# Quantifying the uncertainties within a cross-sectoral, integrated assessment of the impact of climate change on ecosystem services in Europe

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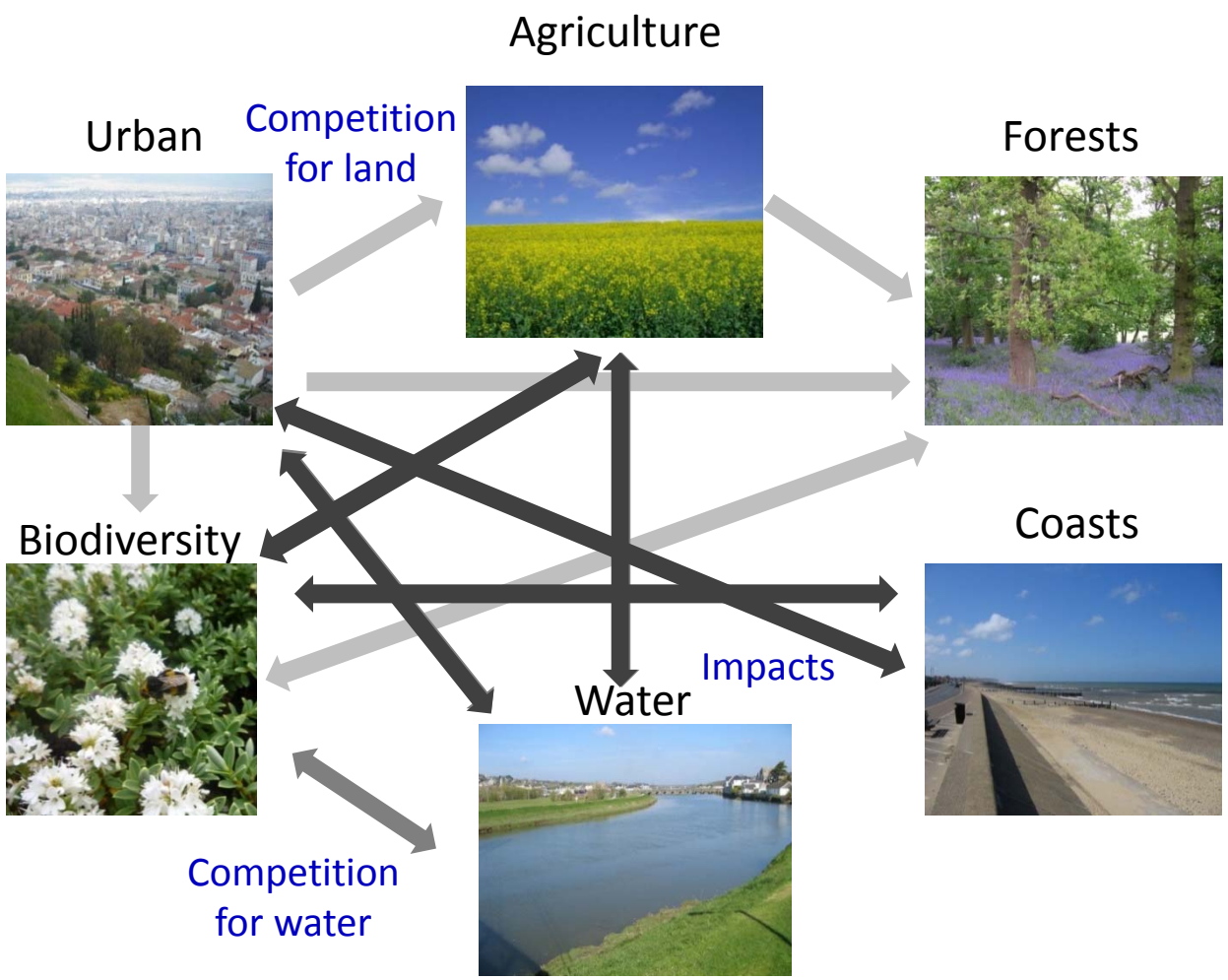
# Modelling cross-sectoral impacts on ecosystem services

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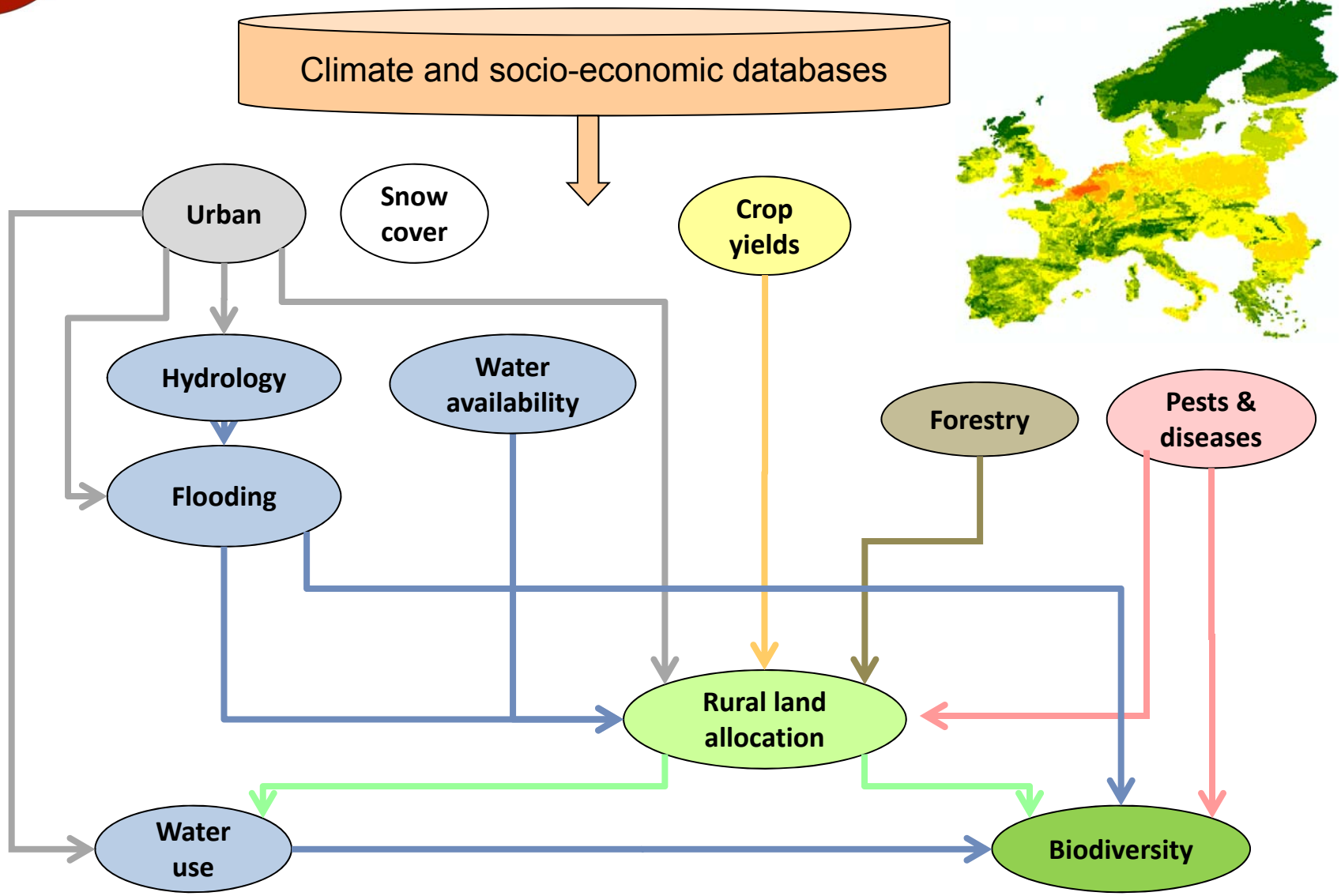
# The CLIMSAVE Integrated Assessment Platform (IAP)

