Exploratory modelling of stochastic land use cover change (LUCC) future scenarios for spatial planning

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Exploratory modelling of stochastic land use cover change(LUCC) future scenarios for spatial planning

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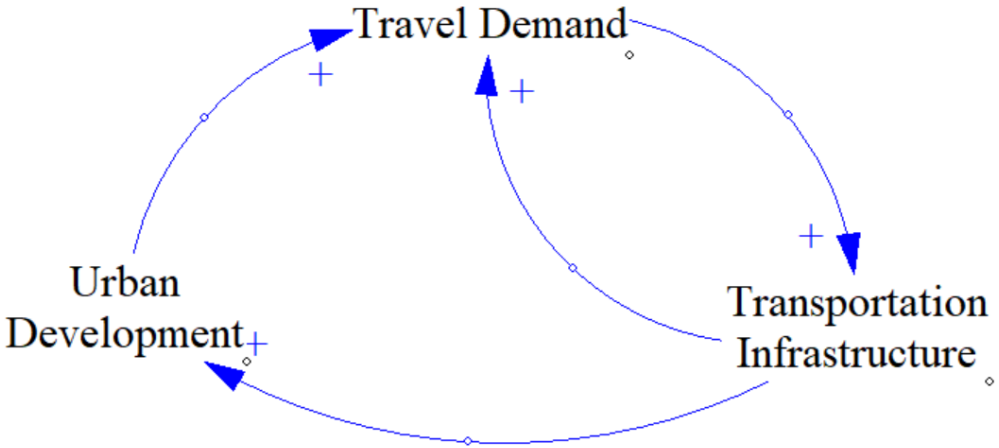
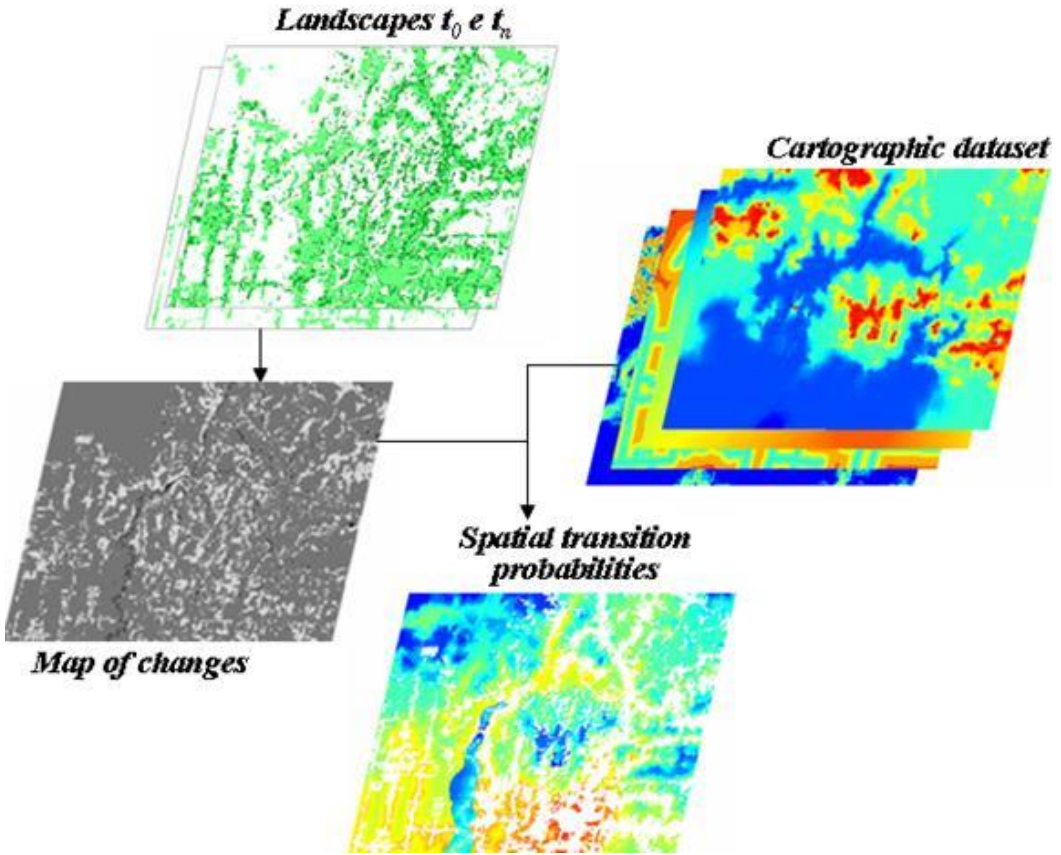
Transportation and urban development feedbacks

- Planning under uncertainty methods usually consider that decisions and uncertainties are independent.
- Transportation is closely linked to urban development.
- Land Use/Transportation interactions have been studied for decades with increasing levels of complexity.



