ref 118/2010)

Agradecimientos

- Participantes en los talleres
- Departamento de Ecología, Universidad Autónoma de Madrid
- Personal del Espacio Natural de Doñana, de forma particular a todos en El Acebuche

MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
ORGANISMO AUTÓNOMO PARQUES NACIONALES

OCT OBSERVATORIO PARA UNA CULTURA DEL TERRITORIO

Universidad de Alcalá
DEPARTAMENTO DE GEOGRAFÍA

DUSPANAC conclusions, issues and limitations

- Objectives met
- Data availability and data quality
- Calibration
- False expectations
- Visualization

3. Bogota Land Development Model (BoLD)

- Economic growth since 2001
- Traffic congestion - Bogota in the top five

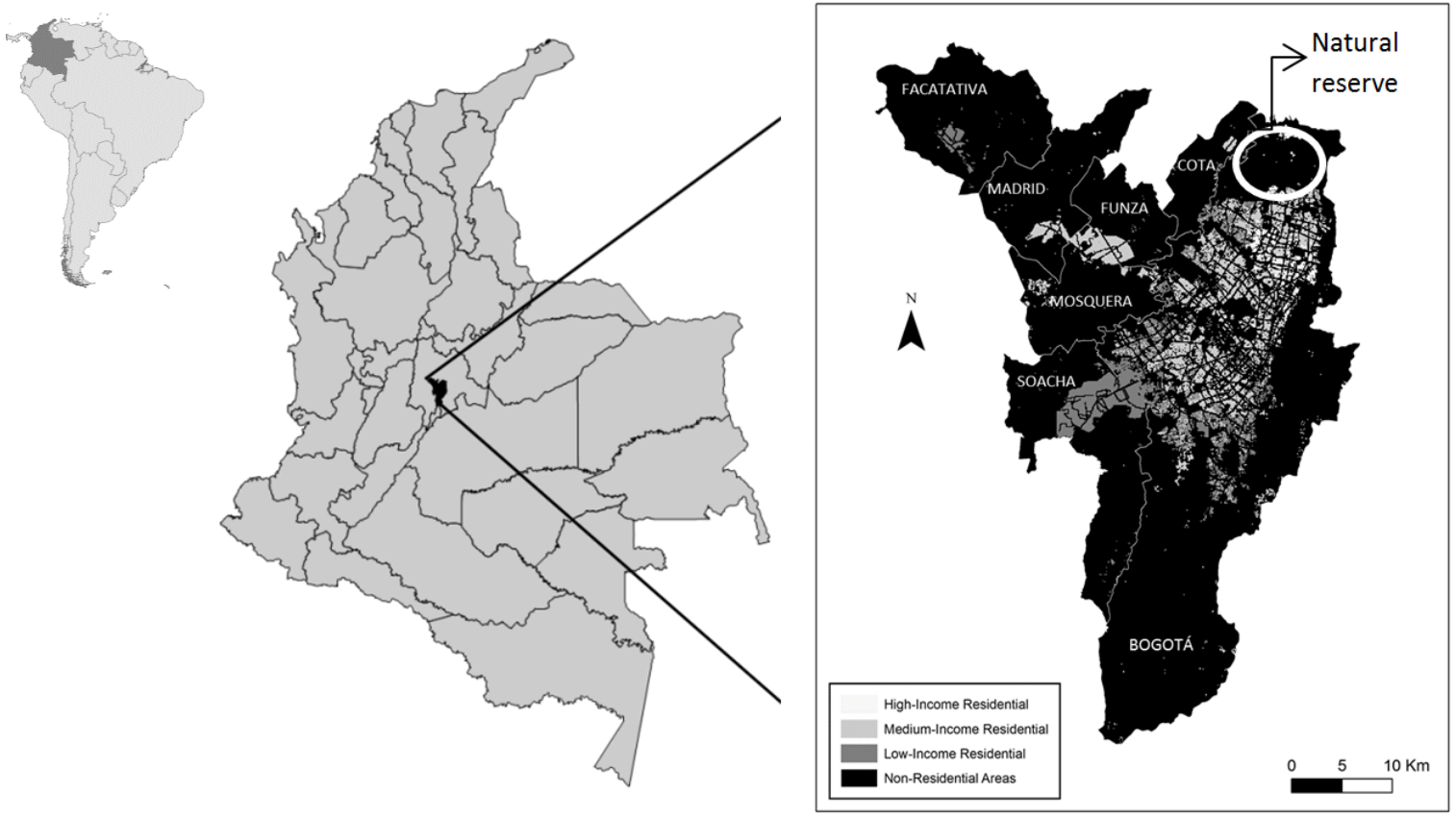
- Pollution
- Public Health issues
- AFD (France AID) project

Context to BoLD

- Traffic congestion in the public and political debate
- 2015 Local elections – public transport proposals
- Objective
  - To develop a LUCC model to evaluate public transport alternatives – Bogota Land Development Model (BoLD)

Methods

- Study area
  - Bogota and the municipalities located to its West: Funza, Mosquera, Madrid, Focatativá, Cota and Soacha
  - 7.5 million inhabitants (Bogota holds 6.5 million)



Data

Dataset	Description	Application in BoLD
2014 cadastral dataset for Bogota	Parcel-based cadaster dataset for Bogota that includes land-use coverage for every land parcel and the fiscal land value of them	Calibration of land-use coverage areas in Bogota
2005 to 2011 planning zones	Planning zones for areas outside Bogota municipality with their intended or authorized land-use coverage	Calibration of land-use coverage areas in Bogota by detecting vacant zones and more likely land-use based on regulatory restrictions
2005 and 2014 water body inventory	Official dataset of rivers, lakes and other water bodies in the area	Determination of areas covered by water not always identifiable by Landsat images
2005 and 2014 national and regional parts and reserves	Official dataset from national government describing legally environmentally protected land in the study area	Separation of parkland from agricultural lands as well as identification of forest reserves

