A Spatial Decision Support System for Natural Hazard Risk Reduction Policy Assessment and Planning

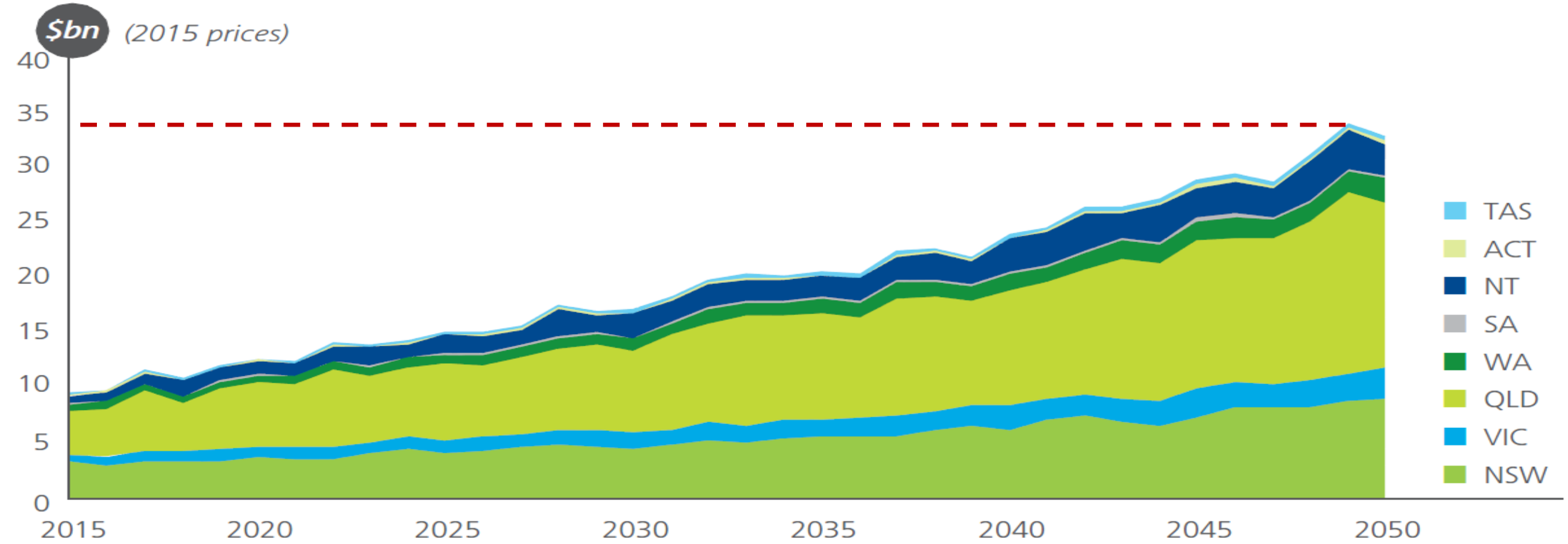
Holger R. Maier, Graeme A. Riddell, Hedwig van Delden, Jeffrey P. Newman, Aaron C. Zecchin, Roel vanHout, James Daniell, Andreas Schäfer, Graeme C. Dandy, Charles P. Newland

Government of South Australia
Department of Environment, Water and Natural Resources

MOTIVATION

NATURAL DISASTERS ARE EXPENSIVE

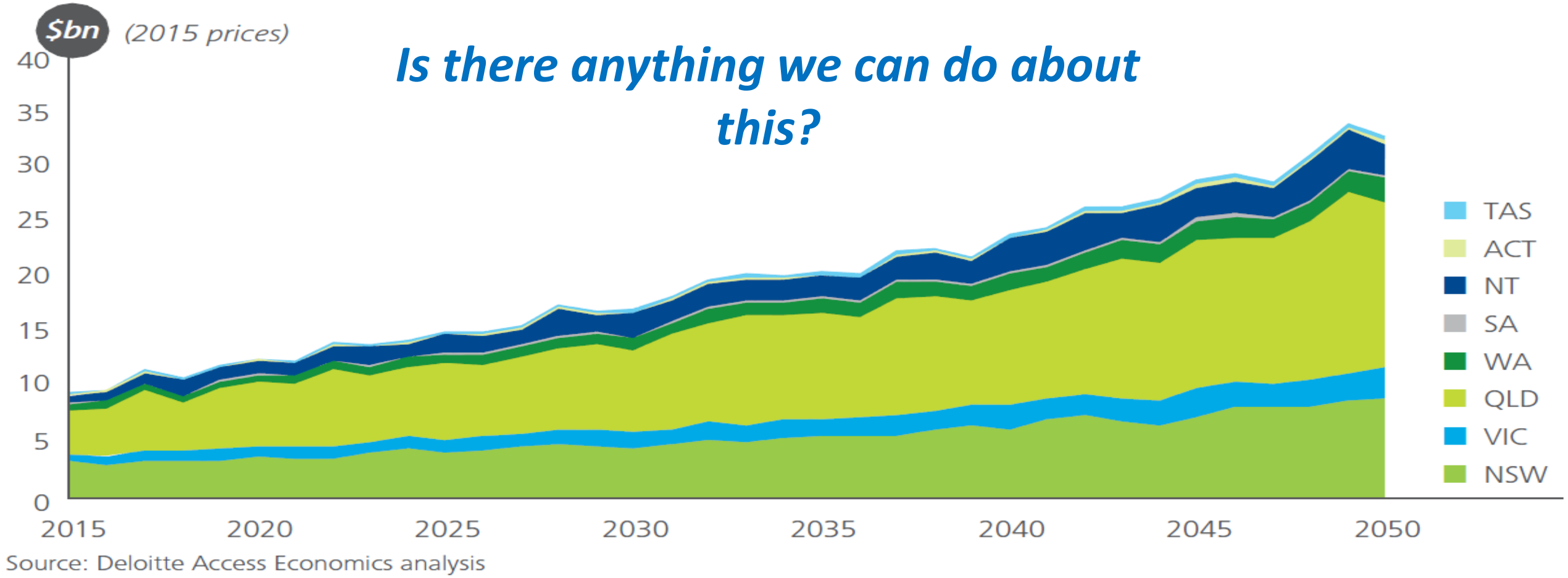
Chart ii: 2015–50 forecast of the total economic cost of natural disasters, identifying costs for each state



Source: Deloitte Access Economics analysis

NATURAL DISASTERS ARE EXPENSIVE

Chart ii: 2015–50 forecast of the total economic cost of natural disasters, identifying costs for each state



Is there anything we can do about this?

Source: Deloitte Access Economics analysis

PREVENTION IS BETTER THAN CURE

"Better to build a fence at the top of a cliff, than park an ambulance at the bottom"

Helen Clark 2015 Sendai

RISK REDUCTION & MITIGATION

"Better to build a fence at the top of a cliff, than park an ambulance at the bottom"

Helen Clark 2015 Sendai

Where to put the fence?

How high should it be?

When to build it?

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- Conceptual Approach
- Modelling Approach & Software Framework

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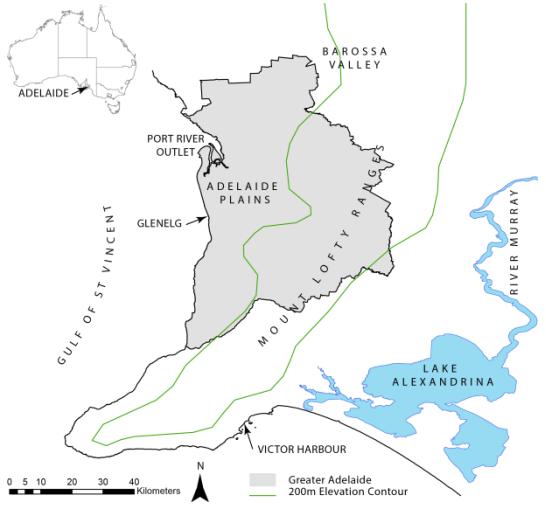

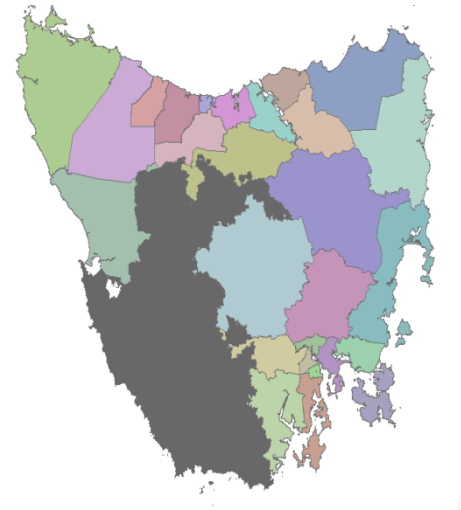

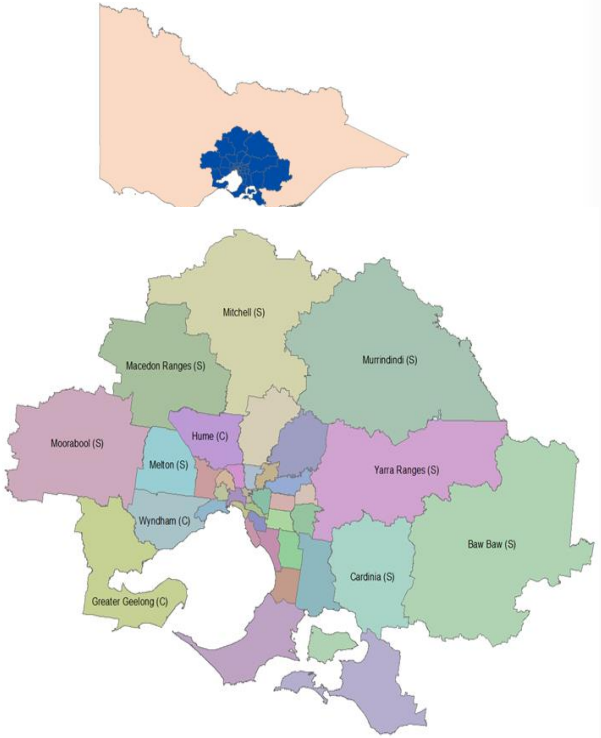

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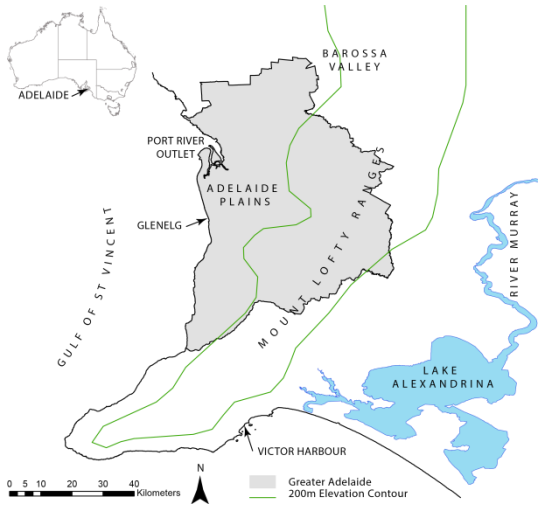
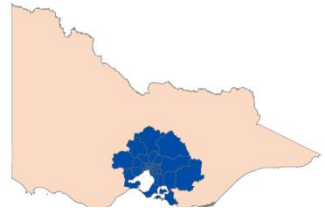
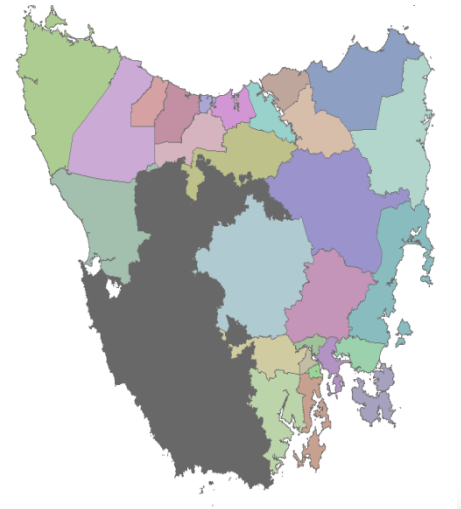
- **Modelling Approach & Software Framework**





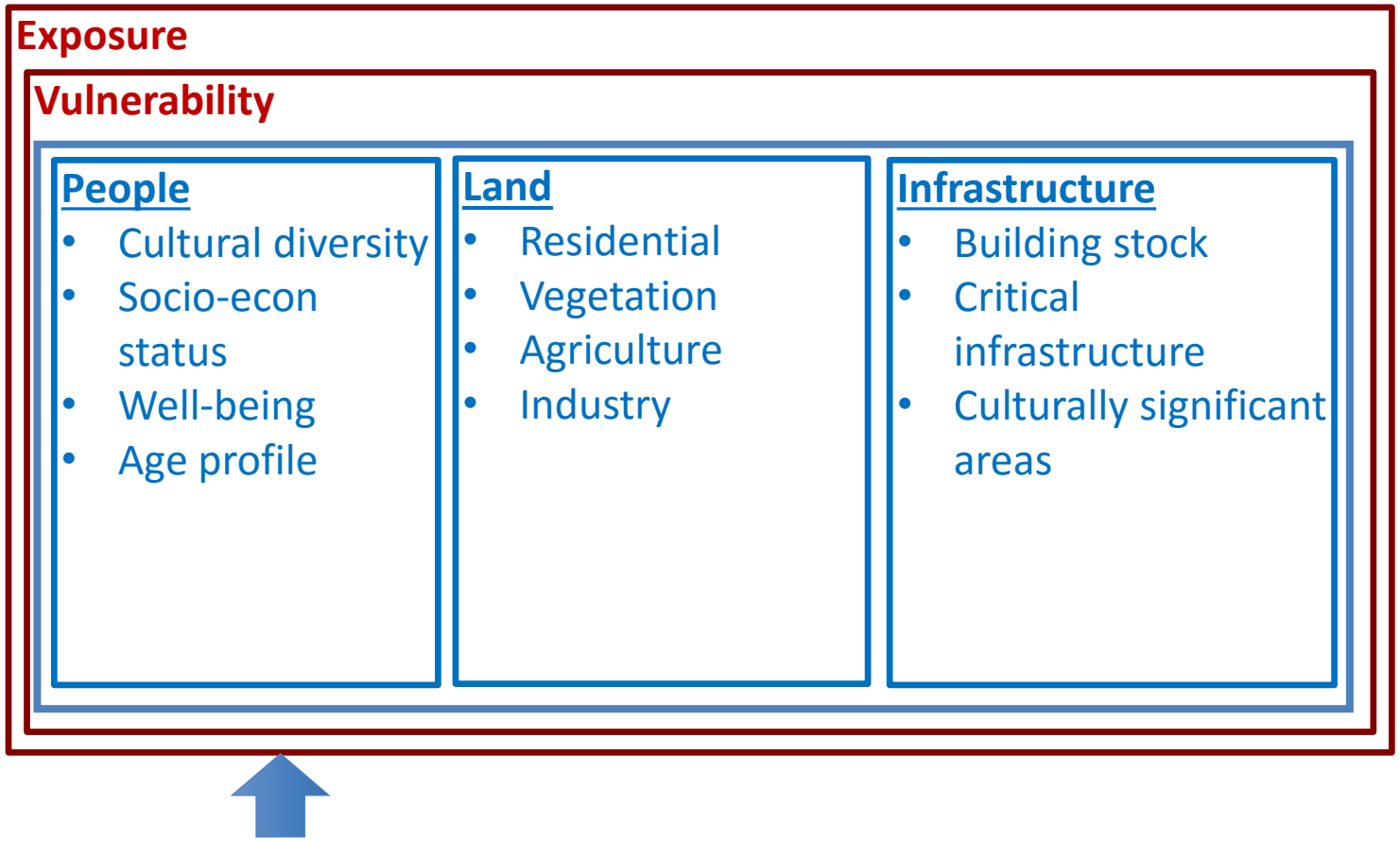


Vulnerability

People
- Cultural diversity
- Socio-econ status
- Well-being
- Age profile

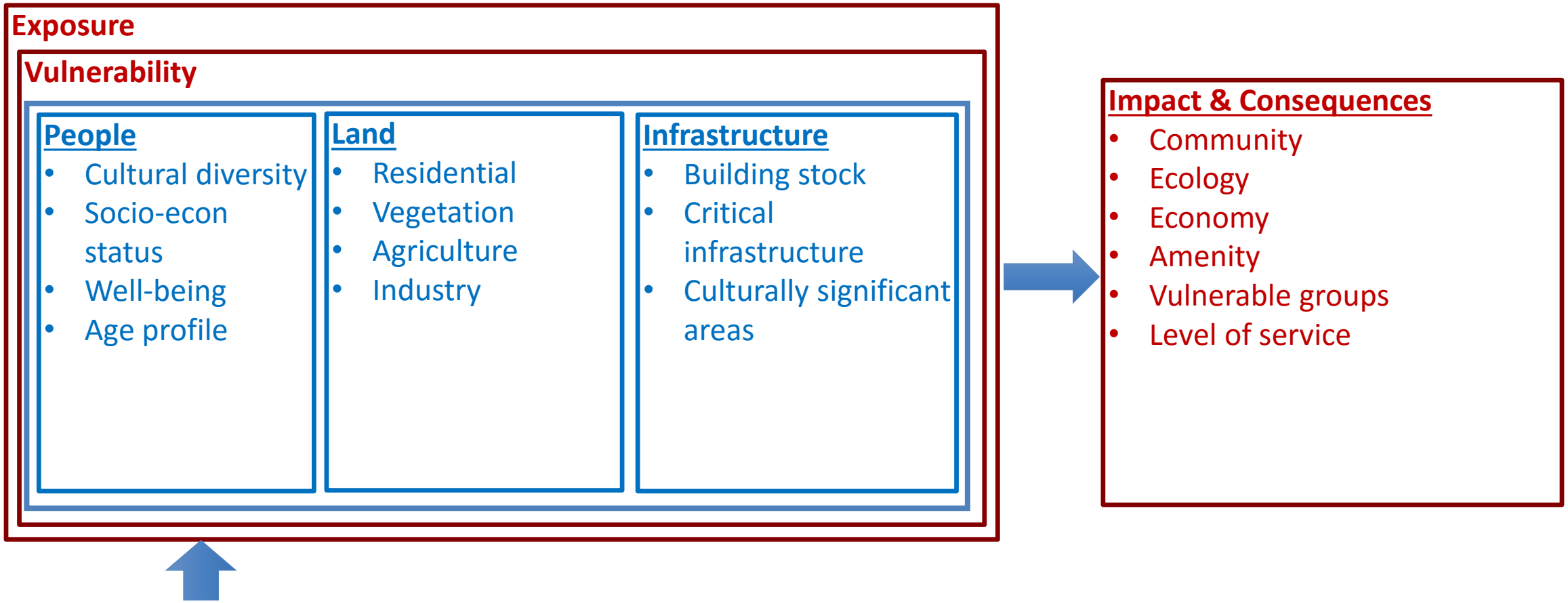
Land
- Residential
- Vegetation
- Agriculture
- Industry

Infrastructure
- Building stock
- Critical infrastructure
- Culturally significant areas



Natural Hazards

- Bushfire
- Flooding
- Coastal inundation
- Earthquake
- Heatwave



Impact & Consequences

- Community
- Ecology
- Economy
- Amenity
- Vulnerable groups
- Level of service

Natural Hazards

- Bushfire
- Flooding
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Exposure

Vulnerability

People
- Cultural diversity
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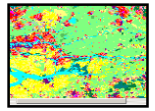
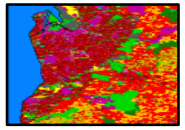


Land
- Residen[illegible]
- [illegible]

MODEL



Infrastructure
- Building stock
- [illegible]
- [illegible]frastructure
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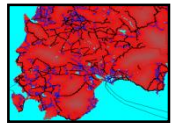

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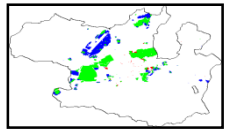
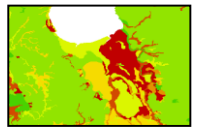


Natural Hazards
- Bushfire
- Flo[illegible]
- [illegible]
- [illegible]
- He[illegible]wave

MODEL



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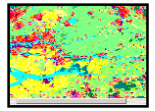

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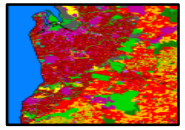

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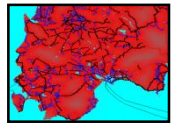

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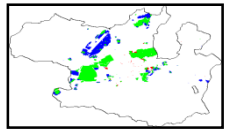

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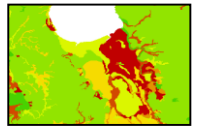
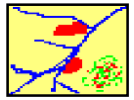


Risk Reduction
- Landuse planning
- Community education
- Structural measures



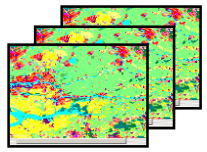
Tomorrow's risk is being built today. We must therefore move away from risk assessments that show risk at a single point in the present and move instead towards risk assessments that can guide decision makers towards a resilient future.

Global Facility for Disaster Reduction and Recovery (2016)

Exposure

Vulnerability

People
- Cultural diversity
- Socio-econ status
- Well-being
- Age profile



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- Vegetation
- Agriculture
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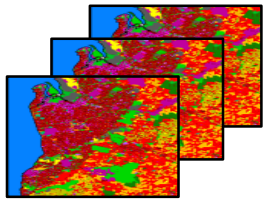

Infrastructure
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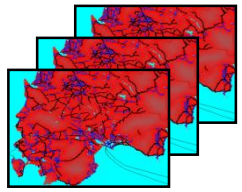

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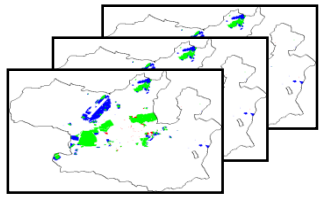

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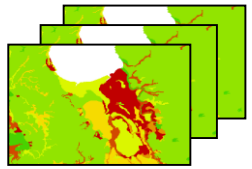

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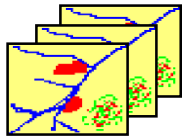
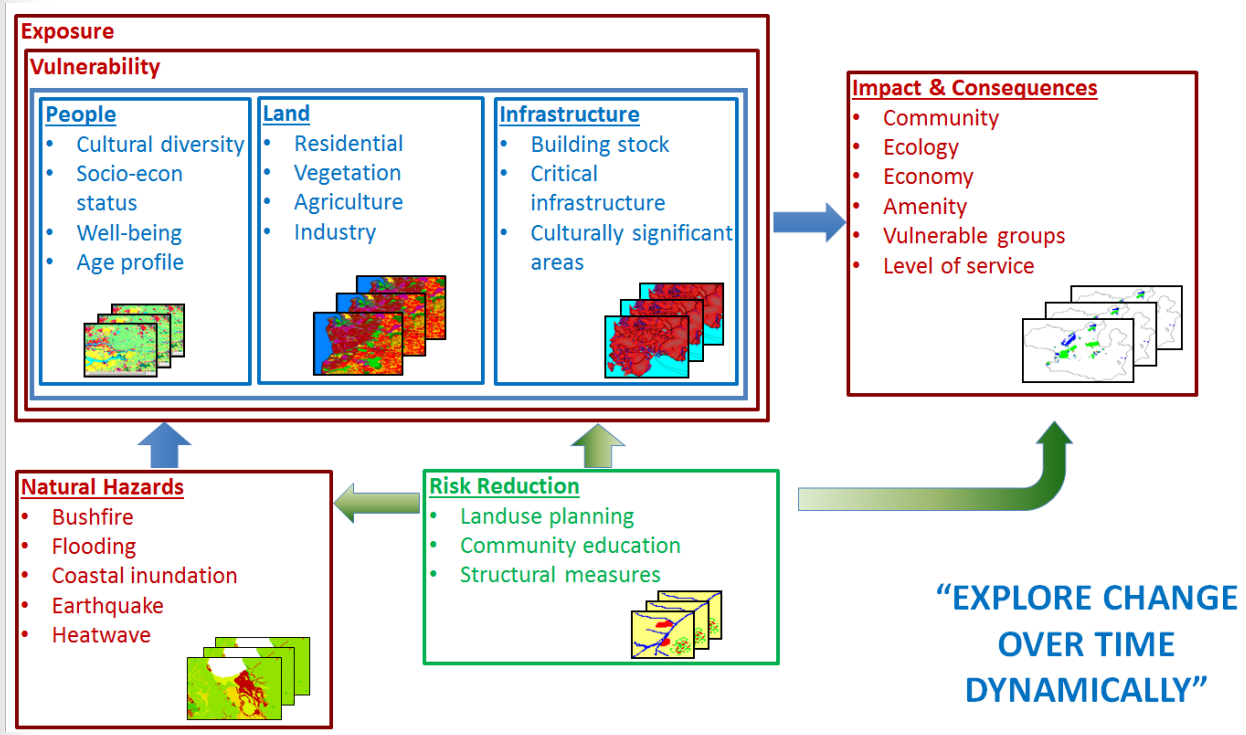


"EXPLORE CHANGE OVER TIME DYNAMICALLY"

WHAT ARE EXPECTED OUTCOMES?