How does a LUCC model work?

- Landscapes or Land Use maps are analyzed to estimate their changes
- A cartographic dataset of drivers are analyzed in their ability to explain Land Use changes.
- Spatial transition probability maps are estimated.
- Changes are allocated through cellular automata algorithms

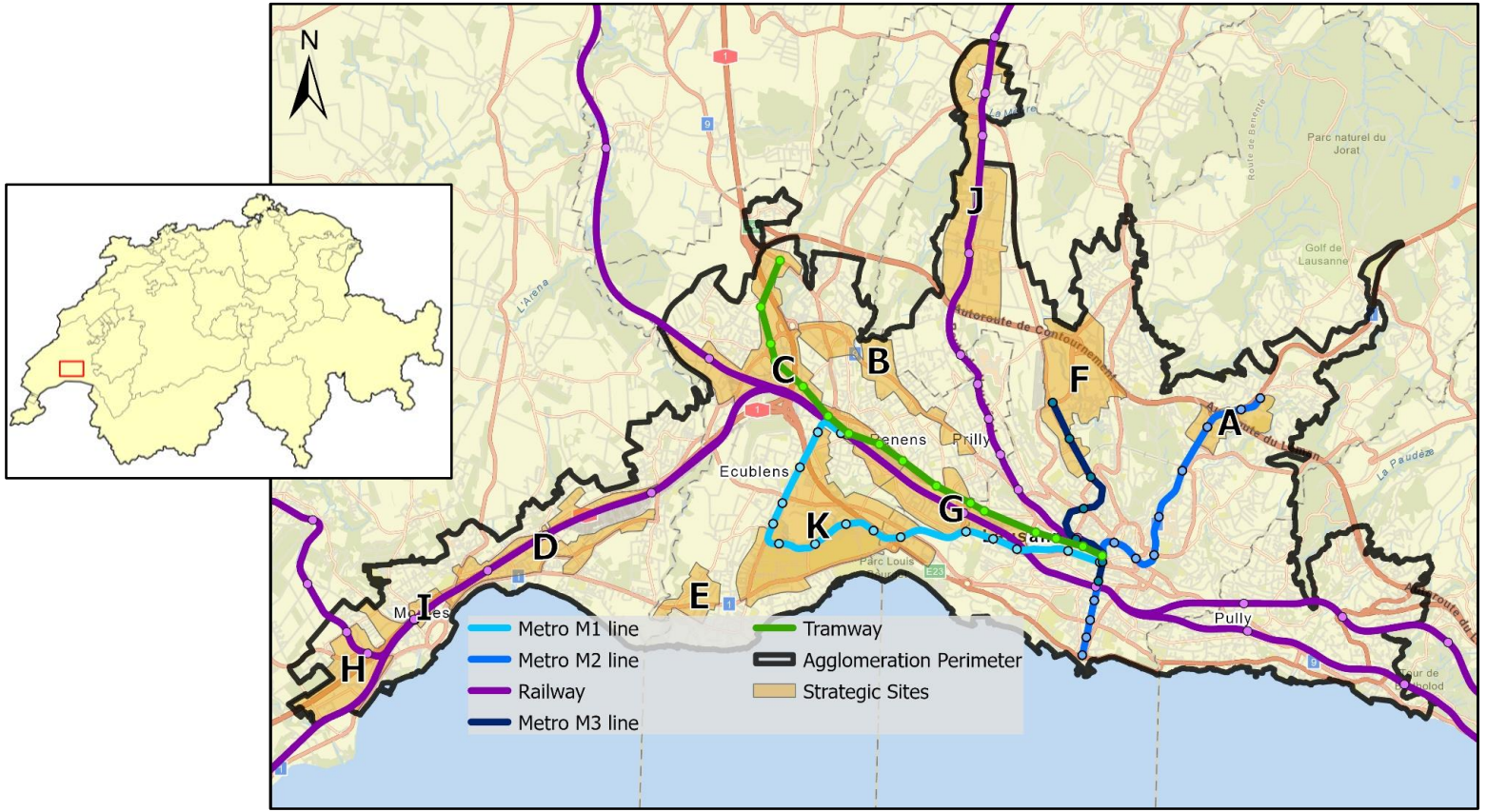


From Dinamica EGO, Guidebook 2.0 (Leite-Filho et al., 2020)

Previous uncertainty research in LUCC modelling

Research Item	Sources of Uncertainty	Purpose	Inclusion of planning decisions	Inclusion of model stochasticity
(White & Engelen, 1997)	Parameter Uncertainty	Model Evaluation	No	Yes
(Kocabas & Dragicevic, 2006)	Data uncertainty	Model Evaluation	No	No
(Dendoncker et al., 2008)	Data and Future uncertainty	Model Evaluation	No	No
(Pontius & Neeti, 2010)	Future uncertainty	Model Evaluation	No	No
(Ligmann-Zielinska & Sun, 2010)	Parameter Uncertainty	Model Evaluation	No	No
(Pan et al., 2010)	Data Uncertainty	Model Evaluation	No	No
(García et al., 2011)	Model structure uncertainty	Model Evaluation	No	Yes
(Verburg et al., 2013)	Future uncertainty	Model Evaluation	No	No
(van Vliet et al., 2013)	Parameter uncertainty	Model Evaluation	No	Yes
(Li et al., 2014)	Parameter and Model structure uncertainty	Model Evaluation	No	Yes
(Schmitz et al., 2014)	Model structure and Future uncertainty	Model Evaluation	No	No
