The evaluation of forest crop damages due to climate change

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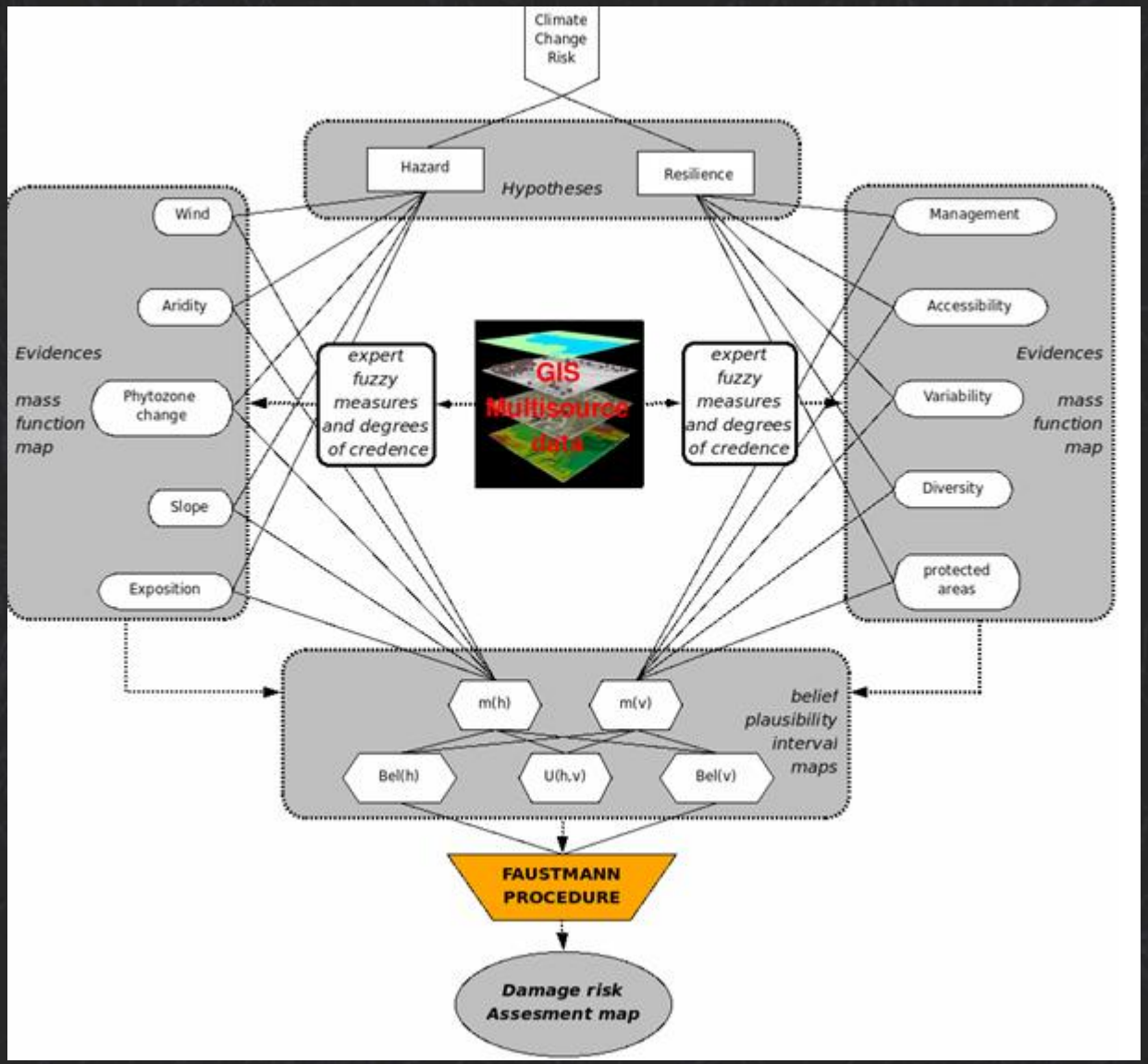
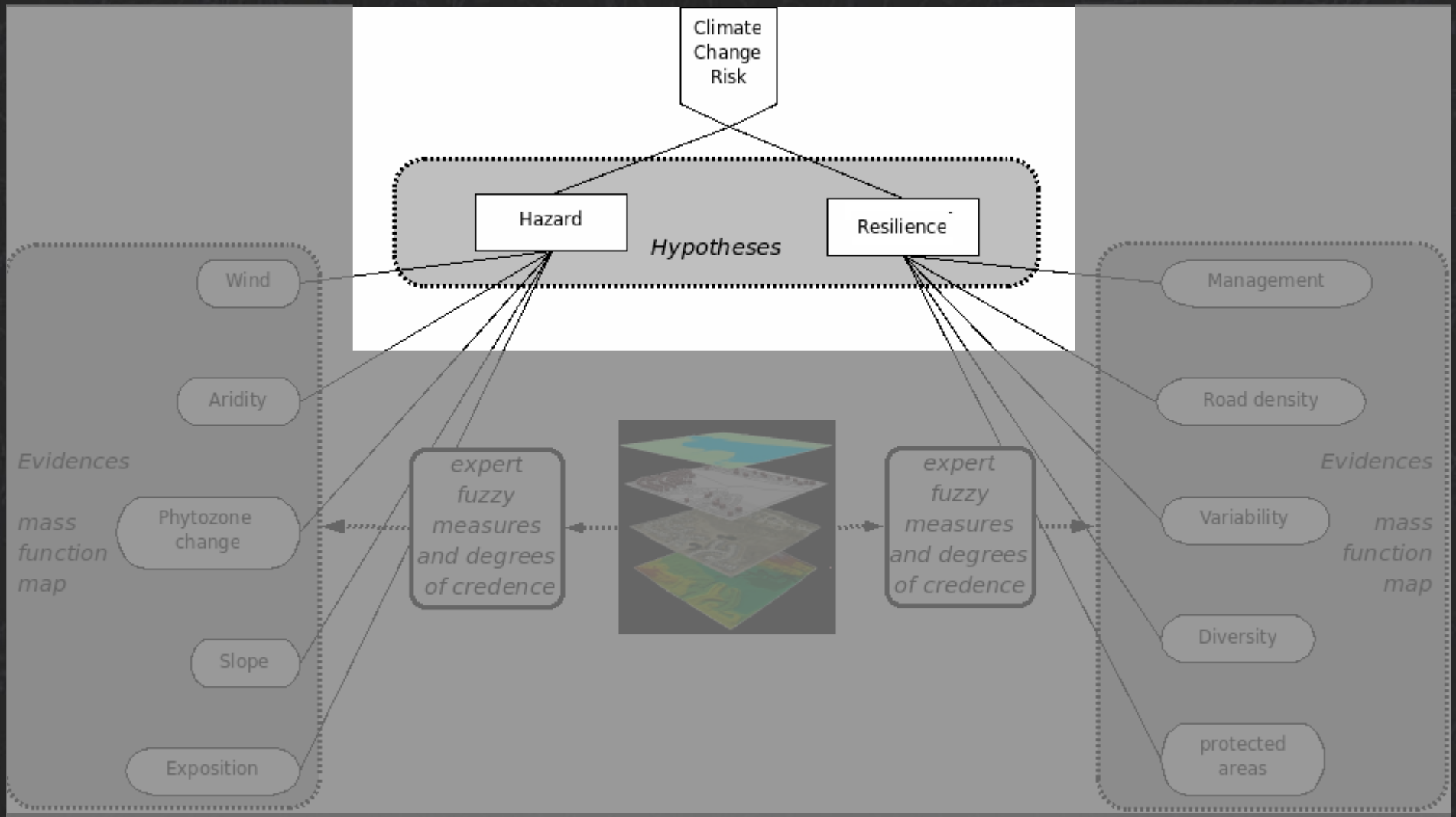
Aim of the work