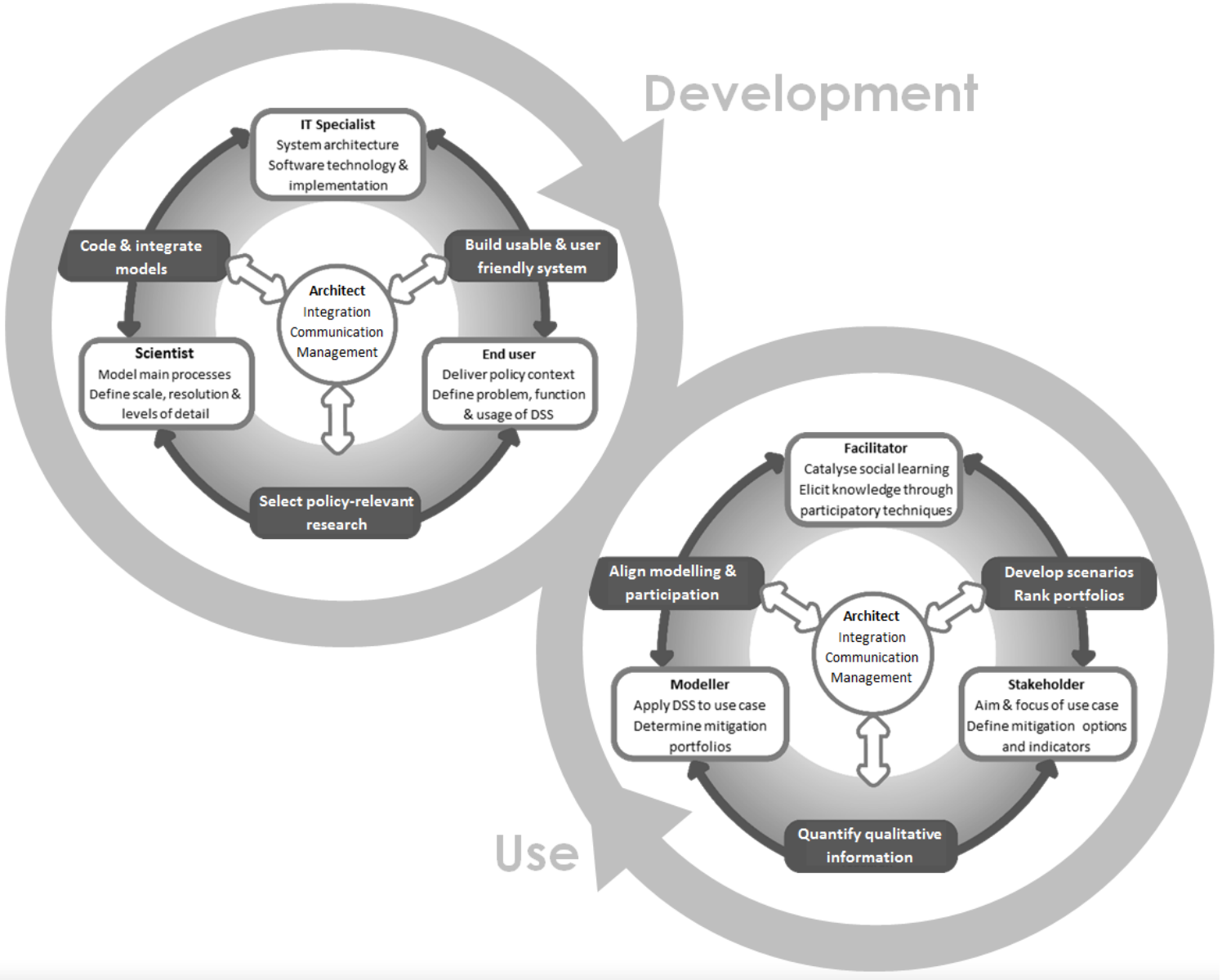


- Best-practice approach to identification of outcomes that represent value of money
  - Evidence-based decision-making
  - Increased transparency, efficiency and effectiveness in decision-making processes
- Development of shared understanding of risks, how they interact and what can be done about them
- Understanding of relative importance of different factors in specific decision contexts
- Development of flexible, adaptable pathways to reducing disaster risk

Process

Process


Information Technology
Science
User


Development
IT Specialist
System architecture
Software technology & implementation
Code & integrate models
Build usable & user friendly system
Architect
Integration
Communication
Management
Scientist
Model main processes
Define scale, resolution & levels of detail
End user
Deliver policy context
Define problem, function & usage of DSS
Select policy-relevant research
Use
Facilitator
Catalyse social learning
Elicit knowledge through participatory techniques
Align modelling & participation
Develop scenarios
Rank portfolios
Architect
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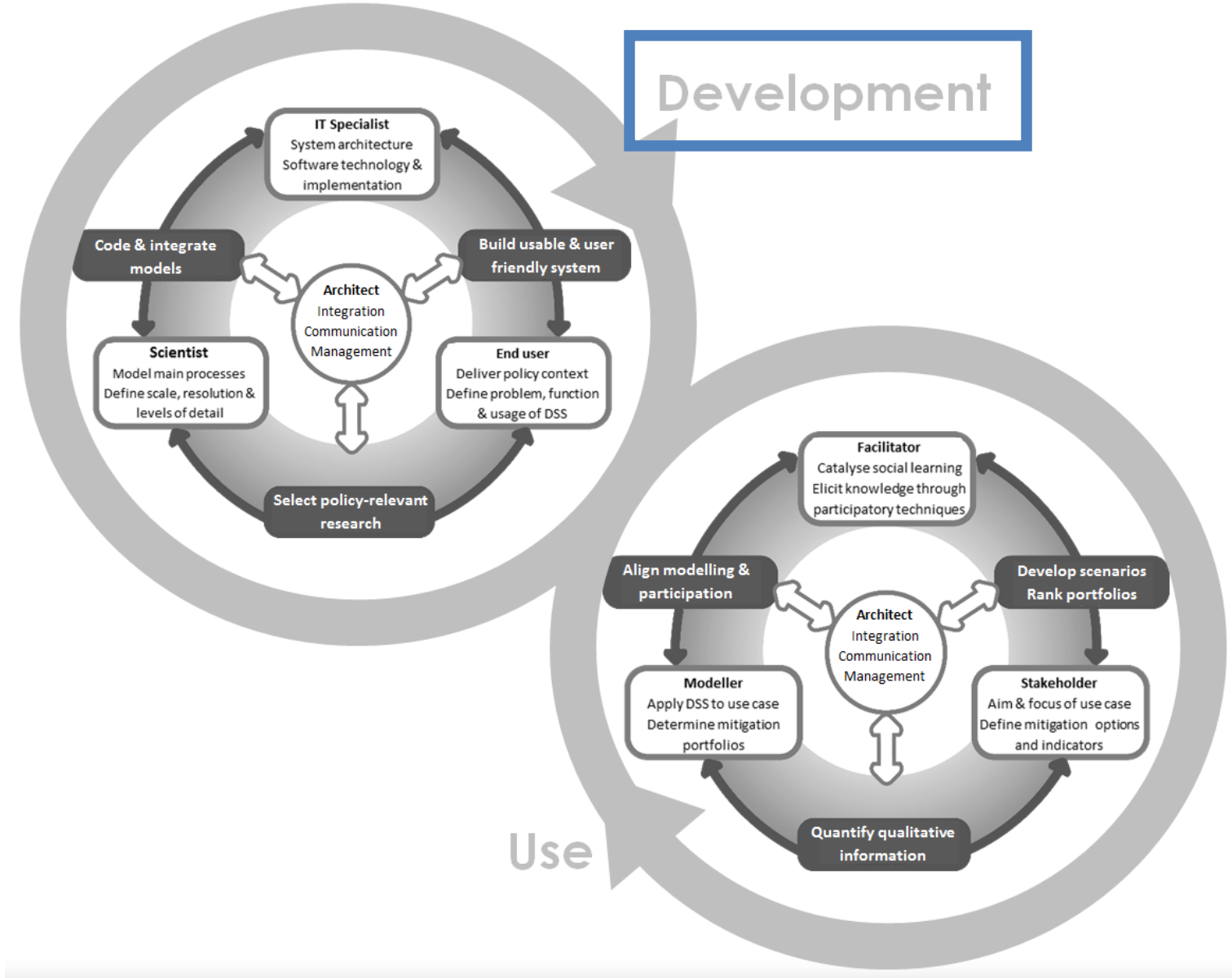
Modeller
Apply DSS to use case
Determine mitigation portfolios
Stakeholder
Aim & focus of use case
Define mitigation options and indicators
Quantify qualitative information

Process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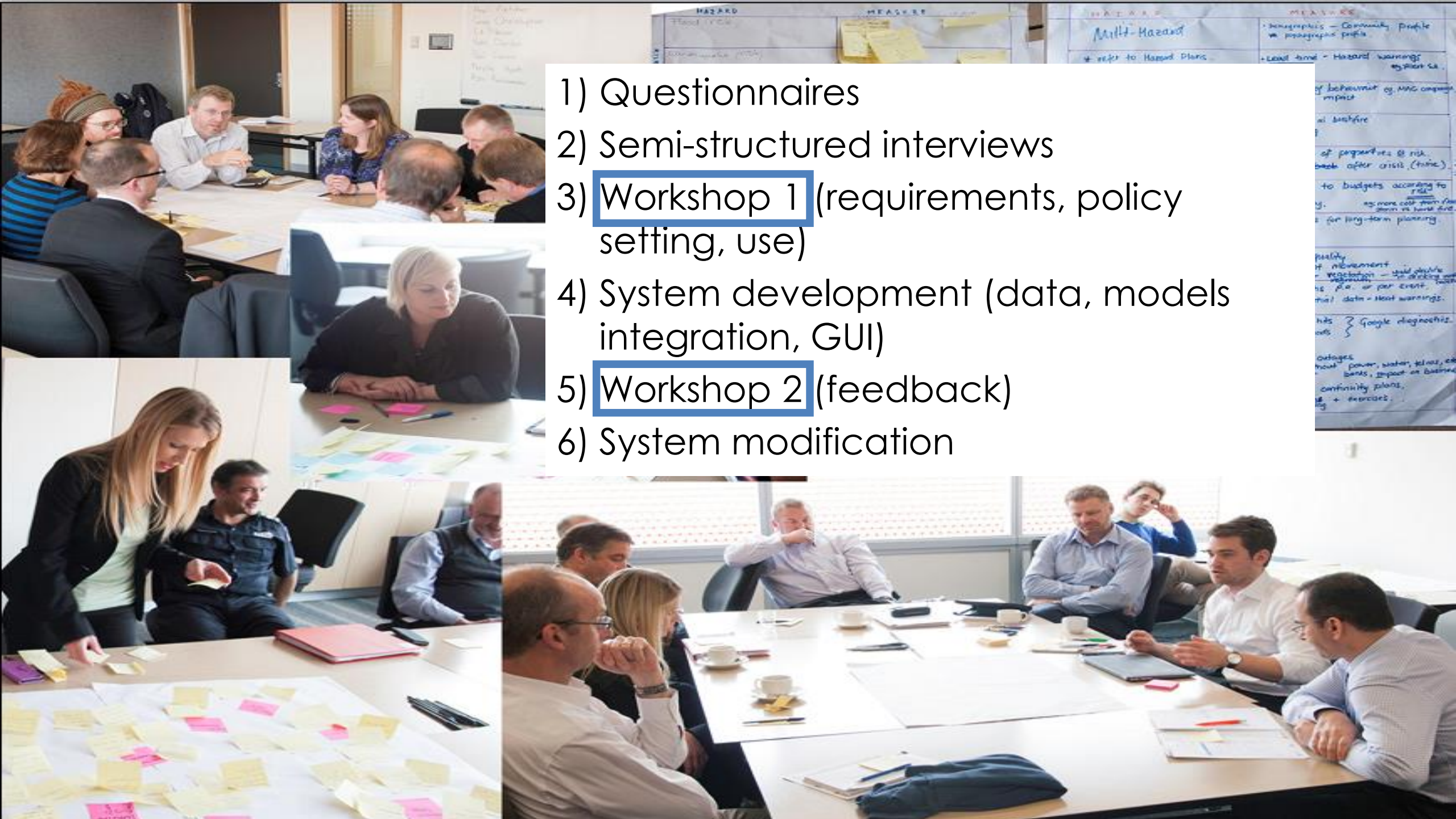
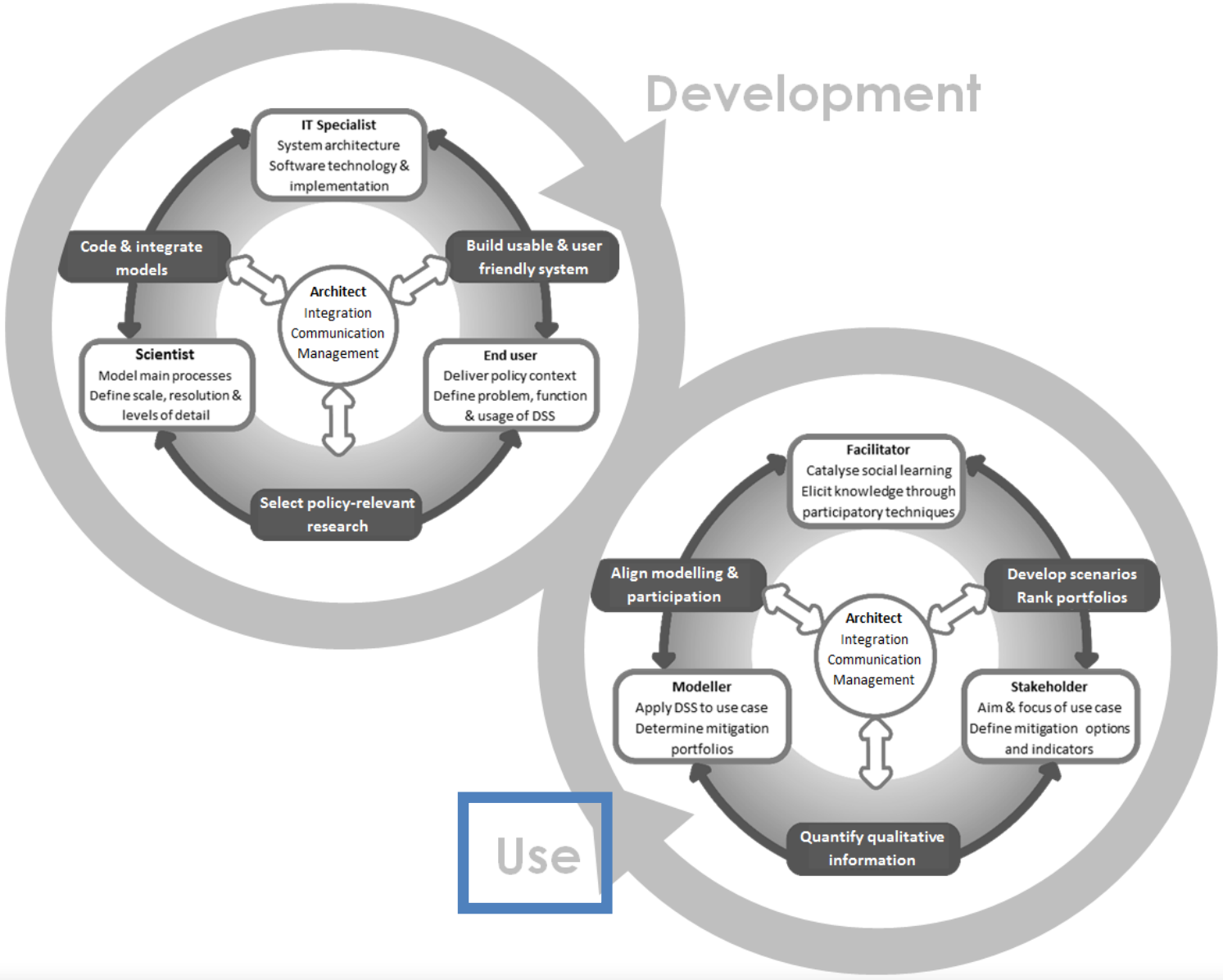


1) Questionnaires
2) Semi-structured interviews
3) Workshop 1 (requirements, policy setting, use)
4) System development (data, models integration, GUI)
5) Workshop 2 (feedback)
6) System modification

Process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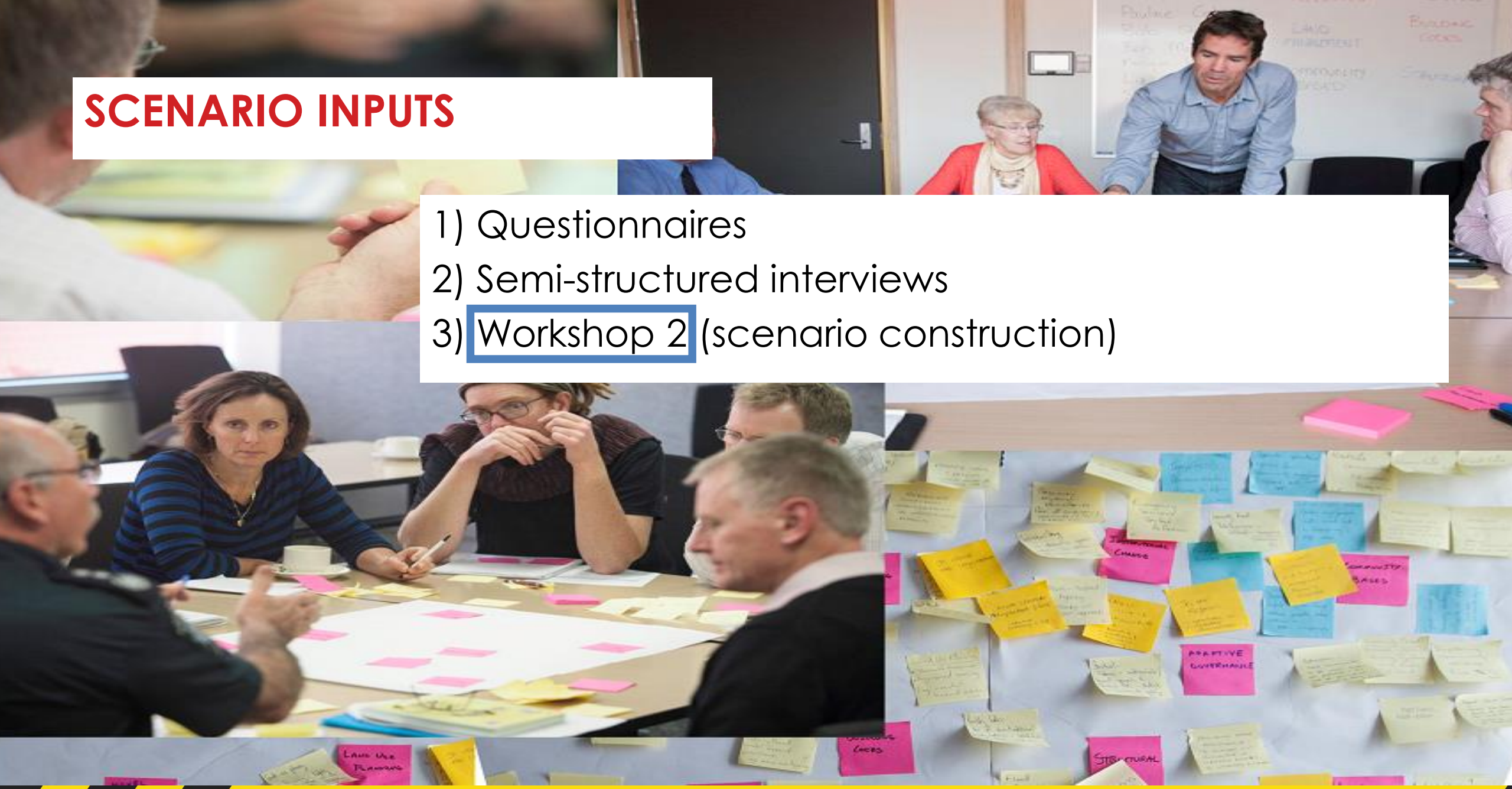
Quantify qualitative information
Use

SCENARIO INPUTS

1) Questionnaires
2) Semi-structured interviews
3) Workshop 2 (scenario construction)



SCENARIO OUTPUTS

1) Modelling of scenarios
2) Workshop 3 (scenario validity and outputs)

BENEFITS OF PROPOSED APPROACH

End users involved in:

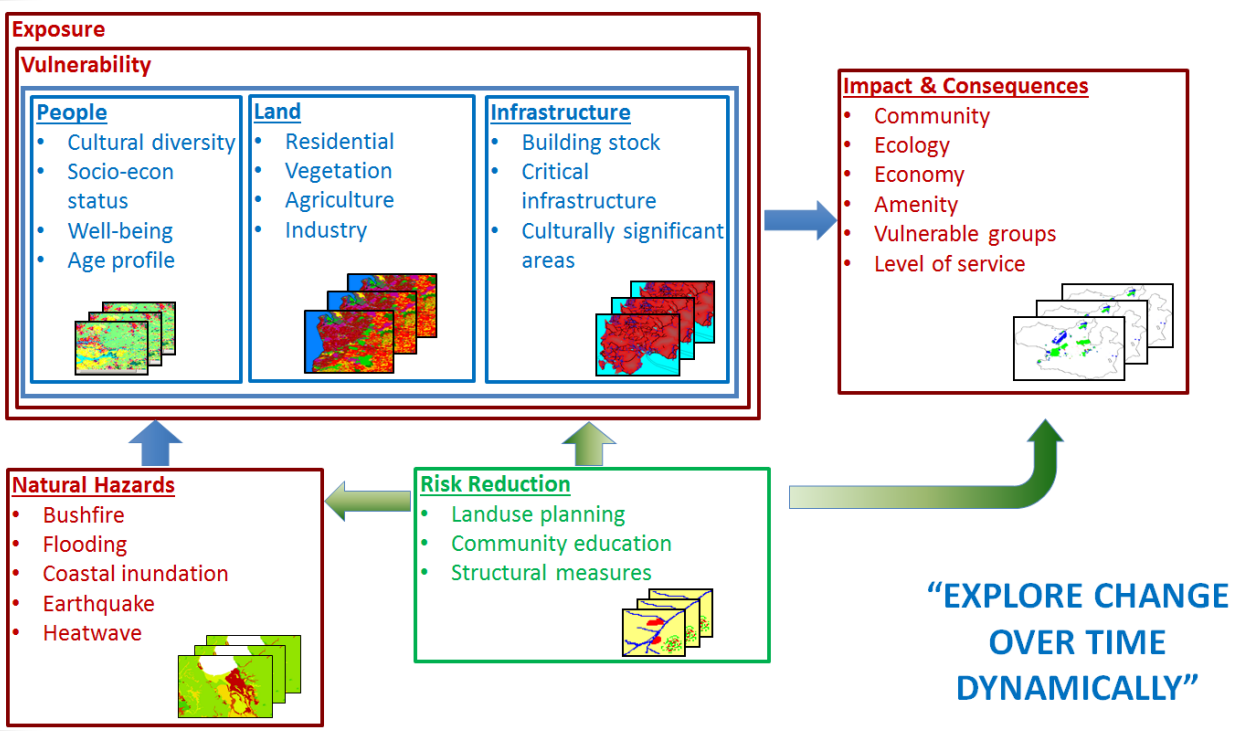
- Model development & selection
- User interface design
- Scenario development
- Policy assessment & planning

Social learning occurs when stakeholders, modellers and facilitators explore and evaluate policy options through group interaction with the DSS

Builds strategic capacity by exploring future risk profiles

Looks towards integration of system within organisations

BENEFITS OF PROPOSED APPROACH



- Flexibility / Customisation
  - Policy / risk-reduction options
  - Hazards (e.g. single- or multi-hazard)
  - Spatial extent
  - Temporal scale (e.g. short- or long-term)
  - Outputs / indicators