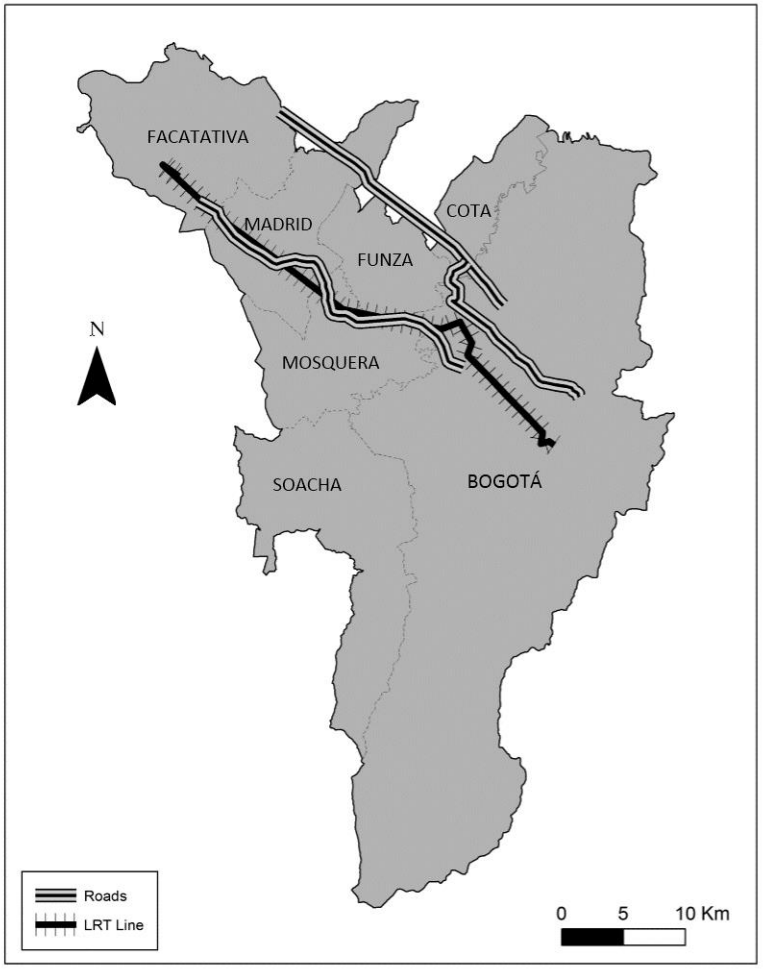
Scenarios

- Stakeholders workshops and interviews with administration officials

	Road infrastructure	Suburban train infrastructure
Natural reserve maintained	Scenario 1: Road infrastructure continues to be the main source of transport for growth areas in the West. New roads allow additional connections between municipalities and Bogota. No changes to existing restrictions to urbanization in the VDH reserve.	Scenario 2: Existing freight rail infrastructure upgraded to provide a suburban service for passengers in Bogota and municipalities in the West. New road constructions or upgrades are limited to areas were no infrastructure currently exists.
Natural reserve urbanized	Scenario 3: As in scenario 1, roads are upgraded to provide accessibility in the West. However, land regulations are changed so VDH reserve is urbanized by providing additional road infrastructure as well as BTR services.	Scenario 4: As in scenario 2, a new train service is developed for the West. However, land regulations are changed so the VDH reserve is urbanized

Scenarios

- New road and train alternatives



Transmilenio

- Current Bus Rapid Transit (BRT) system in Bogota

Guillermo Torres (Revista Semana). Available at
http://www.semana.com/tecnologia/novedades/articulo/transmilenio-estas-son-las-estaciones-con-wifi-gratis/380288-3

Van der Hammen reserve

El Tiempo (http://www.eltiempo.com/bogota/voy-y-vuelvo-reserva-thomas-van-der-hammen-41019)

Estimating future land demands (*Business as usual*)

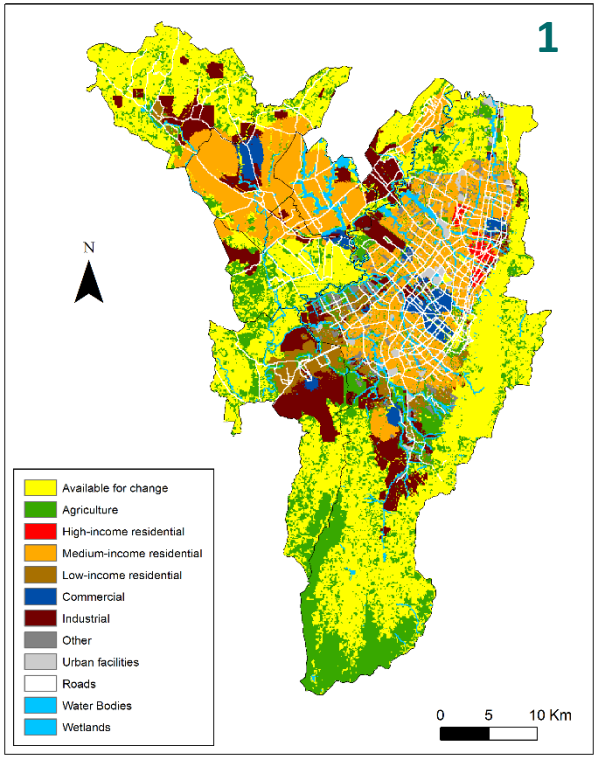
- Forecast population growth (DANE, National Agency for Statistics)
- Forecast economic growth (Bank of the Republic and FENALCO)

Year	**2014**	**2023**	**2032**	**2040**	**% Cells per land-use for** 2040
Residential High Income	1359	1411	1566	1704	4,22
Residential Medium Income	11607	15519	18530	21582	53,41
Residential Low Income	7949	6584	6003	5112	12,65
Commercial	1146	1510	1970	2495	6,18
Industrial	5633	6798	8124	9519	23,55
Total **Cells**	27694	31821	36193	40412	**100,00**
Cells Increment (%)		13%	12%	10%	

Modelling software METRONAMICA (RIKS)

- Calibration
  - Future land demands
  - Current and future land zoning changes and suitability conditions (heritage, hydrology, environmental risks…)
  - Neighbouring relationships between land-uses
  - Accessibility analysis based on transport infrastructure.