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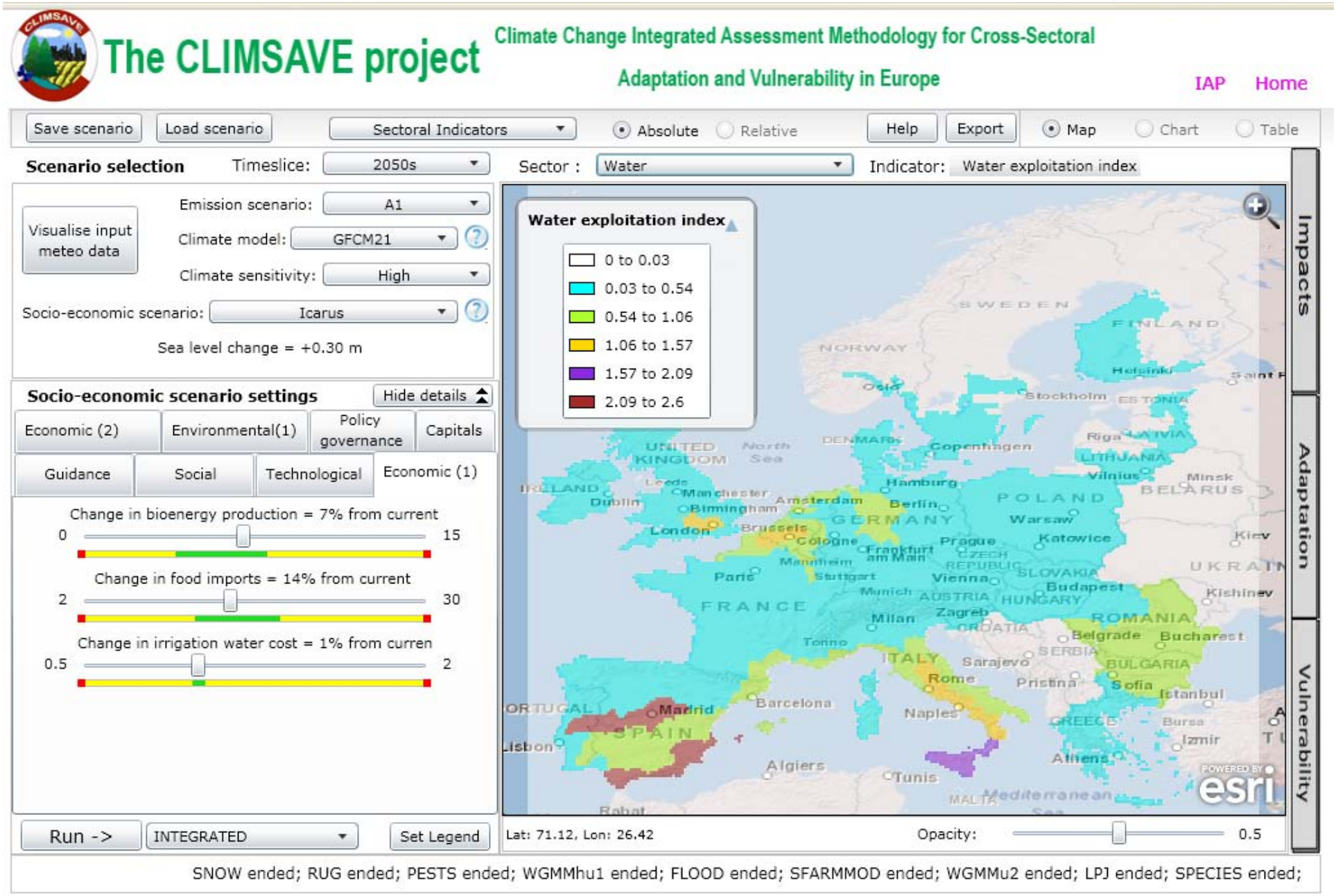
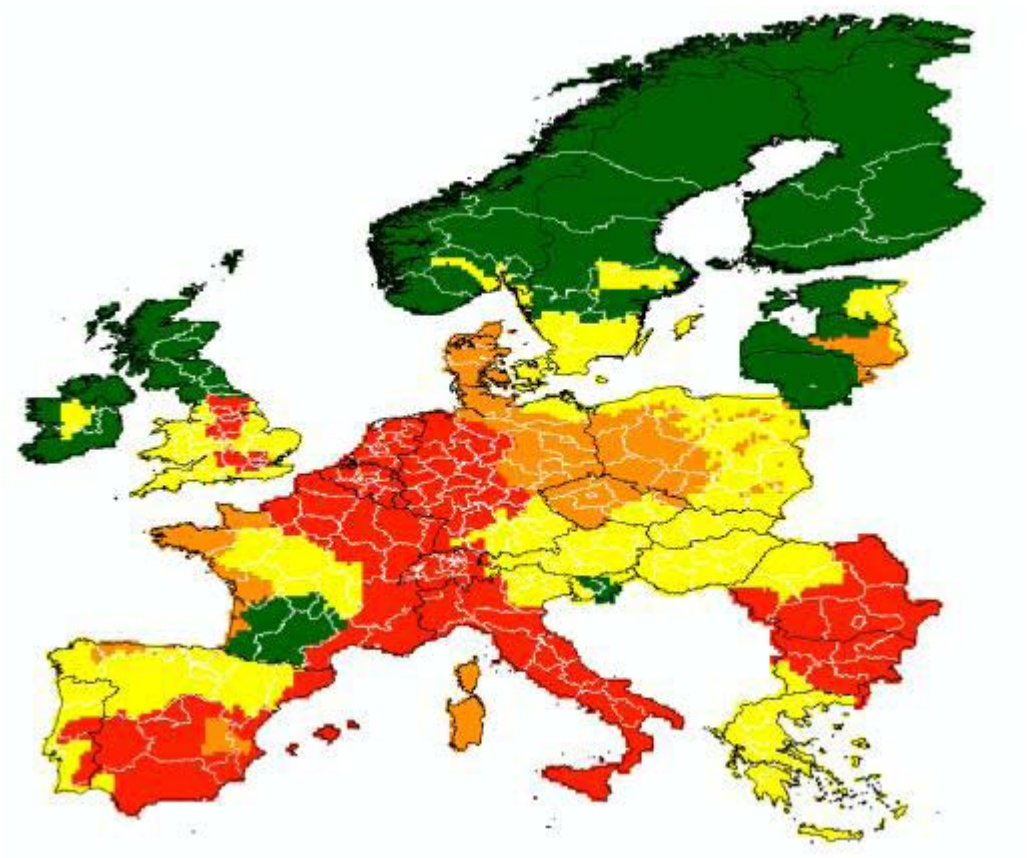