- To develop a framework for the assessment of economic forest damage due to climatic change.
- Methodologies applied
  - Fuzzy maps
  - Dempster Shaffer theory of evidence
  - Faustmann formula
- The framework was then tested on Tuscany forestry crops.

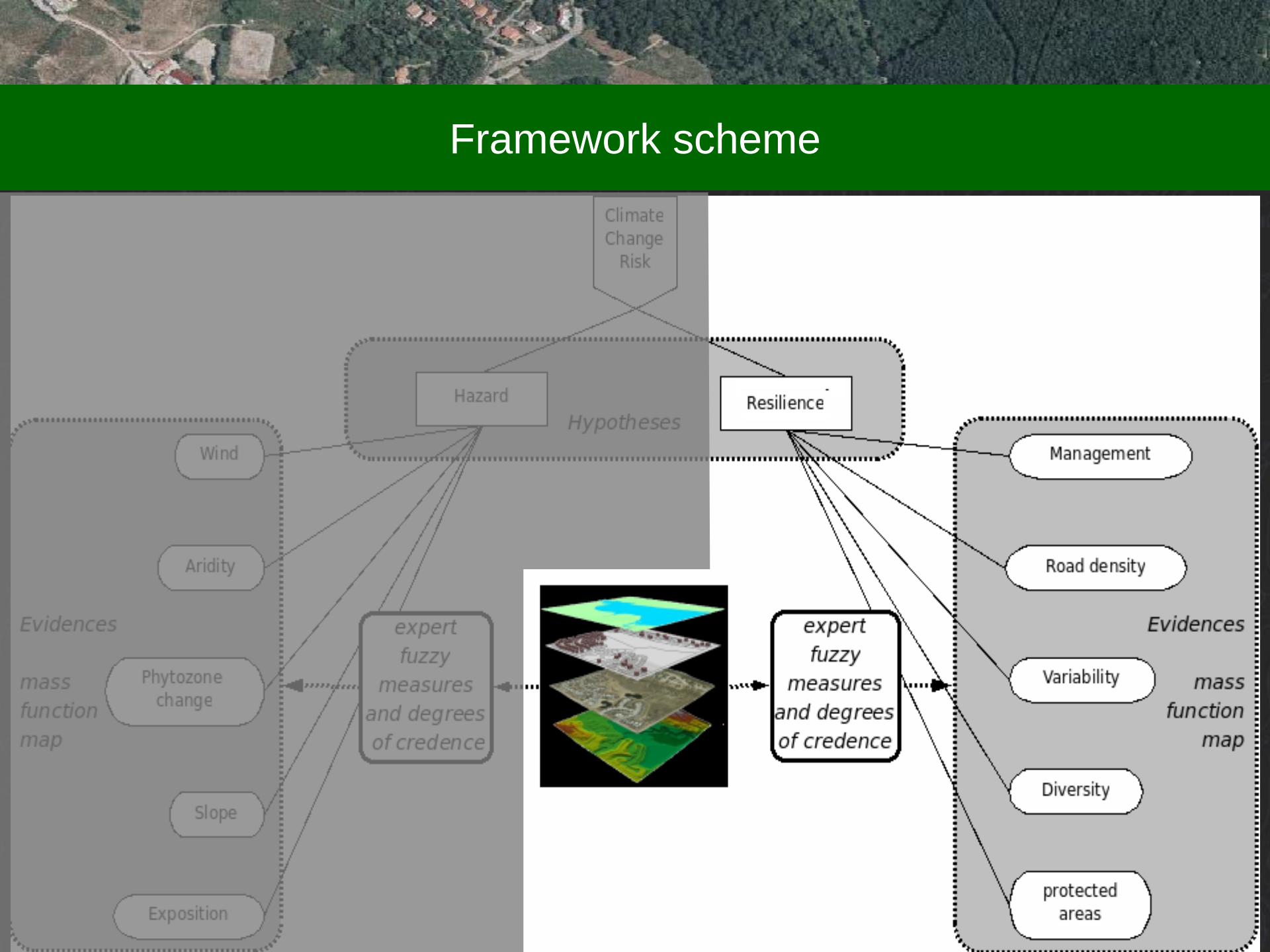
Framework scheme



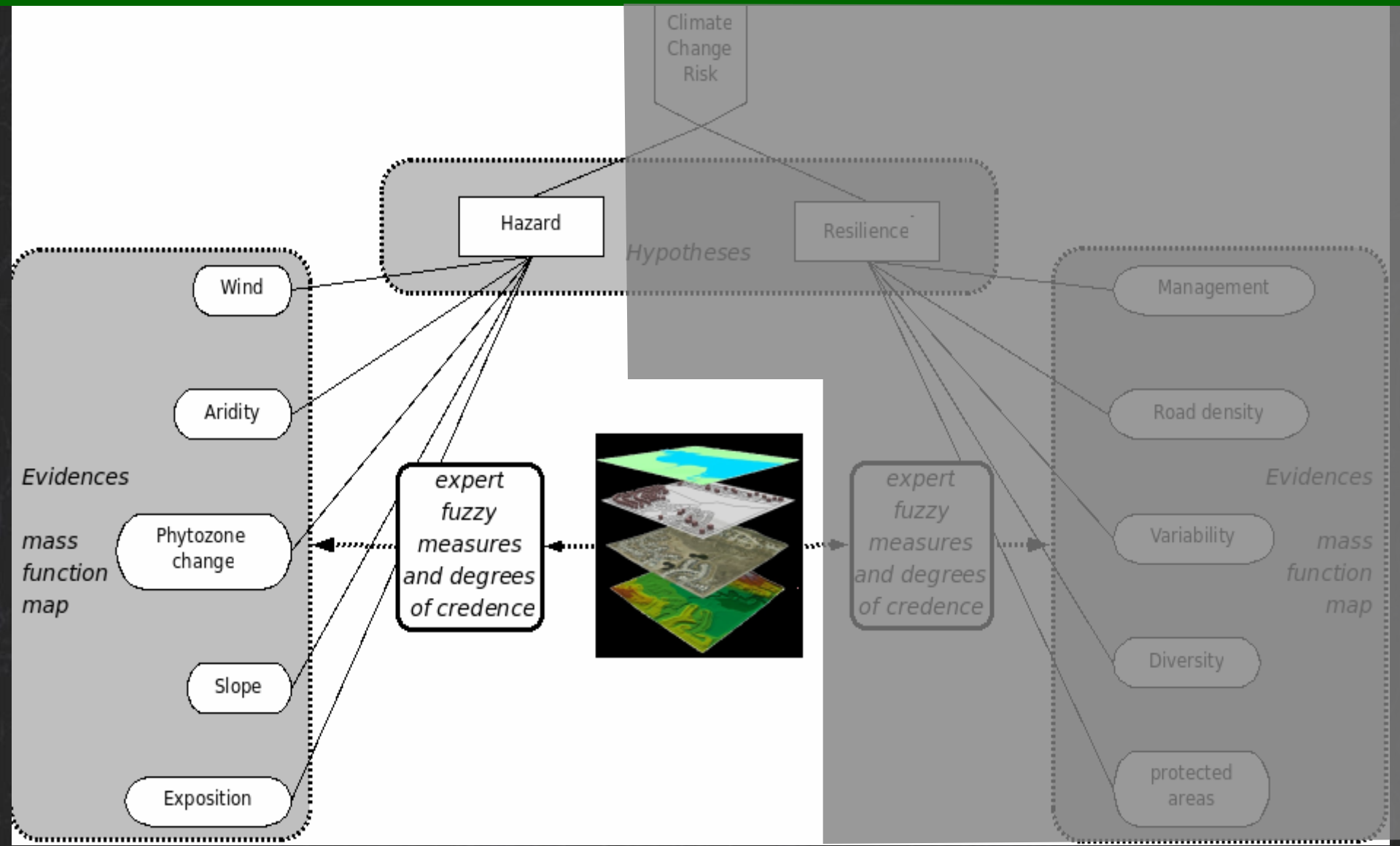
Framework scheme



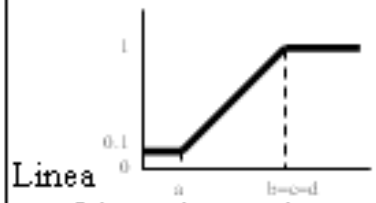
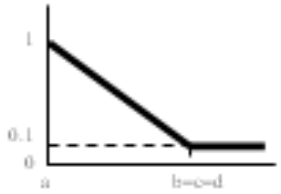
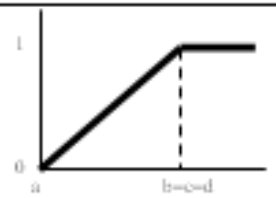
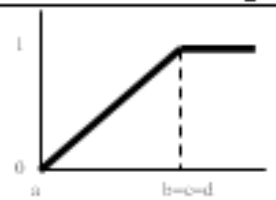
Framework scheme



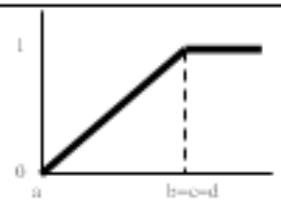
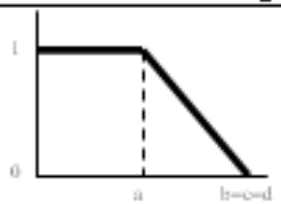
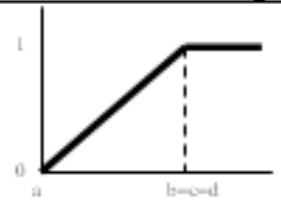