Results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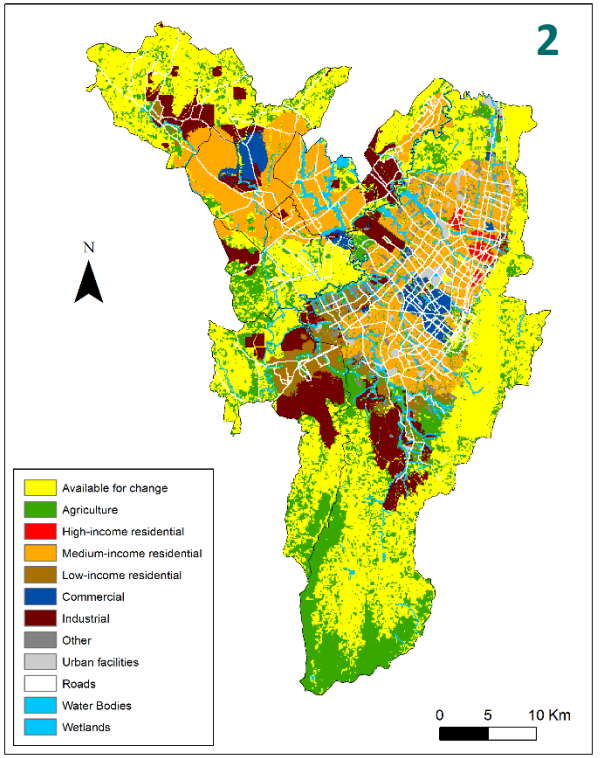
Available for change
Agriculture
High-income residential
Medium-income residential
Low-income residential
Commercial
Industrial
Other
Urban facilities
Roads
Water Bodies
Wetlands
0 5 10 Km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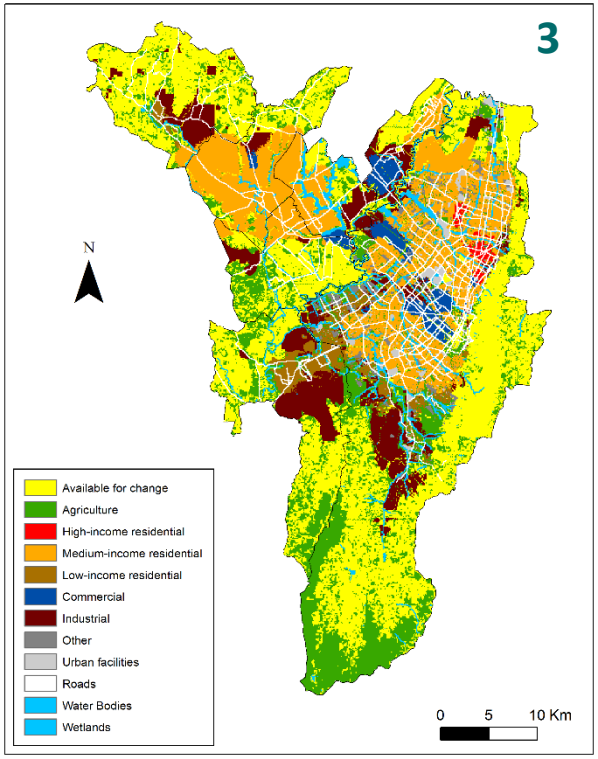
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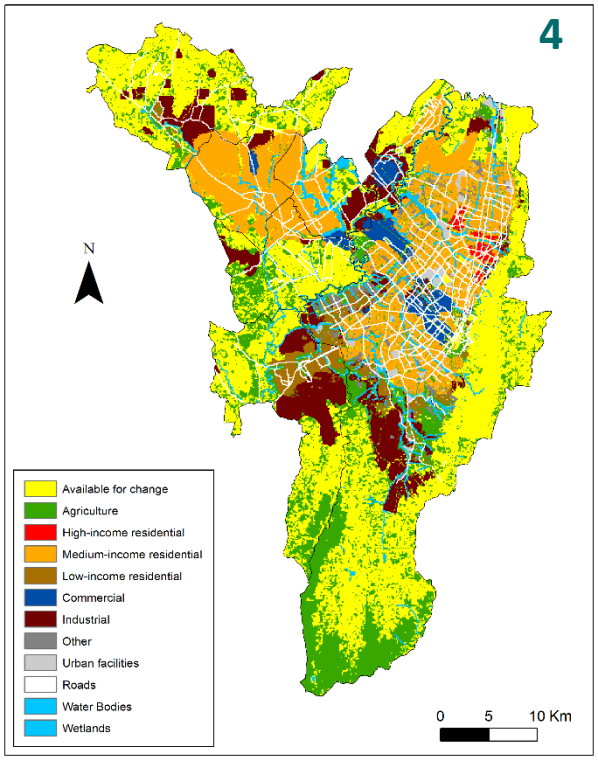
0 5 10 Km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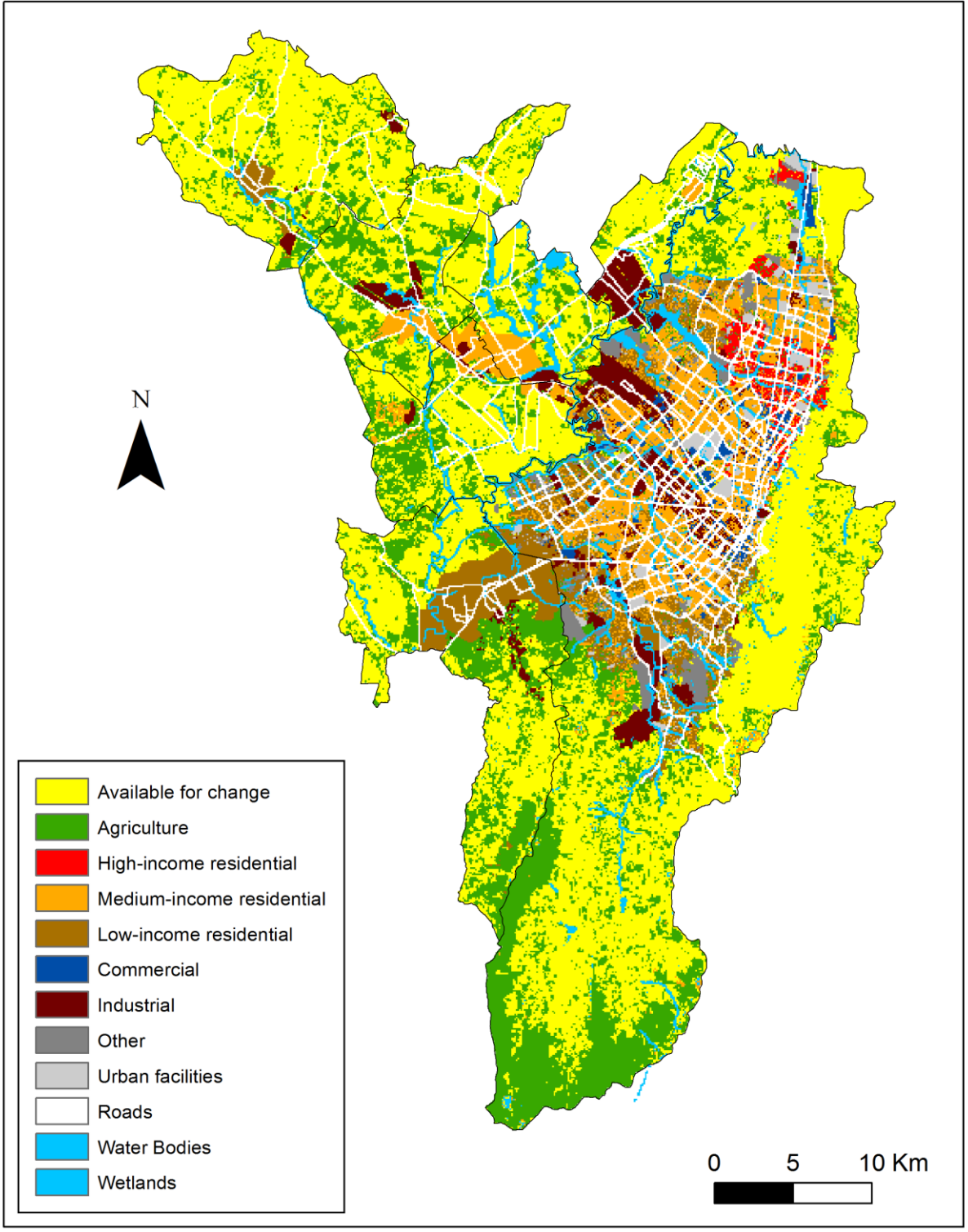
2014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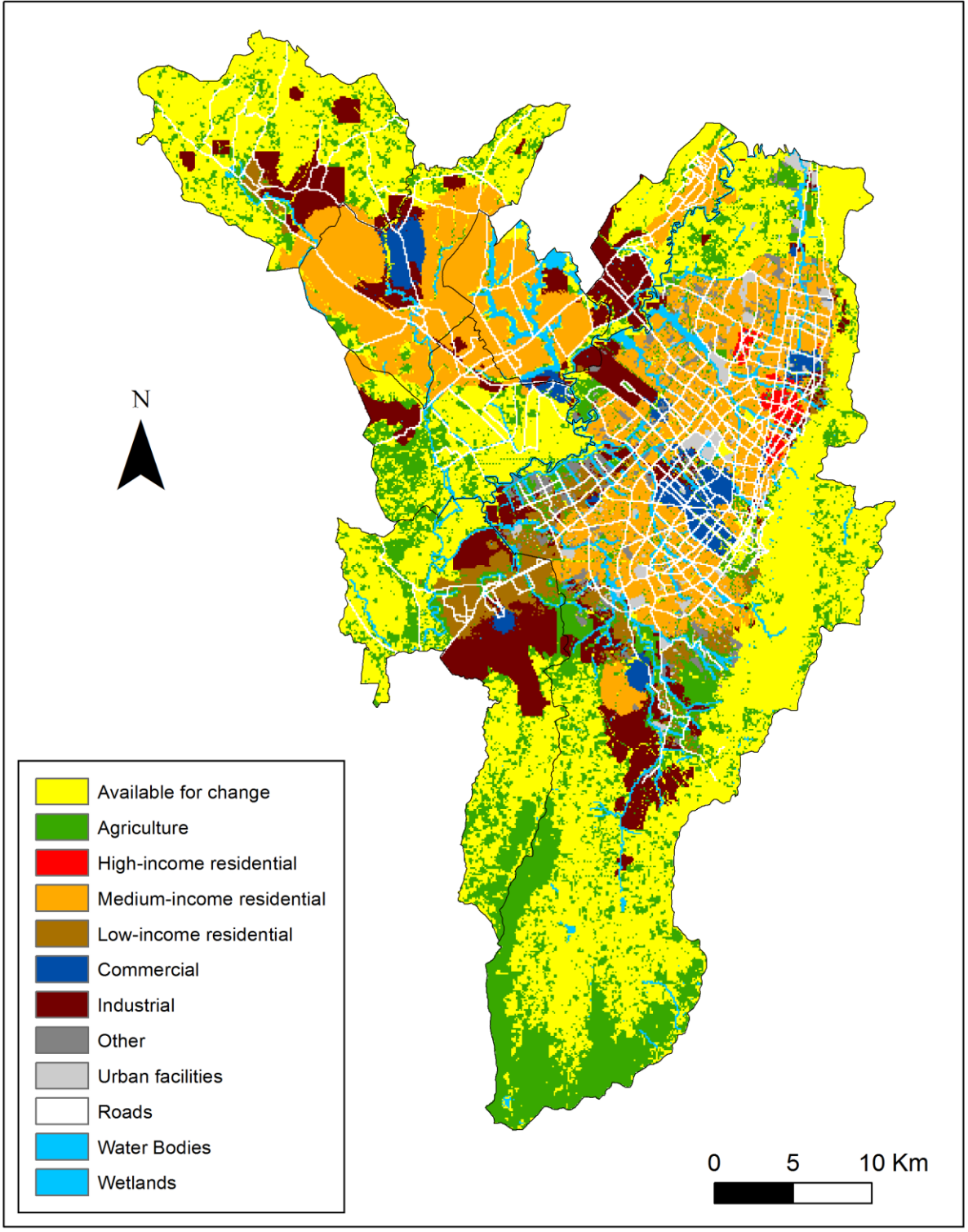