(Liao et al., 2016)	Parameter and Model structure uncertainty	Model Evaluation	No	Yes
(Gao et al., 2016)	Future uncertainty	Model Refinement	No	No
(Grinblat et al., 2016)	Data uncertainty	Model Evaluation	No	No
(Tayyebi et al., 2016)	Data uncertainty	Model Evaluation	No	No
(Prestele et al., 2016)	Data, Model structure and Future uncertainty	Model Evaluation	No	No
(Verstegen et al., 2016)	Model structure and Future uncertainty	Model Evaluation	No	No
(Gao & Bryan, 2017)	Future uncertainty	Exploratory Modelling	Yes	No
(Alexander et al., 2017)	Data, Model structure and Future uncertainty	Model Evaluation	No	No
(Hewitt & Díaz-Pacheco, 2017)	Data and Model structure uncertainty	Model Evaluation	No	Yes
(Boulila et al., 2017)	Parameter uncertainty	Model Evaluation	No	No
(Şalap-Ayça et al., 2018)	Parameter and Operational uncertainty	Model Evaluation	No	No
(Ligmann-Zielinska, 2018)	Parameter and Operational uncertainty	Model Refinement	No	No
(Ferchichi et al., 2018)	Parameter and Model structure uncertainty	Model Refinement	No	No
(Palmate et al., 2022)	Data uncertainty	Model Refinement	No	No
(García-Álvarez et al., 2022)	Model structure uncertainty	Model Evaluation	No	No
(Aydin et al., 2022)	Future uncertainty	Exploratory Modelling	No	No
(Mannucci et al., 2023)	Future uncertainty	Exploratory Modelling	No	No