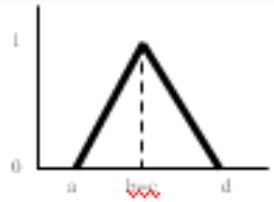
Framework scheme



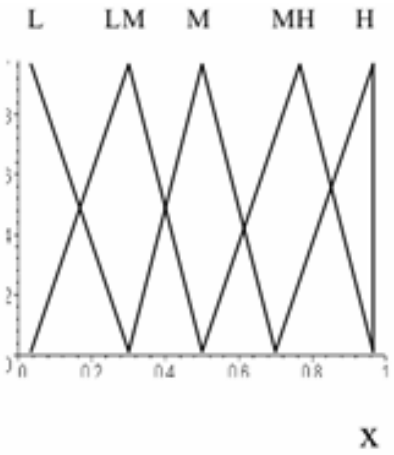
Indicators: Resilience

	Line of evidence k	*Map data*	μ_k	*Control point*			
				a	*b*	*c*	*d*
Vulnerability/Resilience	Management interventions on the forest crops	% of Communes forest surface with management interventions	 Linear increasing	30	70		
	Accessibility to the forest areas for the managing intervention	Accessibility expressed in terms of "cumulative" difference in heights of the forest viability (m)	 Linear decreasing	0	100		
	Ecological diversity	Variety density index	 Linear increasing	0	Maximum value in area		
	Landscape diversity	Edge density index	 Linear increasing	0	Maximum value in area		