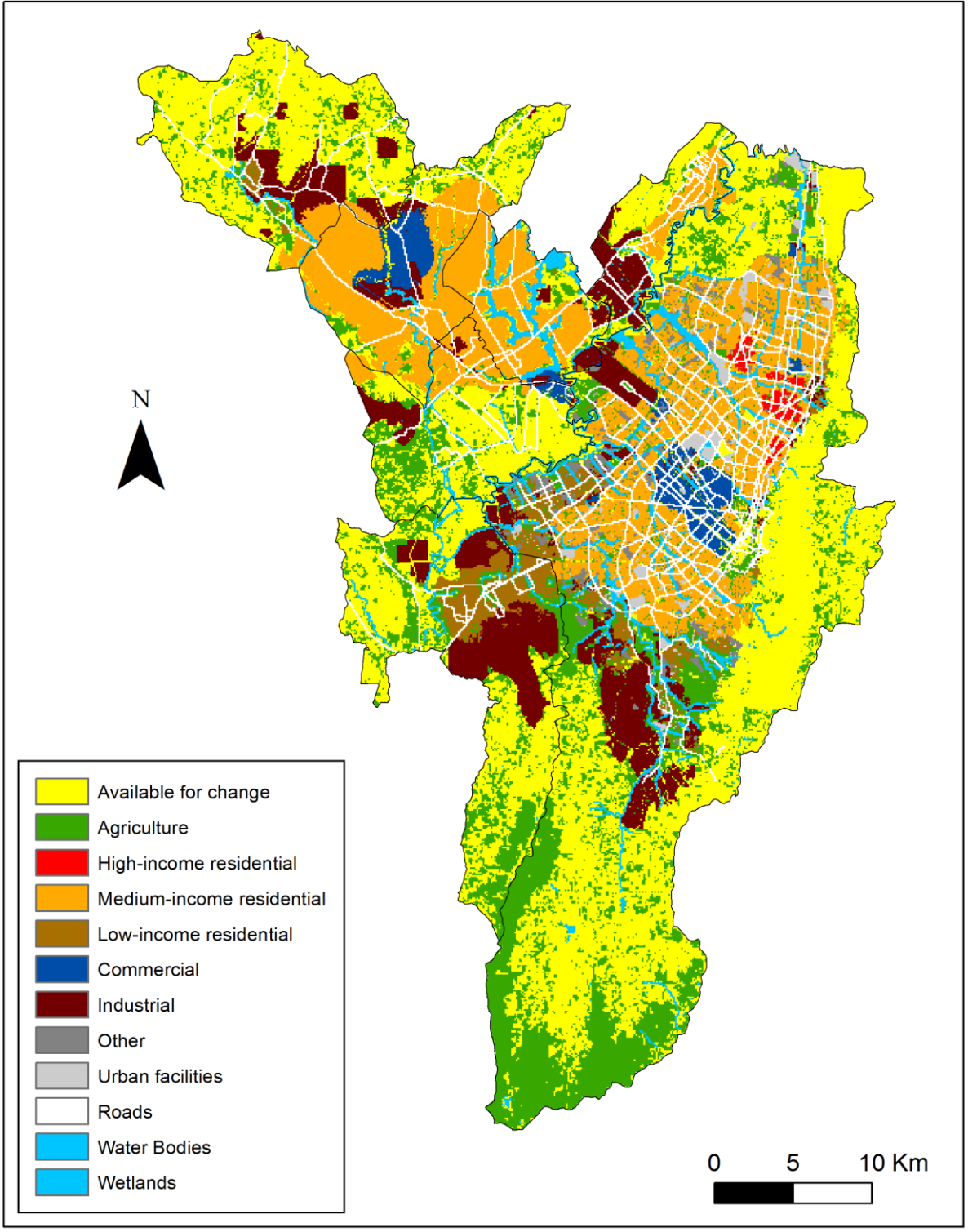
Scenario 1

Road development and reserve maintained

- Increased commercial development along the proposed road

- Additional industry in their surrounding areas

- Industrial areas appear in the far West among farming zones

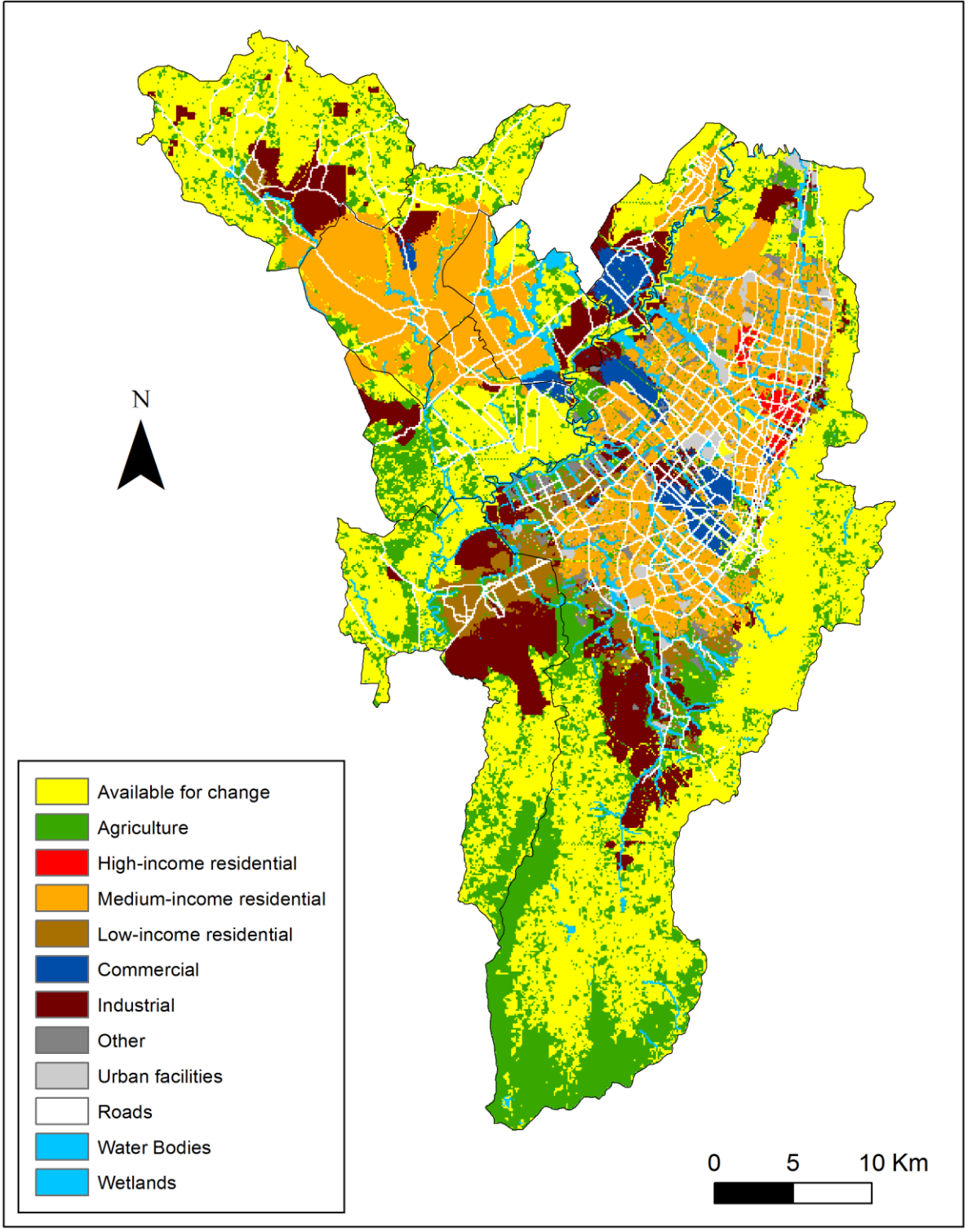


Scenario 2

Train development and reserve maintained

- Residential and commercial development concentrates along proposed stations

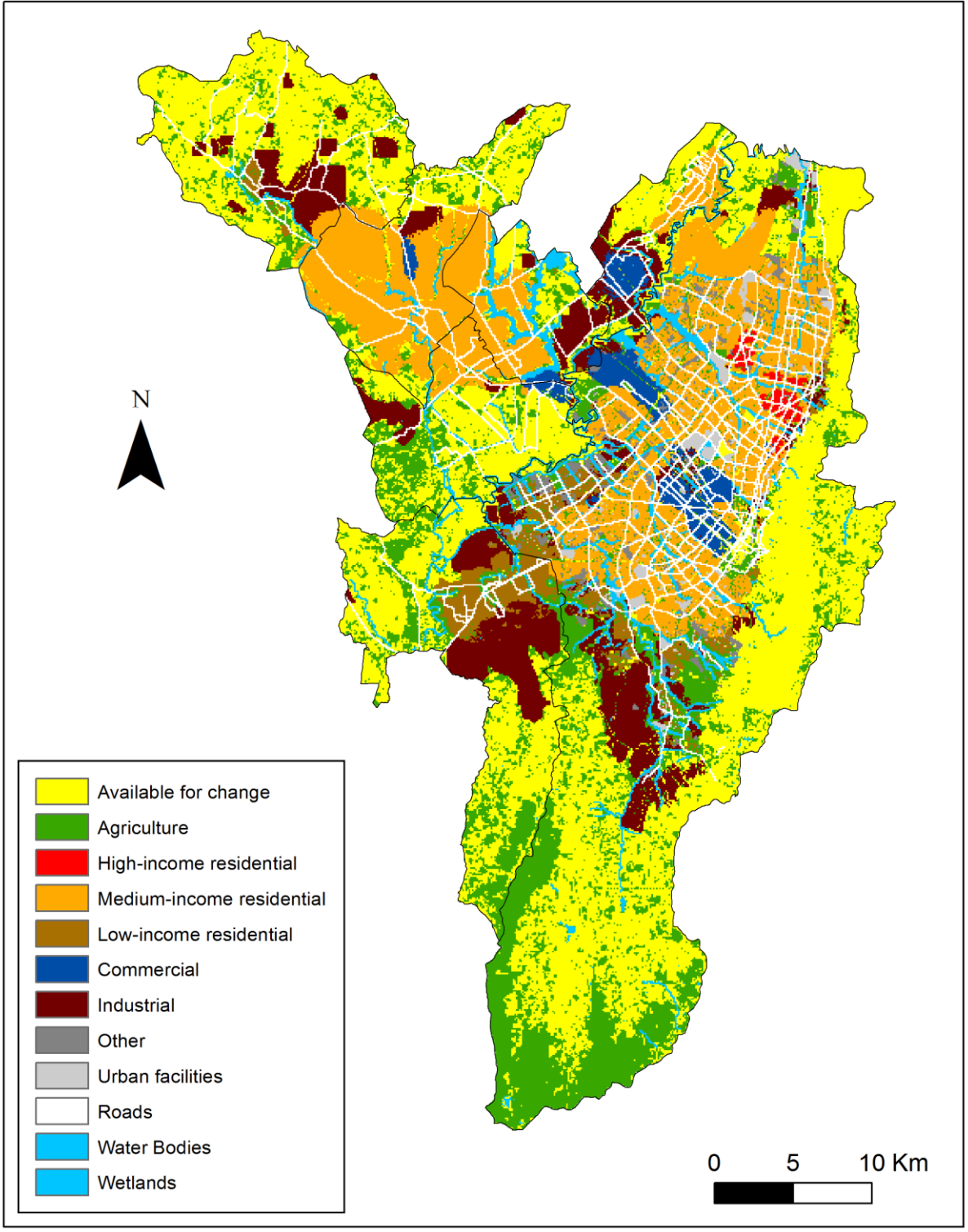