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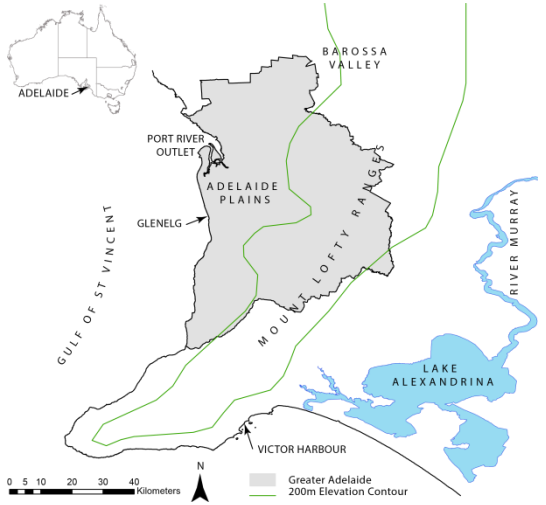
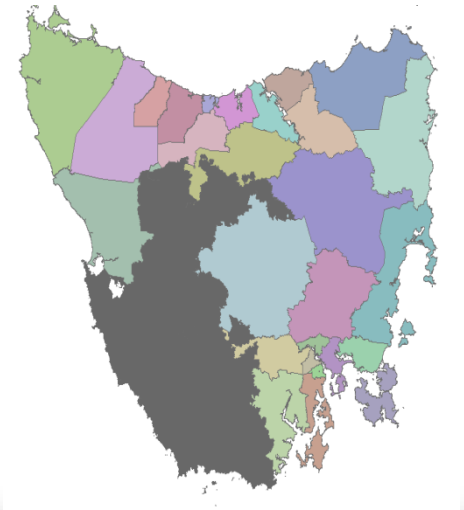
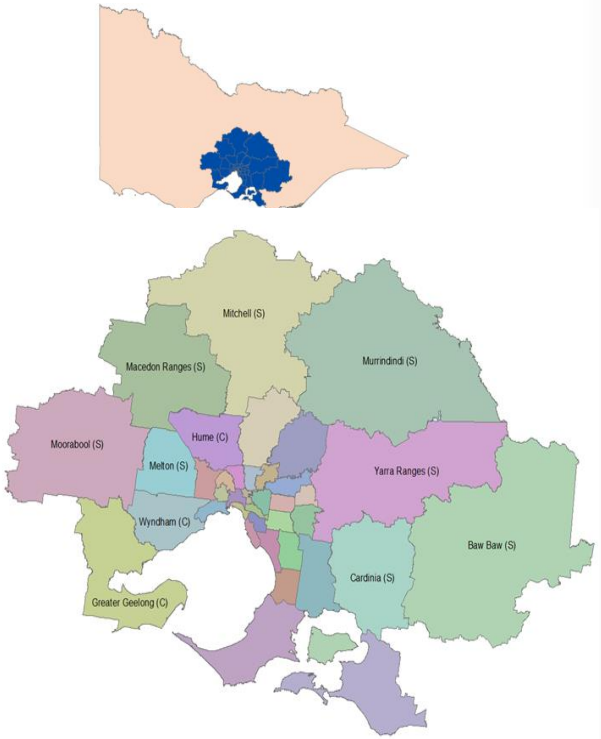
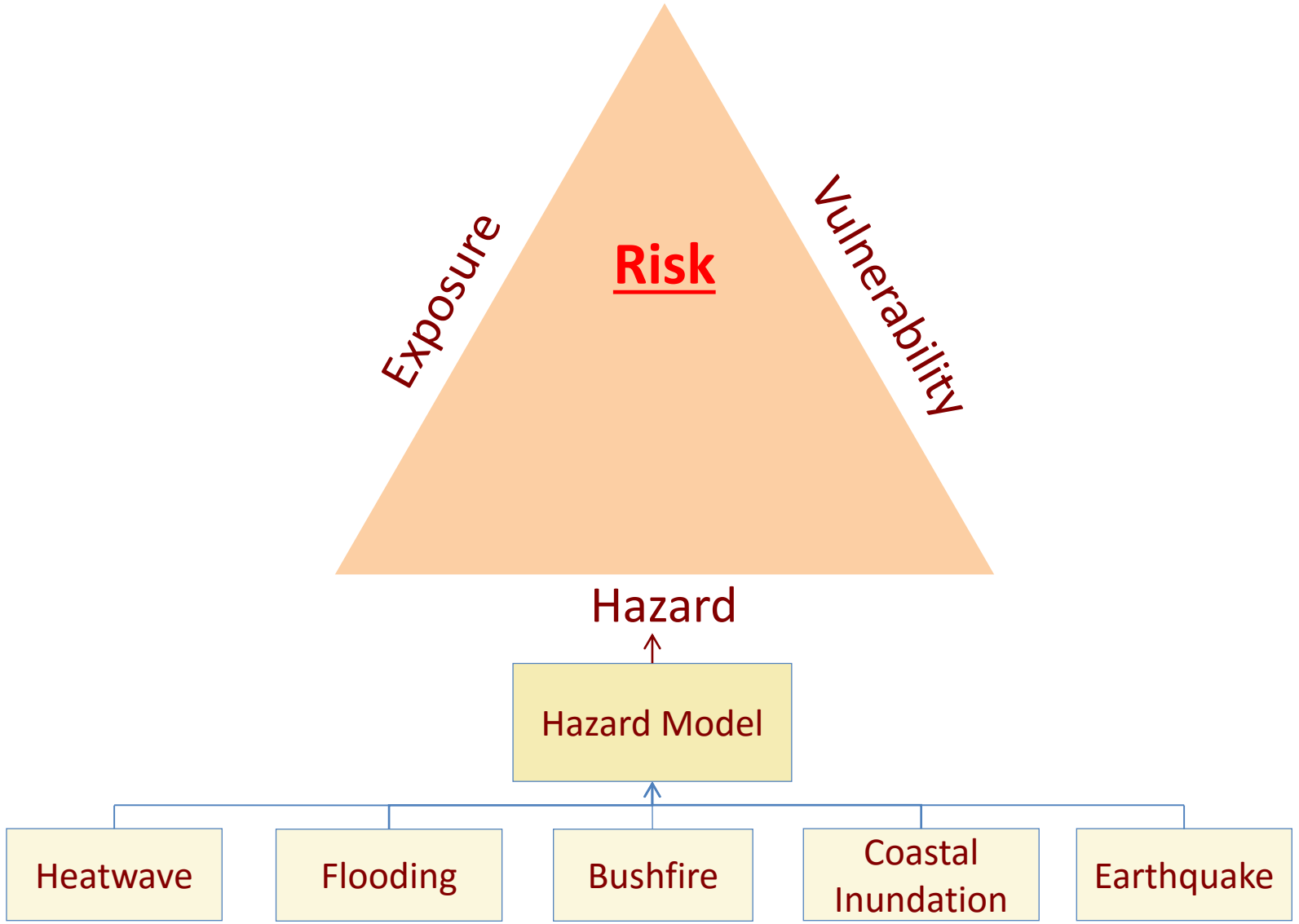
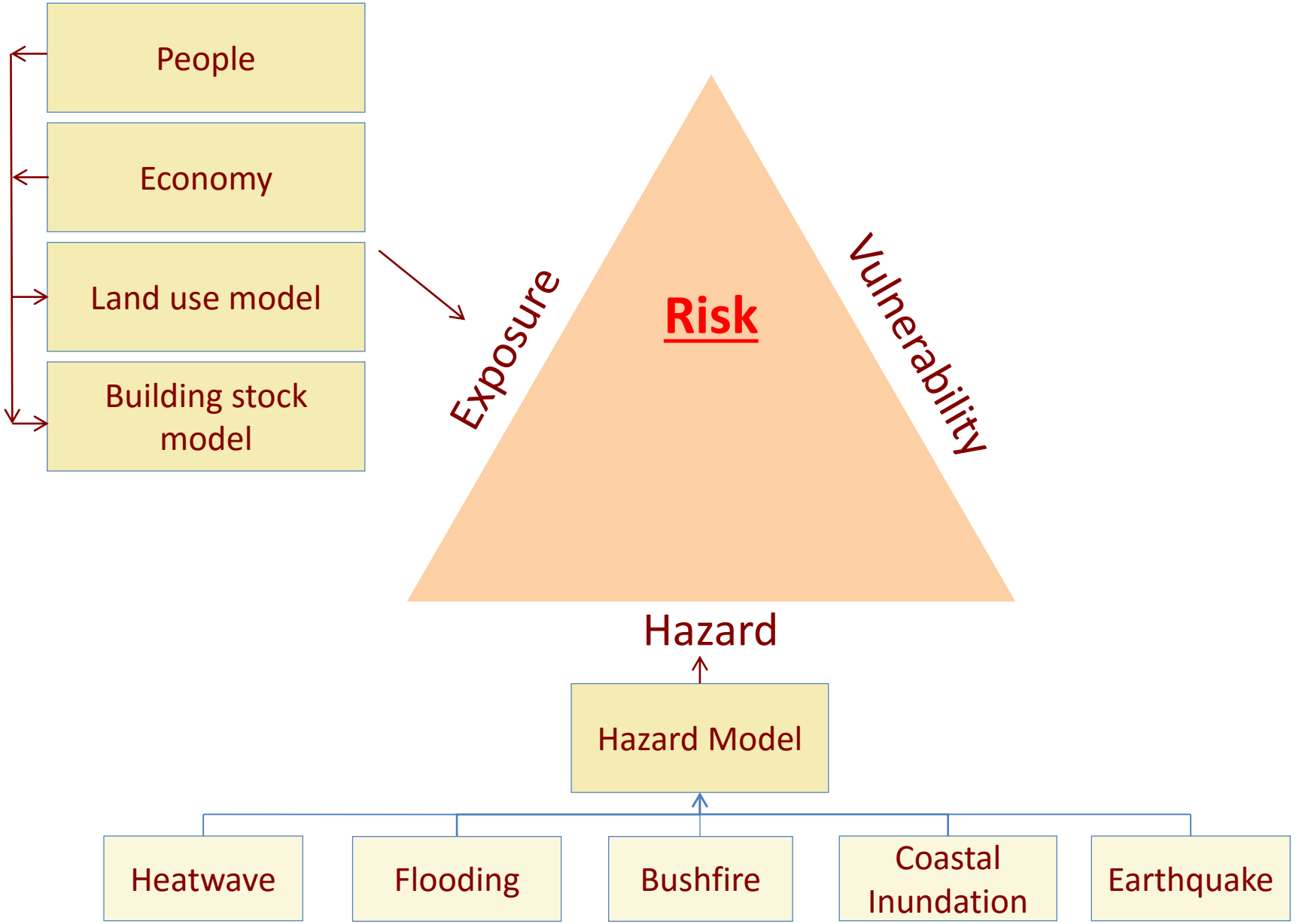







Exposure
Risk
Vulnerability
Hazard


Exposure
Risk
Vulnerability
Hazard
Hazard Model
Heatwave
Flooding
Bushfire
Coastal Inundation
Earthquake


People
Economy
Land use model
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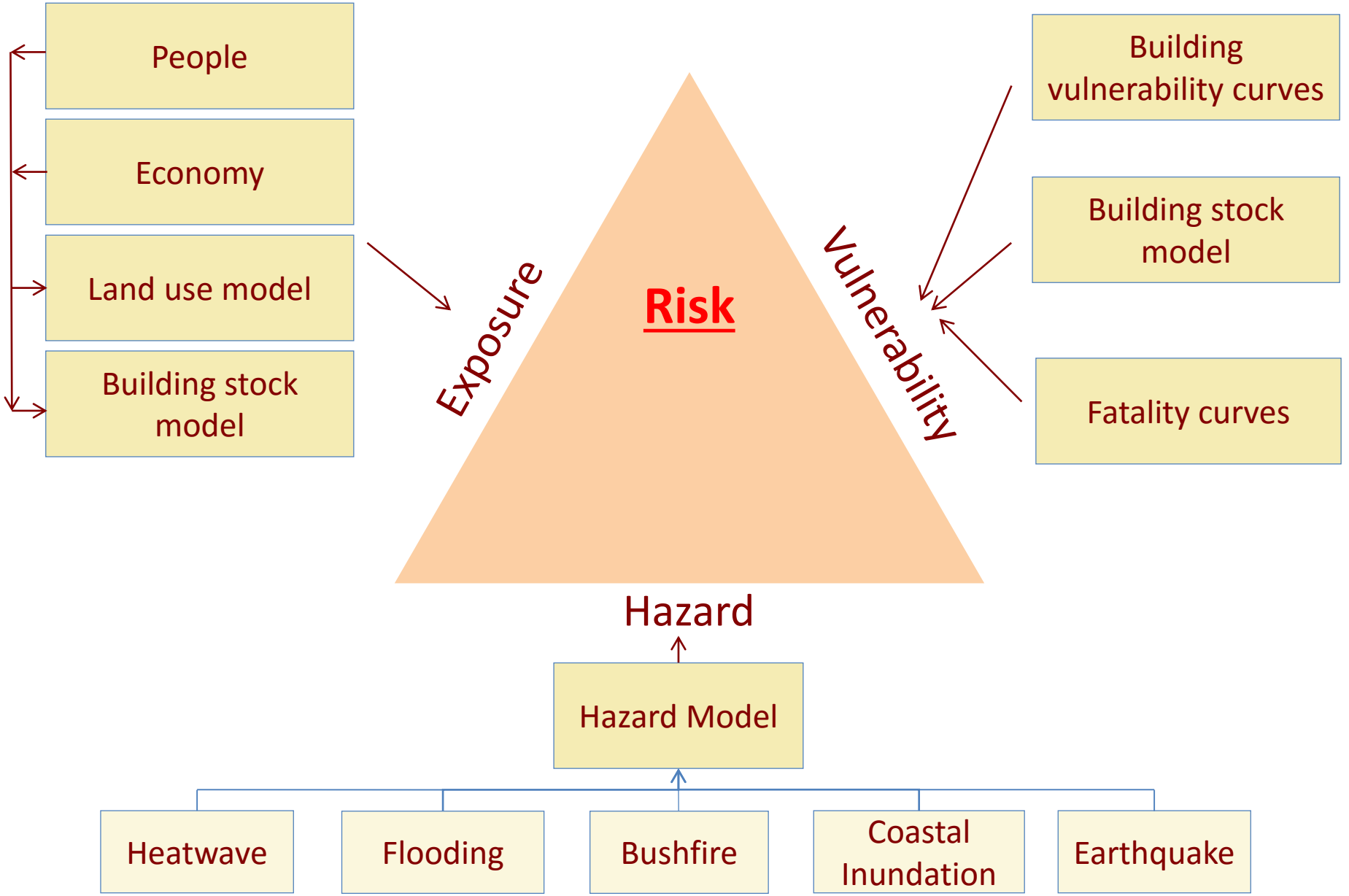
People
Economy
Land use model
Building stock model
Exposure
Risk
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Building vulnerability curves
Building stock model
Fatality curves
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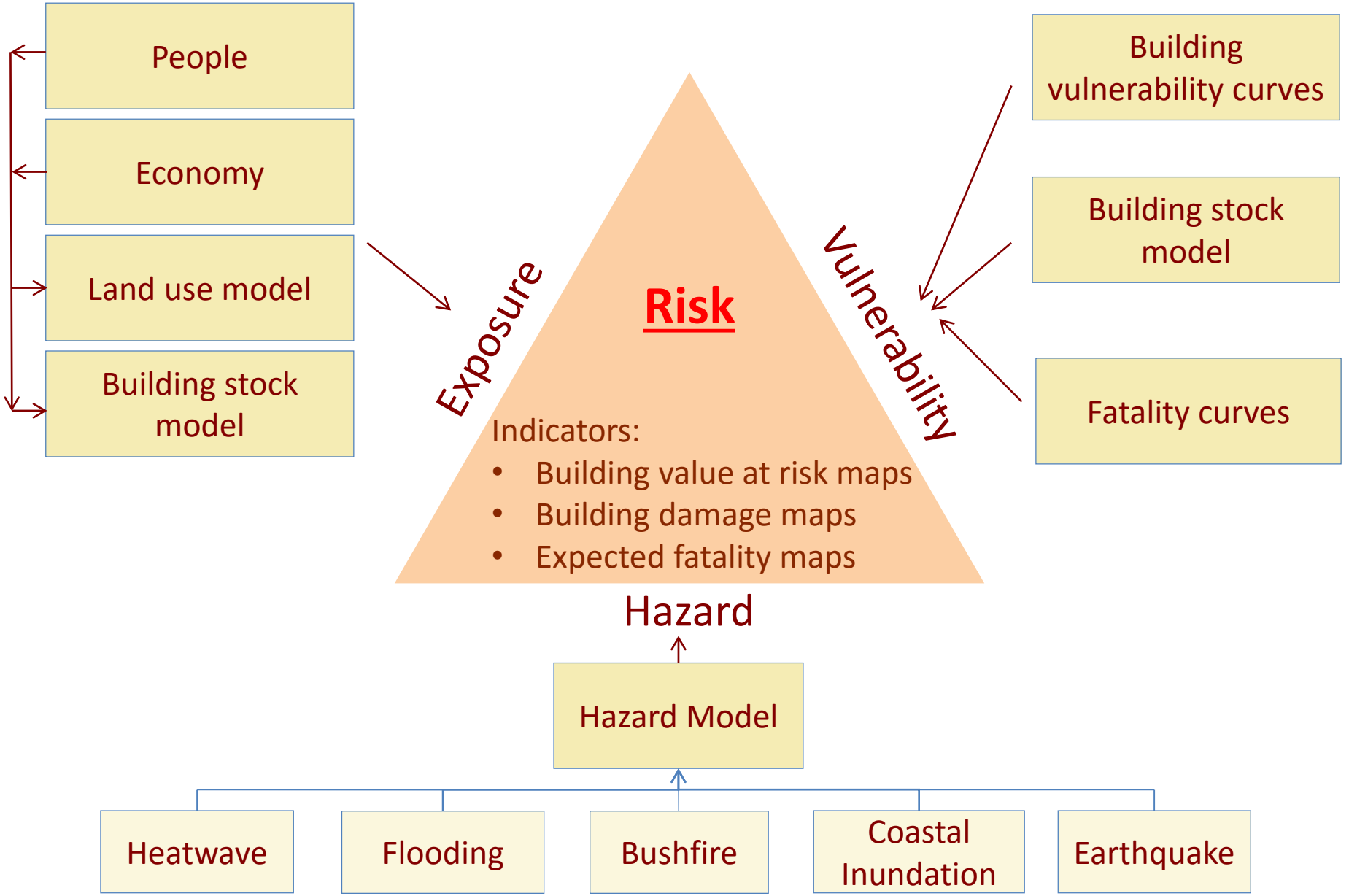
People
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Building stock model
Exposure
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Vulnerability
Indicators:
• Building value at risk maps
• Building damage maps
• Expected fatality maps
Building vulnerability curves
Building stock model
Fatality curves
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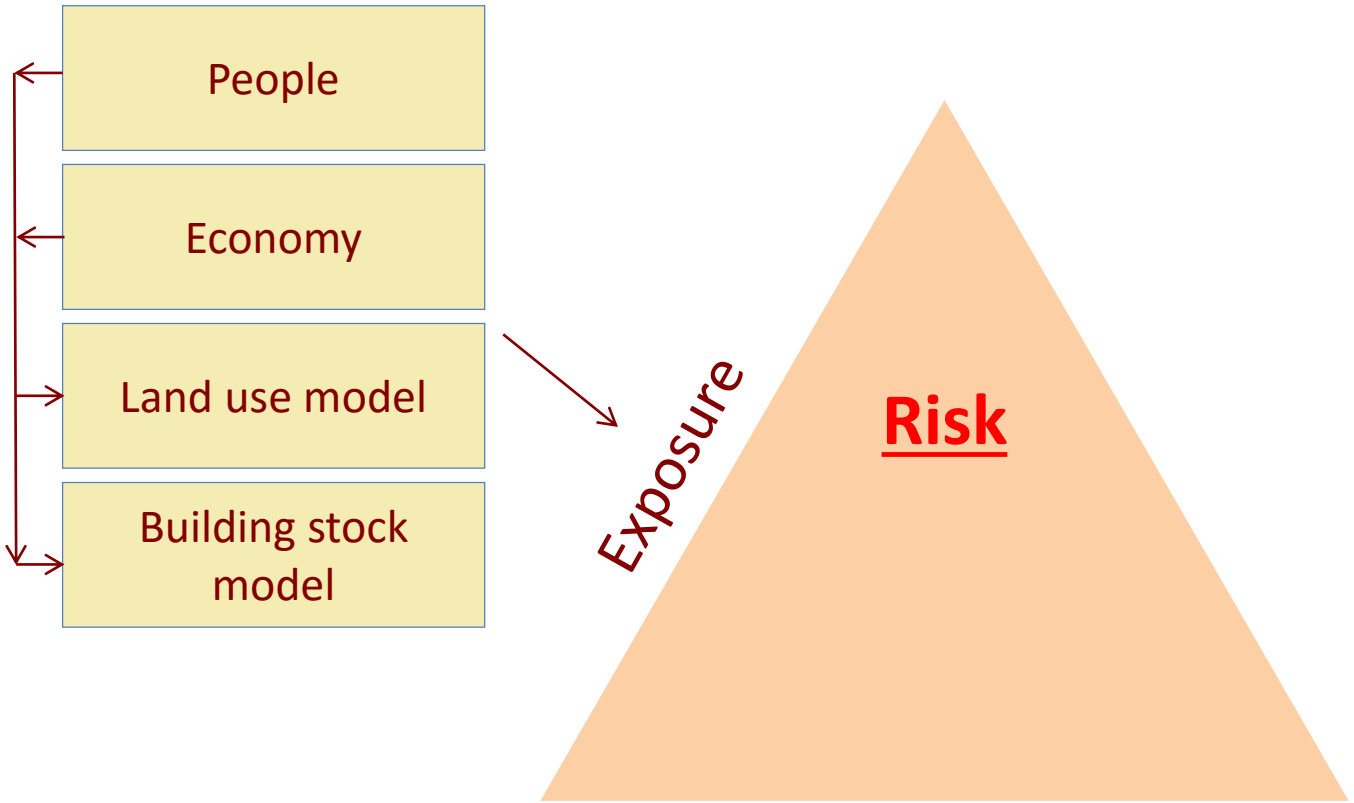
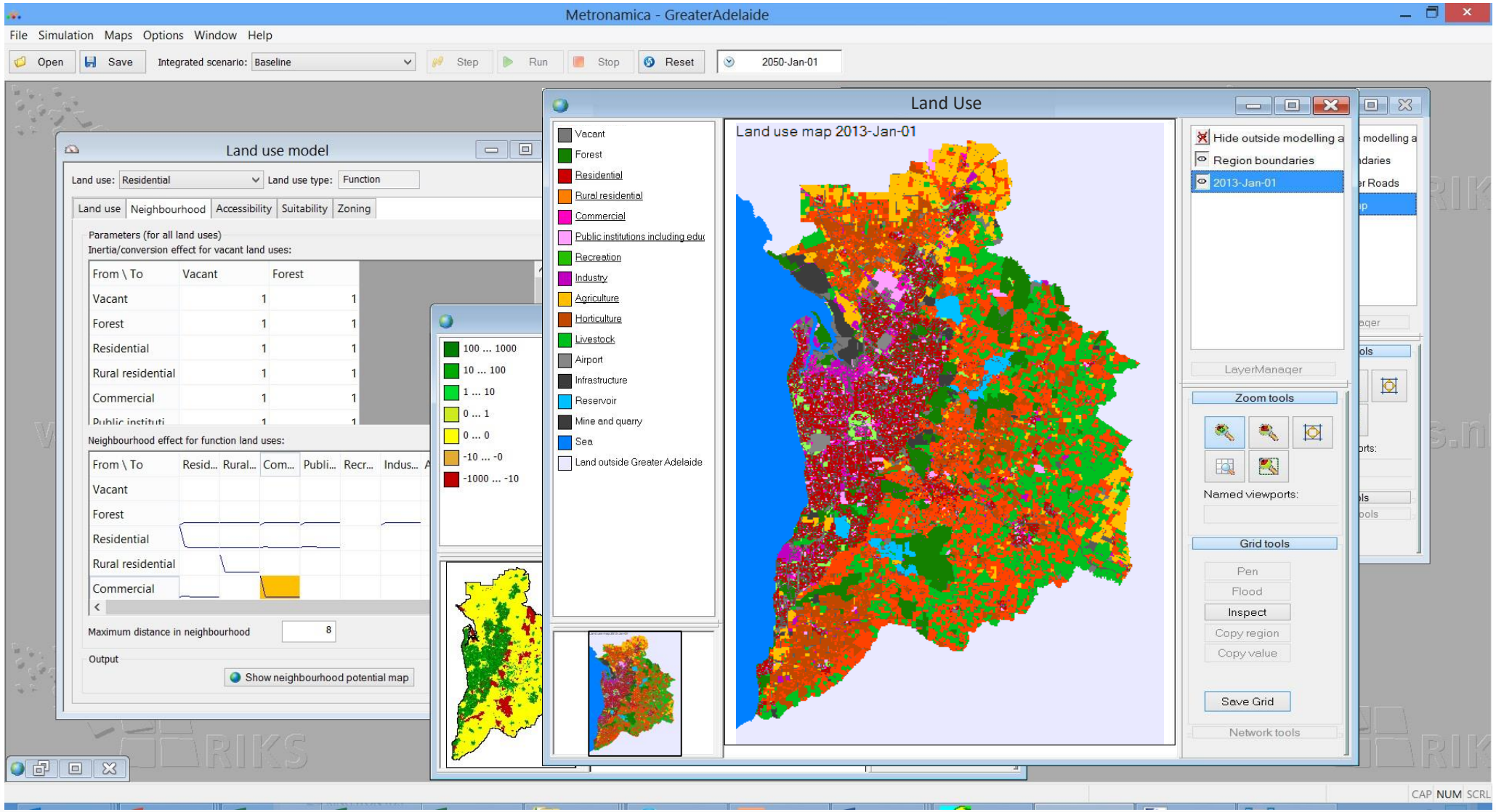
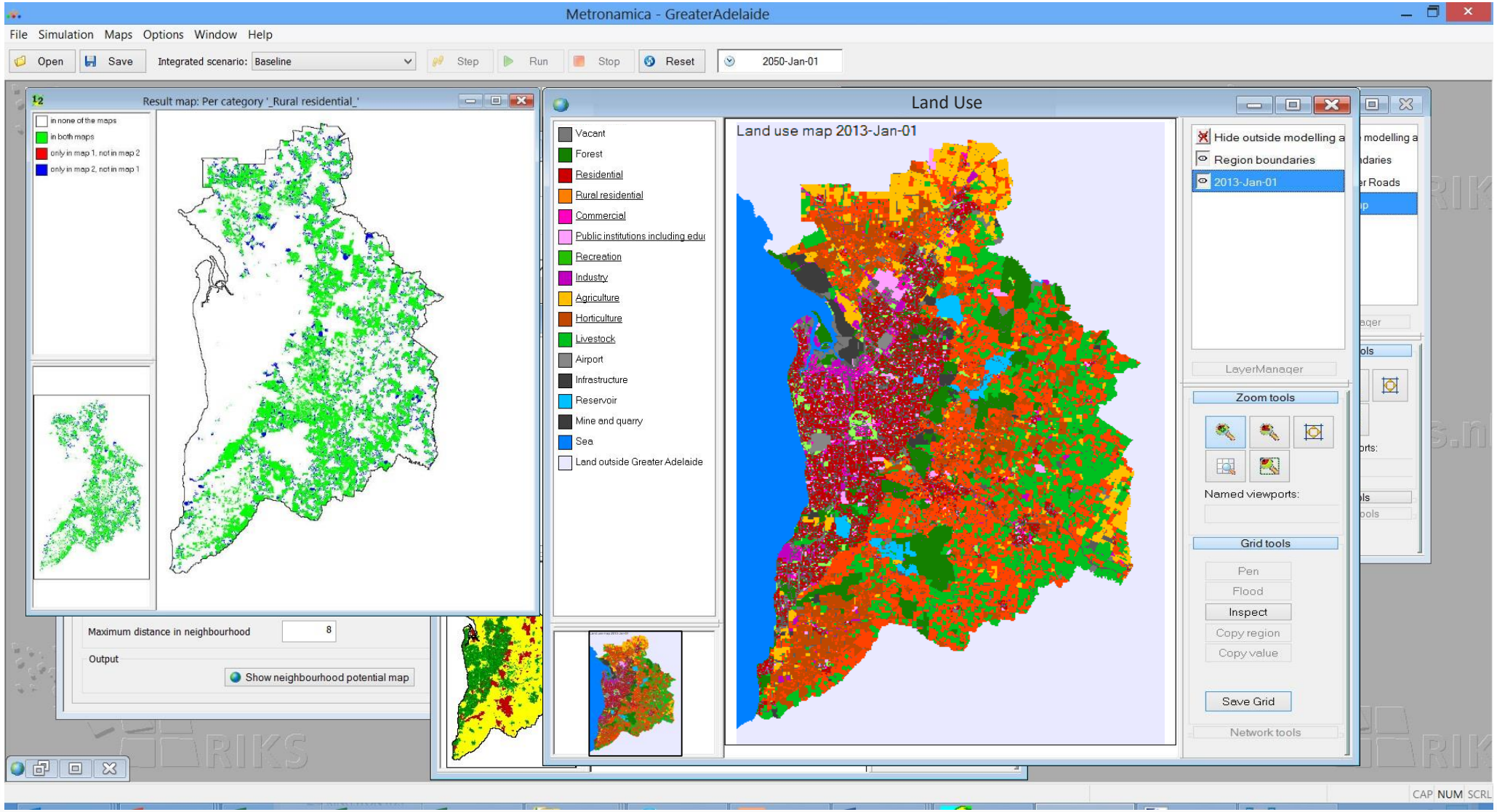
DYNAMIC EXPOSURE MODELLING