Lausanne Case Study – Transportation Networks and Strategic Sites



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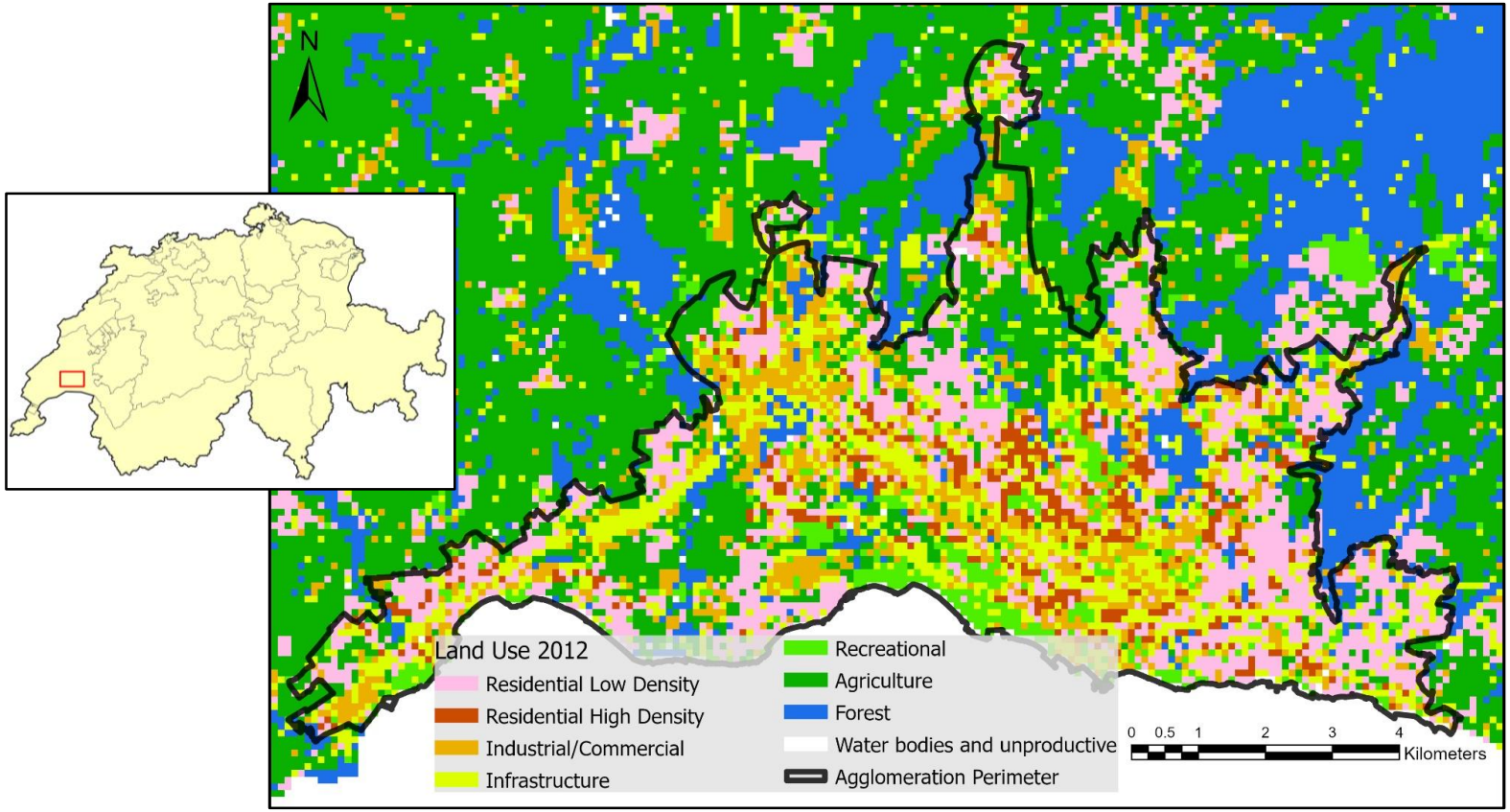
Lausanne Case Study – Land Use (100x100m pixels)