Meta-modelling for rapid run-times to use the IAP in stakeholder discourses

# Vulnerability hotspots

**Water Exploitation Index**

Extreme scenario for the 2050s: Temp+6°C, Rain-50%



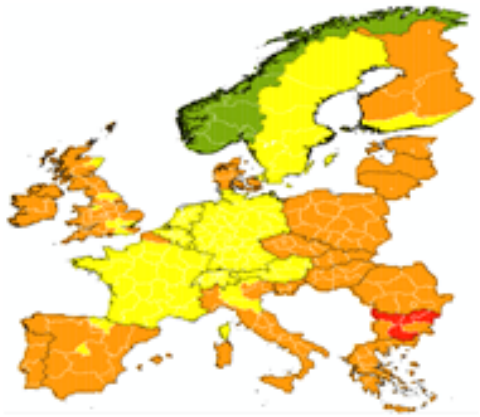
- No impact
- Impact but coping
- Vulnerable (not able to cope)
- Vulnerable (impact to high)

Vulnerability defined in terms of impacts and coping capacity

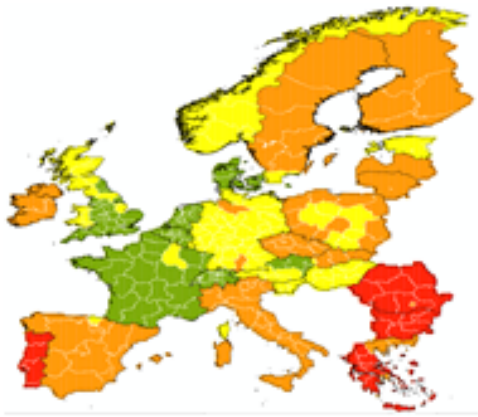
# Capital indicators to interpret coping capacity

HUMAN
(life expectancy[N2] and tertiary education[N2])

SOCIAL
(income inequality[N0] and help when threatened [N0])



FINANCIAL
(household income [N2] and household savings rate[N0])



MANUFACTURED
(transport (area)[N2] and produced capital[N0])

| Class | Standardised Index Value |
|---|---|
| Very High | > 0.8 |
| High | 0.6-0.8 |
| Medium | 0.4-0.6 |
| Low | 0.2-0.4 |
| Very Low | < 0.2 |