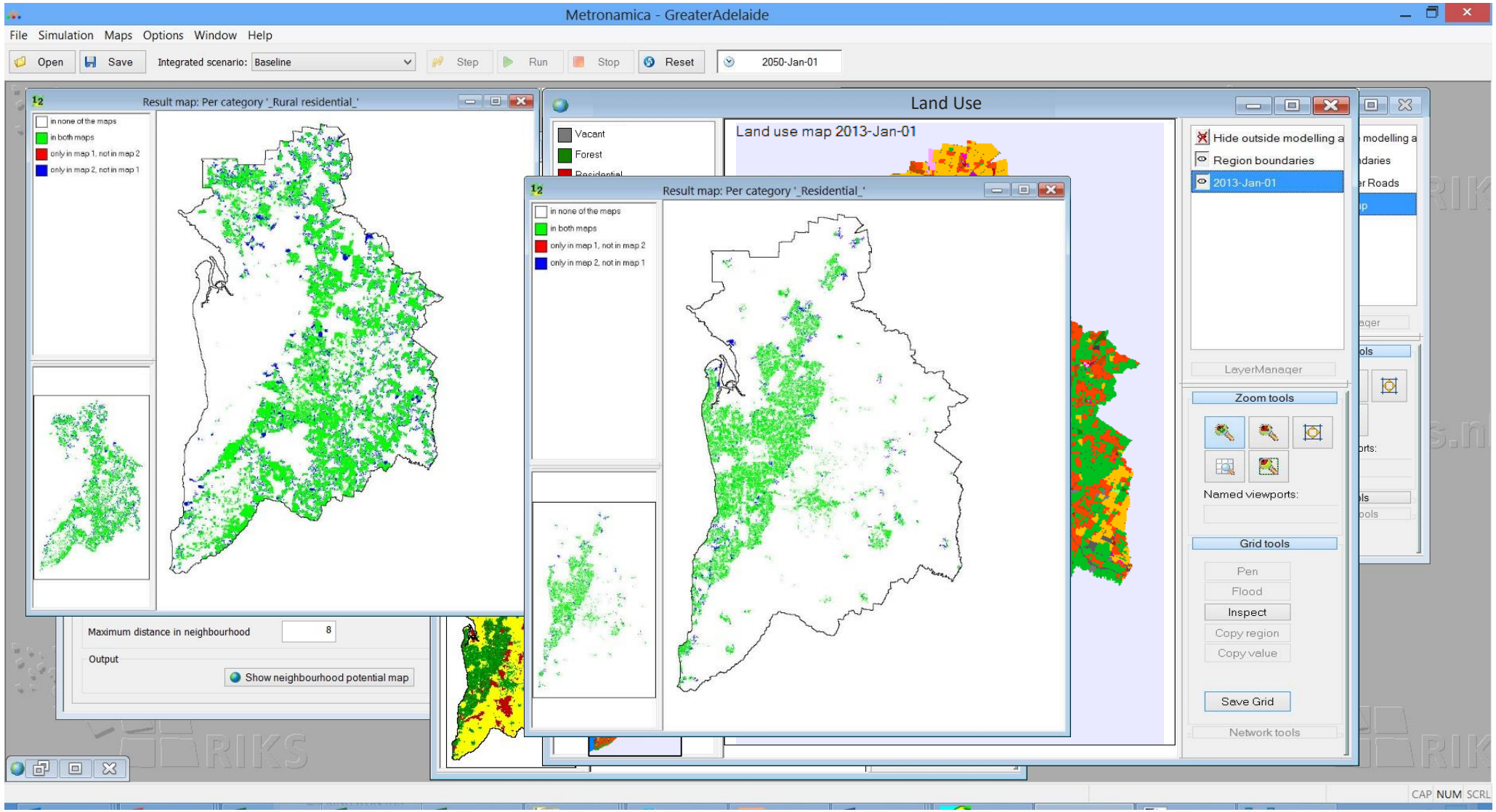
GREATER ADELAIDE LANDUSE MODEL



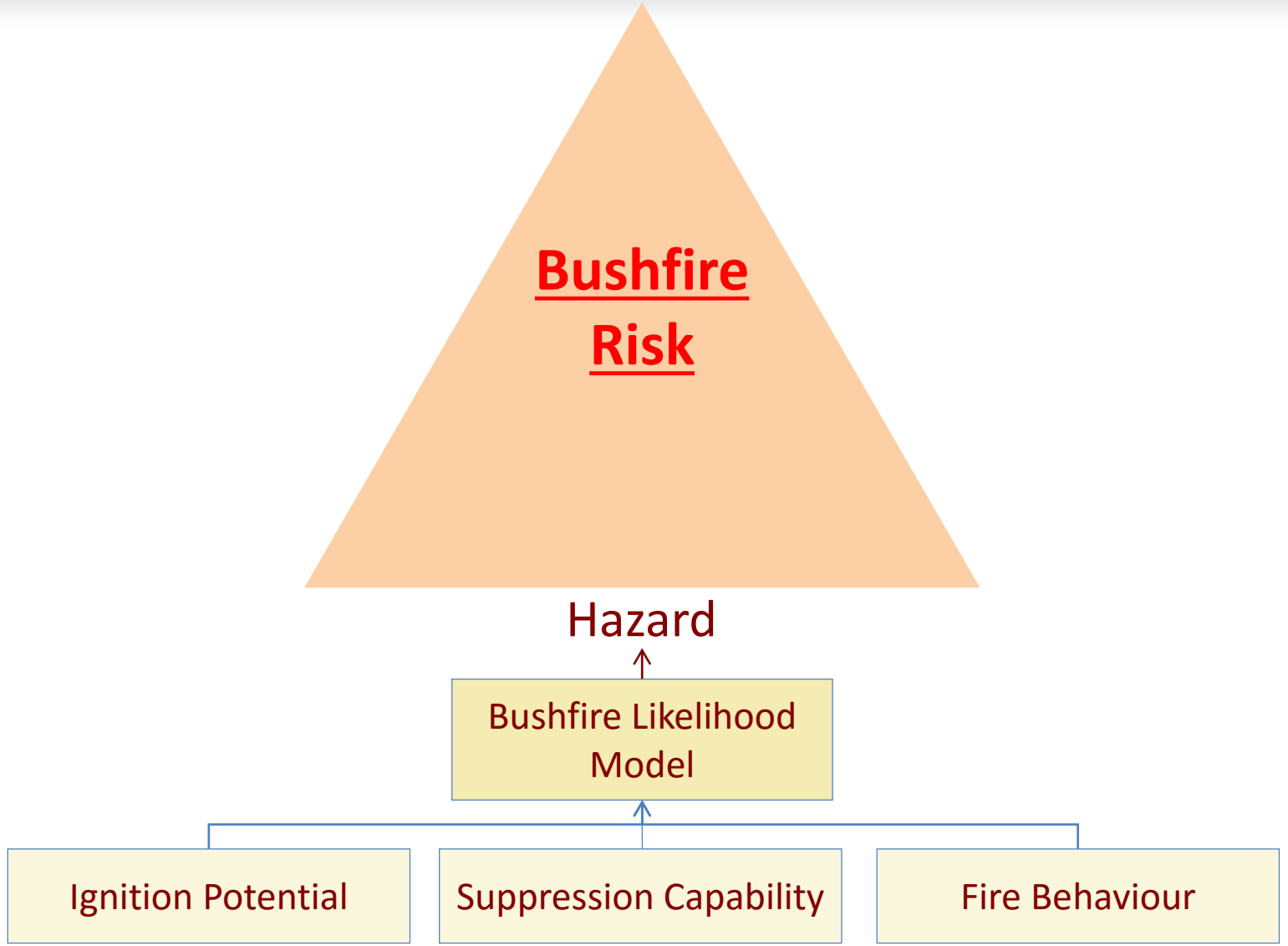
GREATER ADELAIDE LANDUSE MODEL



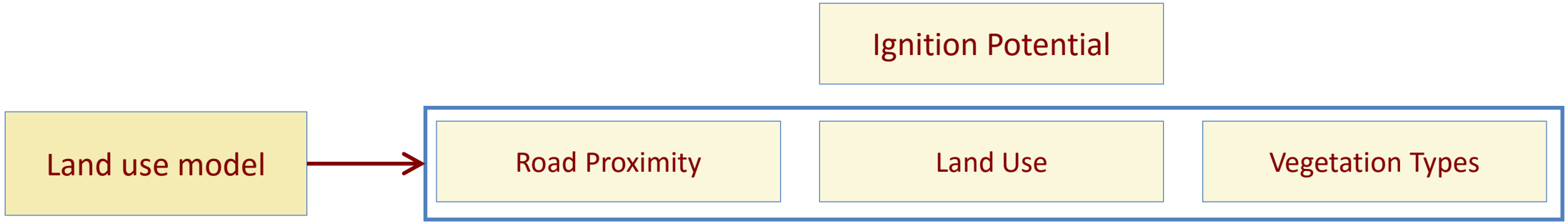
GREATER ADELAIDE LANDUSE MODEL



HAZARD MODELLING



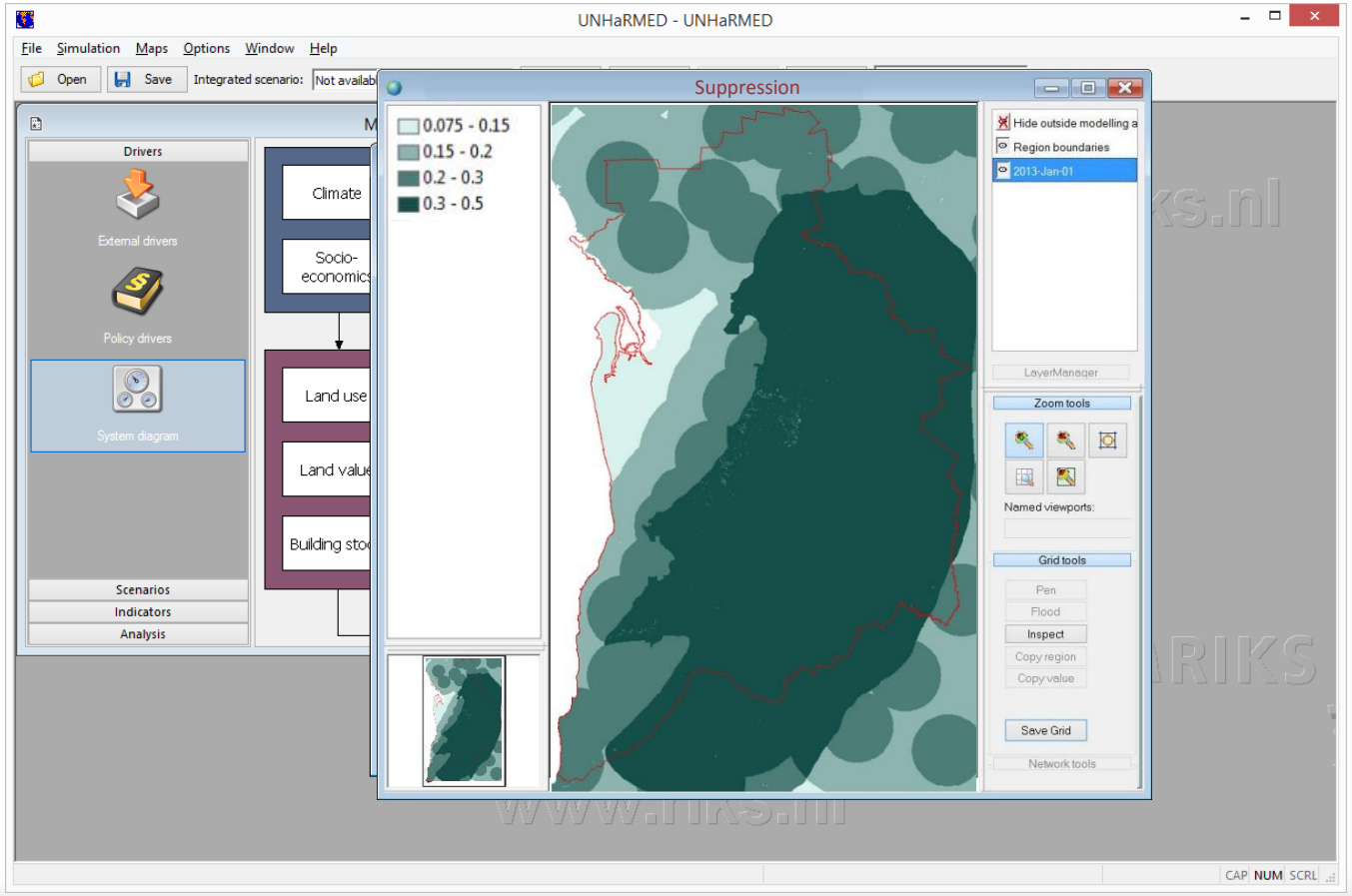
IGNITION POTENTIAL



SUPPRESSION

Probability map of the initial attack being successful - higher values indicate greater suppression capability

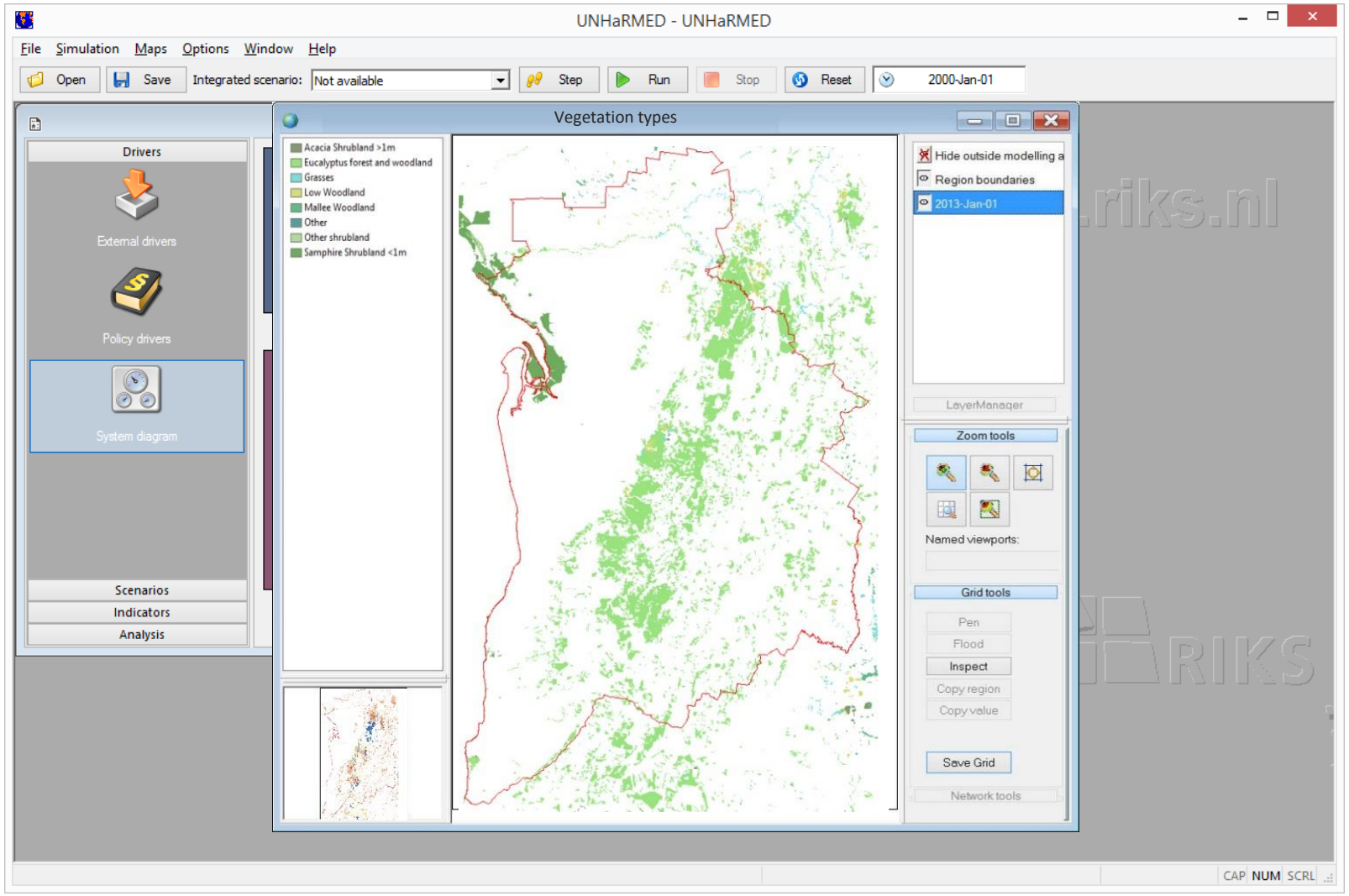
- Aircraft response time (location, priority response zones)
- Brigade response time (location, road network)
- Accessibility (slope, rockiness)
- Detection (population density, tower locations, road proximity)



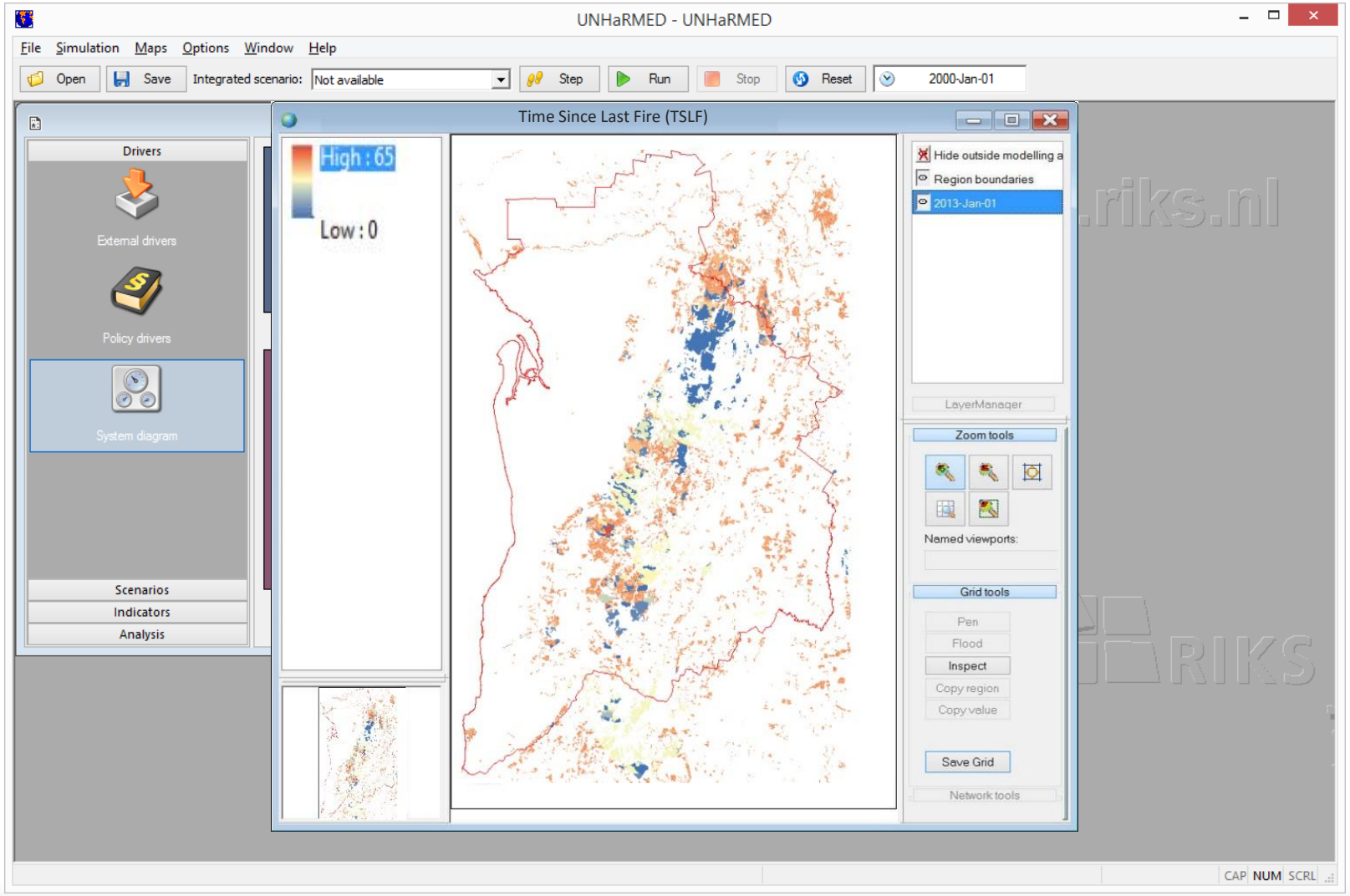
FIRE BEHAVIOUR

- Expressed in energy intensity per cell (kW/m)
-
- Grassland intensity
  - Heat of Combustion
  - Fuel Load
  - Rate of Spread
- Woodland intensity
  - Forest Fire Danger Index (FFDI)
  - Fuel Load
  - Rate of Spread
- Climatic variables (T_{95}, RH) linked to climate change scenarios
- Fire path (based on outputs from Phoenix model runs)