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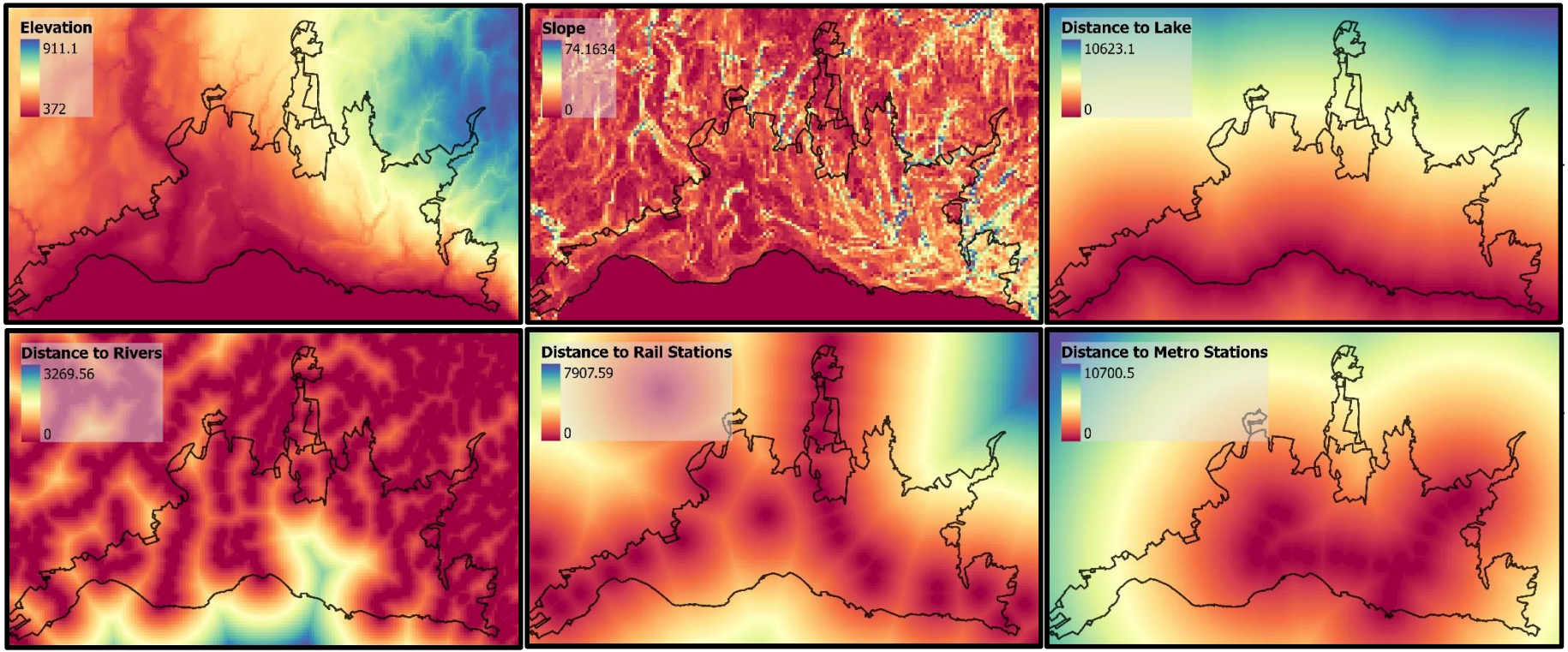
Lausanne Case Study – Land Use Changes

	Land Use	Change	
		1992-2004	2004-2012
1	Residential Low Density	14.4%	7.5%
2	Residential Medium/High Density	2.2%	11.1%
3	Industrial, Commercial, Public and other buildings	3.5%	3.4%
4	Infrastructure	2.7%	1.6%
5	Recreational	3.3%	-0.6%
6	Agriculture	-4.7%	-3.5%
7	Forest	0.0%	-0.1%
8	Lakes and Rivers		
9	Other unproductive		