Indicators: hazard

	Line of evidence k	*Map data*	μ_k	*Control point*			
				a	*b*	*c*	*d*
Hazard	Wind	N° of yearly extreme events	 Linear increasing	0	Maximum value in area		
	Aridity	Aridity index as for De Martonne	 Linear decreasing	15	30		
	Slope	%	 Linear increasing	0	100		
	Exposition	Degrees in respect to North (°)	 Symmetric	90	180		270

Indicators weights

Hypothesis	**Evidence from factor *k***	**Degree of credence** $\mu_k(T)$	*Linguistic evaluator*
Vulnerability/ Resilience	Management	MEDIUM-LOW	
	Difference in height	MEDIUM	
	Protected areas	MEDIUM-LOW	
	Forest variability	MEDIUM	
	Landscape diversity	MEDIUM	
Hazard	Wind	MEDIUM -HIGH	
	Aridity	MEDIUM -HIGH	
	Change in phytoclimatic zones	HIGH	
	Slope	MEDIUM	
	Exposition	MEDIUM-LOW	

Scale 4

$$BPA_{\substack{x=\{h;r\}}}^{k} = \mu_k(T) \cdot \mu_k(k)$$

Wall of equations

$$\underset{h\in\Omega;h\subseteq i,k}{\boldsymbol{m(h)}} = BPA_i^h \cdot BPA_k^h + BPA_k^h(1-BPA_i^h) + BPA_i^h(1-BPA_k^h)$$

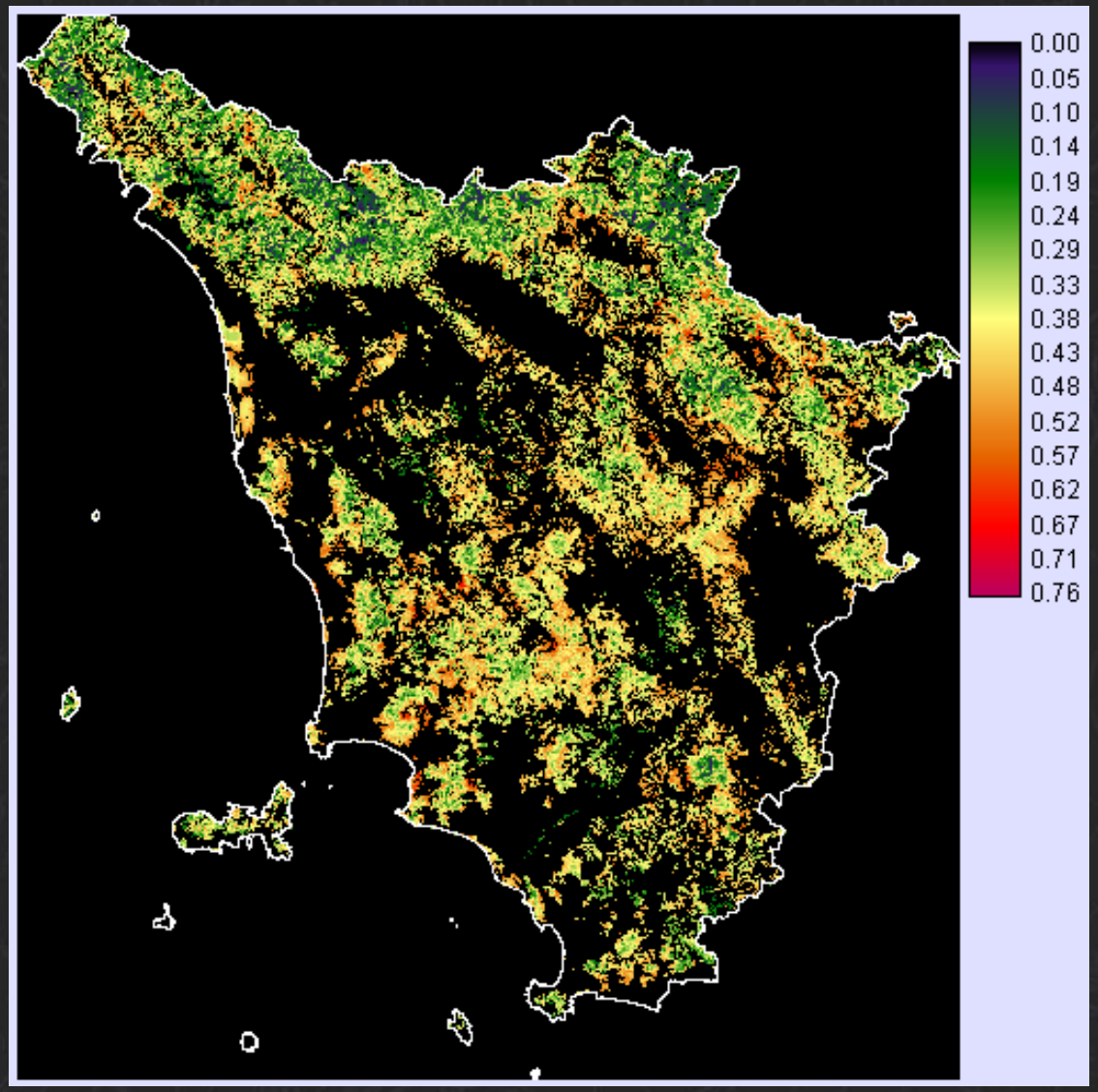
$$\underset{r\in\Omega;h\subseteq i,k}{\boldsymbol{m(r)}} = BPA_i^r \cdot BPA_k^r + BPA_k^r(1-BPA_i^r) + BPA_i^r(1-BPA_k^r)$$