# Socio-economic & climate scenarios


**Climate scenarios:**

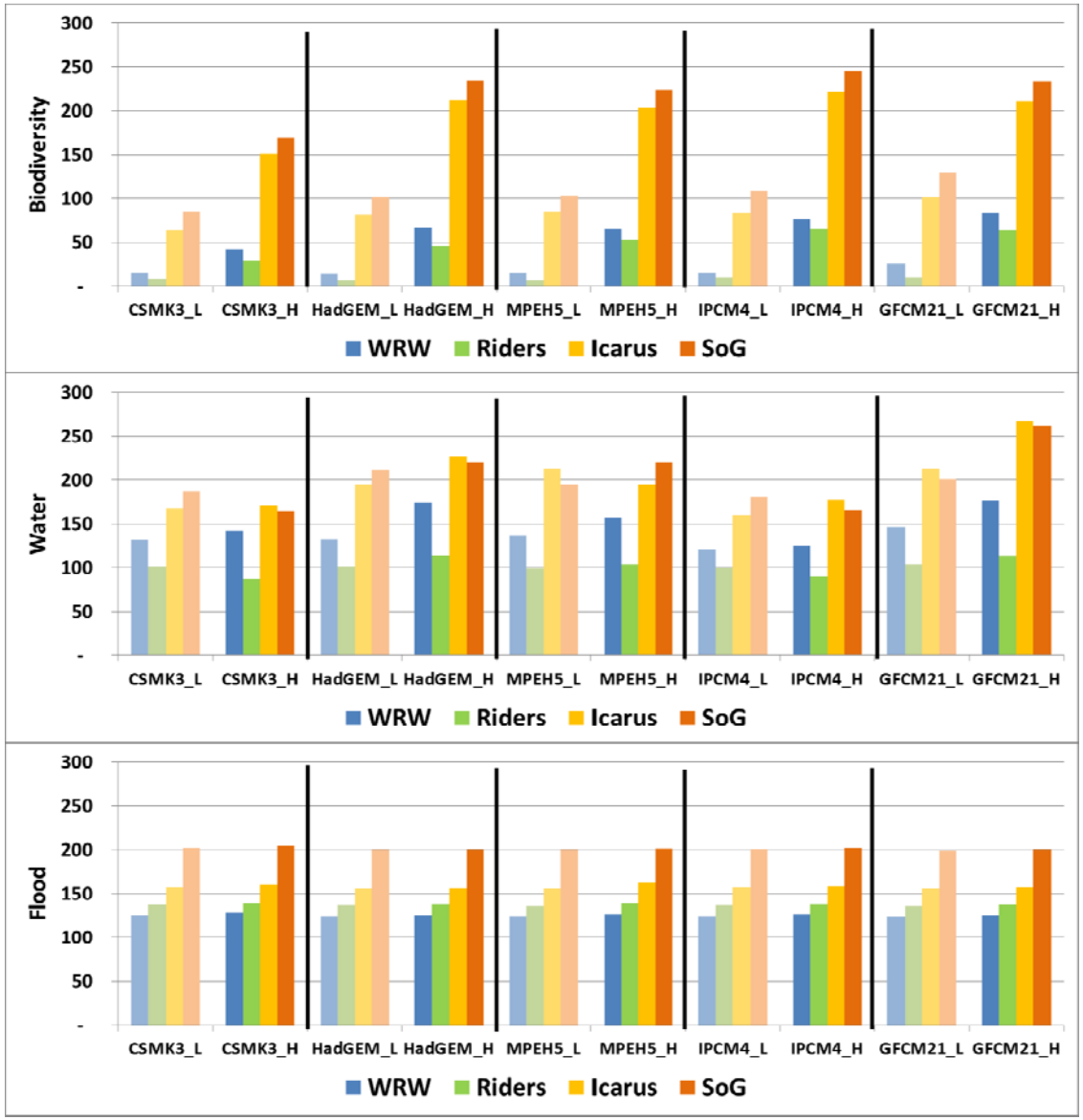
- 5 GCMs
- 3 climate sensitivities (high, medium, low)
- 4 emissions scenarios (SRES)
- Several spatially variable climate variables
- Sea level rise linked to scenarios

# Number of vulnerable people

Biodiversity Index

Water Exploitation

Flooding (people affected by a 1 in 100 year event)



# Water exploitation vulnerability

| Icarus 2050<br>MPEH5,Low Emissions | Icarus 2050<br>MPEH5, High Emissions |
|---|---|
|  |  |
| Vulnerable Area: 14000 kha | Vulnerable Area: 13600 kha |
| Vulnerable People: 213,000,000 | Vulnerable People: 200,000,000 |
| Not vulnerable, negligible Impact | Vulnerable, not coping |
| Not vulnerable, coping | Vulnerable, impossible to cope |
| Water Exploitation Vulnerability | |
| We are the World 2050<br>MPEH5, High Emissions, | Stay or Go 2050<br>MPEH5, High Emissions |
|  |  |
| Vulnerable Area: 14200 kha | Vulnerable Area: 12800 kha |
| Vulnerable People: 156,000,000 | Vulnerable People: 220,000,000 |
| Not vulnerable, negligible Impact | Vulnerable, not coping |
| Not vulnerable, coping | Vulnerable, impossible to cope |

# Sources of uncertainty

| Type | Examples | Tools |
|---|---|---|
| Unpredictability* | Projections of ecosystem service provisioning are not able to be modeled because of chaos, complexity or technical challenges. | Scenario planning, subjective judgment, stochastic tools. |
| Structural Uncertainty* | Inadequate models or incomplete models from science. Disagreement on the system, components or functions. | Model comparisons to understand difference. Divide model up based on confidence |
| Data Uncertainty* | Missing, inaccurate of incomplete data. Poorly known or changing model parameters. Field data or entry error. | Statistical tools to test variation and to project possible ranges. Standardized data tools. |
| Risk/ Consequence** | Model outputs involve high stakes and uncertainty emerges out of caution. | Break decisions or consequences into parts. |
| Political** | Stakeholders likely to question or challenge model results causing uncertainty about agreement. | Co-production of models or separating contested parts of models. |

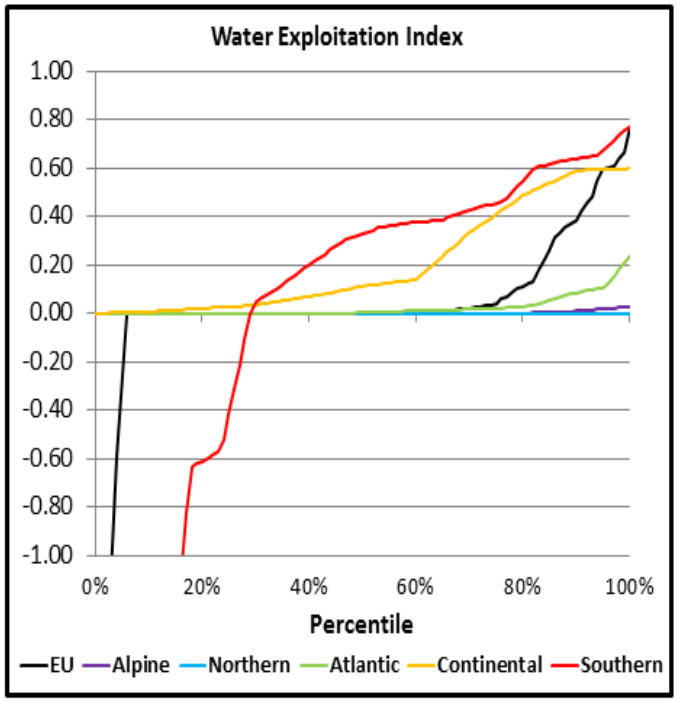
*Adapted from: Intergovernmental Panel on Climate Change, Guidance to Lead Authors, 2005
** Adapted from: Sarewitz 2004

