

Disentangling uncertainties in risk-based planning of water resources in the UK

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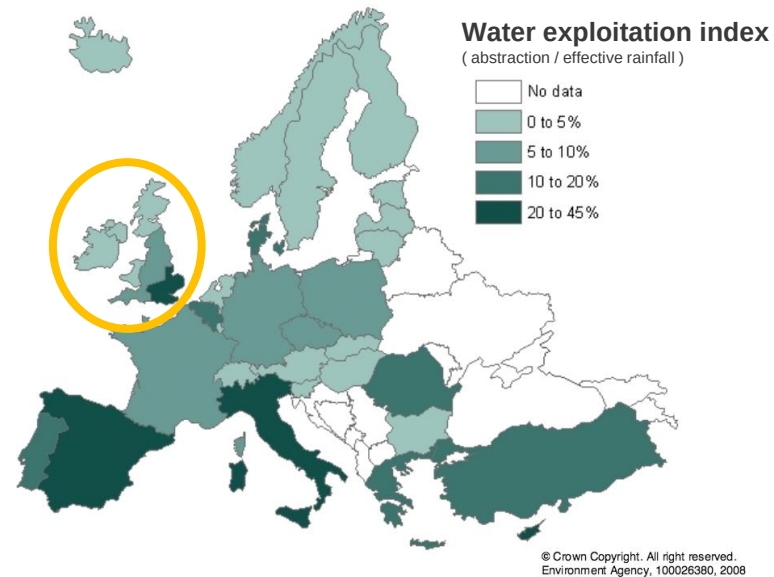
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Water resources in the UK are (and are predicted to be) under increasing pressure

Pressure on water resources is already high in the South East



Environment Agency (2008) *Water resources in England and Wales – current state and future pressures*

Looking ahead, an extra 4000 MI/day is predicted to be needed at national scale to maintain current level of service



National Infrastructure Commission (2018) *Preparing for a drier future*

In the UK, water resources are managed by several water companies, through 5-years planning cycles

Water Resources Management Plans (WRMPs) are delivered every 5 years for a 25-years planning period

Questions that ultimately the company need to answer in their WRMPs:

- **What** are good options to invest on (e.g. new supply infrastructure, leakage reduction, water re-cycling, ...)?
- **When** will they need to be realised?

Uncertainties affecting model-based analysis of options:

- long-term change (“**epistemic**” uncertainty, as in Beven et al. 2018 *NHESS*)
- intrinsic variability (“**aleatory**” uncertainty)

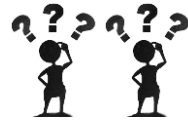
Models used to help answer these questions:

- highly aggregate **Supply-Demand Balance** (SDB) models: typically used to assess the effects of long-term change
- more detailed **Water Resource Systems** (WRS) models: typically used to assess intrinsic variability

In the current planning cycle (2019-2024) water companies are requested a step change in the way they analyse tradeoffs and uncertainties

Water Resources Management Plans (WRMPs) due in 2024 will have to:

- Seek for “best-value” plan – i.e. move from “Cost-efficiency” to “Multi-criteria” analysis ✓
- Use “risk-based” approach – i.e. better handle model uncertainties – not fully clear how to do this!
- Be “adaptive” – not clear at all!



The “Water resources planning guidelines” mention the word “uncertainty” 61 times and the word “risk” 74 times in 82 pages!

Technical guidelines list several methods for “risk-based” (or “bottom-up”) planning but it is unclear to what extent they differ and which should be used when

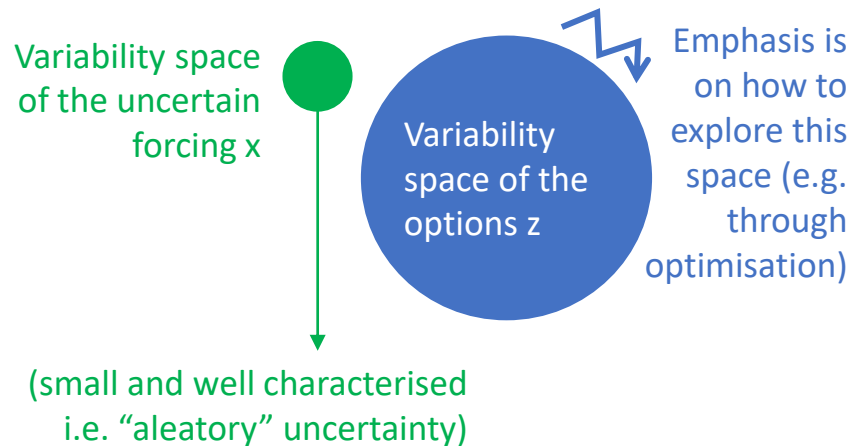
System Sensitivity Analysis
Robust decision-making
Decision scaling
Info-gap



“Risk-based” (or “bottom-up”) approaches: what are they and how do they differ from “traditional” ways of handling uncertainty?