$$Bel(h) = \frac{m(h)\cdot(1-m(r))}{1-m(h)m(r)}$$

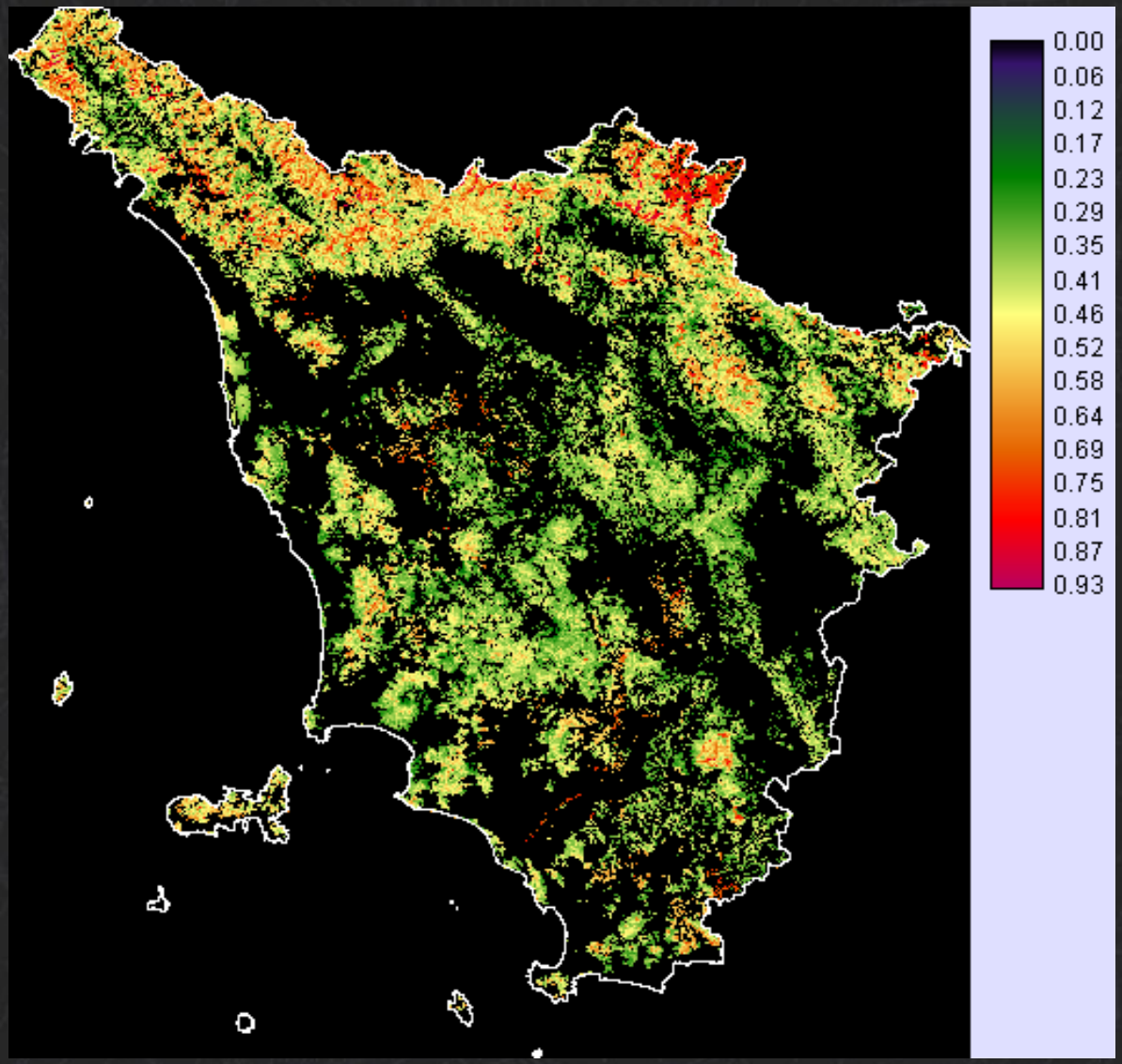
$$Bel(r) = \frac{m(r)\cdot(1-m(h))}{1-m(h)m(r)}$$