- This is particularly notorious in bordering areas between Bogota and the municipalities.



Scenario 3

Road development and reserve urbanized

- Similar trends than scenario 1 + invasion of natural reserve by medium-income residential and industrial



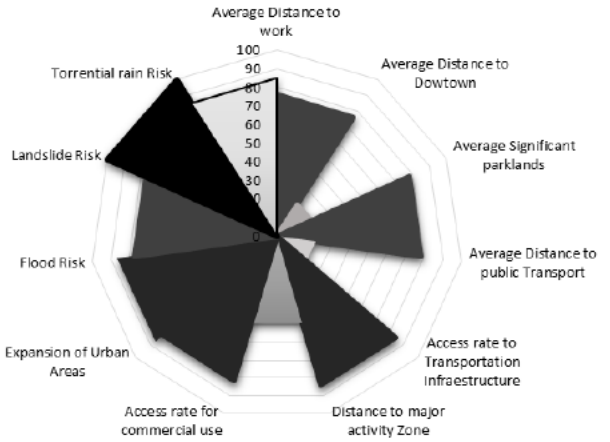
Scenario 4

Rail development and reserve urbanized

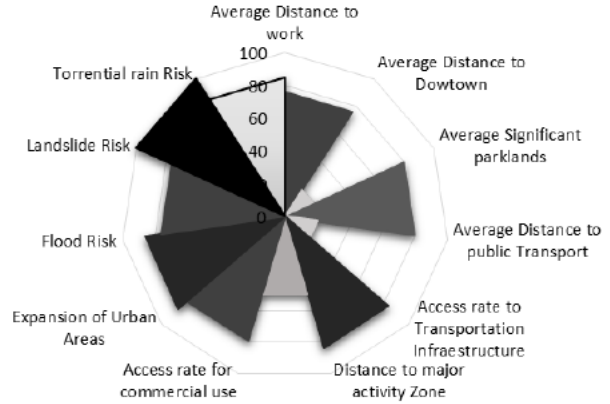
- Similar trends than scenario 2 + invasion of natural reserve by medium-income residential and industrial

