Anglia Ruskin University | Global Sustainability Institute

Real options and robust adaptive management in irrigated agriculture and urban drainage

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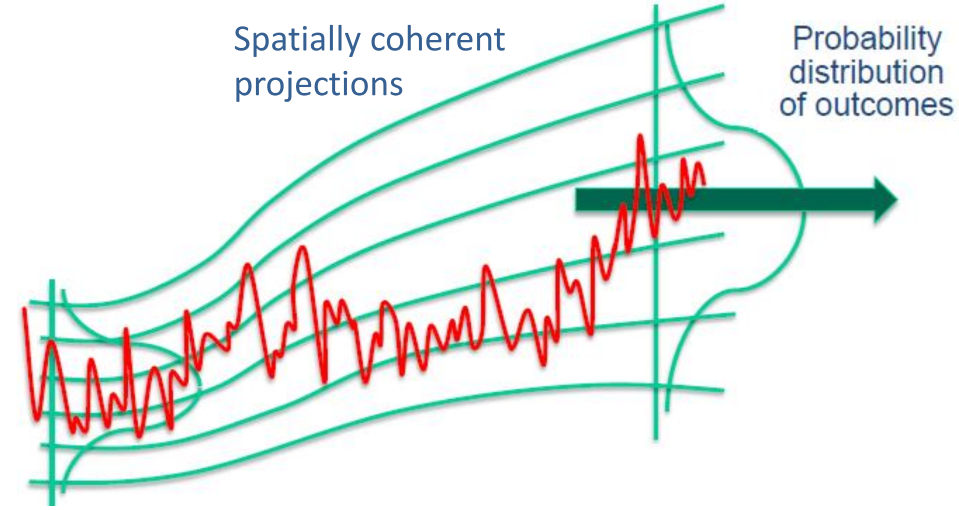
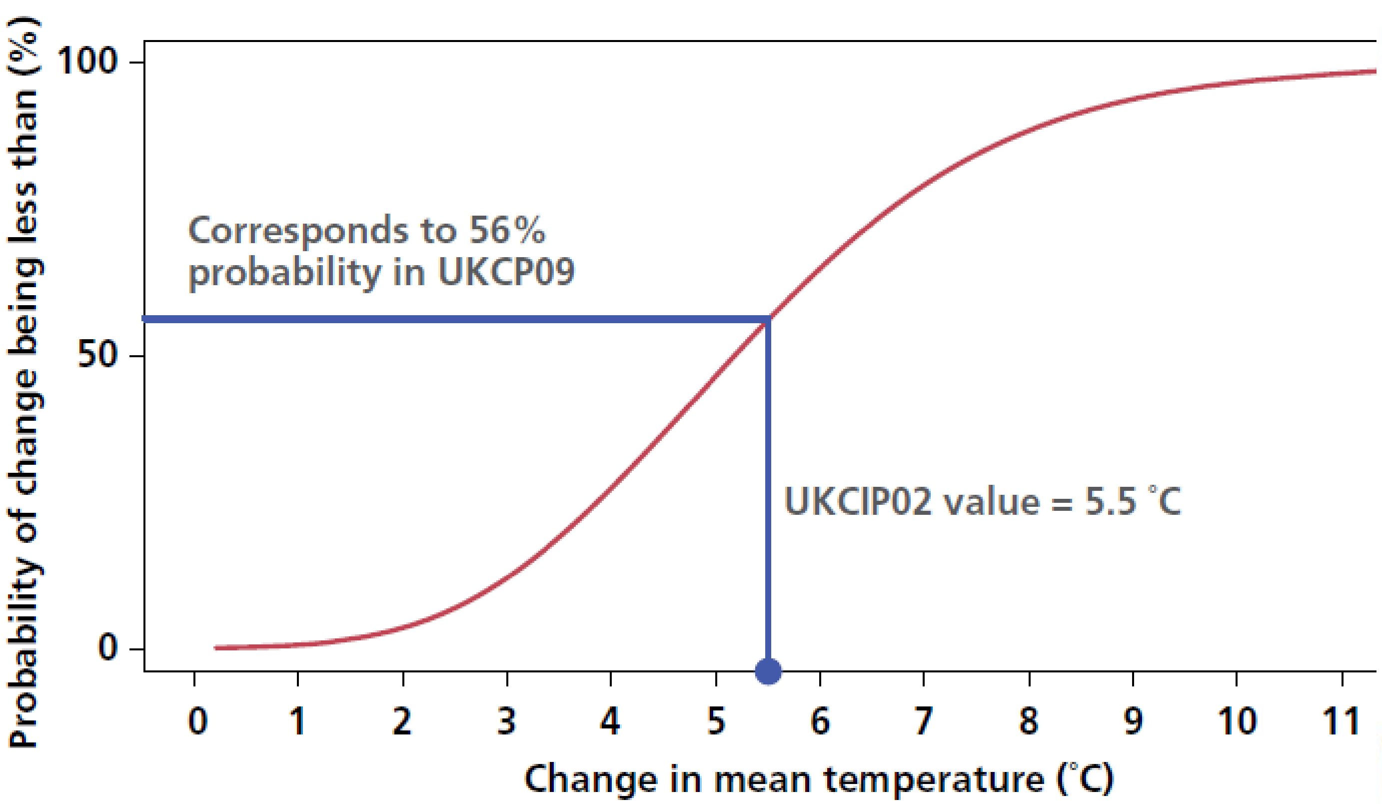
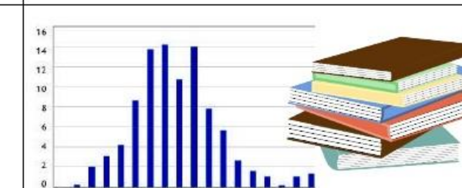
A brief history of UKCP09