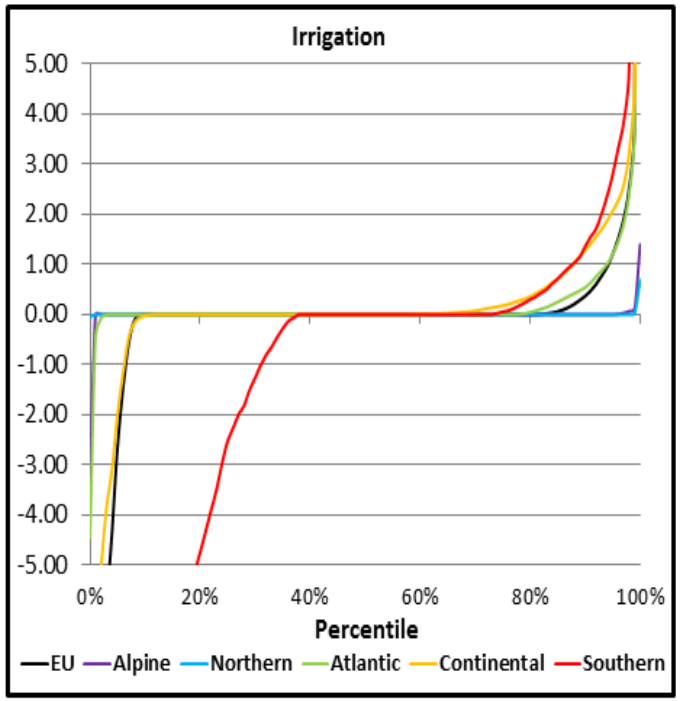
From: Manson and Halsey, 2014

# Evaluating uncertainty in the IAP

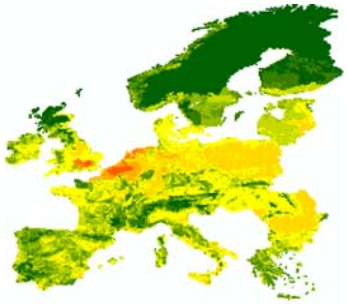
| Source of uncertainty | Evaluation method |
|---|---|
| Data | Quantitative model validation (goodness of fit to observational data) |
| Model process representation | Qualitative model validation (modeller confidence)<br>Quantitative model validation (goodness of fit to observational data) |
| Meta-modelling (emulators) | Quantitative model validation (goodness of fit to full model) |
| Error propagation across coupled models | Network analysis |
| Cross-sectoral integration | Comparing single sector and multi-sector models runs |
| Scenario assumptions | Monte Carlo based uncertainty analysis |

# Cross-sectoral vs single sector assessment




- Change in Water Exploitation Index (WEI) and irrigation requirement for the GFCM21 climate model for the A1 scenario
- WEI is 0 when there is no human appropriation of available water resources, and 1.0 when people use 100% of the resource
- Positive y-axis values are for the cross-sectoral model is > the single sectoral model