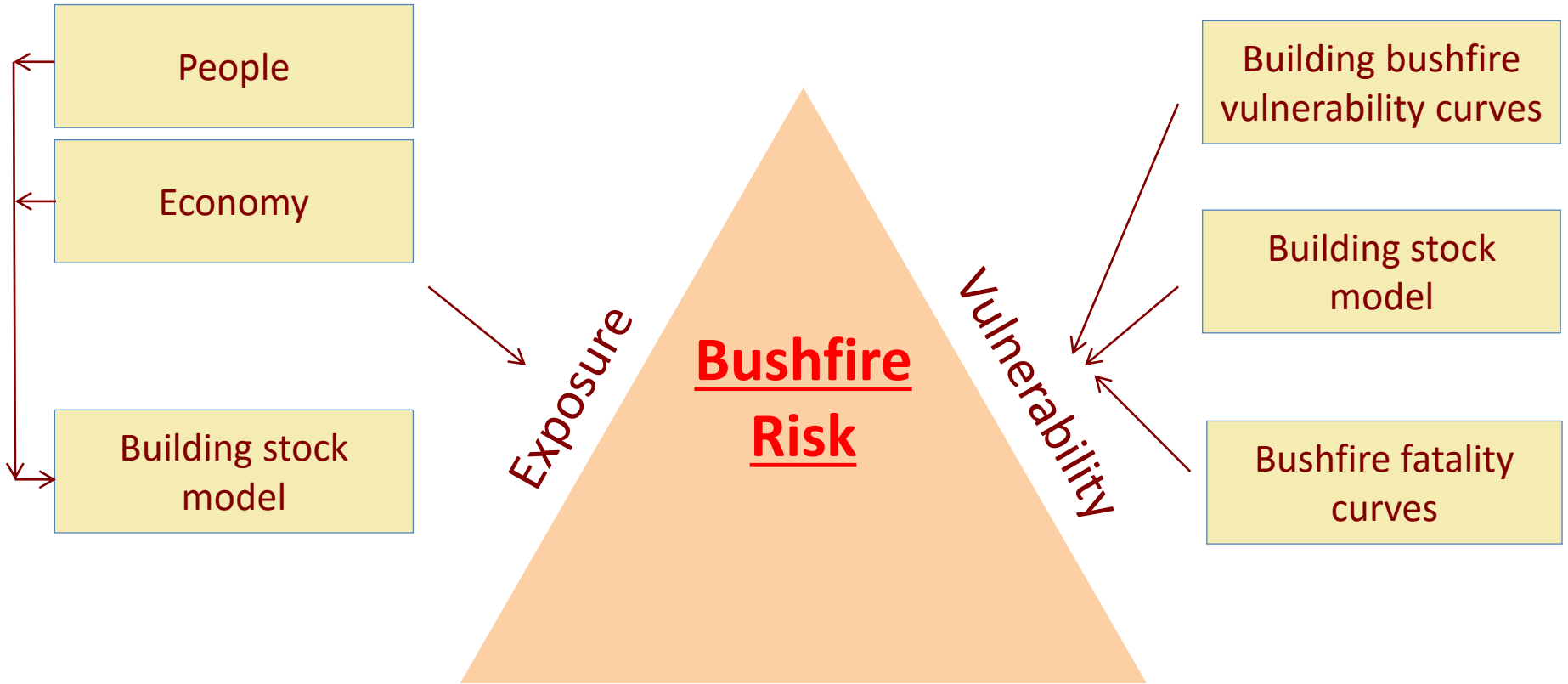
MODELLER INTERFACE BUSHFIRE



MODELLER INTERFACE BUSHFIRE



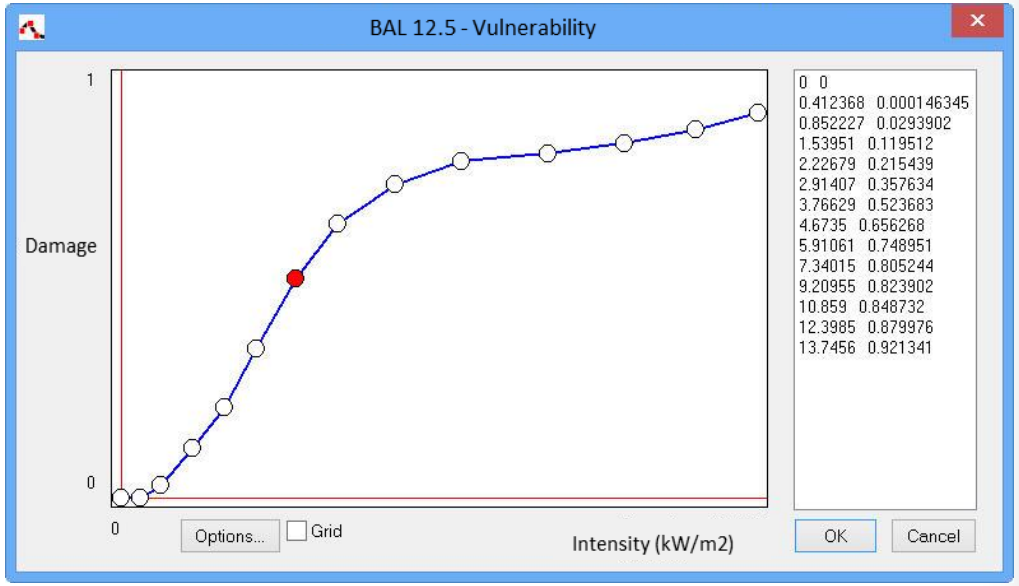
BUILDING STOCK & VULNERABILITY



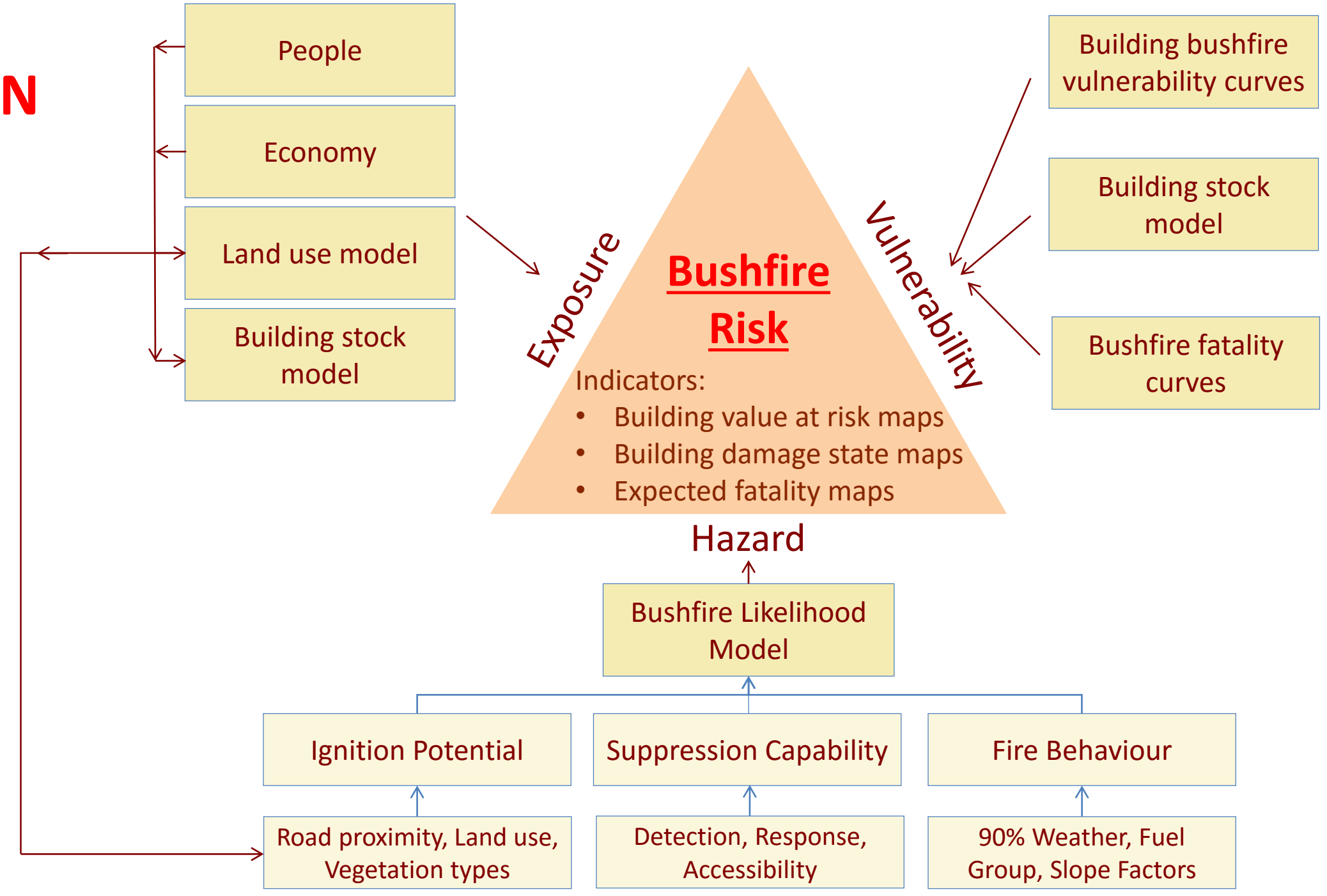
BUILDING STOCK & VULNERABILITY

- Building age from Geoscience Australia's NEXIS database

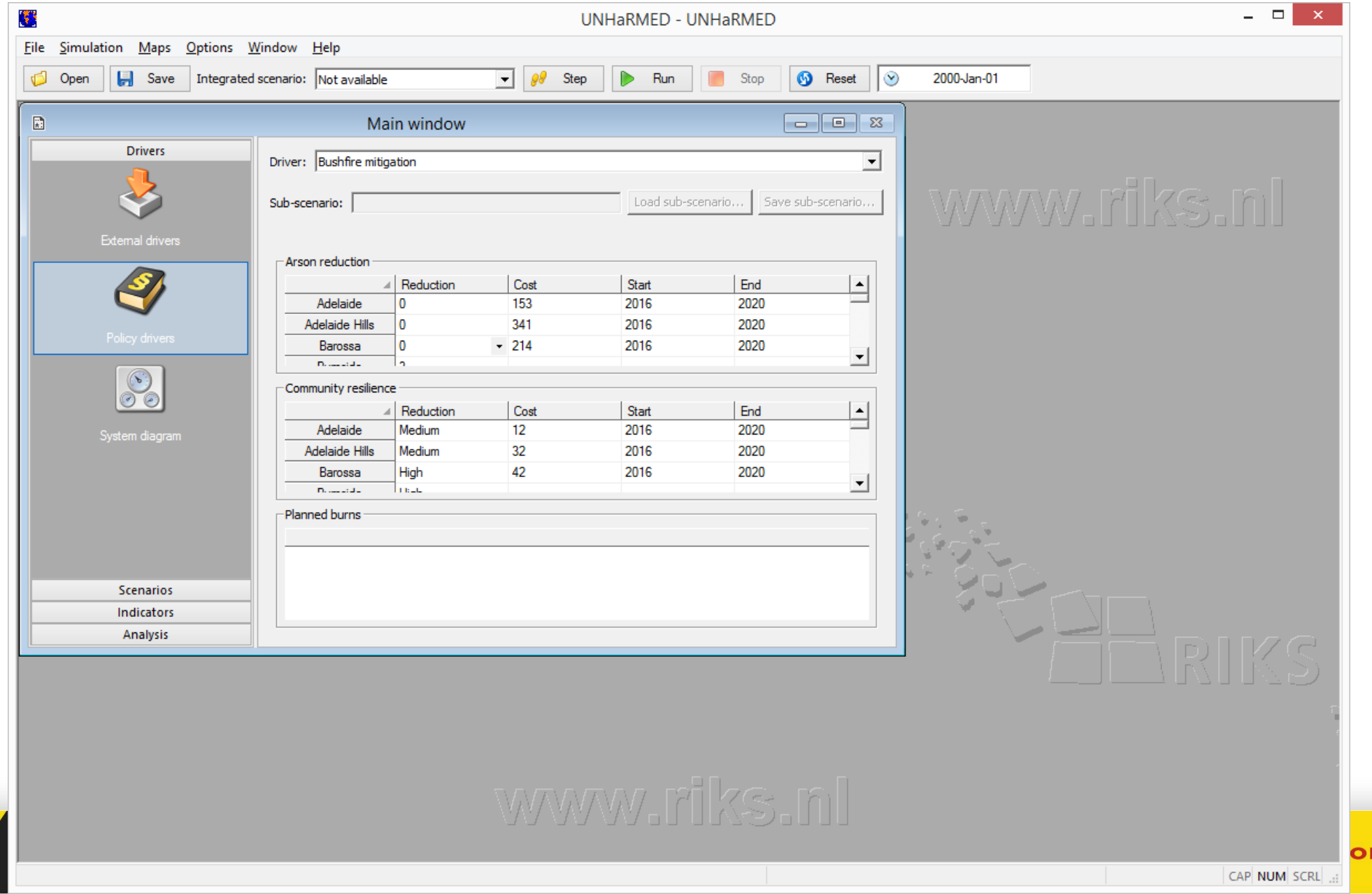
- Building vulnerability:
  - Assumed built to AS 3959 – 2009 and appropriate BAL for estimated intensity after 1980
  - Can be edited and customised by modeller
  - Ember attack (based on outputs from Phoenix model runs)



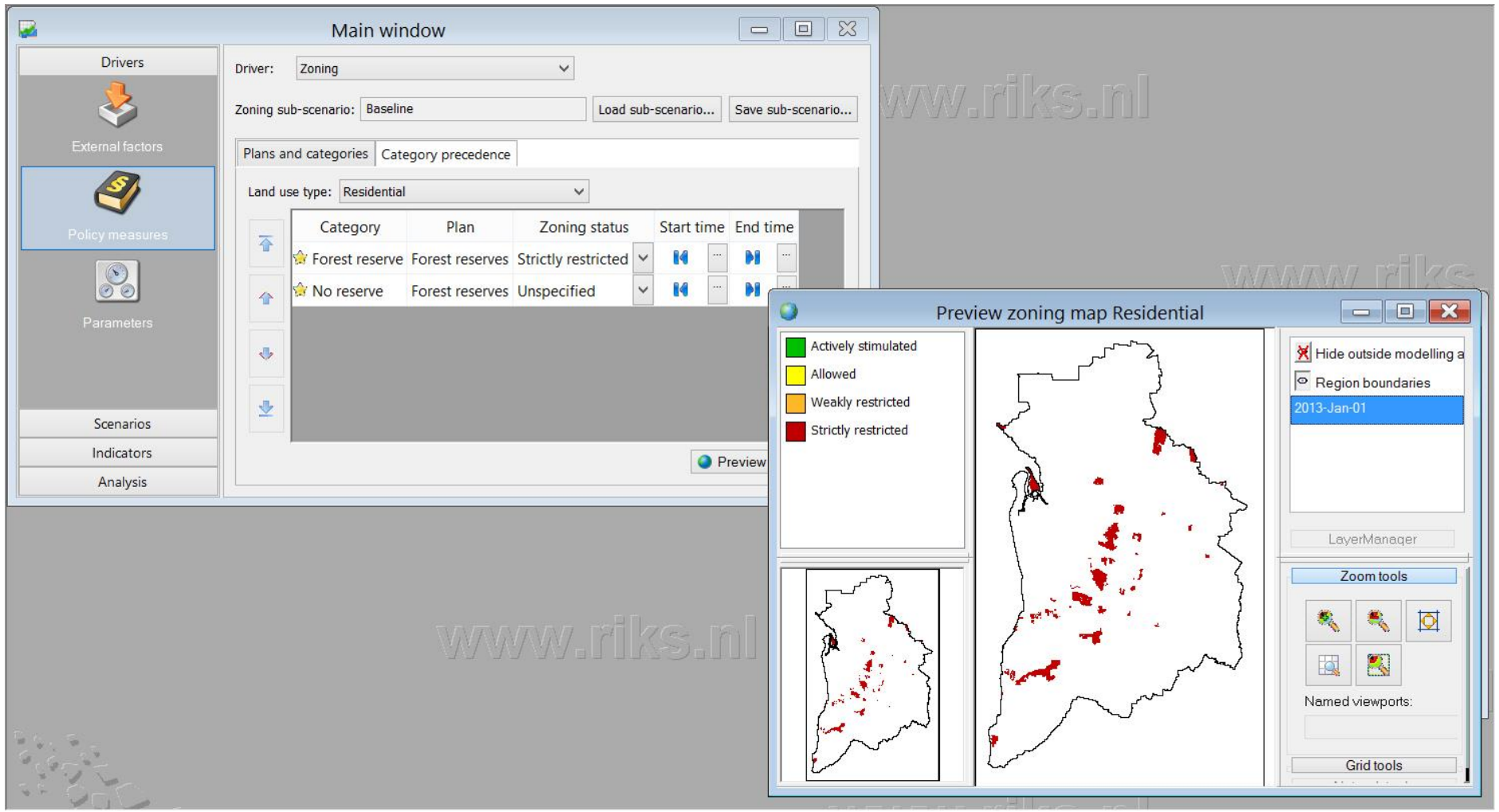
RISK REDUCTION



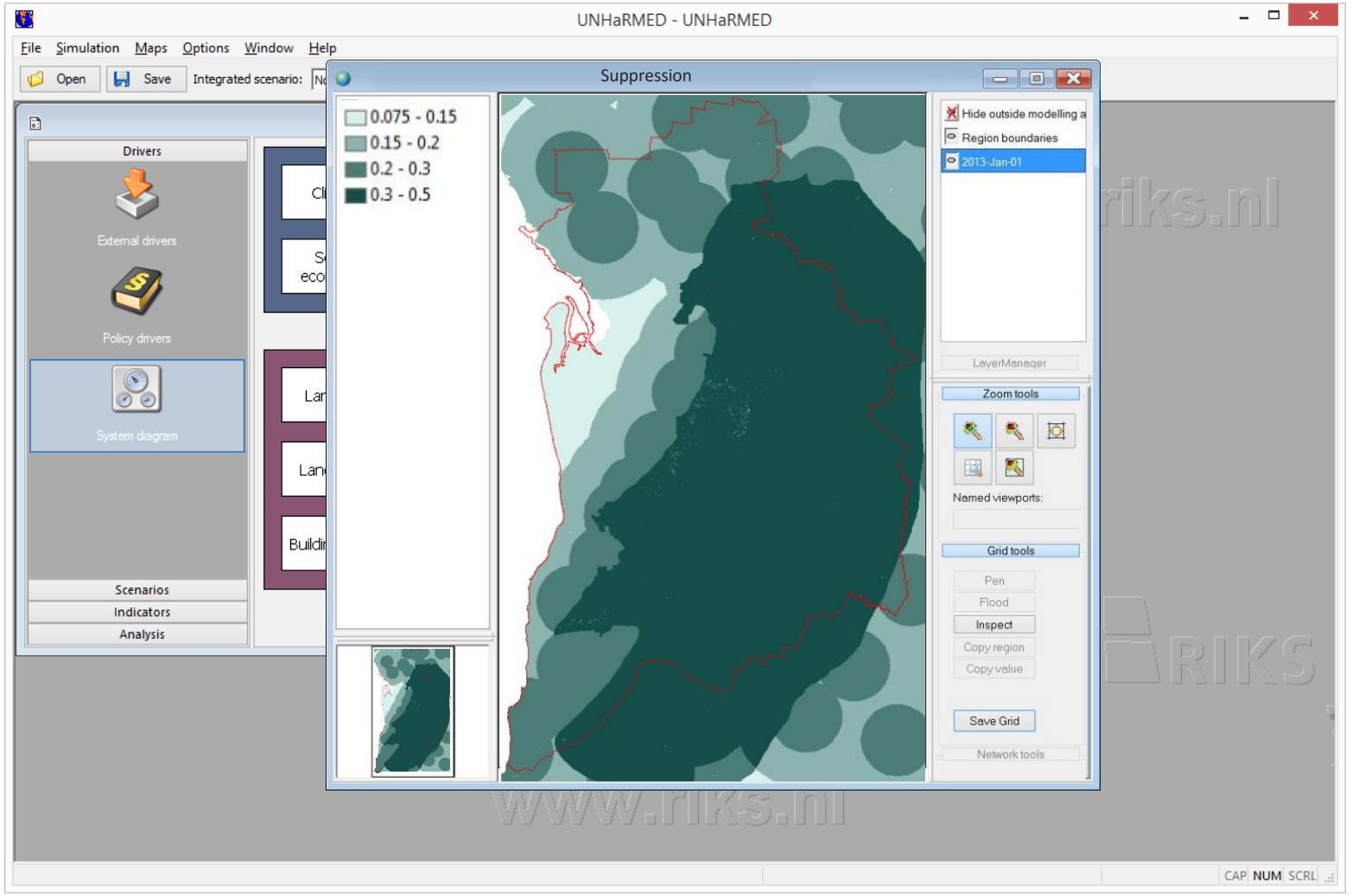
RISK REDUCTION



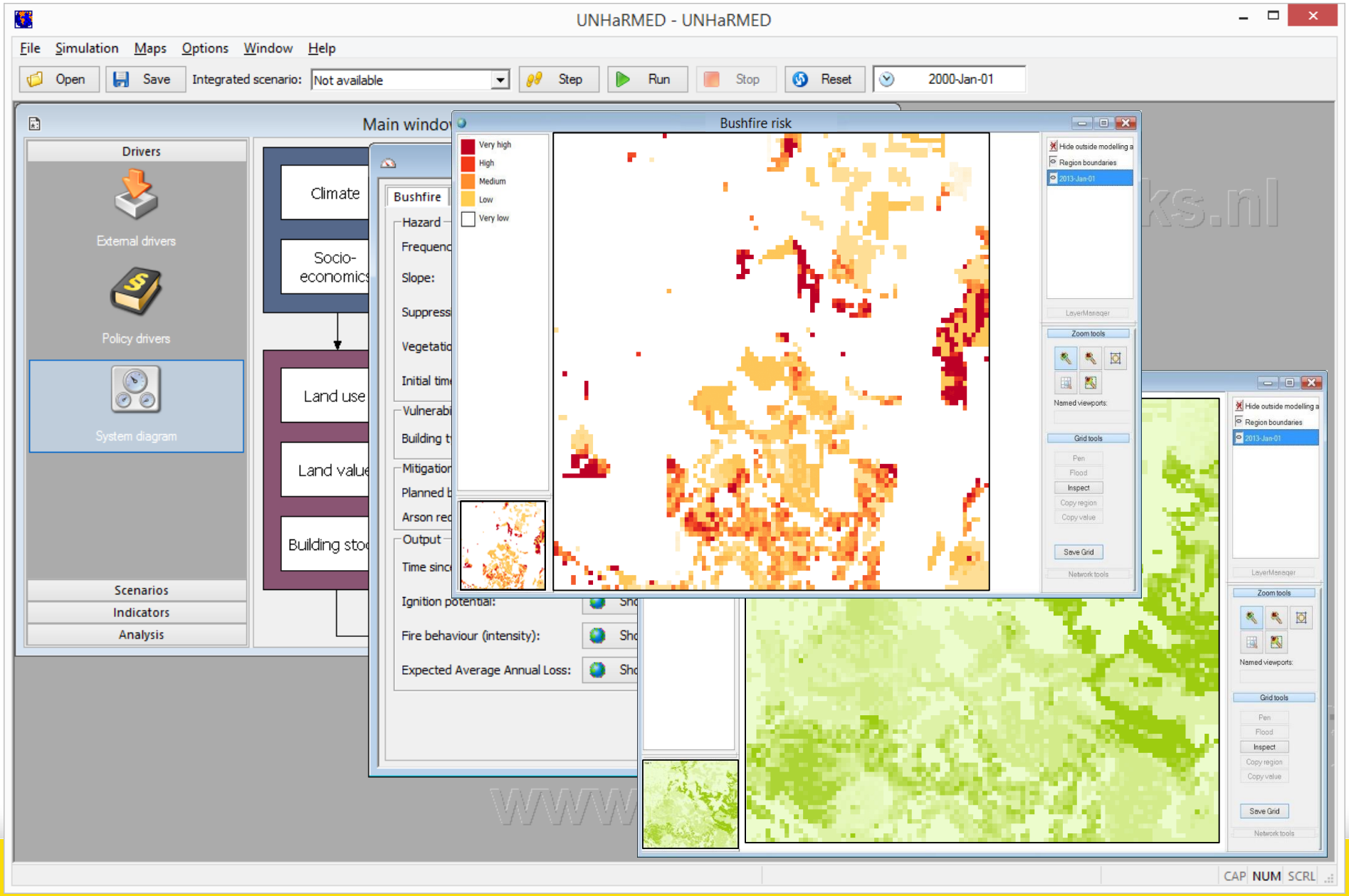
LAND USE PLANNING

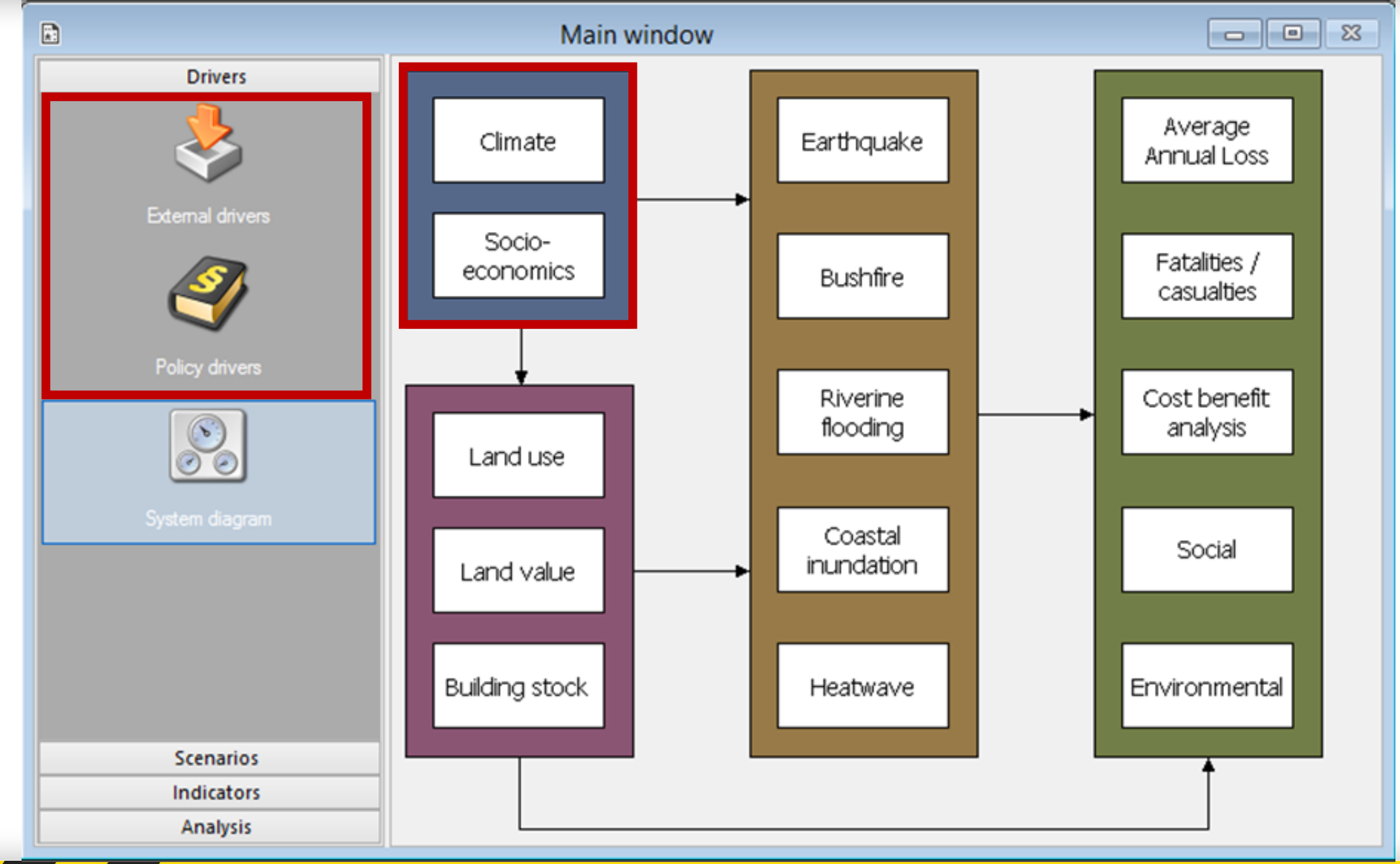


SUPPRESSION LAYER UPDATES

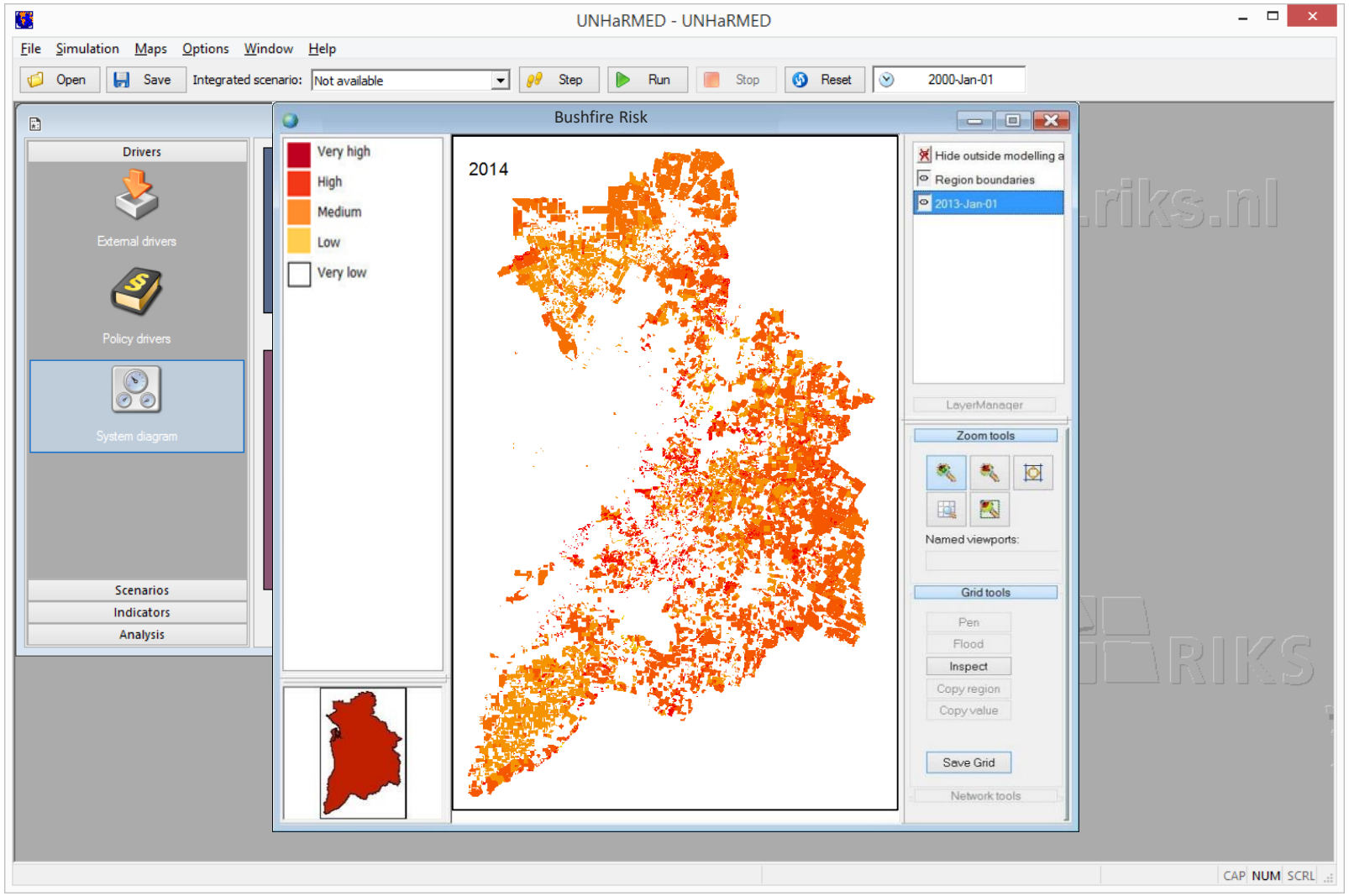


PLANNED BURNS

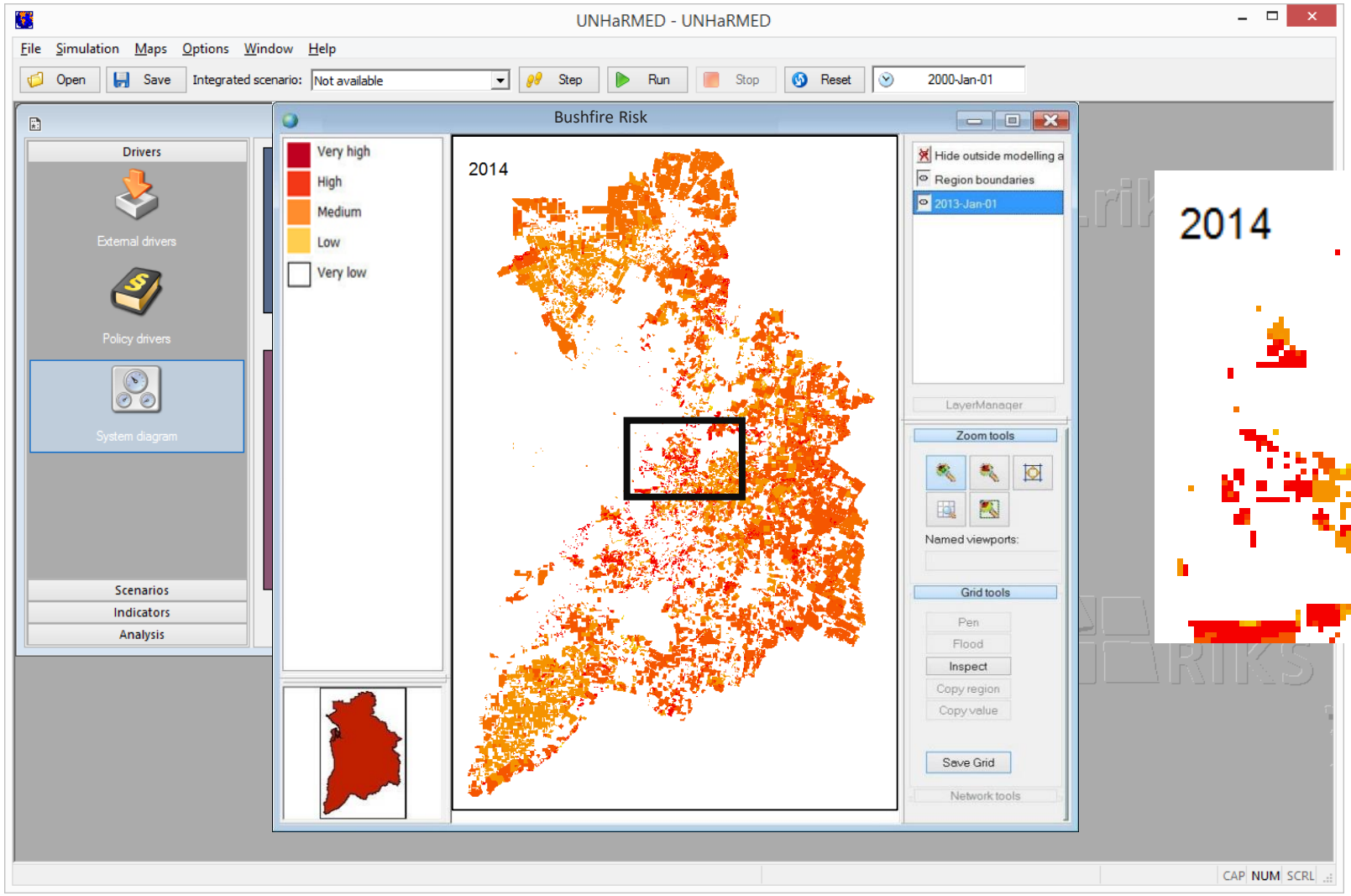


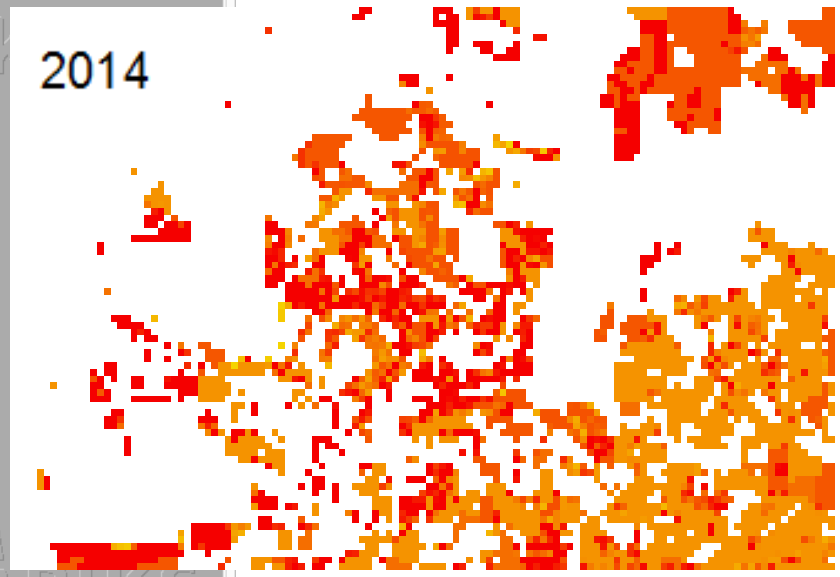

Main window
Drivers
External drivers
Policy drivers
System diagram
Scenarios
Indicators
Analysis
Climate
Socio-economics
Land use
Land value
Building stock
Earthquake
Bushfire
Riverine flooding
Coastal inundation
Heatwave
Average Annual Loss
Fatalities / casualties
Cost benefit analysis
Social
Environmental