CCIRG91 CCIRG96 UKCIP98 UKCP02 UKCP09 .... UKCP18



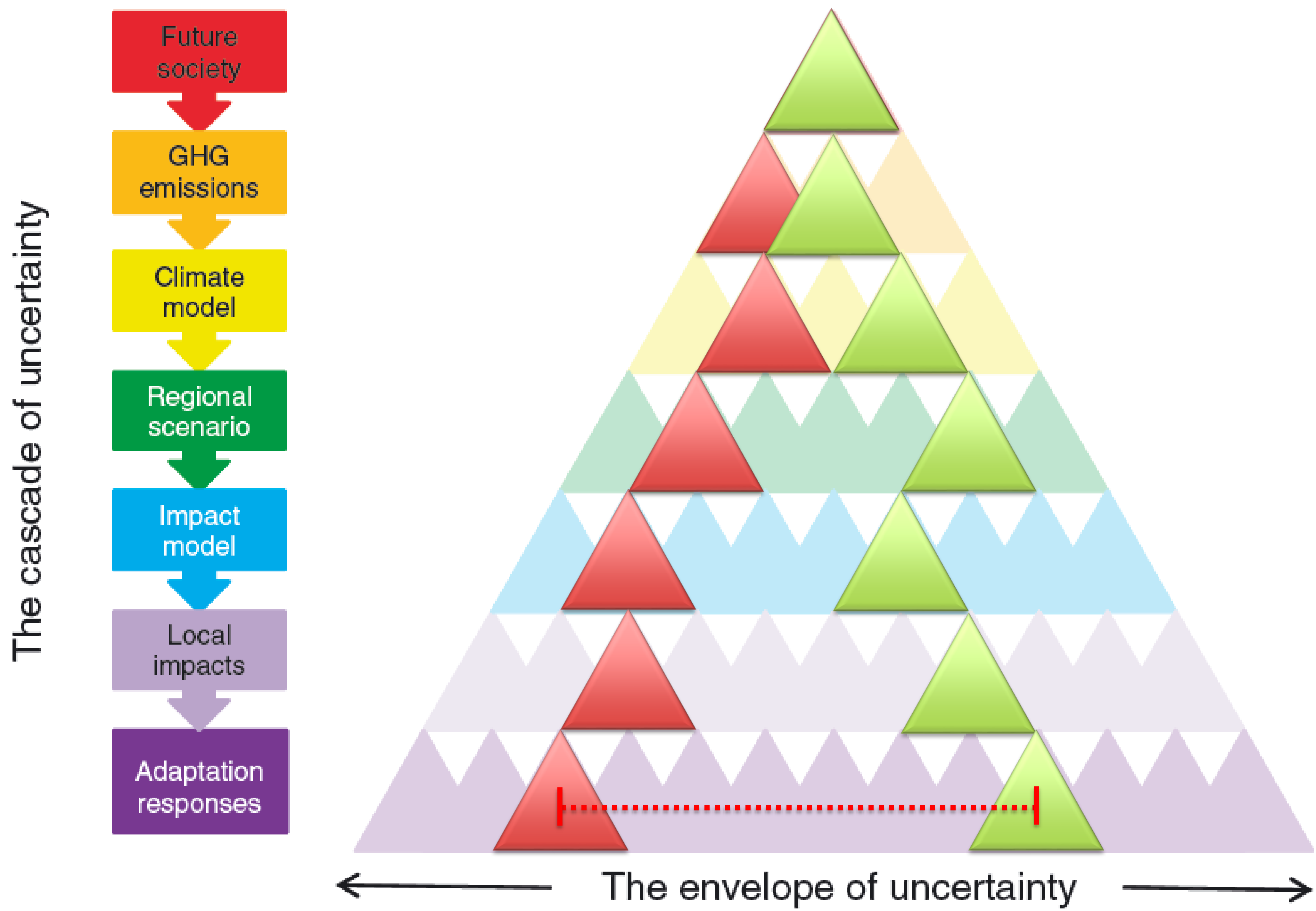
Uncertainty: " How hot?"