Circles of mobility

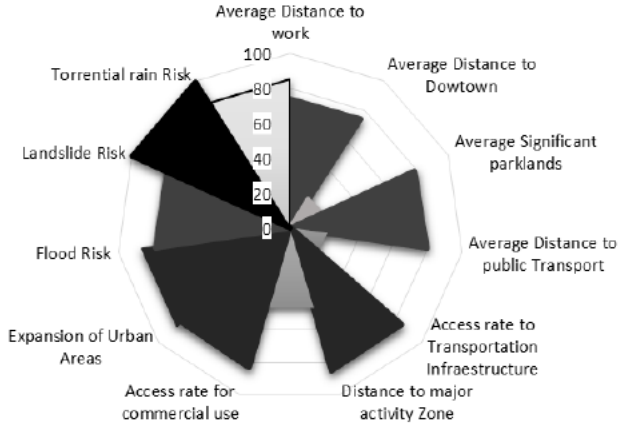
Scenario No.1 - Highway development & VDHR Restricted



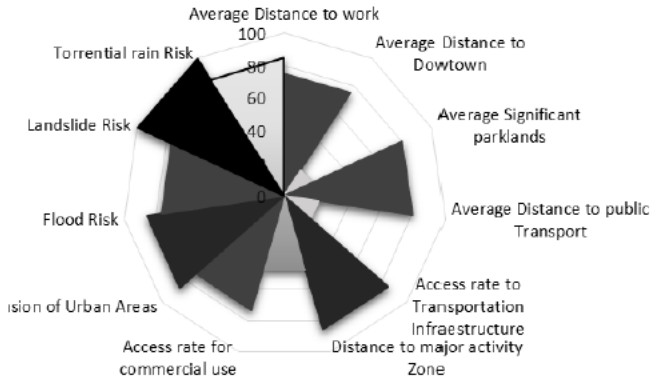
Scenario No.2 - Train & VDHR Restricted



Scenario No.3 - Highway development & VDHR Unrestricted



Scenario No.4 - Train & VDHR Unrestricted



BoLD conclusion

- Supporting decision making; Objectives met
- Integration of land management and public transport policies
- Calibration issues and technical proposal (Accessibility Distance Decay Factor -ADDF- and Overtime Spatial Decay Determination -OSDD-)
- Limitations related to narrow view of scenarios
- Need to develop more efficient visualization and cartographic communication tools

4. Melbourne School Zoning (MELSCH)

Background

- All school children in metro areas should have access to a public school
- Norms are vague
- Gov officials from Metropolitan Planning Authority verbally expressed that 800m would be the ideal maximum distance
- Current issues on school zone allocation (large residential areas lacking school, kids allocated to distant schools… social debate)
- Current methods to establish these catchments can be greatly improved (not taking into account street network, maximum distance undefined, fitness between school kids population and school size not considered…)

Some demonstrated facts and immediate needs

- A Public Health regard
  - School location, catchment areas and zoning + walking/cycling conditions impact on kids' (and parents?) potential for daily exercise and therefore on their health
- A planning regard
  - Foreseen population growth makes it necessary to better understand, plan, optimise… in order to: promote equity, public health, optimisation of resources…
- A technological regard
  - Current development of GIT (availability of georeferenced datasets, hardware and software costs, dynamic modelling developments…) makes it possible:
    - to better (in terms of equity) design these areas
    - to explore different future scenarios (based on different population growth and urban developments in regards to bike roads, walkability conditions…).

Aim and objective

Aim

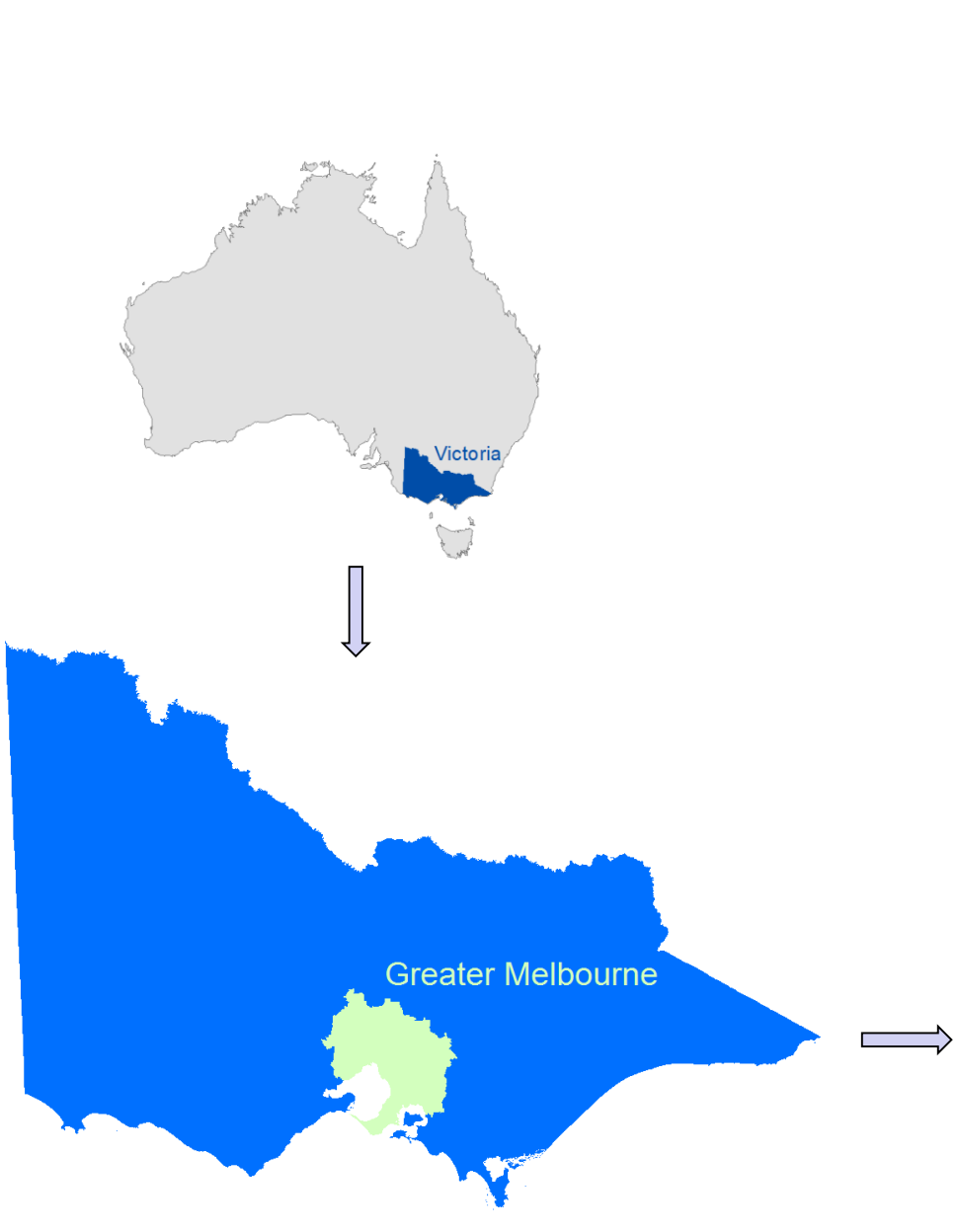
- Improving health conditions for school kids (by means of providing the basis for rational schools zone design and for cycling and/or walking conditions)
- Analysing school zones allocation

Objective

- Modelling school catchment areas
- Developing and analysing future scenarios
  - Increasing population density
  - Improving walking and cycling conditions)