DYNAMIC BUSHFIRE RISK MODELLING



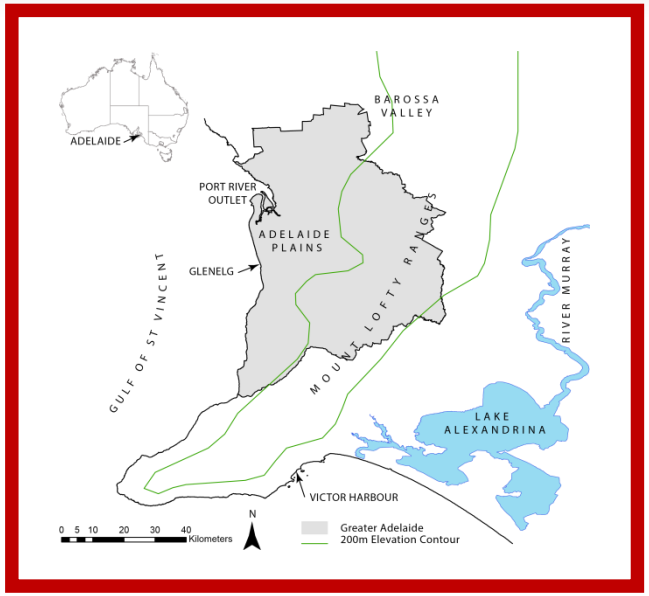
DYNAMIC WILDFIRE RISK MODELLING

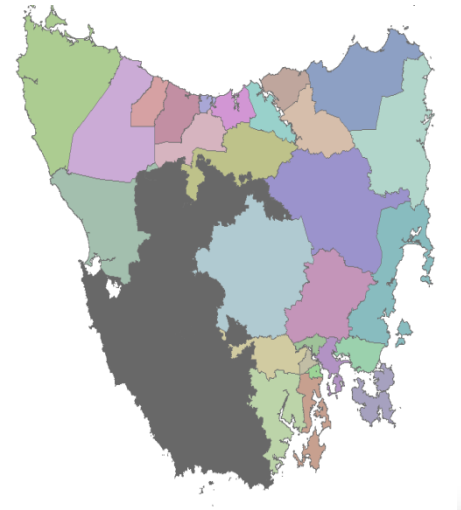


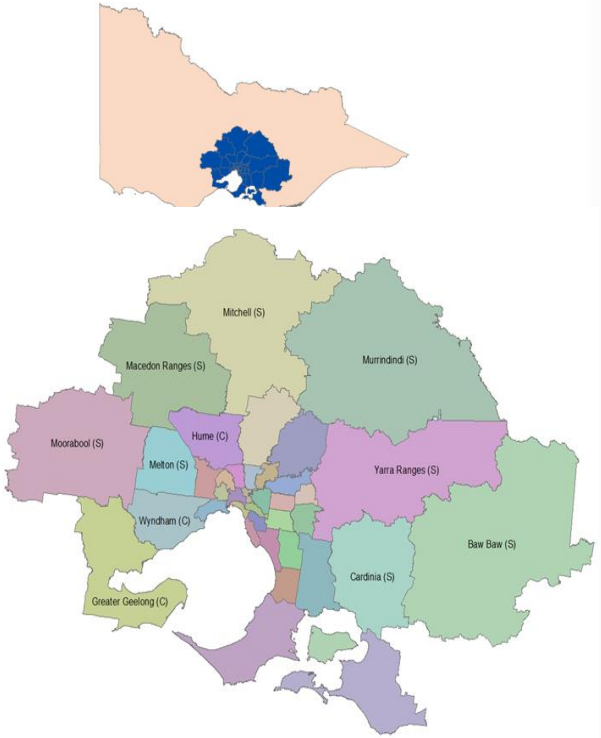


A Spatial Decision Support System for Natural Hazard Risk Reduction Policy Assessment and Planning

- Conceptual Approach
- Modelling Approach & Software Framework

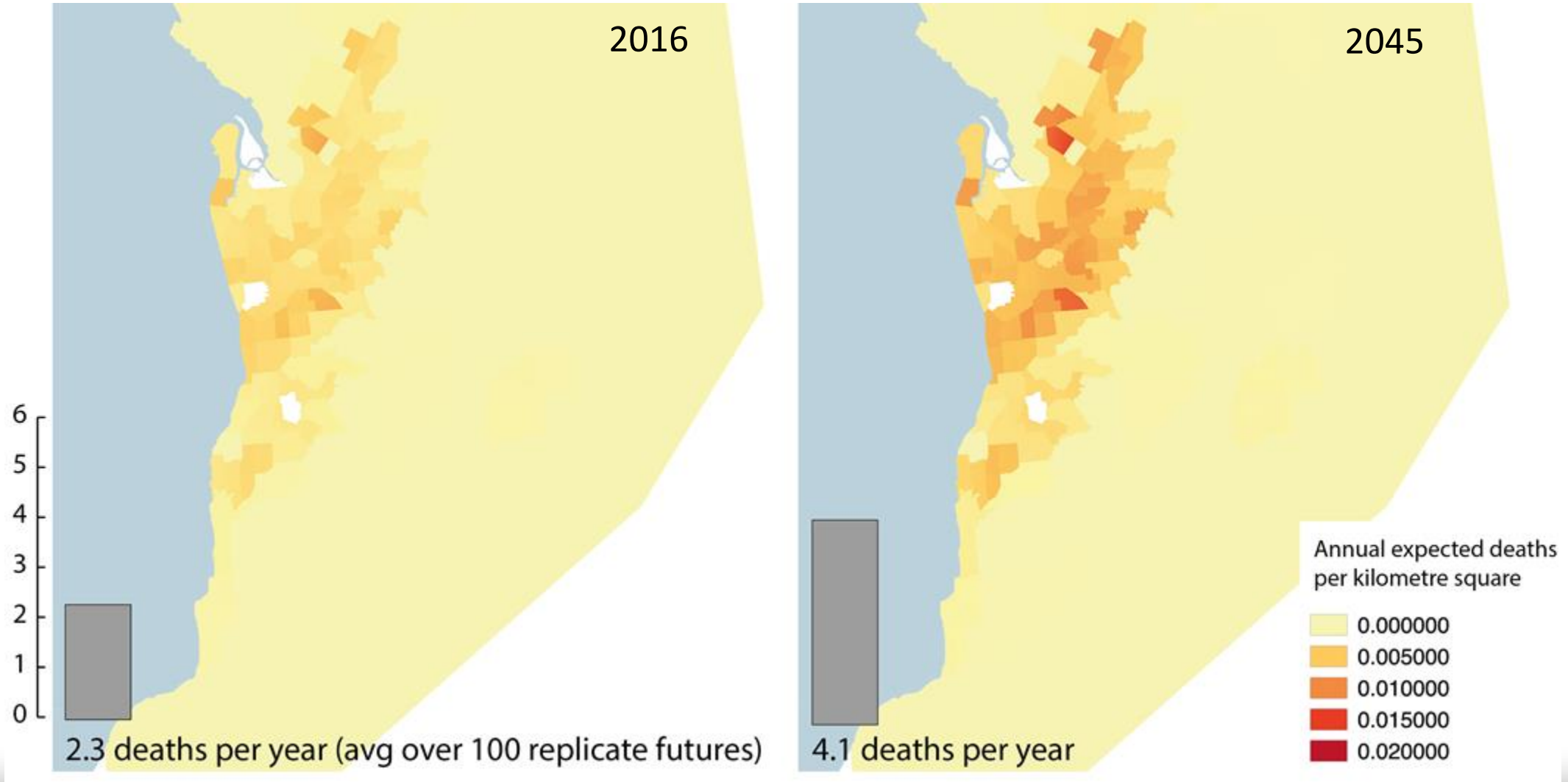






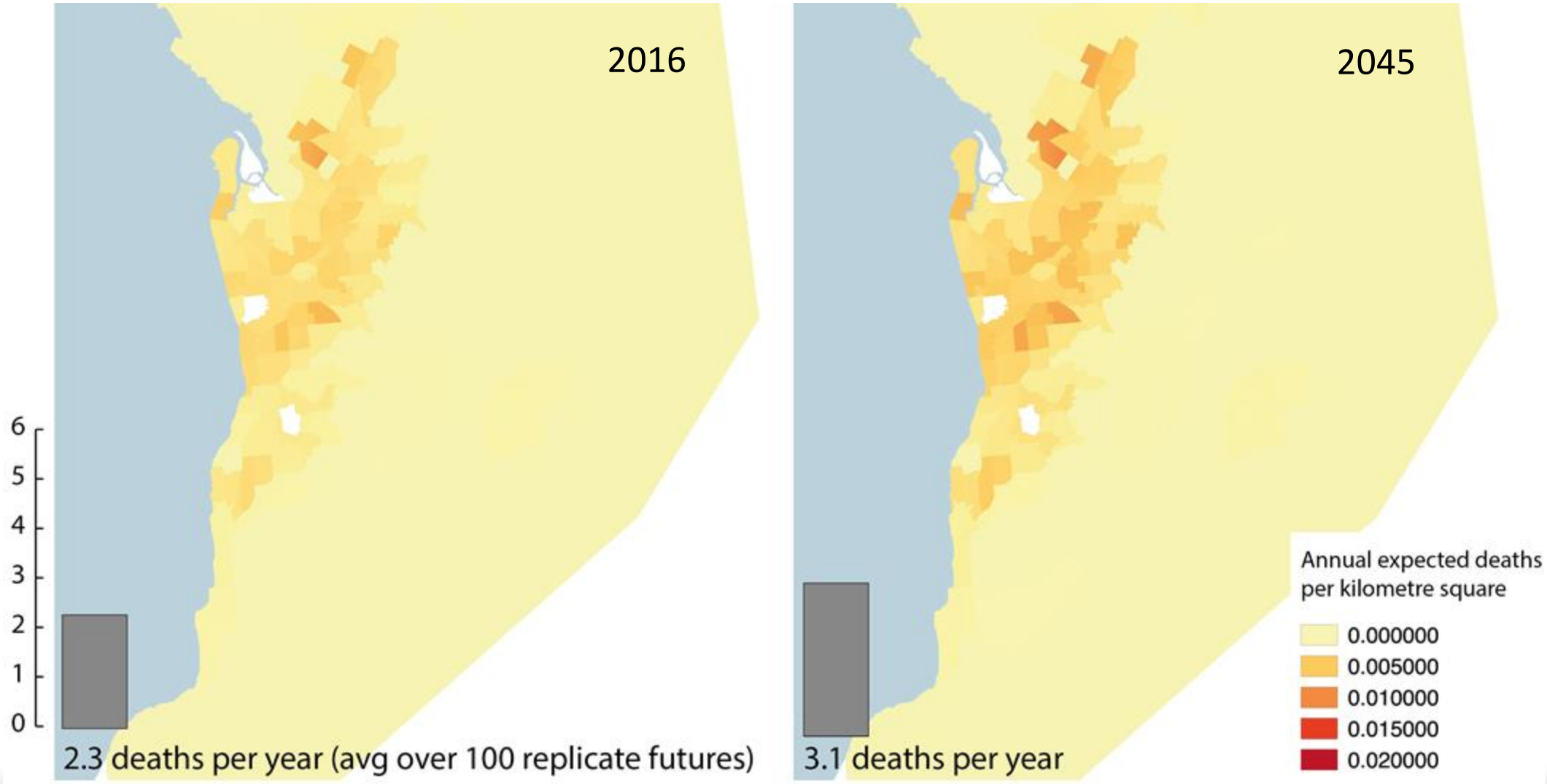
COMPARISON OF PRESENT TO FUTURE HEATWAVE RISK

Impact of Climate Change only (RCP 8.5 – High Emissions)



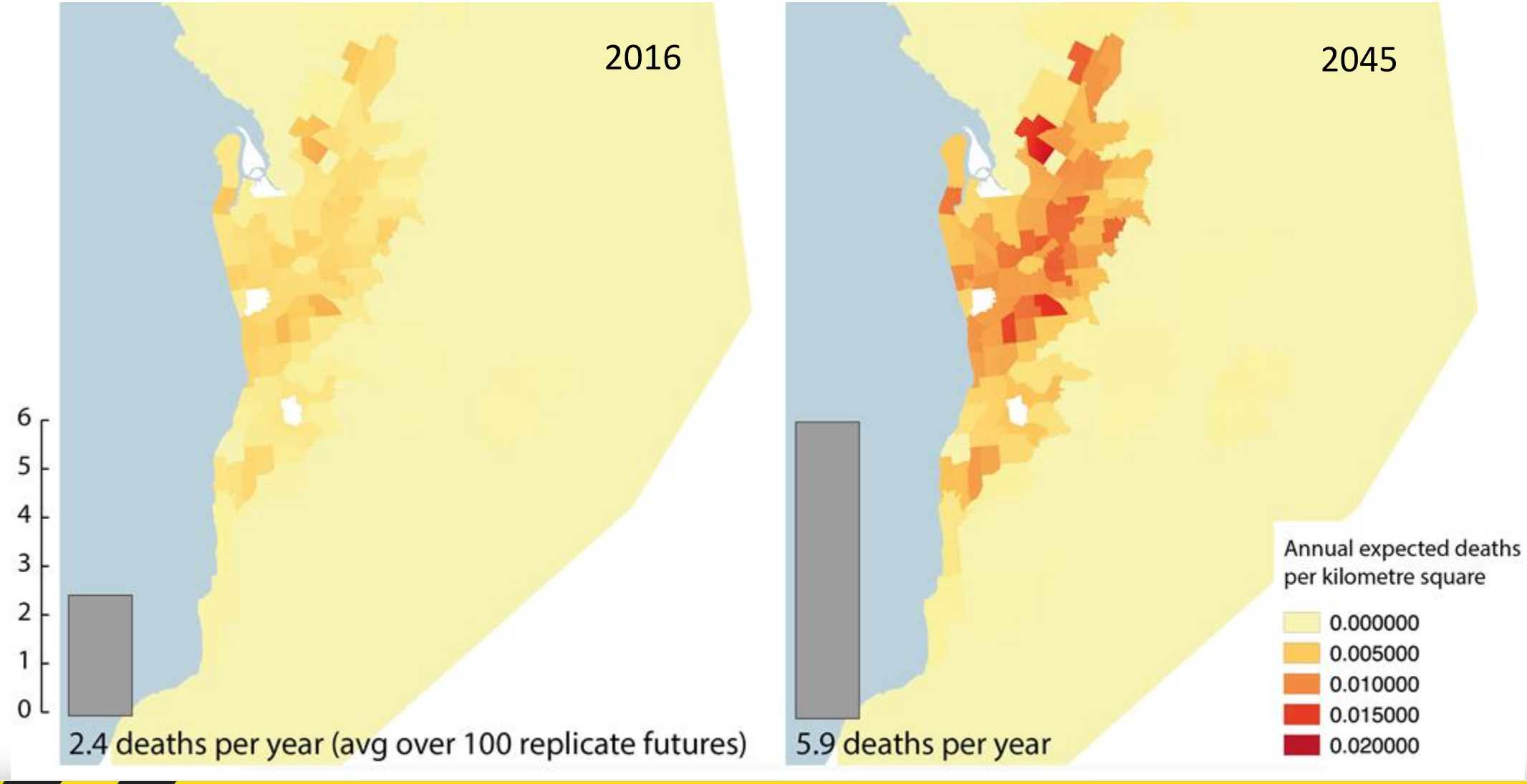
COMPARISON OF PRESENT TO FUTURE HEATWAVE RISK

Impact of Population Growth only (High Growth)

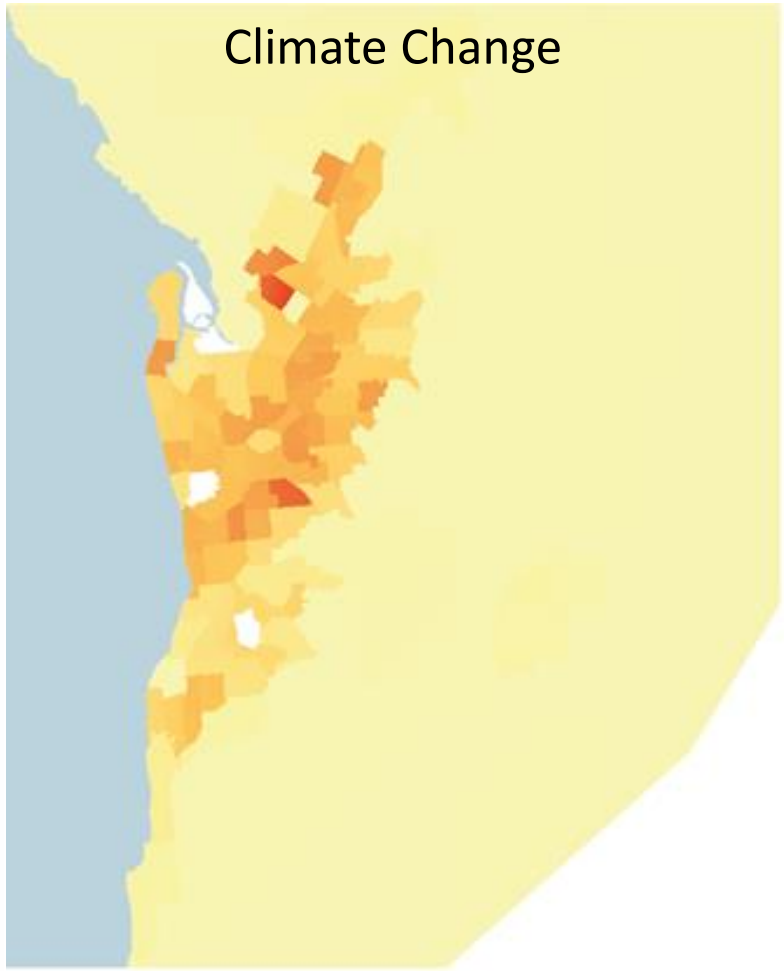


COMPARISON OF PRESENT TO FUTURE HEATWAVE RISK

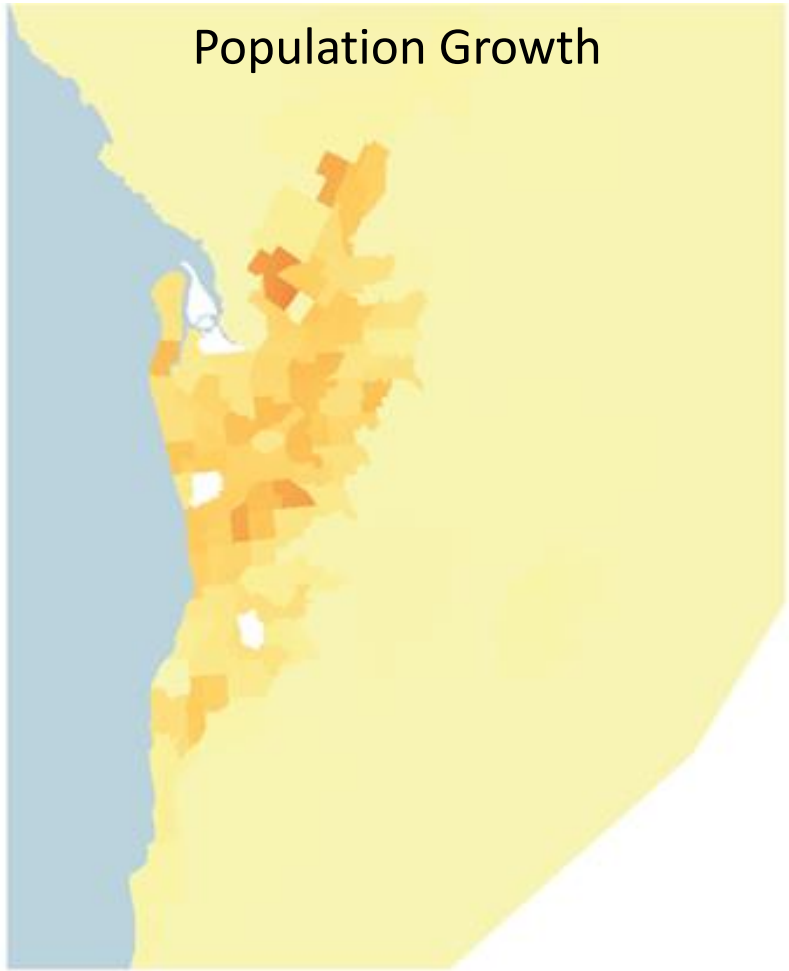
Combined Impact of Climate Change and Population Growth



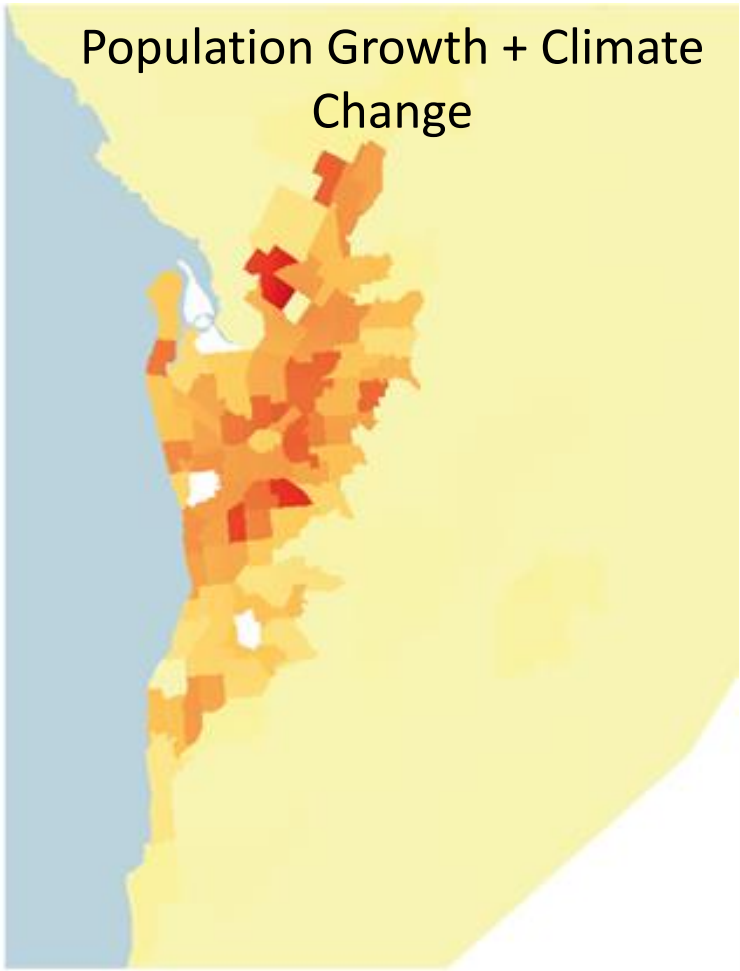
HEATWAVE RELATED DEATHS IN 2045



Annual average deaths: 4.1



Annual average deaths: 3.1



Annual average deaths: 5.9

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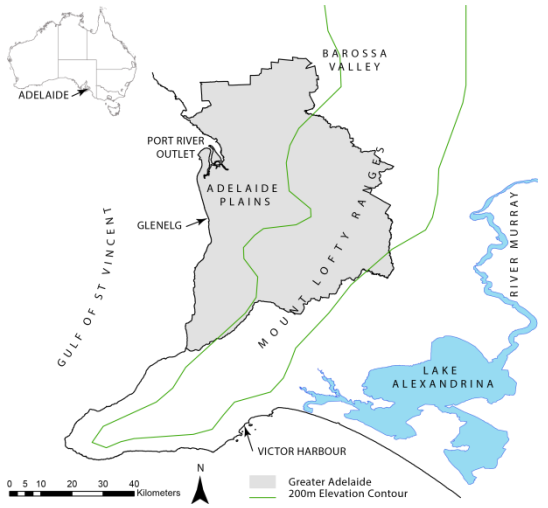