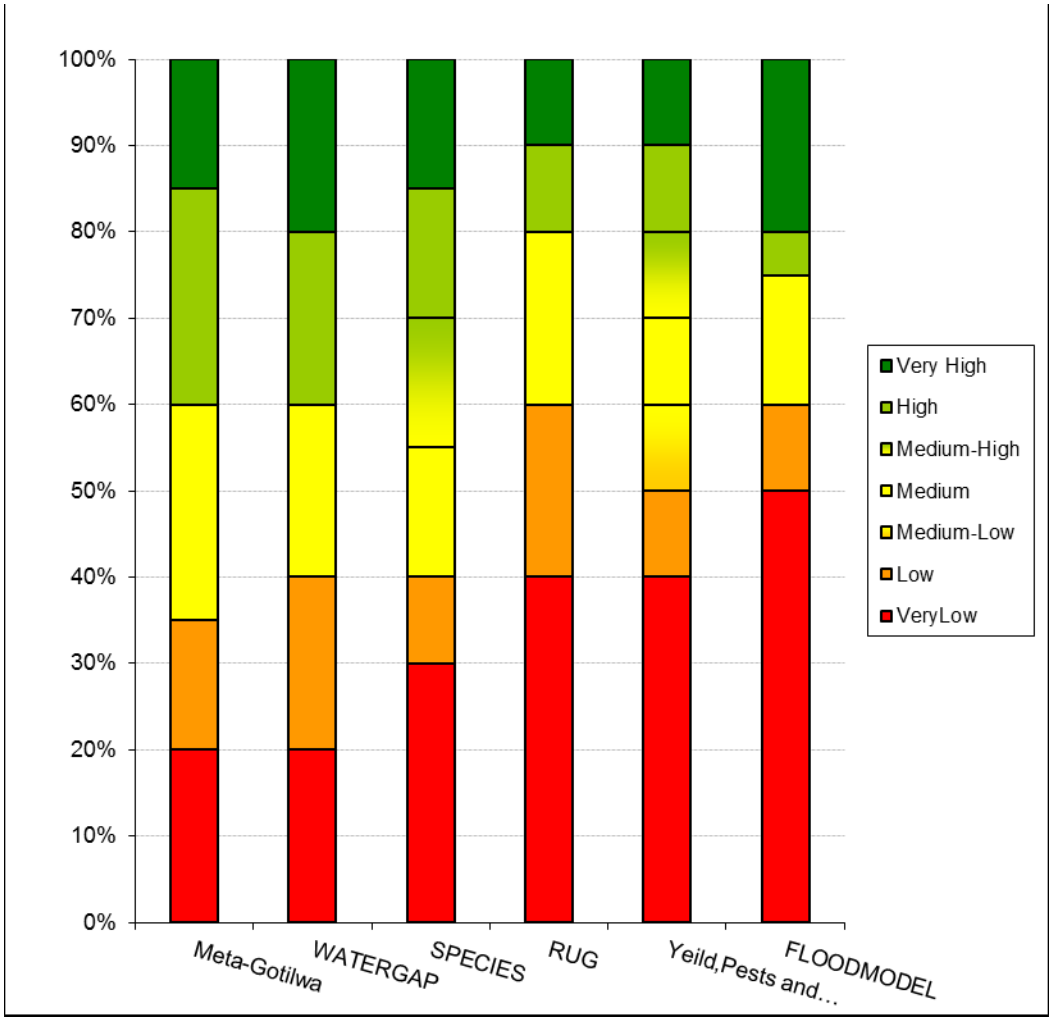


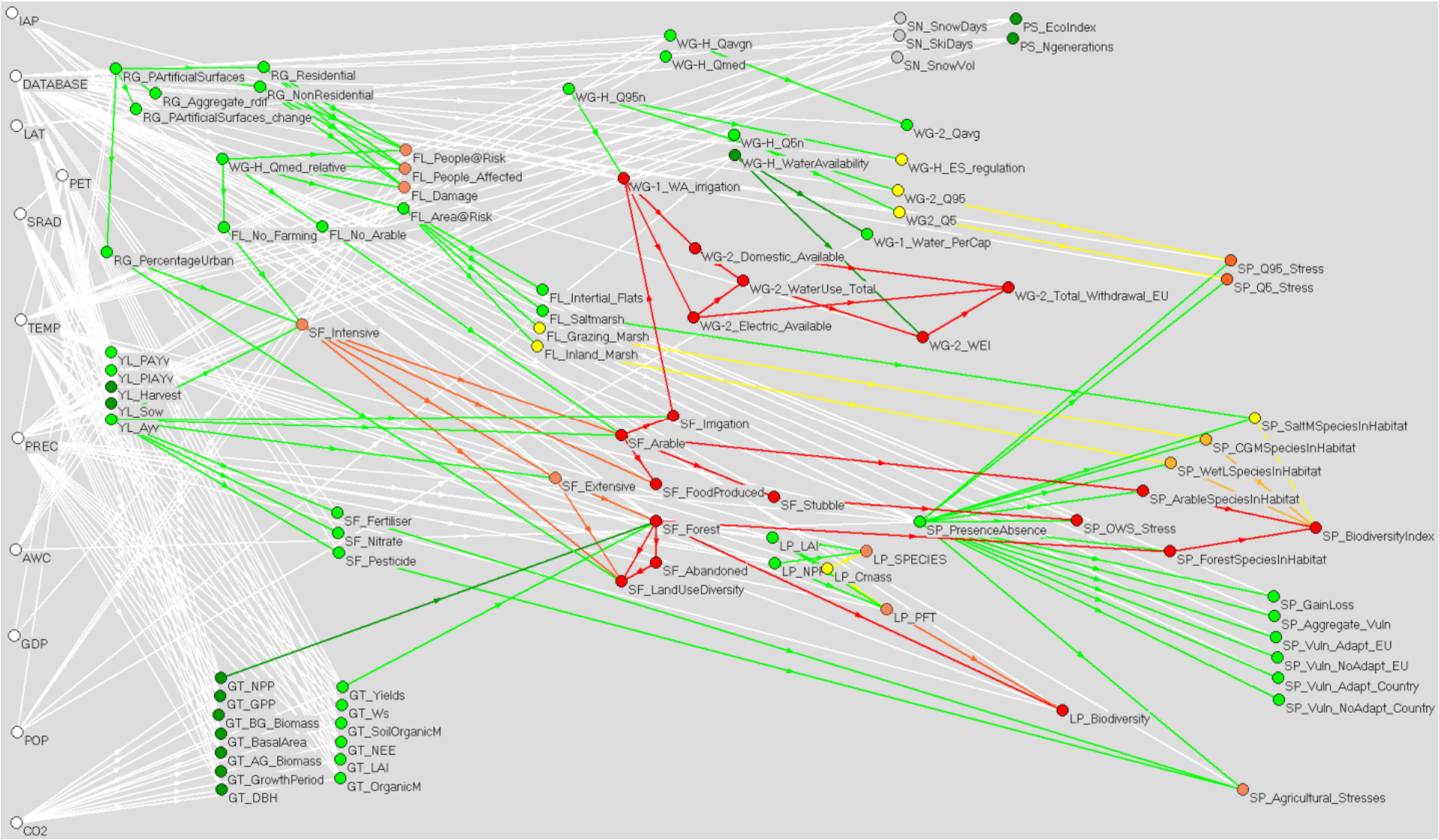
Source: Rob Dunford, University of Oxford

# Qualitative modeller confidence

**Expert Certainty**
- ↑+ Very High
- ↑ High
- ↗ Medium-High
- → Medium
- ↘ Medium- Low
- ↓ Low
- ↓- Very Low

Confidence in model output variables arising from:
- Model process representation (validation);
- Meta-model comparison to original model;
- Error propagation between models






*Uncertainty Index*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | 0-20% | ● | 20-40% | ● | 40-60% | ● | 60-70% | ● | 70-80% | ● | 80-90% | ● | 90-100% |

FL = FLOODMODEL; GT = Meta-GOTILWA; LP= LPJ-GUESS; PS= Pests; SF = SFARMOD; WG=WATERGAP; SP = SPECIES; SN= Snow; YL=Yields.