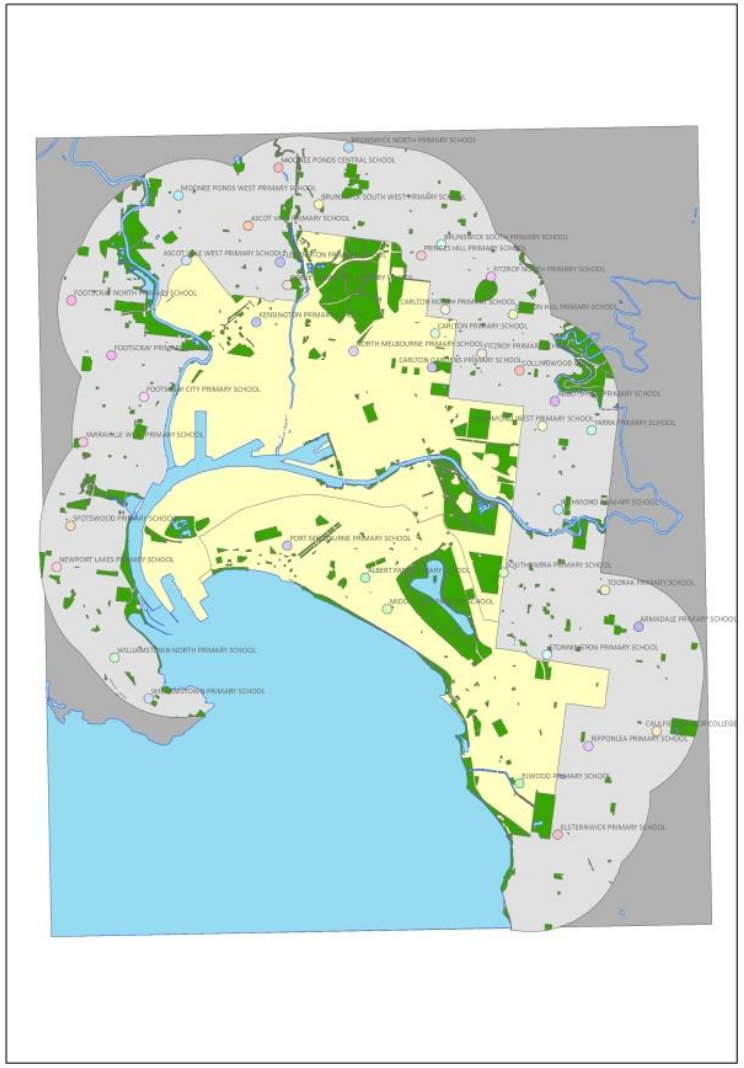
Methods – study area

City of Melbourne and Port Phillip



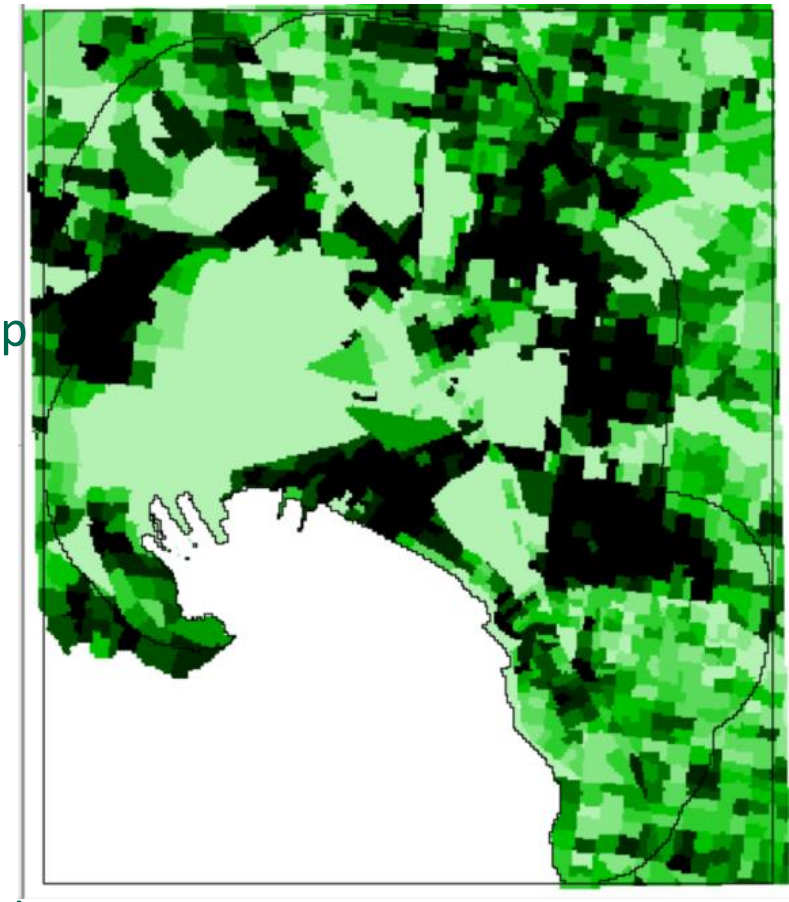
Study area

- Two Local Government Areas (LGA): City of Melbourne and Port Phillip
- Nine government primary schools located in the area
- Modelling area: minimum bounding rectangle of a 2000 m. buffer around the nine schools in the area
- This window includes a total of 42 schools



Techniques - Cellular automata modelling

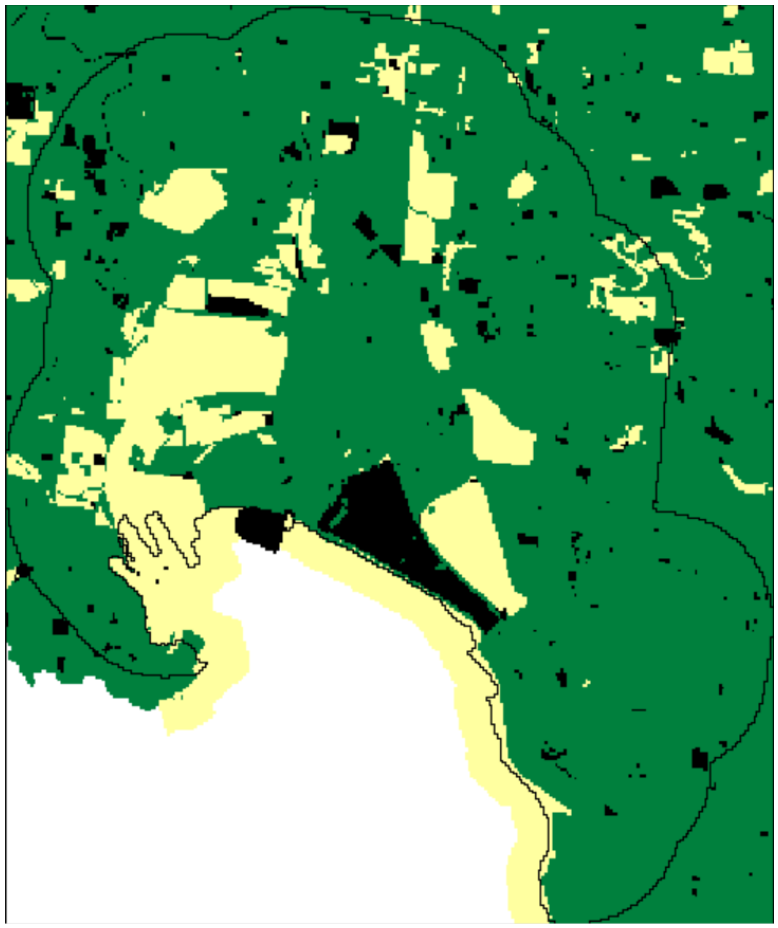
- Parameters for CA-based modelling



  - Modelling area
    - Square window City of Melbourne and Port Phillip LGA + 2000 m.
  - Categories
    - Areas non allocated (vacant)
    - 42 school areas (function)
    - Water and artificial green (feature)
  - Suitability
    - Walkability index (Giles-Corti). This index takes into account population density, land use and type of roads.