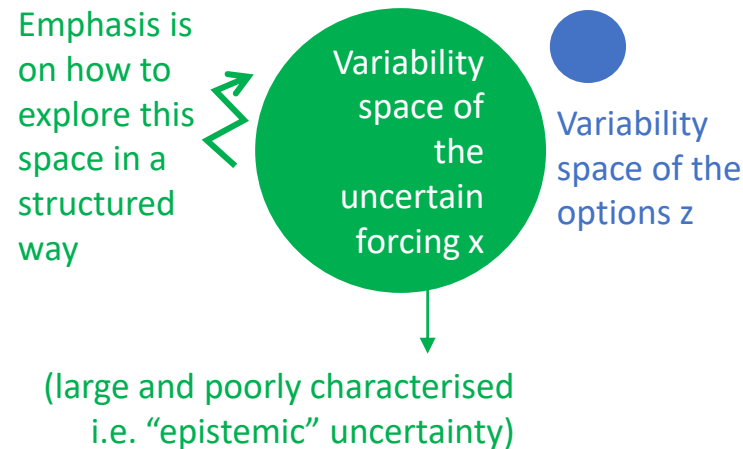
The “traditional” approach to handling uncertainty

$$\max_{\mathbf{z}} \text{stat}_{\mathbf{x}} \mathbf{y} = f(\mathbf{z}, \mathbf{x})$$



The “risk-based” approach to handling uncertainty

find $\mathbf{z} : \mathbf{y} > \mathbf{y}^*$ under as many $\mathbf{x}$ as possible



$\mathbf{z}$ = decision variables that the Decision-Maker can control (“policy Levers” in the XLRM framework by Lempert et al 2003)

$\mathbf{x}$ = uncertain forcings that influence the system and are outside the DM’s control (“eXternal factors”)

$\mathbf{y}$ = set of metrics that characterise the system behaviour (“performance Metric”)

f = relationship (quantified through the model equations) linking $\mathbf{z}$ and $\mathbf{x}$ to $\mathbf{y}$ (“Relationships”)

stat = statistical operator, for instance *Expected Value* or *Min*

What we are doing and what are open questions

What we are working on:

Develop Global Sensitivity Analysis (Wagener and Pianosi, 2019 *ESR*) methods to explore the space of variability of the uncertain forcings x *and simultaneously* of the options z in a structured way

Develop interactive visualisation tools to support the exploration and communication of GSA results

Demonstrate them in proof-of-principle case studies for a water company in the South-West of England

Open questions:

How do we link different models (Supply-Demand Balance and Water Resource Systems)?

How do we treat consistently the two sources of uncertainty - aleatory and epistemic?

How do we simplify the implementation and communication of “risk-based” approaches so that they become more applicable in practice?

How do we bring in the temporal dimension – i.e. the “adaptive planning” idea – also considering that WRMPs are revised every 5 years so some level of adaptation is already embedded in the planning process itself?

Questions? Suggestions? Get in touch: francesca.pianosi@bristol.ac.uk

References and further info

Beven, K. J., Almeida, S., Aspinall, W. P., Bates, P. D., Blazkova, S., Borgomeo, E., ... Wilkins, K. L. (2018). Epistemic uncertainties and natural hazard risk assessment - Part 1: A review of different natural hazard areas. *Natural Hazards and Earth System Sciences*, 18(10), 2741-2768. <https://doi.org/10.5194/nhess-18-2741-2018>

R.J. Lempert, S. Popper and S. Bankes (2003) *Shaping the Next One Hundred Years: New Methods for Quantitative, Long Term Policy Analysis*, RAND, Santa Monica, CA

Wagener and Pianosi, 2019, What has Global Sensitivity Analysis ever done for us? A systematic review to support scientific advancement and to inform policy-making in earth system modelling, *Earth-Science Review*

Our work on Global Sensitivity Analysis: www.safetoolbox.info

Our work on Reservoir Operations Simulation and Optimisation: www.resimop.info

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