Drivers of change



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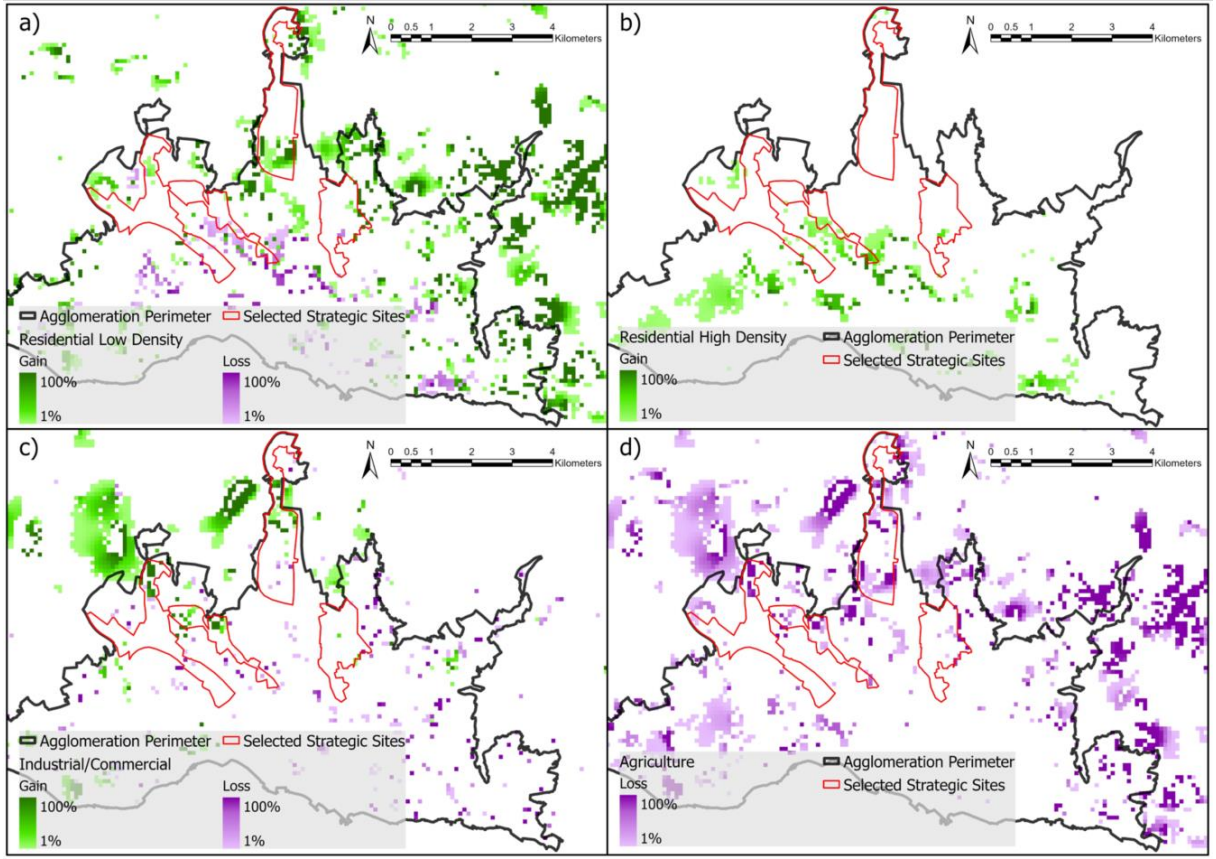
Experimental Design

Uncertain Factor	Pseudonym	Min Value	Max Value	PDF	Type of Uncertainty
Annual transition rate from Residential Low Density to Residential High Density	Densification 1	0.05%	0.20%	Uniform	External Factor
Annual transition rate from Agriculture to Residential High Density	Densification 2	0.01%	0.04%	Uniform	External Factor
Annual transition rate from Agriculture to Residential Low Density	Sprawl	0.22%	0.25%	Uniform	External Factor
Annual transition rate from Agriculture to Industrial/Commercial	Industrial/Commercial expansion	0.09%	0.12%	Uniform	External Factor
Annual transition rate from Industrial/Commercial to Residential Low Density	Industrial/Commercial reduction	0.2%	0.4%	Uniform	External Factor
WOE of urban rail infrastructure	Influence of urban rail infrastructure	-50%	+50%	Uniform	External Factor/Planning Decision
Development of new tramway	Tramway	No	Yes	Bernoulli	Planning Decision
Development of new metro line 3	Metro Line 3	No	Yes	Bernoulli	Planning Decision