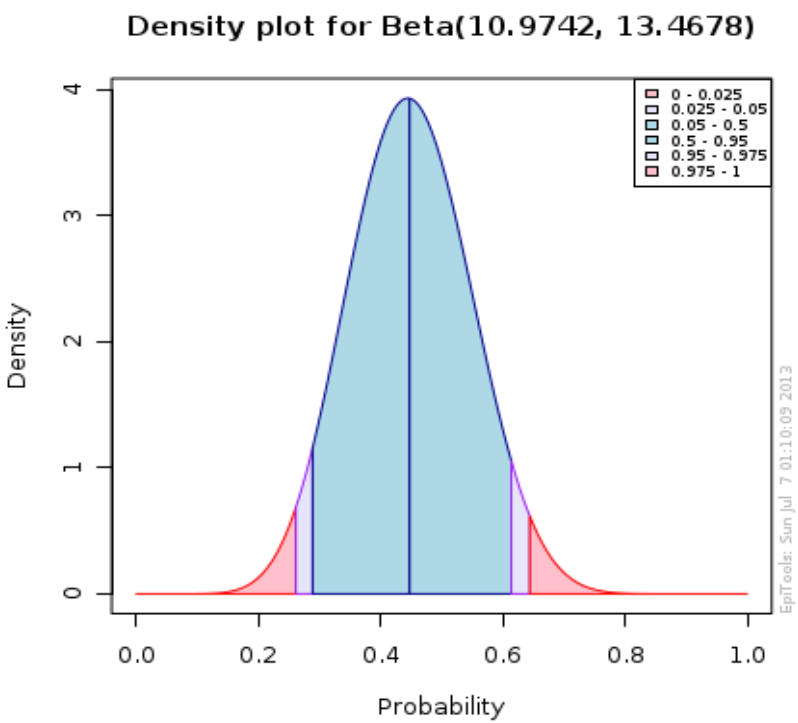
# Variable-to-variable network

# Quantitative uncertainty analysis: Probability Density Function (PDF)


The β distribution takes the form:

$$\frac{1}{B(\alpha,\beta)} x^{\alpha-1}(1-x)^{\beta-1}$$

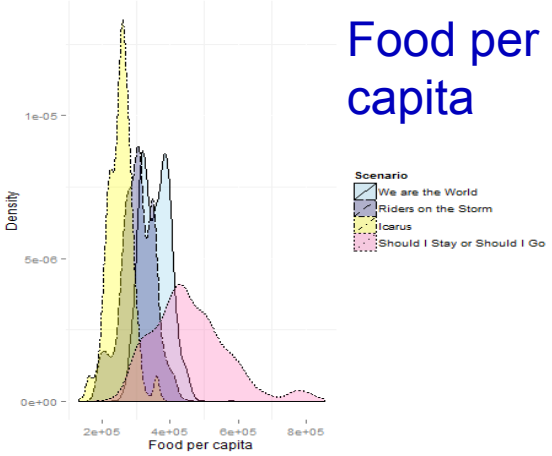
where *B(α,β)* is the beta function and α and β are shape parameters.



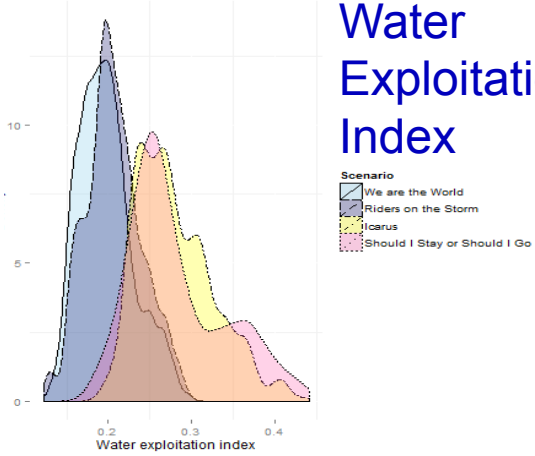
**PDFs of model outputs: number of vulnerable people**

European wide climate and socio-economic change impacts on 4 vulnerability indicators:

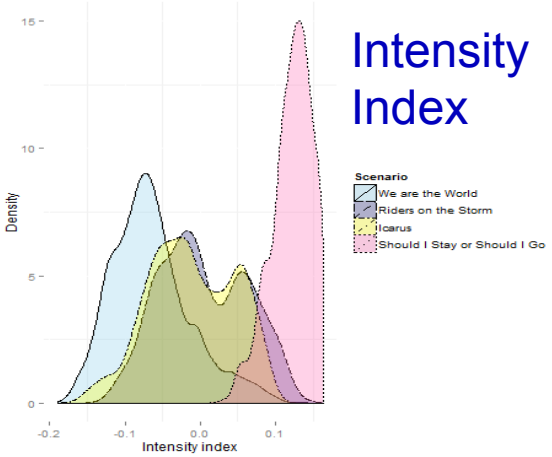
Mean number of vulnerable people for Europe