$$U(h,r) = Bel(r) - (1-Bel(h)) = \frac{(1-m(h))\cdot(1-m(r))}{1-m(h)m(r)}$$

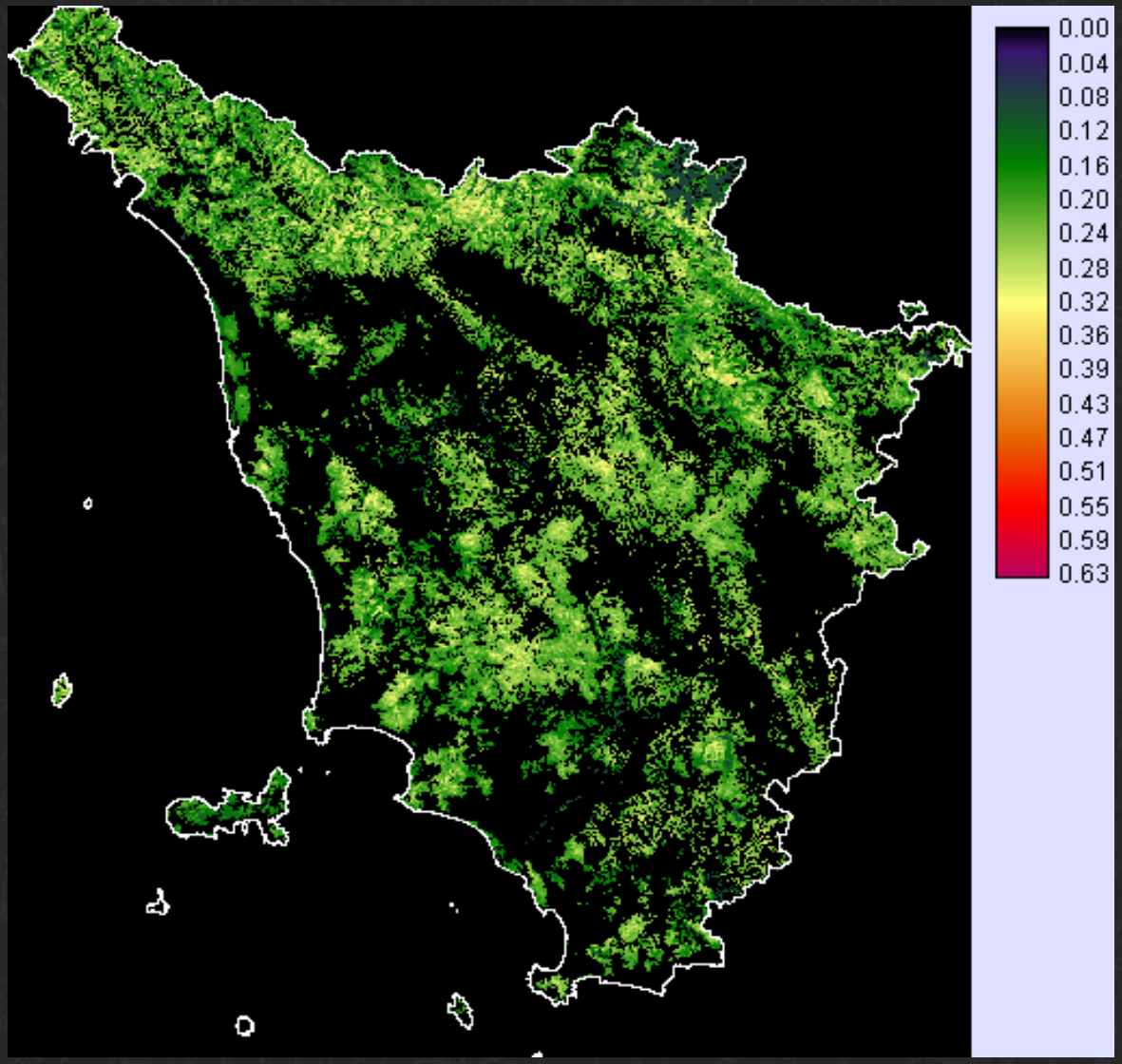
Resilience


0.00
0.05
0.10
0.14
0.19
0.24
0.29
0.33
0.38
0.43
0.48
0.52
0.57
0.62
0.67
0.71
0.76

Hazard


0.00
0.06
0.12
0.17
0.23
0.29
0.35
0.41
0.46
0.52
0.58
0.64
0.69
0.75
0.81
0.87
0.93