Techniques - Cellular automata modelling

- Parameters for CA-based modelling
  - Zoning
    - Industrial and zoo (+ other recreational areas): strictly restricted
    - Residential and commercial: weakly restricted / weakly encouraged
    - Community blocks, federal/state land, car park: strongly encouraged

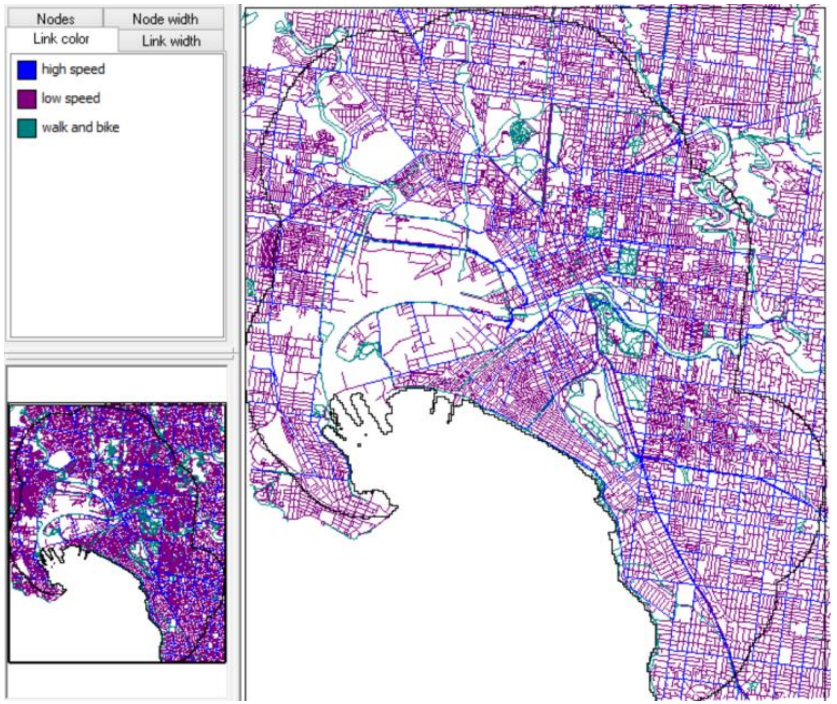


Techniques - Cellular automata modelling

- Parameters for CA-based modelling

  - Accessibility
    - Poor accessibility: Class_code 0 to 3(high speed traffic)
    - Medium accessibility: class_code 4 to 6 (local roads)
    - High accessibility: class_code 11 and 12 (walking track and bike roads)

  - Neighbourhood effect
    - Distance decay up to 800m (beyond which, schools are not attractive)



Techniques - Cellular automata modelling

- Parameters for CA-based modelling

  - Other parameters
    - Calibration time period: 1990-2015
    - Looking ahead time? In accordance to State/City plans. 2051?
    - Scenarios
      - New biking facilities
      - Urban development (increased population density)
      - New school, two possible locations (Ferrars St / Gladstone St or Park Rd / Aughtie Dr)

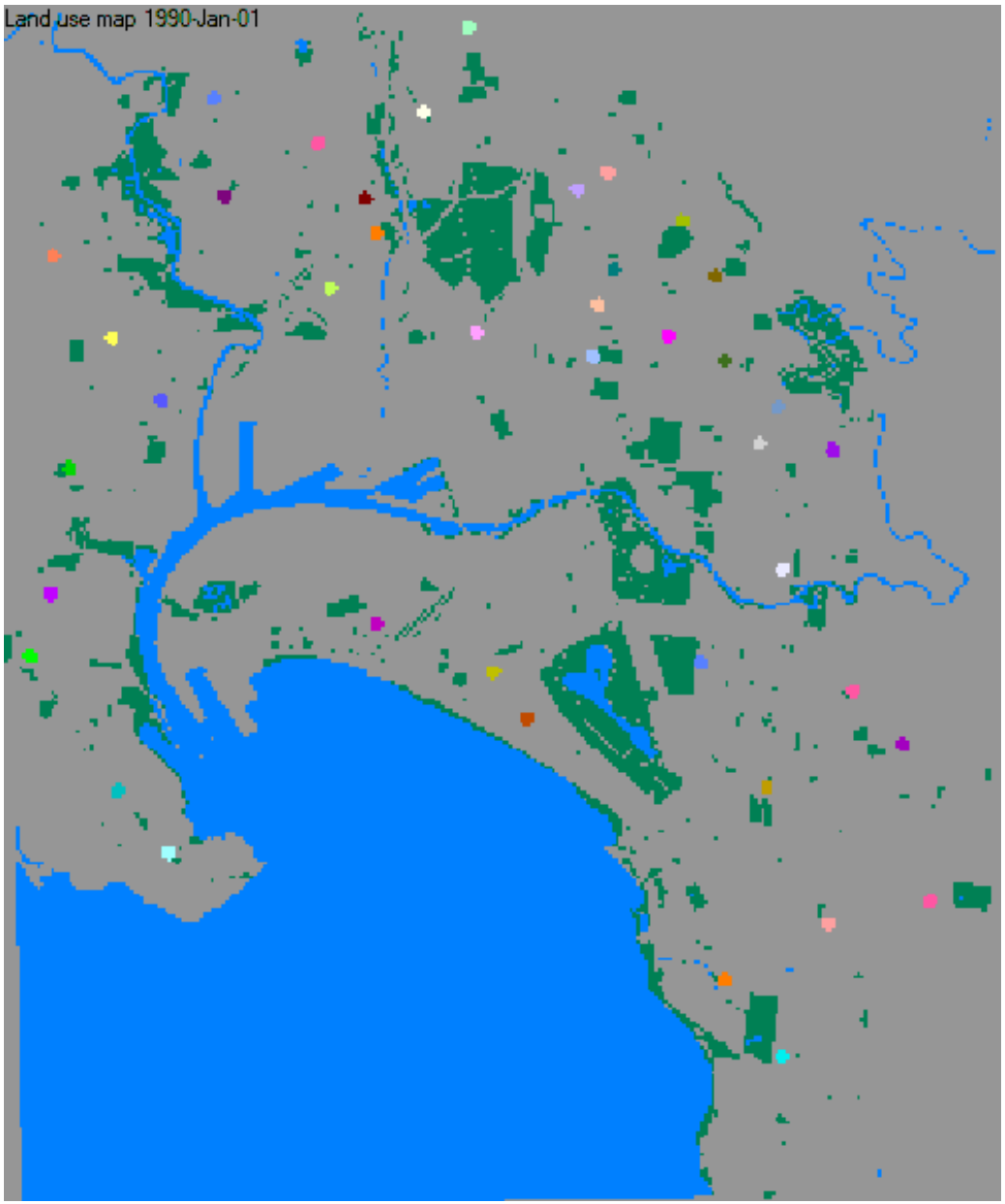
Expected outcomes

- Diagnose of current conditions derived from school catchment areas (areas non serviced, kids residing out of threshold, over or under sized schools

- Evaluation of methods applied

- Setting the basis for interactive scenarios

Results so far



Preliminary conclusions to MELSCH

- Cellular automata have been proven as a valuable tool for school zoning design and modelling
- Public Health constraints have been ingested into the model
- Education conditions have also been ingested into the model

- Far from accomplished
  - Need better calibration and validation
  - Scenario development

Concluding remarks

- These and other examples demonstrate the maturity of CA models
- However… they are still in the hands of researchers
  - New tools are needed
  - Calibration process must be mort affordable to non expert users
  - Awareness and trust are to be developed
- Data availability and data quality is still an issue (more so in developing countries… big data is the solution?)
- Better cartographic communication is urgently needed
- Misuse/misinterpretation/false expectations
- Scale choice
- Better integration with GIS
- Cost – particularly when applying participatory techniques

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- DUSPANAC team: Richard Hewitt, Verónica Hernández and Lara Román
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Merci pour votre attention

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