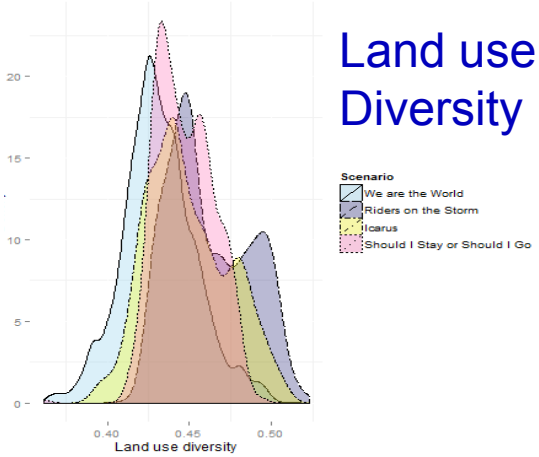

Food per capita



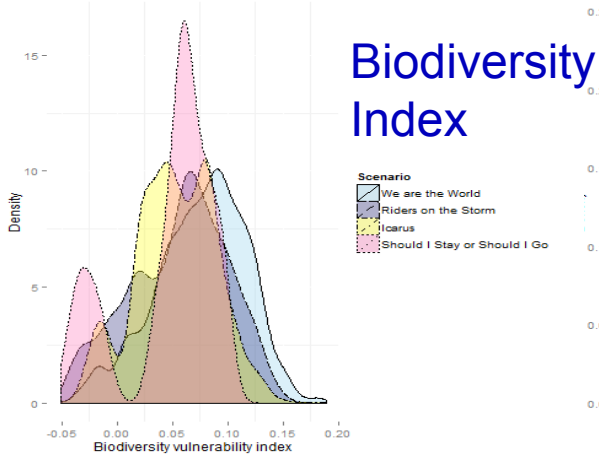

Water Exploitation Index



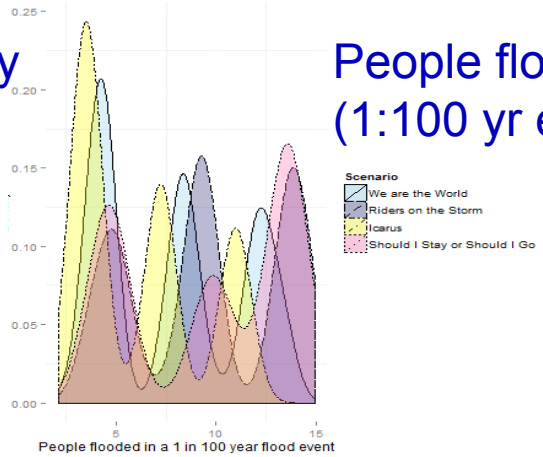

Intensity Index




Land use Diversity

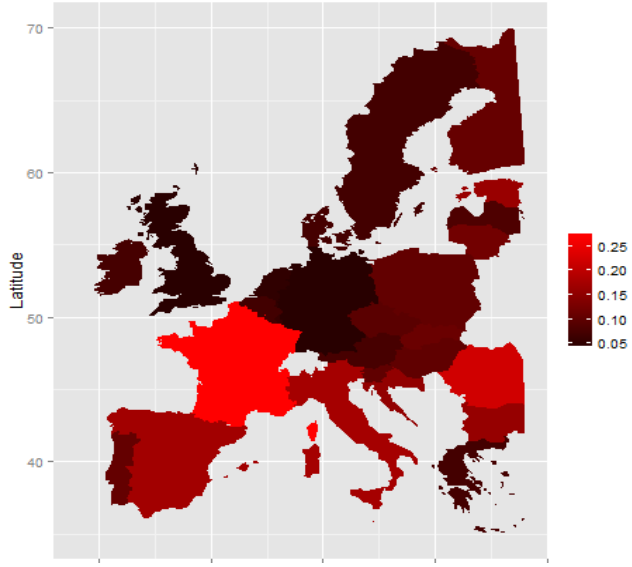


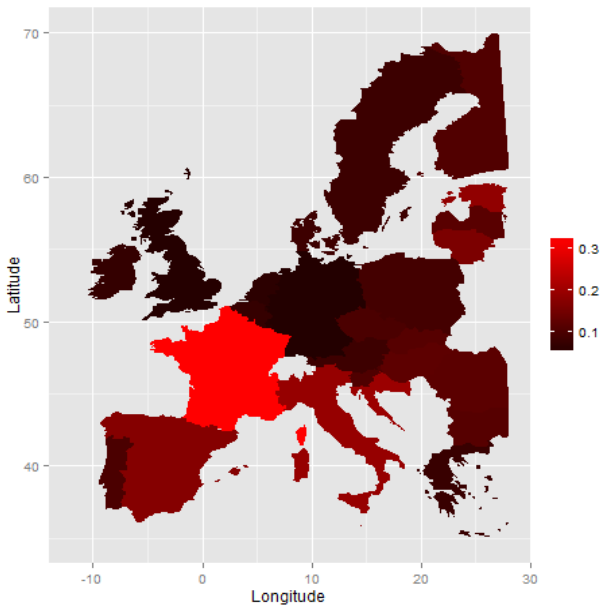

Biodiversity Index

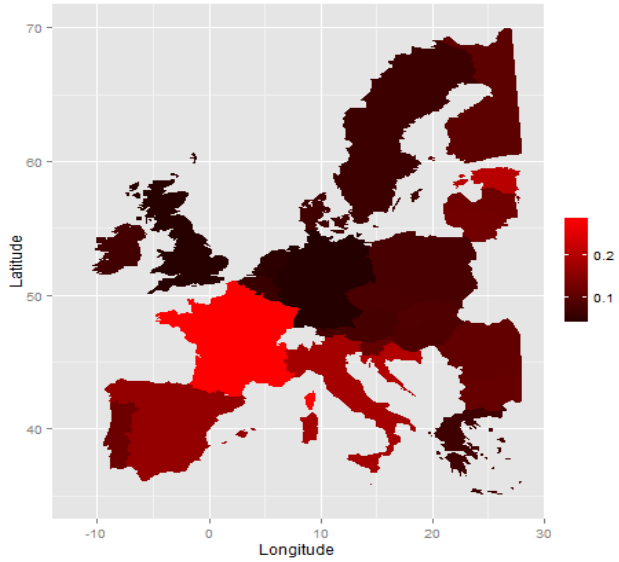



People flooded (1:100 yr event)

# Spatial uncertainty in the biodiversity index




***Scenarios***:

*We are the World* (top left)
*Riders on the Storm* (top-right)
*Icarus* (left)

# Concluding remarks

- The assessment of climate change impacts on ecosystem services requires a cross-sectoral and multi-diver perspective in order to avoid either over- or under-estimating impacts
- Cross-sectoral and multi-scalar assessments within a scenario framework introduces a number of uncertainties, including data quality, process representation in models, scenario assumptions about future development pathways and error propagation across coupled models
- Formalised uncertainty assessment (both qualitative and quantitative) can help in understanding whether the provision of ecosystem services within alternative future worlds (represented in scenarios) will converge or diverge in their response to climate change

# Further reading …


- Brown, C., Brown, E., Murray-Rust, D., Cojocaru, G., Savin, C. & Rounsevell, M.D.A. (2014). Analysing uncertainties in climate change impact assessment across sectors and scenarios. *Climatic Change*, DOI 10.1007/s10584-014-1133-0
- Dunford, R., Harrison, P.A., Jager, J., Rounsevell, M.D.A. & Tinch, R. (2014), Exploring climate change vulnerability across sectors and scenarios using indicators of impacts and coping capacity. *Climatic Change*, DOI 10.1007/s10584-014-1162-8
- Dunford, R., Harrison, P.A. & Rounsevell, M.D.A. (2014). Exploring scenario and model uncertainty in cross-sectoral integrated assessment approaches to climate change impacts. *Climatic Change*, DOI 10.1007/s10584-014-1211-3
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- Jäger, J., Rounsevell, M.D.A., Harrison, P.A., Omann, I., Dunford, R., Kammerlander, M. & Pataki, G. (2014). Assessing policy robustness of climate change adaptation measures. *Climatic Change,* DOI 10.1007/s10584-014-1240-y


ANY QUESTIONS?