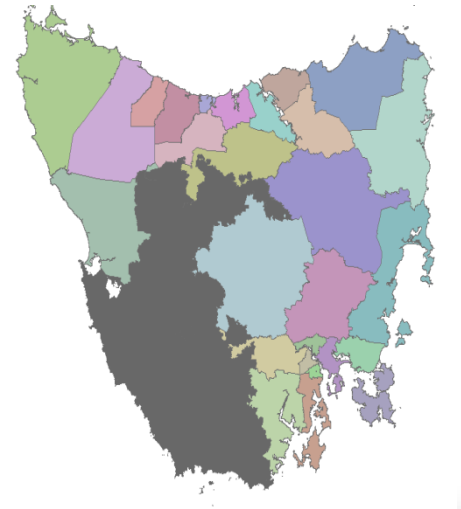

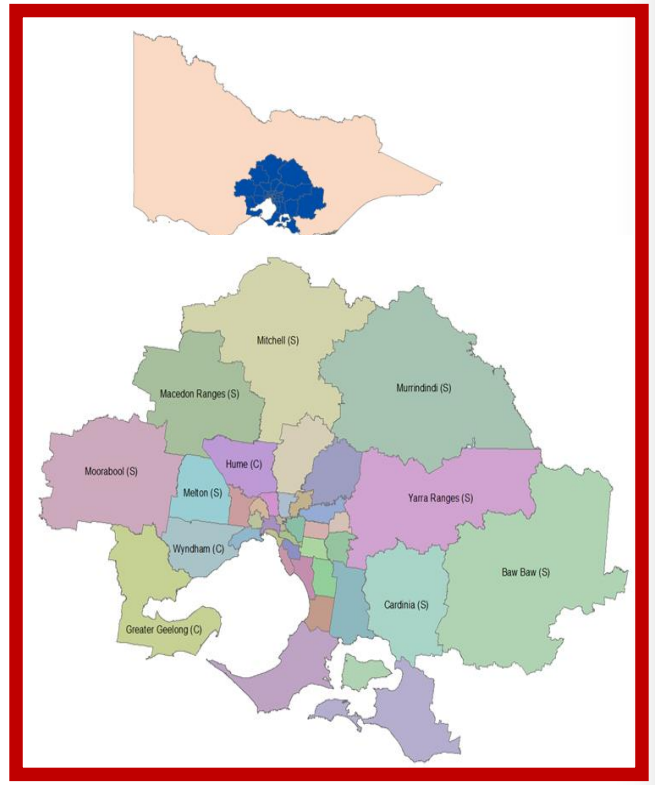

A Spatial Decision Support System for Natural Hazard Risk Reduction Policy Assessment and Planning

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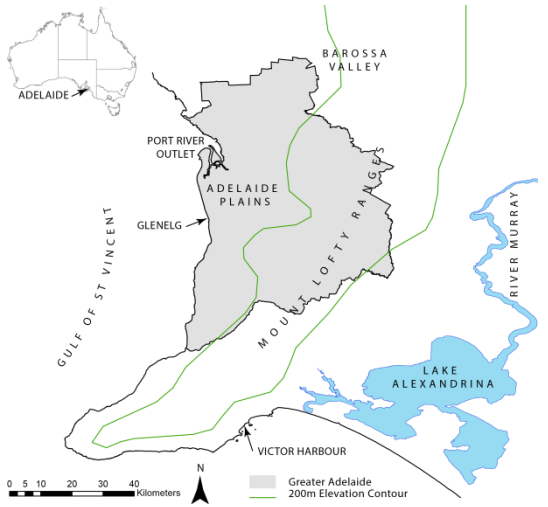

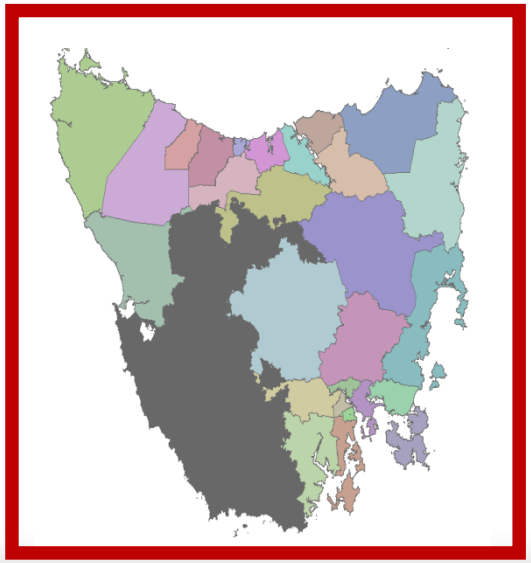

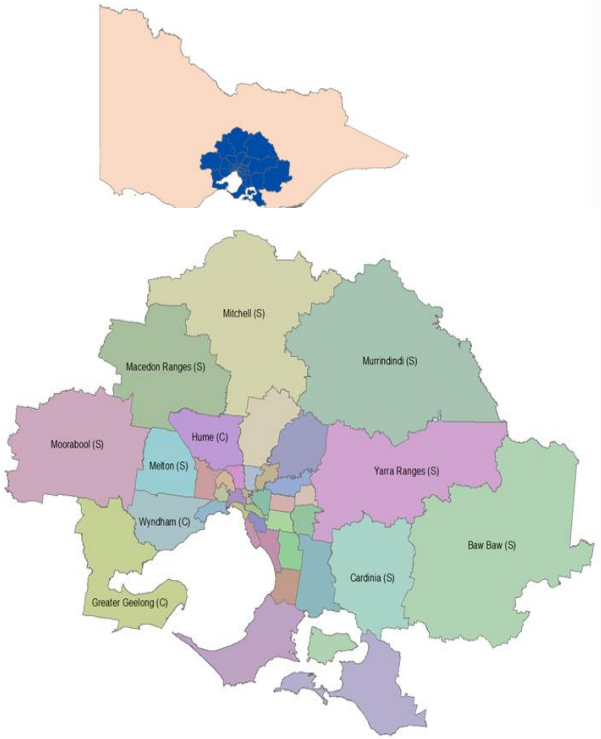

A Spatial Decision Support System for Natural Hazard Risk Reduction Policy Assessment and Planning

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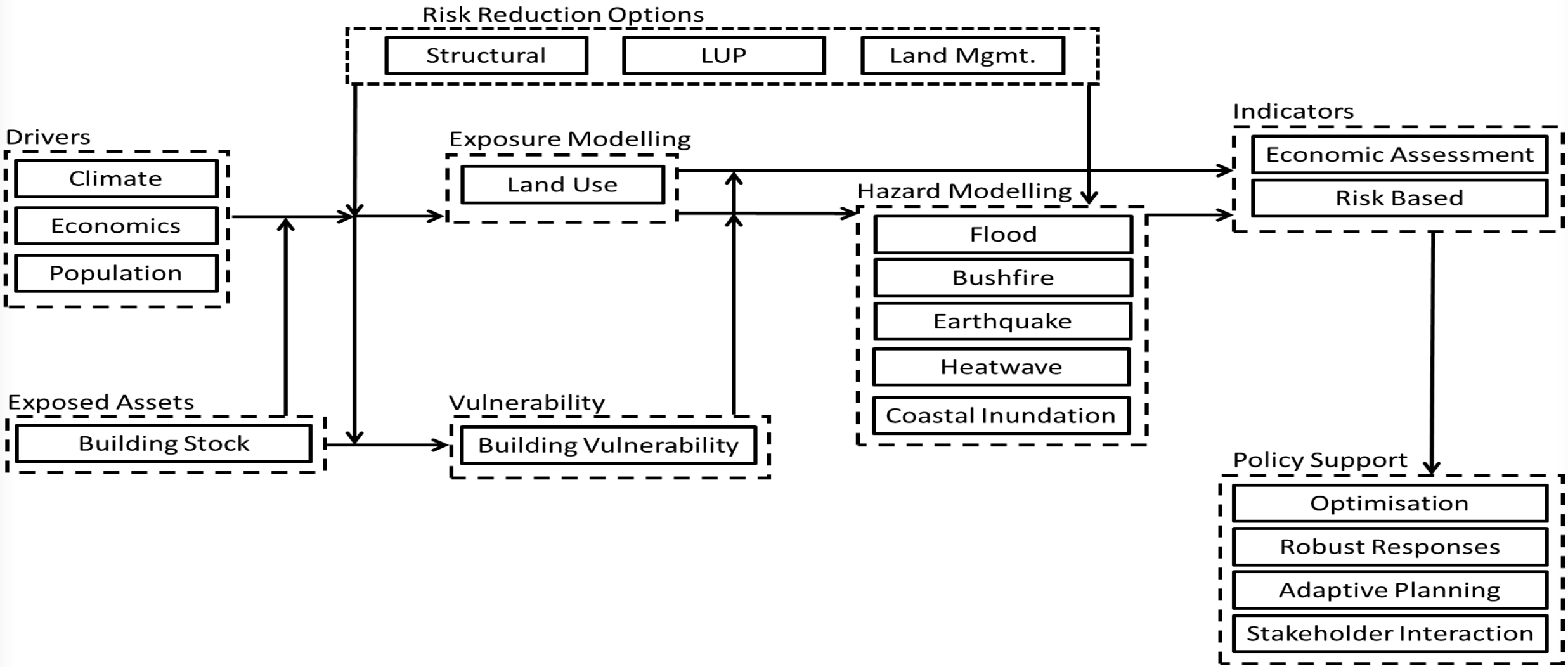
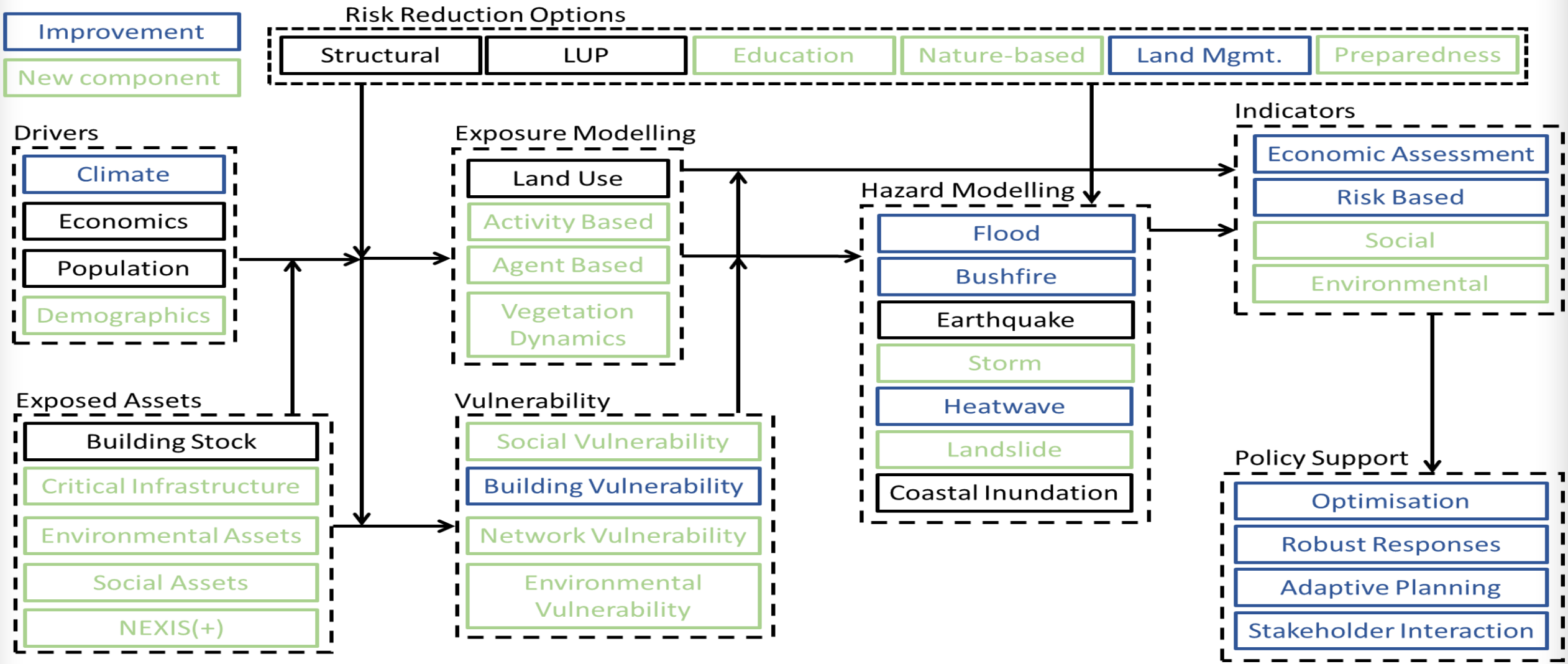
POTENTIAL FUTURE EXPANSION

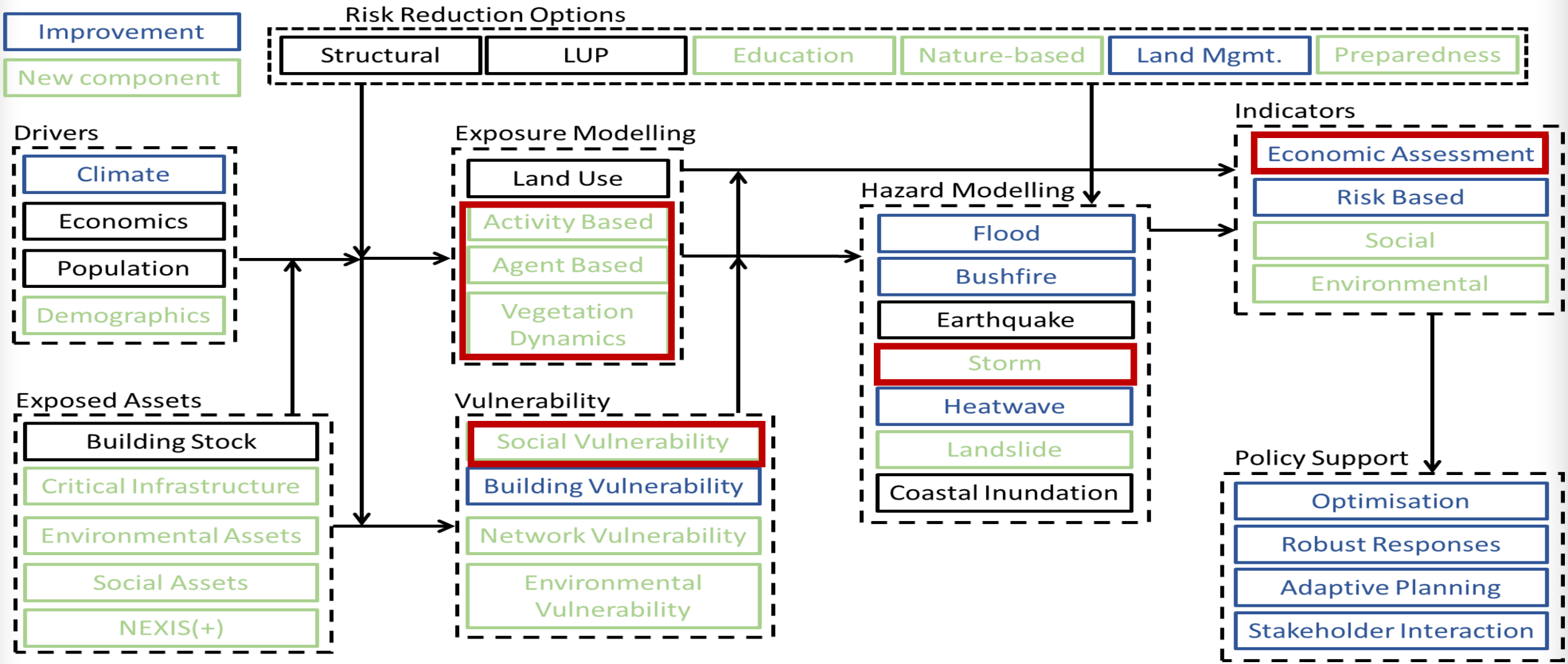
CURRENT SYSTEM COMPONENTS



PROPOSED FUTURE EXPANSION



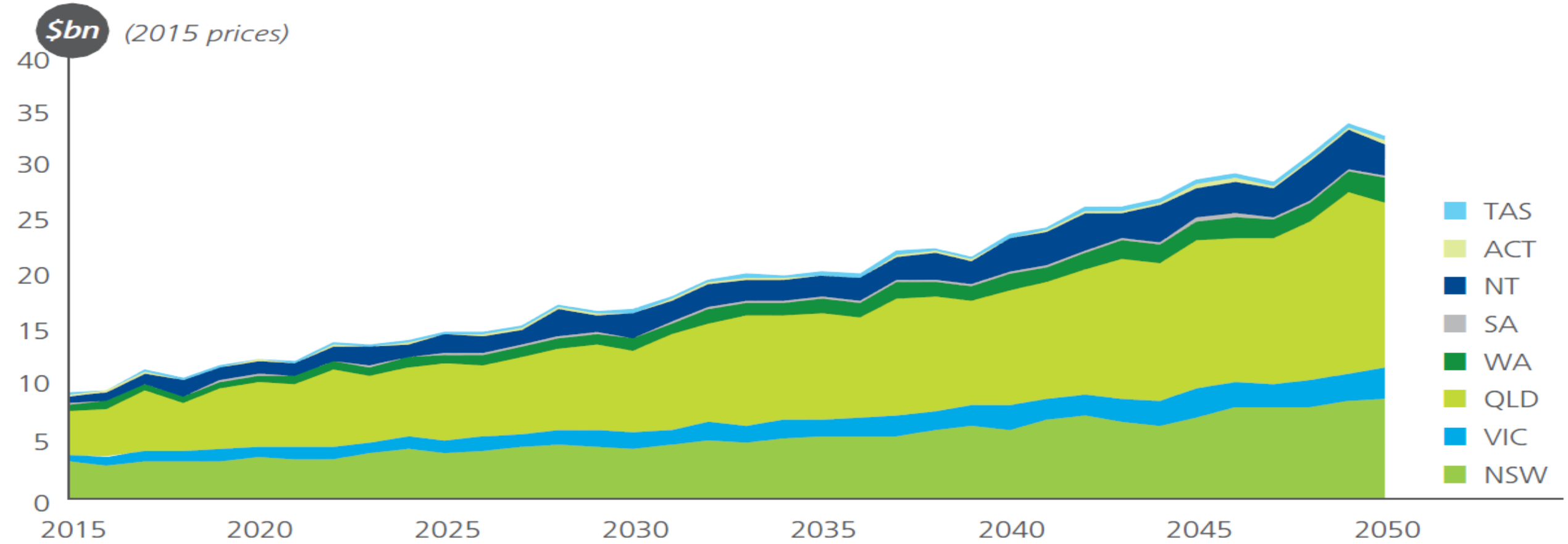
PROPOSED FUTURE EXPANSION



CONCLUSIONS

NATURAL DISASTERS *ARE* EXPENSIVE

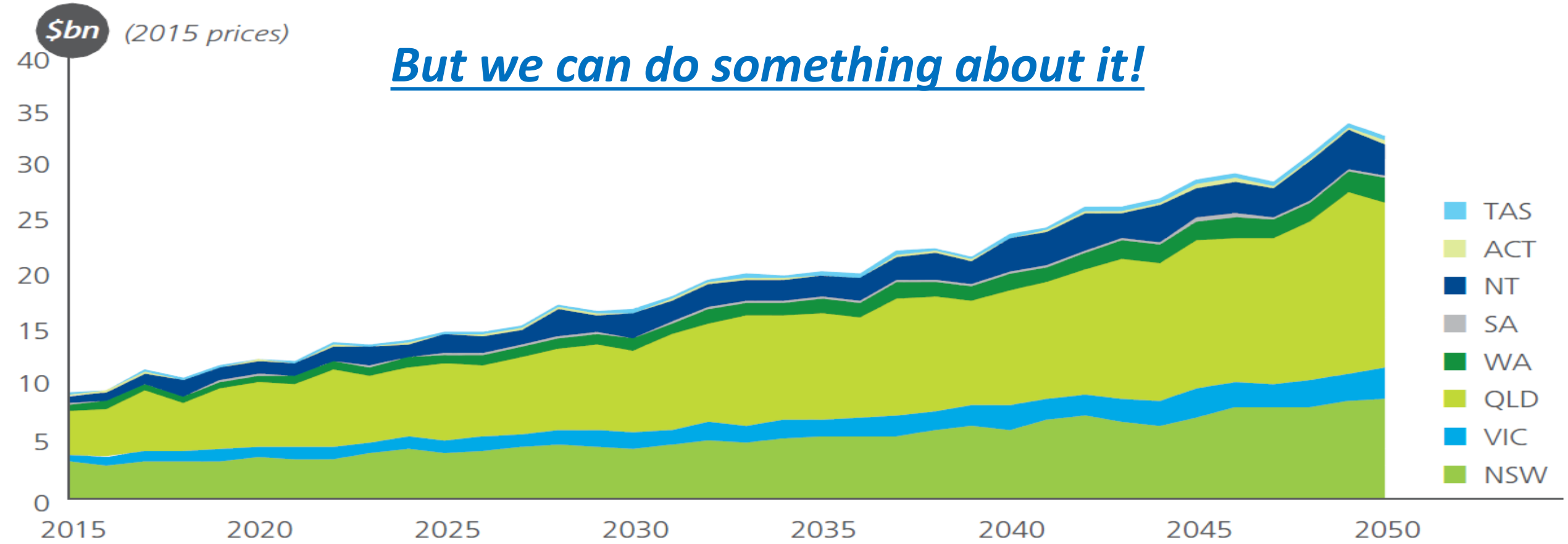
Chart ii: 2015–50 forecast of the total economic cost of natural disasters, identifying costs for each state



Source: Deloitte Access Economics analysis

NATURAL DISASTERS ARE EXPENSIVE

Chart ii: 2015–50 forecast of the total economic cost of natural disasters, identifying costs for each state



But we can do something about it!

Source: Deloitte Access Economics analysis

Major outcomes

1) A systematic and transparent approach to evaluating natural hazard risk reduction options.

2) A framework for making more strategic and less responsive decisions.

3) Building strategic capacity across governments and agencies for considering the future challenges of natural hazard risk in dynamic and growing regions.

4) The ability to sift through, evaluate and rank a large number of risk reductions options.

5) Understanding the trade-offs between economic, environmental and/or social objections for risk reduction options.

THANK YOU

Holger Maier
holger.maier@adelaide.edu.au

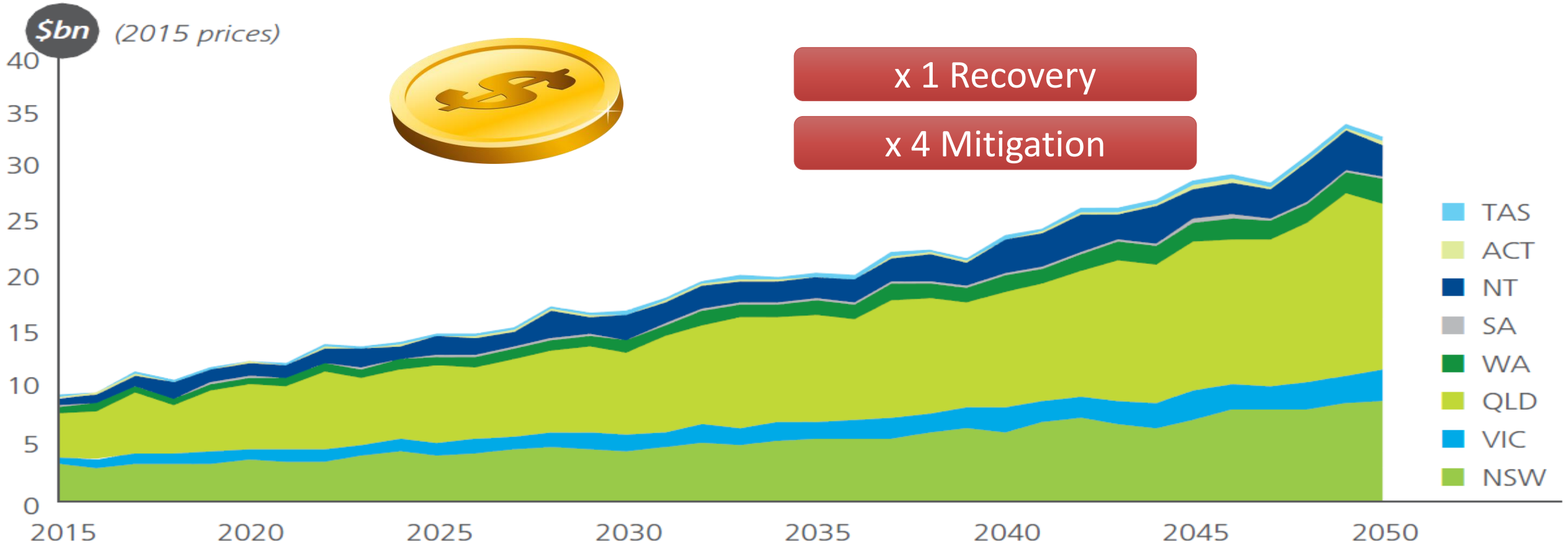
PREVENTION IS BETTER THAN CURE

COST

BENEFIT

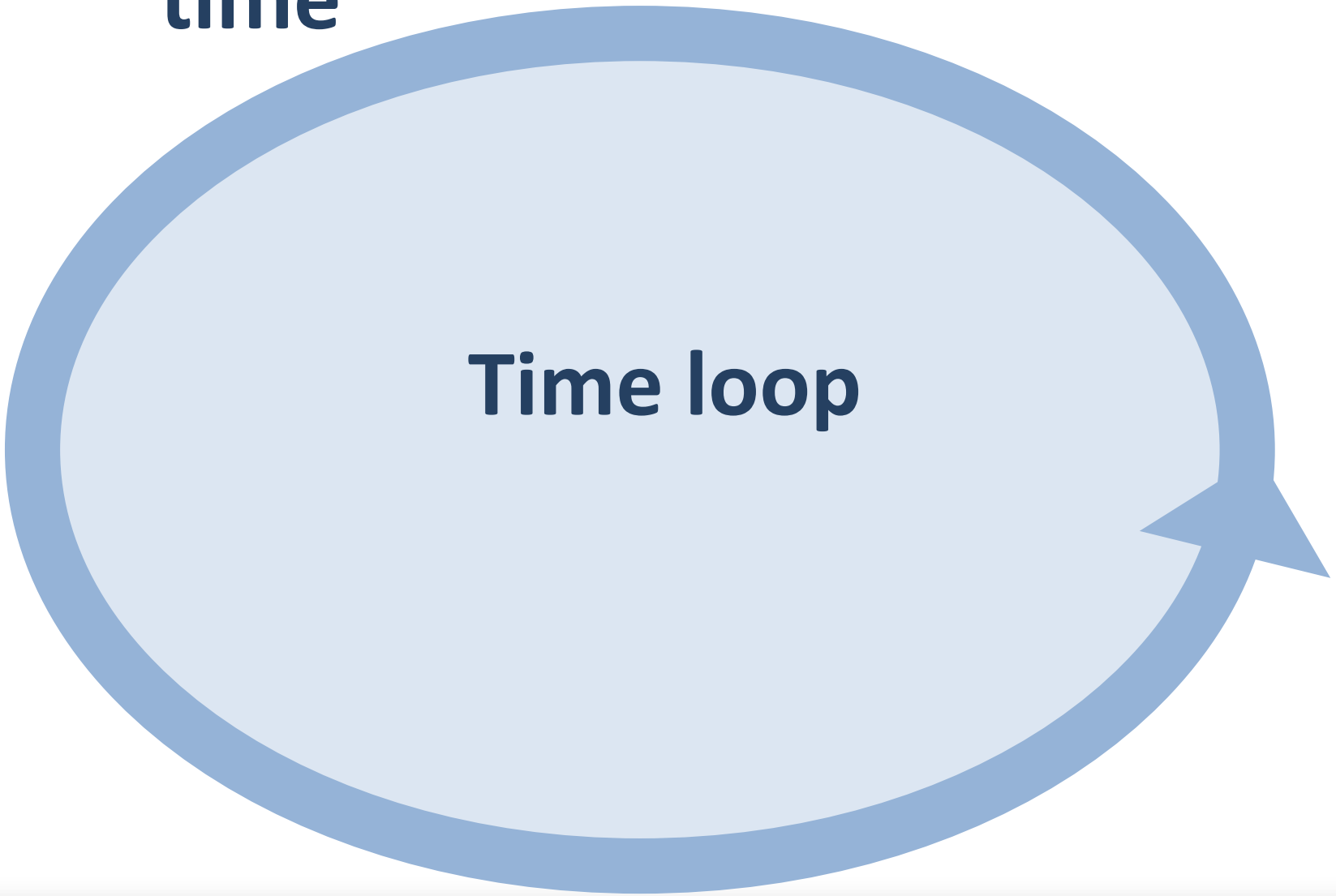
x 1 Recovery

x 4 Mitigation



Source: Deloitte Access Economics analysis

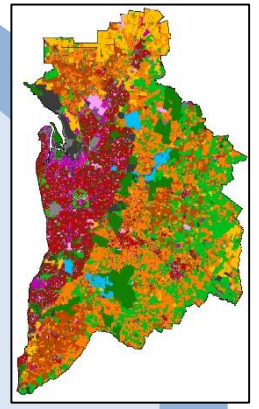
Land use change with time



Time loop

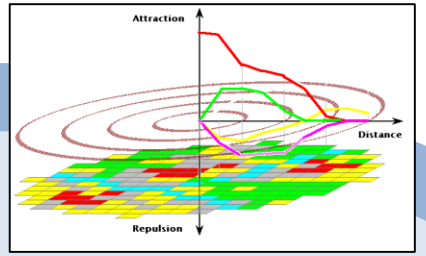
Land use at time T

&



Interaction Rules

&



Land use at time T

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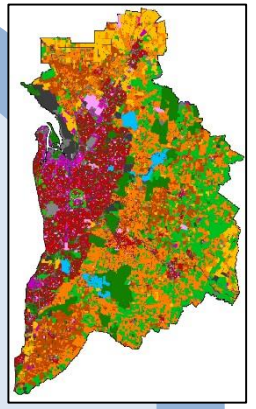
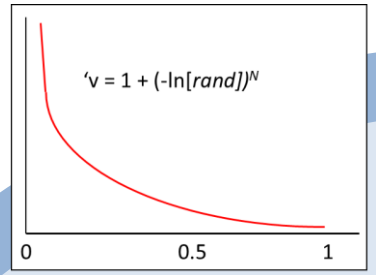