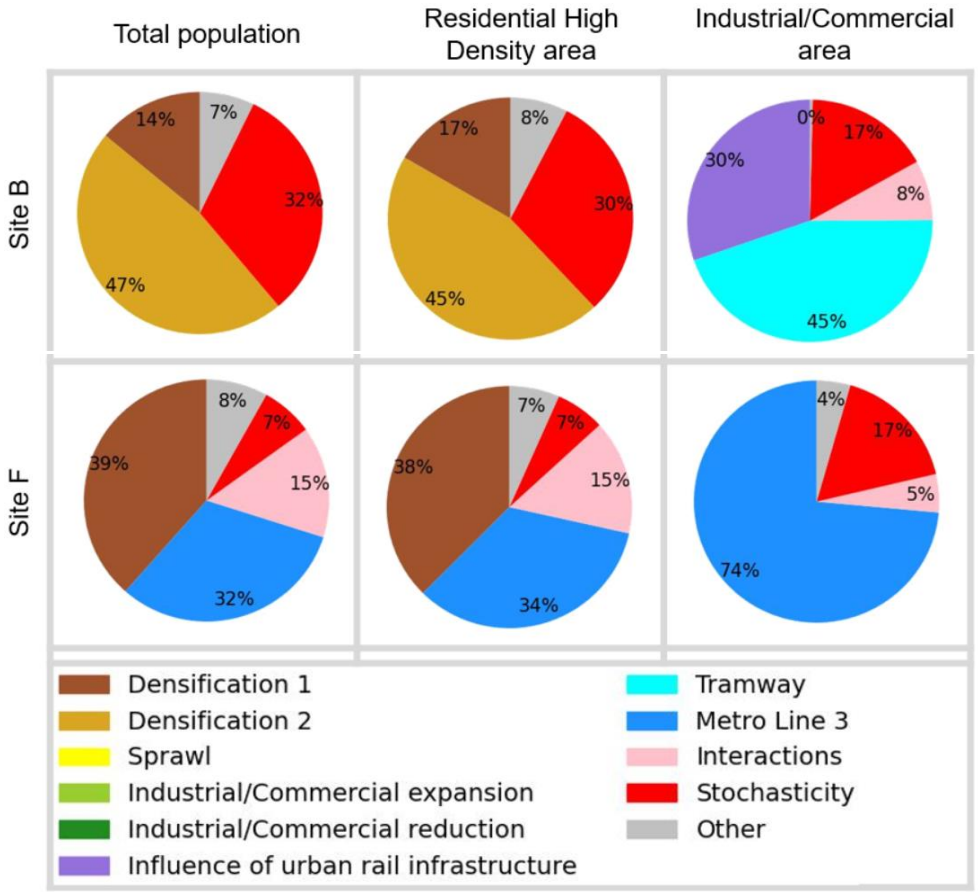
Uncertainty Analysis – over 5000 simulations to 2050

- Visualization of spatial variability for the frequency of change
- 4 different Land use Classes: Residential Low Density, Residential High density, Industrial/Commercial and Agriculture.



Global Sensitivity Analysis (GSA) – Sobol Indices

- Identification of the most important factors influencing the variability of model outcomes.
- Including planning decisions and stochasticity