Uncertainty



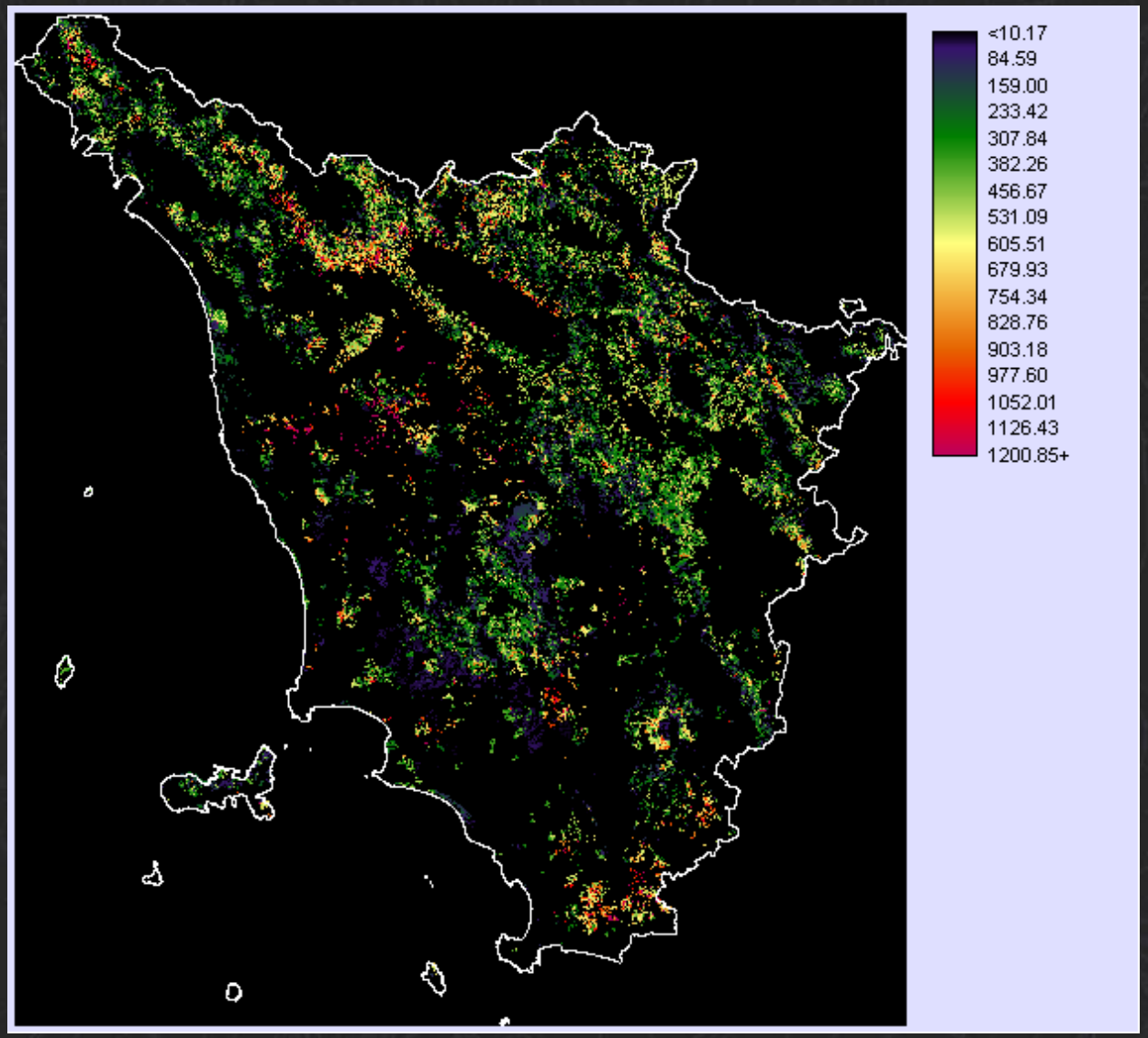
Evaluation of economics damage

$$E(damage) = P_m \cdot Bel(h) \Big/ ((1+r)^t - 1)$$

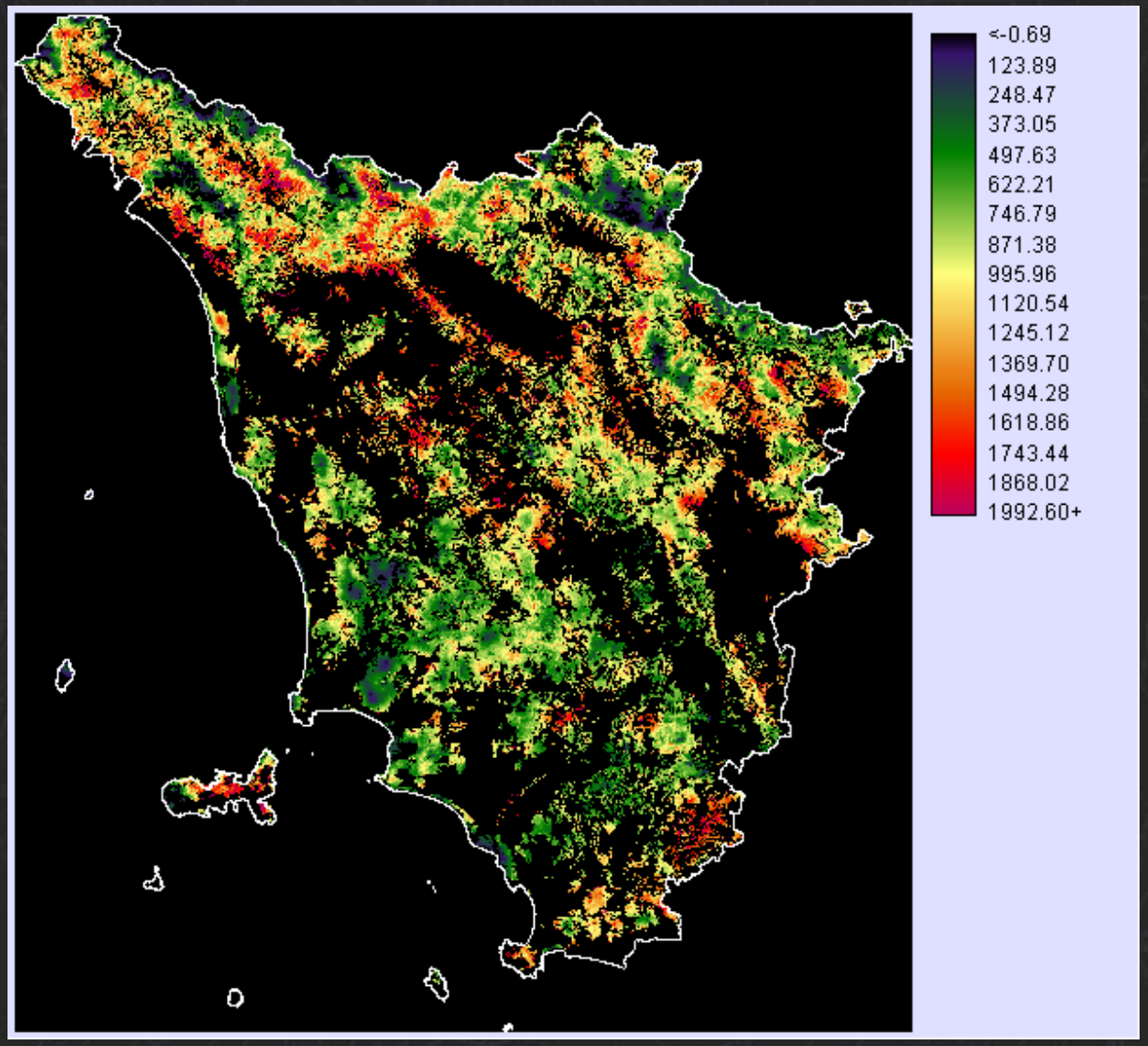
$$E(mitigation) = ((P_{cd} - P_{rd}) \cdot (1-r)^{t-d} / ((1-r)^t - 1) + (A_v / r)) \cdot (1 - Bel(v))$$