Time loop

Stochastic Perturbation

&



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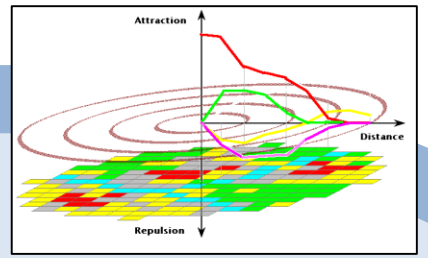
Interaction Rules



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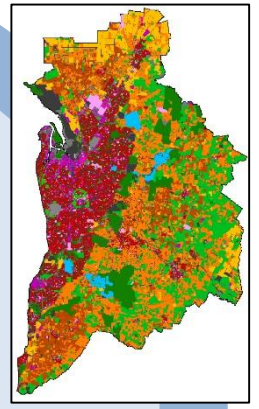
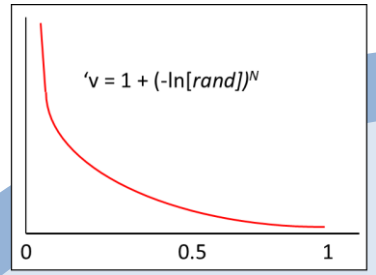
Land use at time T



Time loop

Stochastic Perturbation



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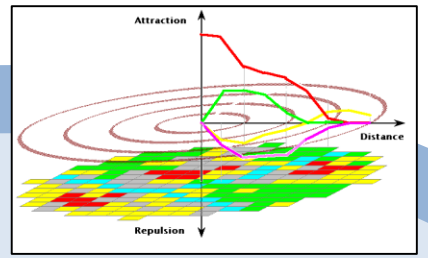
Interaction Rules



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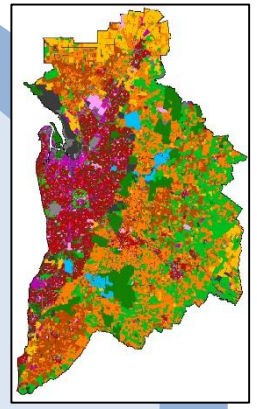
Land use at time T



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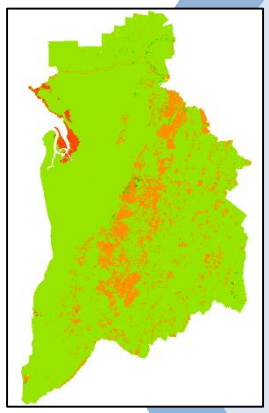
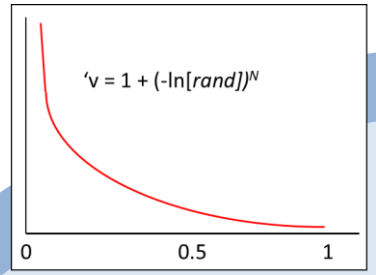
Suitability



&

Time loop

Stochastic Perturbation



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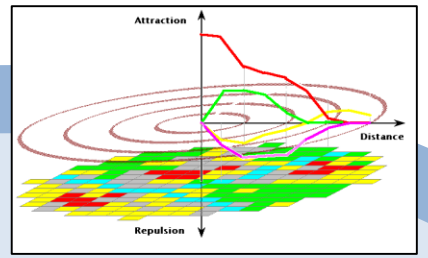
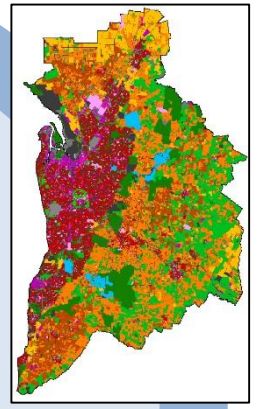
Interaction Rules



&

Land use at time T



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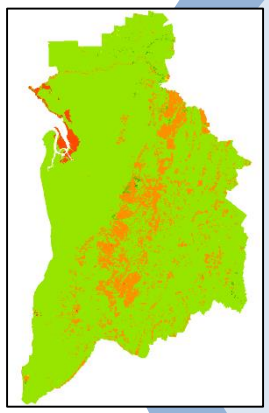
Suitability



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Accessibility

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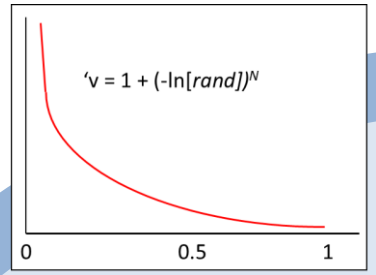
Time loop

Time loop

Stochastic Perturbation



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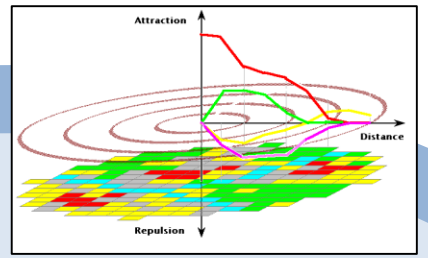
Interaction Rules



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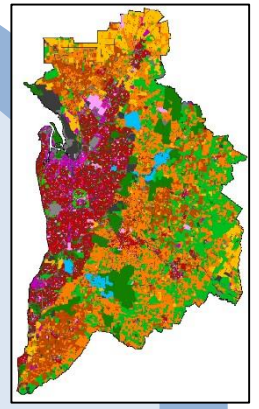
Land use at time T



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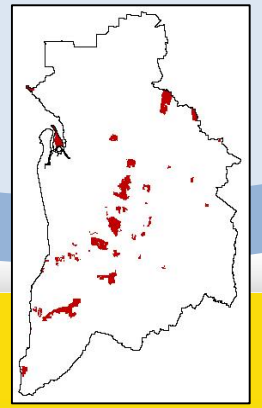
Spatial Planning



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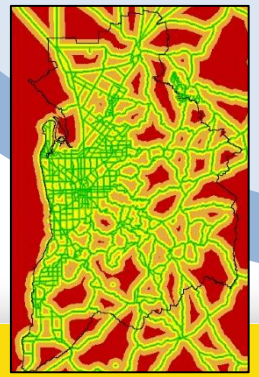
Accessibility



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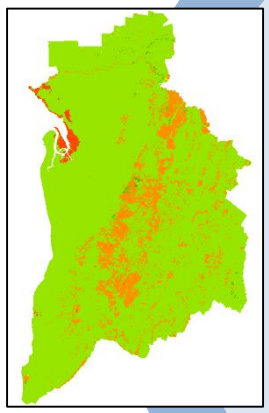

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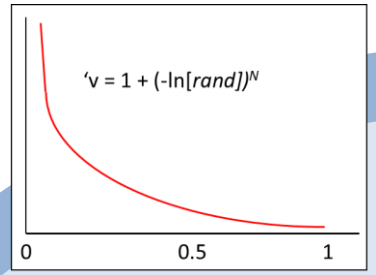
Time loop

Stochastic Perturbation



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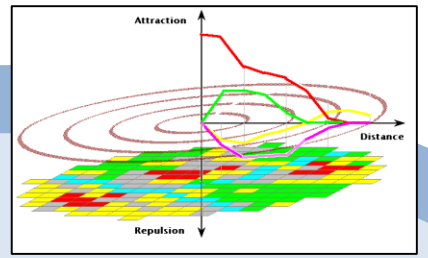
Interaction Rules



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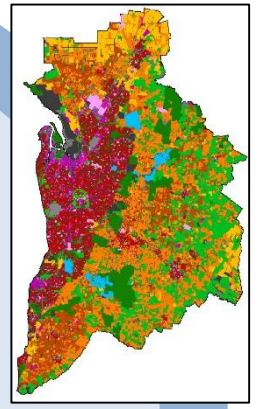
Land use at time T



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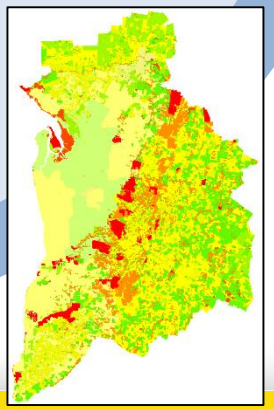
Transition Potential



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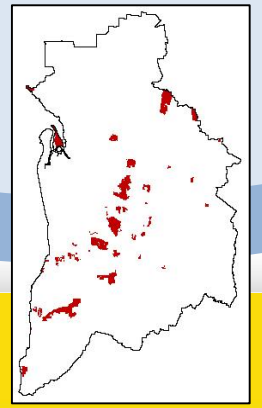
Spatial Planning



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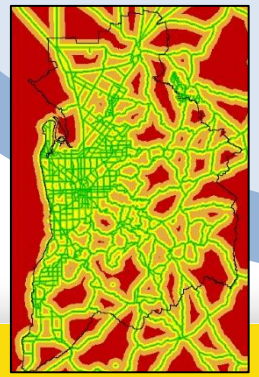

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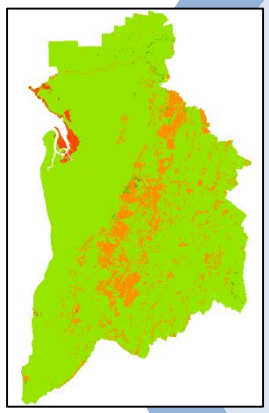
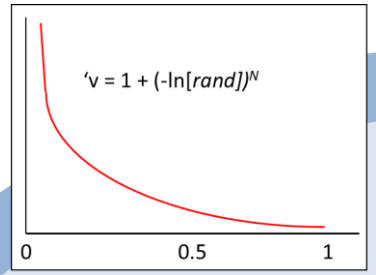


Stochastic Perturbation



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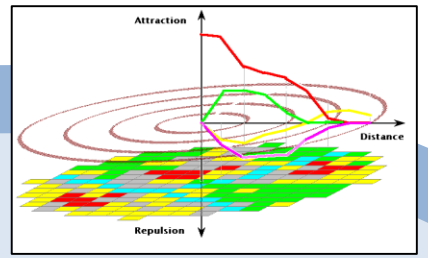
Interaction Rules



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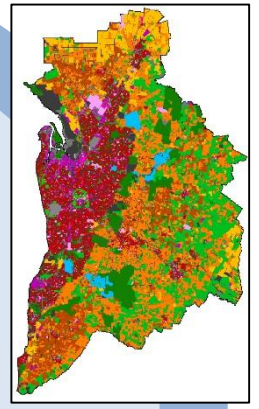
Land use at time T



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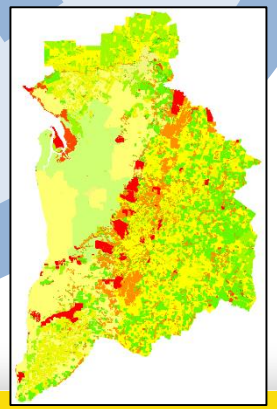
Transition Potential



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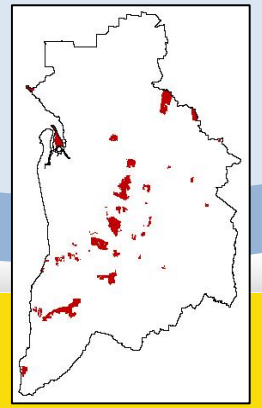
Spatial Planning



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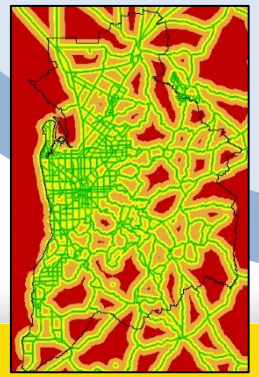

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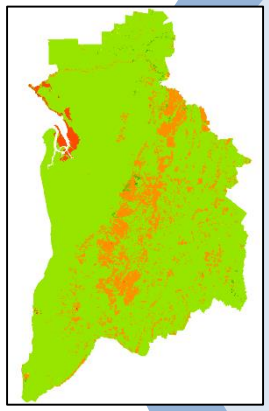
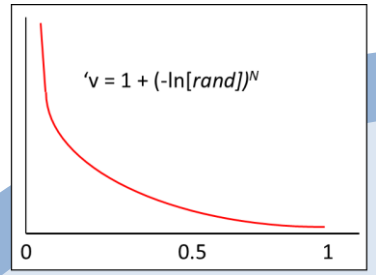


Transition Rule

Change cells to the land use for which they have the highest transition potential *until regional demands are met*

Stochastic Perturbation



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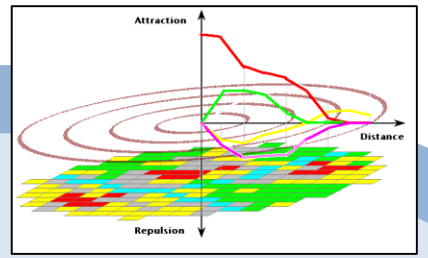
Interaction Rules



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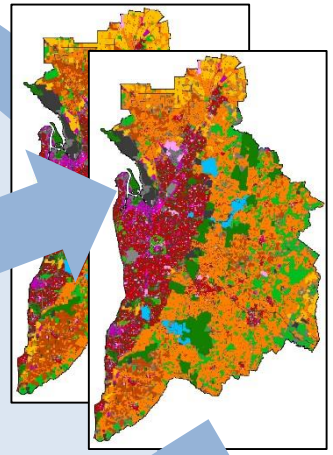
Land use at time T

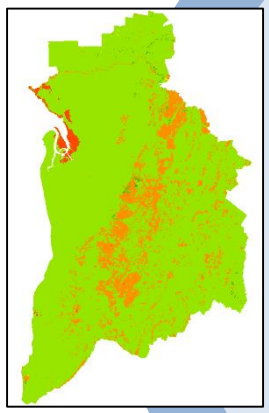


Land use at time T+1

Transition Rule

Change cells to the land use for which they have the highest transition potential *until regional demands are met*

Suitability



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Accessibility

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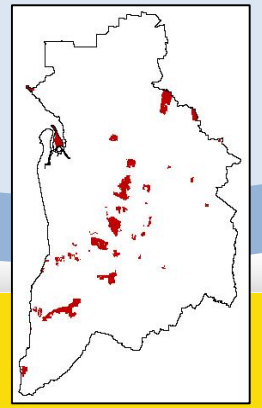
Spatial Planning



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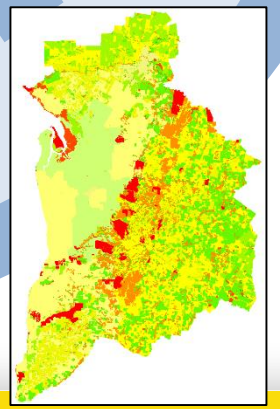
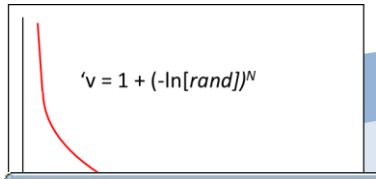
Transition Potential



Stochastic Perturbation



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Interaction Rules

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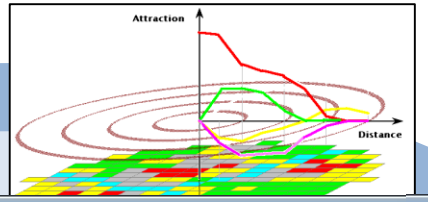
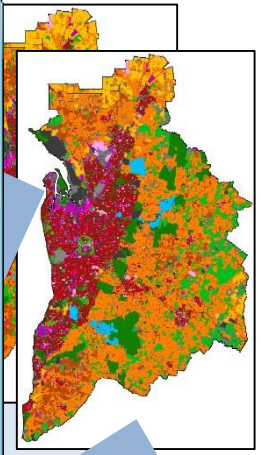
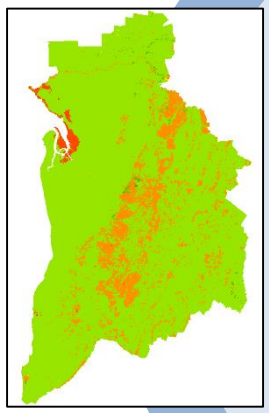


Land use at time T



Land use at time T+1

Suitability



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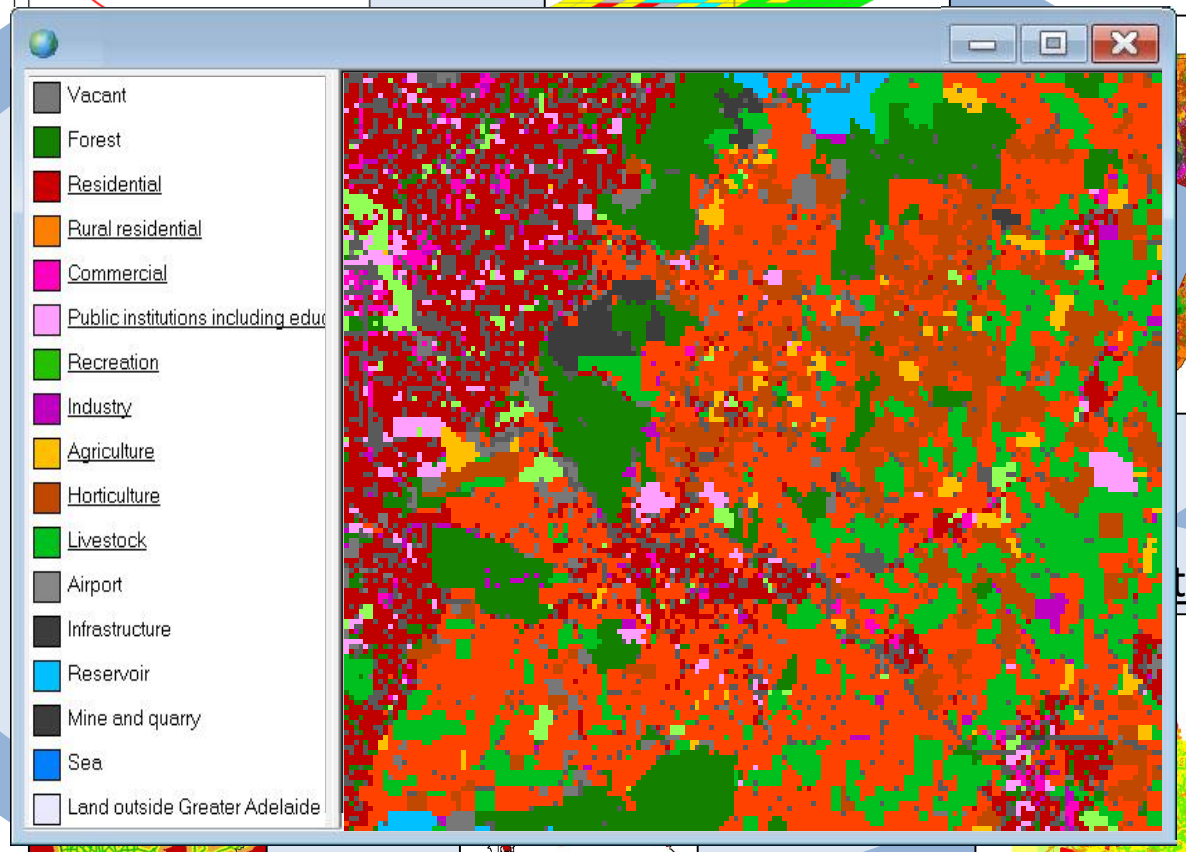

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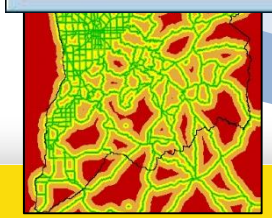

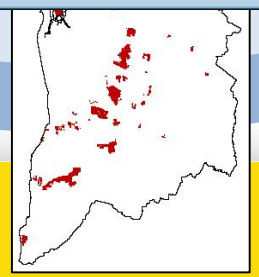

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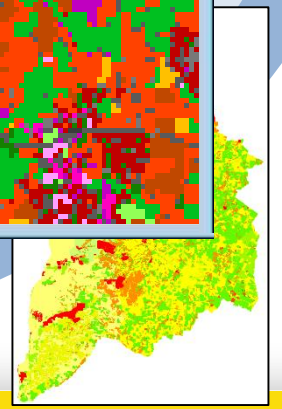
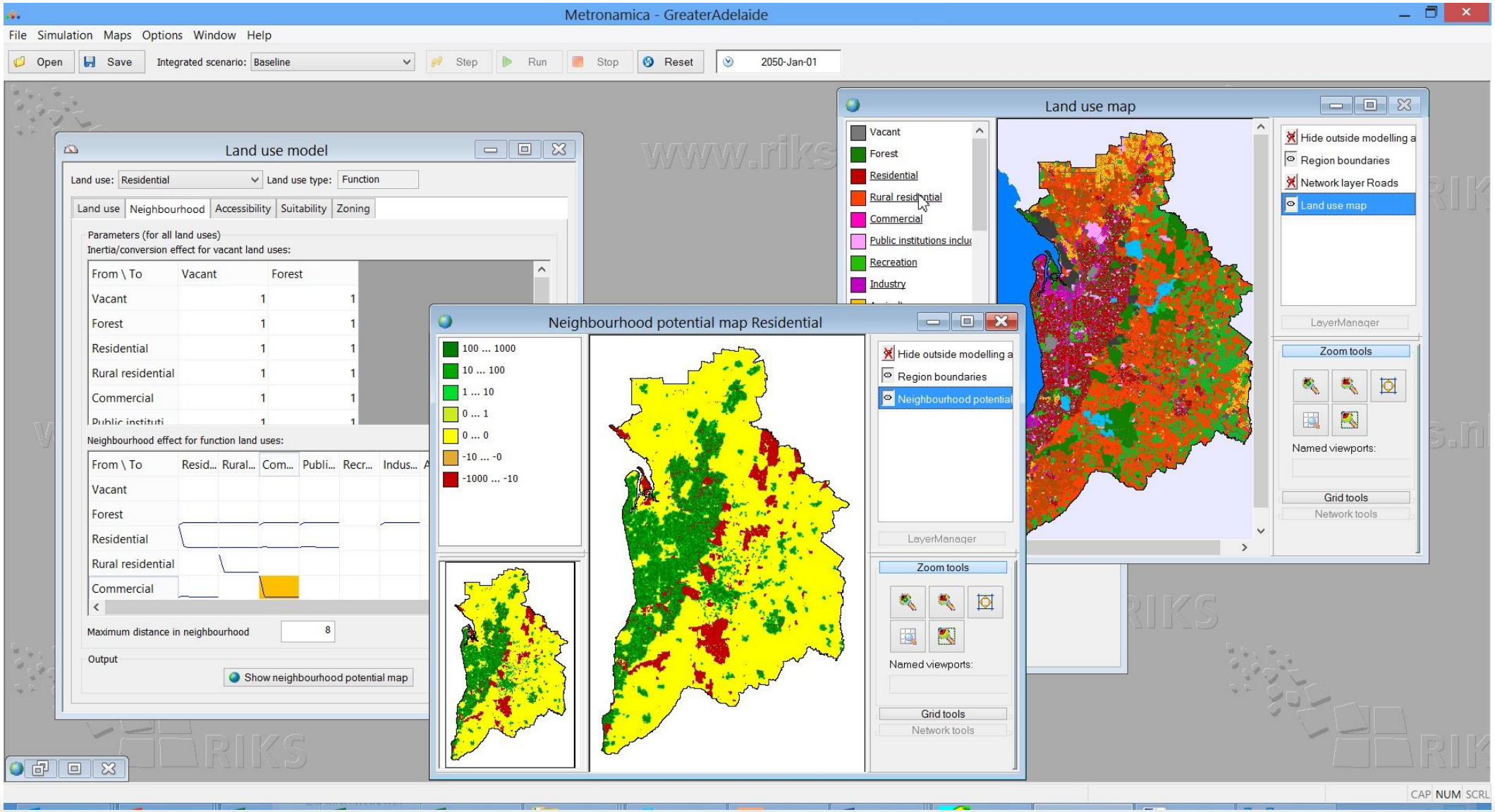


GREATER ADELAIDE LANDUSE MODEL



INDICATORS

- Risk
  - Average annual loss: Map + Table with total per LGA
  - Number of fatalities / casualties: Map + Table with total per LGA
- Cost benefit analysis
  - Cost of mitigation options selected
  - Reduction in average annual loss from a reference base
- Social impacts
  - Side effects of mitigation options, e.g. land use planning impacts on average distance from residential locations to CBD, services and recreation
- Environmental impacts
  - Side effects of mitigation options, e.g. land use planning impacts on total natural area and connectivity of natural area