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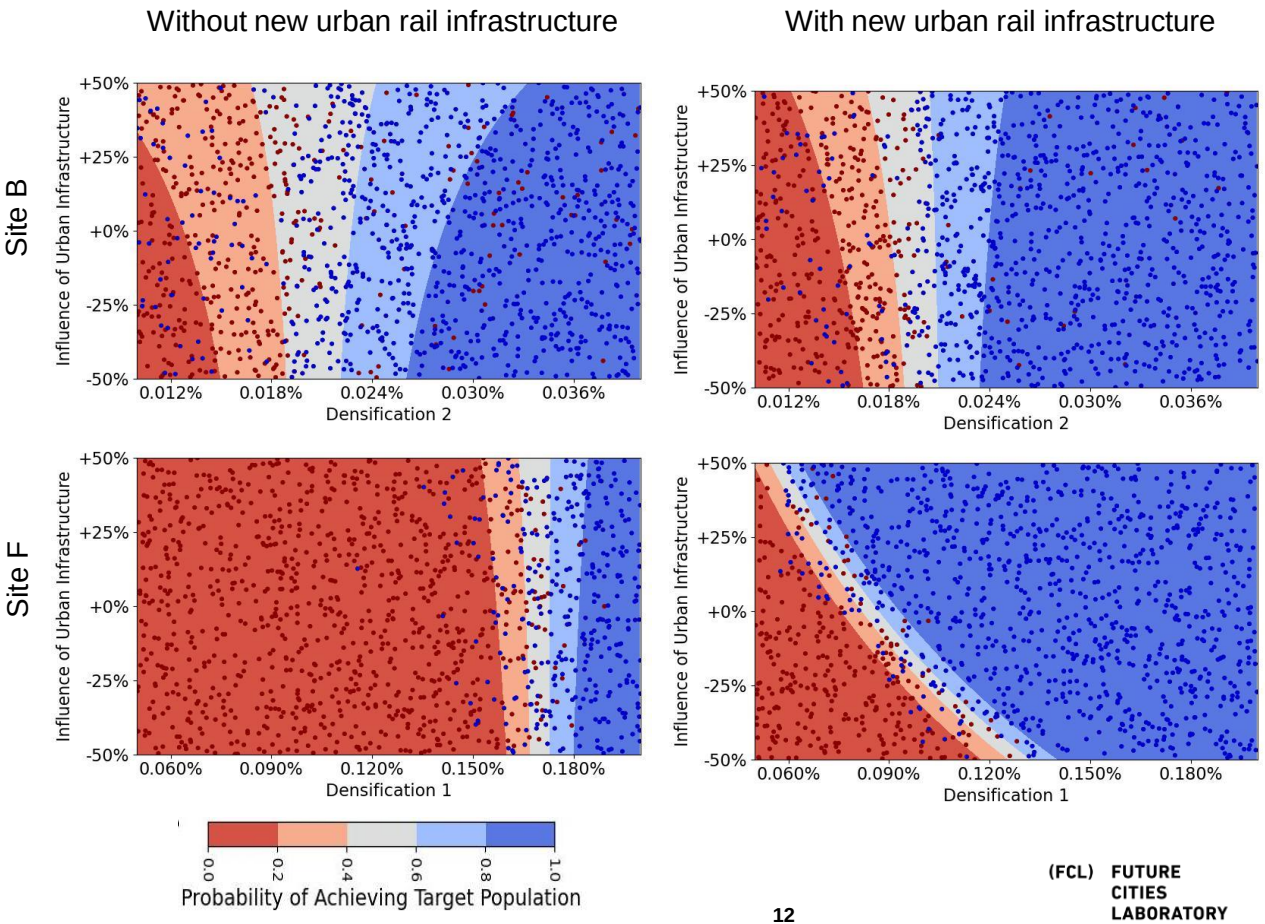
Scenaro Discovery – Logistic regressions

- Evaluation of decision boundaries to achieve a target population with and without infrastructure.
- «Discovery» of the combination of factors that produce desirable and undesirable outcomes



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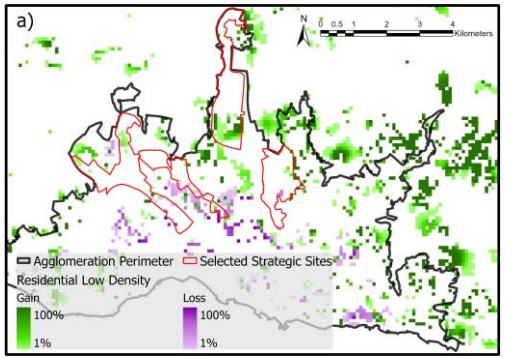
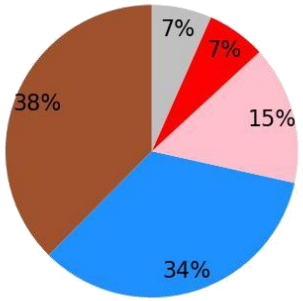
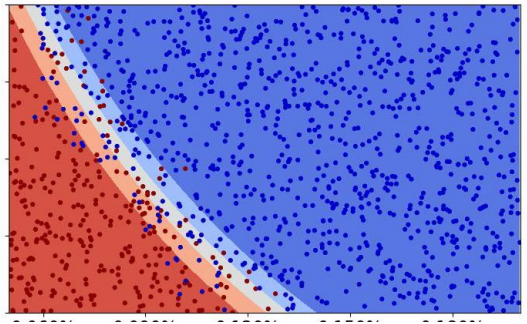
Conclusions

- LUCC modelling has addressed uncertainty mainly aiming to improve model accuracy and the credibility of future simulations.
- The use of LUCC models as devices for simulating a large ensemble of future scenarios is almost non-existent in the literature.
- For the first time, future trends, planning decisions and model stochasticity are investigated with sensitivity analysis in a LUCC model.
- We used Sobol indices and Scenario discovery for robust urban planning under uncertainty.
- Valuable insights for planning urban development and infrastructure under future uncertainty.







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Thank you for your attention

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