$$strategic\ cost = min\{E(damage),\ E(mitigation)\}$$

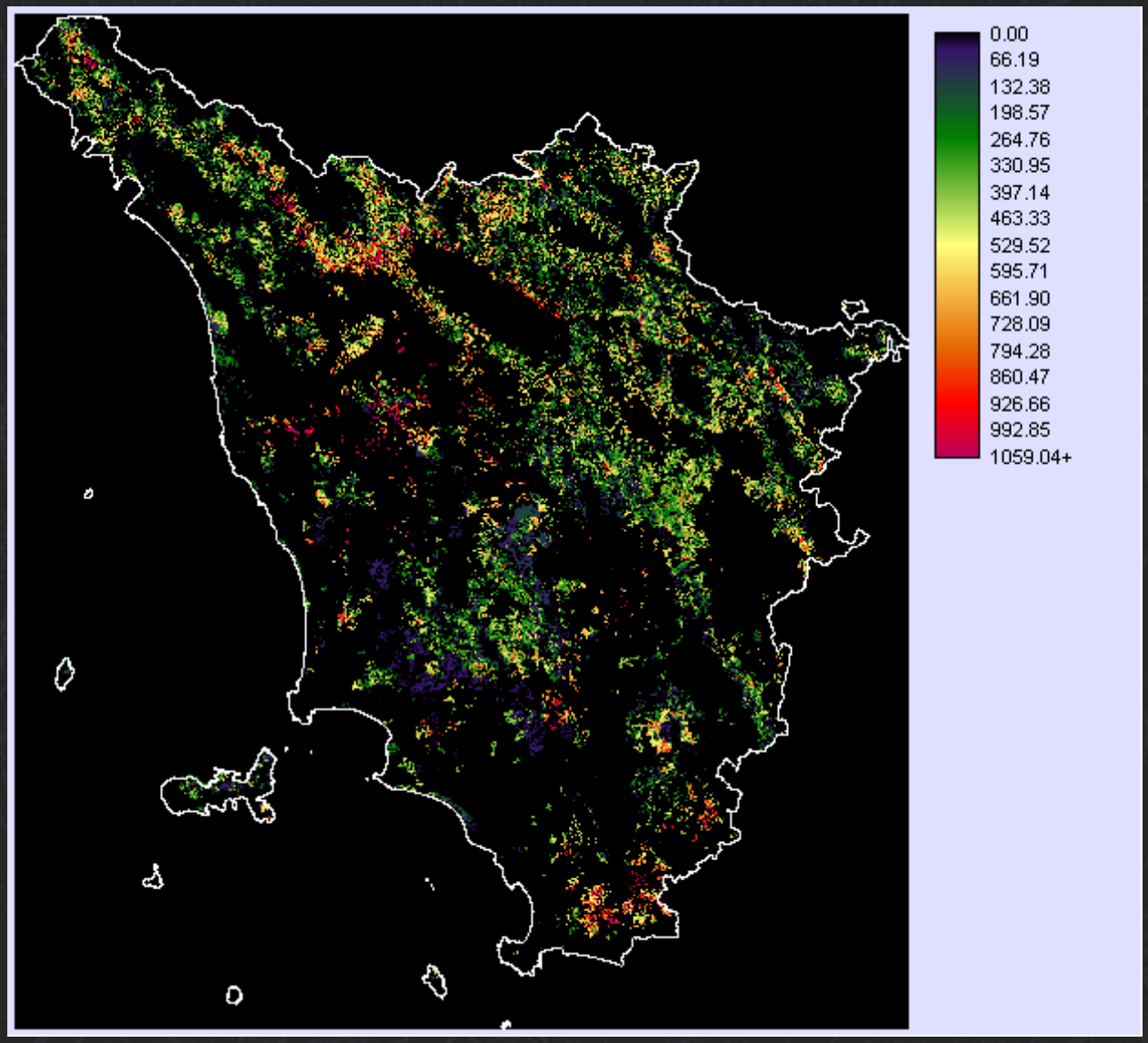
Expected damage

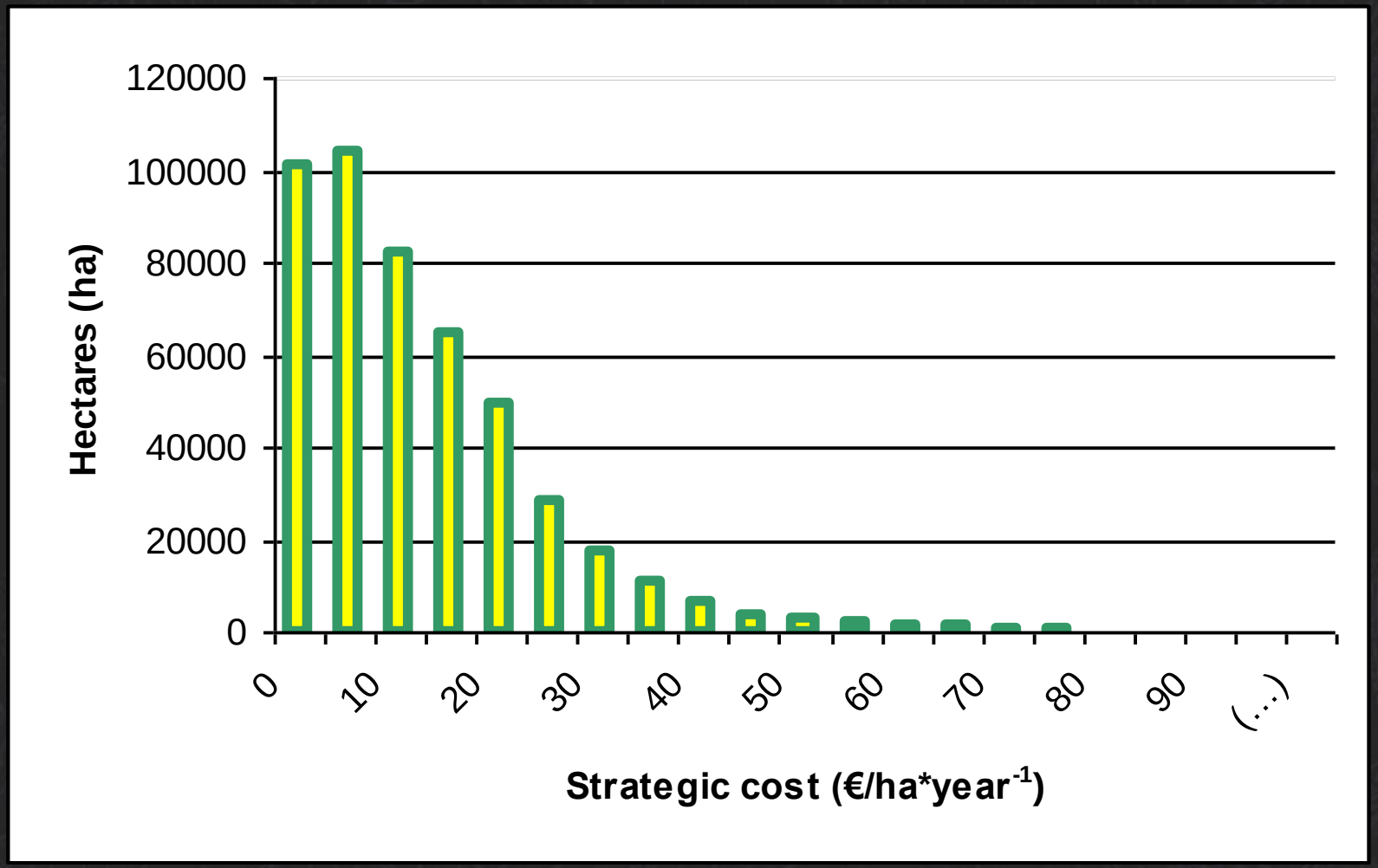


Mitigation cost



Strategic cost




120000
100000
80000
60000
40000
20000
0
Hectares (ha)
0
10
20
30
40
50
60
70
80
90
(…)
Strategic cost (€/ha*year-1)

Conclusions

- Pros:
  - seems to be an adeguate tool for uncertainty analysis;
  - it aggregates all variables in a unique frame of discernment that is the most needed and most effective holistic analysis of climate change risk of damage;
  - in environmental decision making, it provides useful guidance for resource protection and mitigation plans based on the level of probable damage in different locations
- Future development:
  - To extent analysis to not market values
    - Recreation
    - Hydrologic defense
    - Biodiversity and other natural value
  - To implement model validation and verification procedures