Answer 1	Answer 2
"42°c"	
No information on uncertainty Very acceptable to some May be misunderstood as "no uncertainty"	Uncertainty is explicit May be unwelcome – much more work required Better decisions possible

UK CLIMATE PROJECTIONS

UKCP09, 2009

Increasing envelope of uncertainty



Wilby and Dessai, 2010

Methodology

GHG Emission Scenarios (SRES>RCP) → GCM (HadCM3> HadGEM3) → Downscaling procedure → Hydraulic model → Optional appraisal model (CBA>NMV) → Decision model Outcome

Rural irrigation scheme

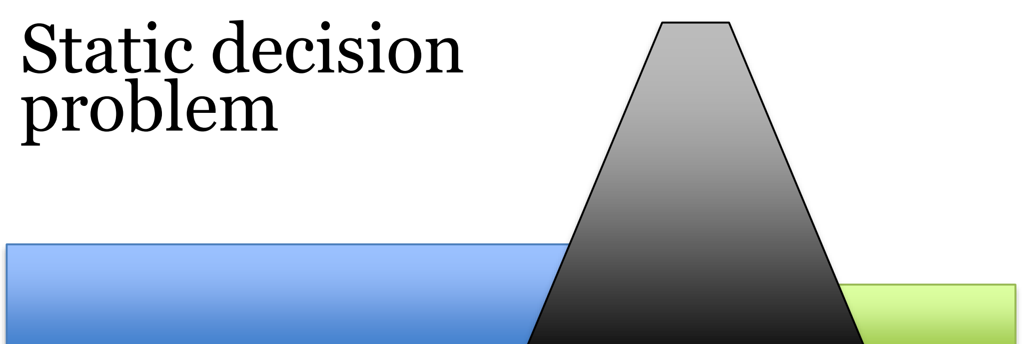
Urban SUDS scheme

Risk appetite

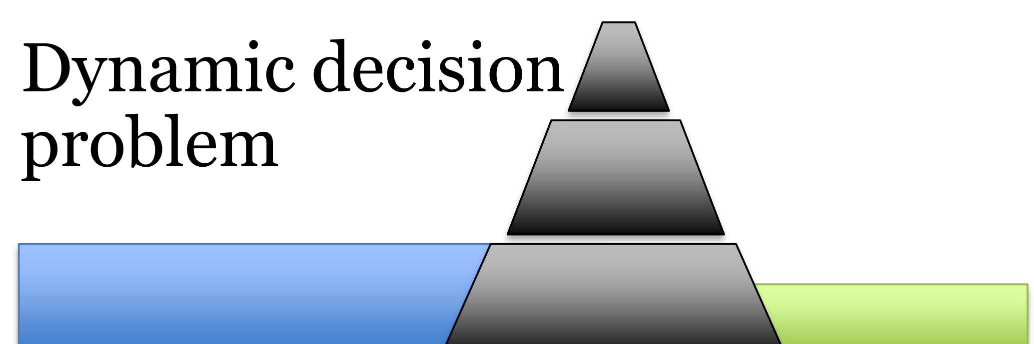
Non-probabilistic decision criteria

	State of nature (Scenario)				*Non-probabilistic decision criteria/payoff*				
Option (irrigation reservoir/SUDS)	S1	S2	S3	etc.	Average (*Laplace*)	Minimum (*Maximin*)	Maximum (*Maximax*)	Minimum regret (*Minimax regret*)	Weighted average (*Hurwicz*)
A	10	20	50	100	45	10	100	900	55
B	2	3	3	1000	252 ✓	2	1000 ✓	199 ✓	501 ✓
C	200	200	202	202	201	200 ✓	202	798	201
D	100	110	120	410	185	100	410	590	255
etc.									
Largest payoff	200	200	202	1000	Non-probabilistic decision outcome (✓)				
"Optimum" option	C	C	C	B	B	C	B	B	B

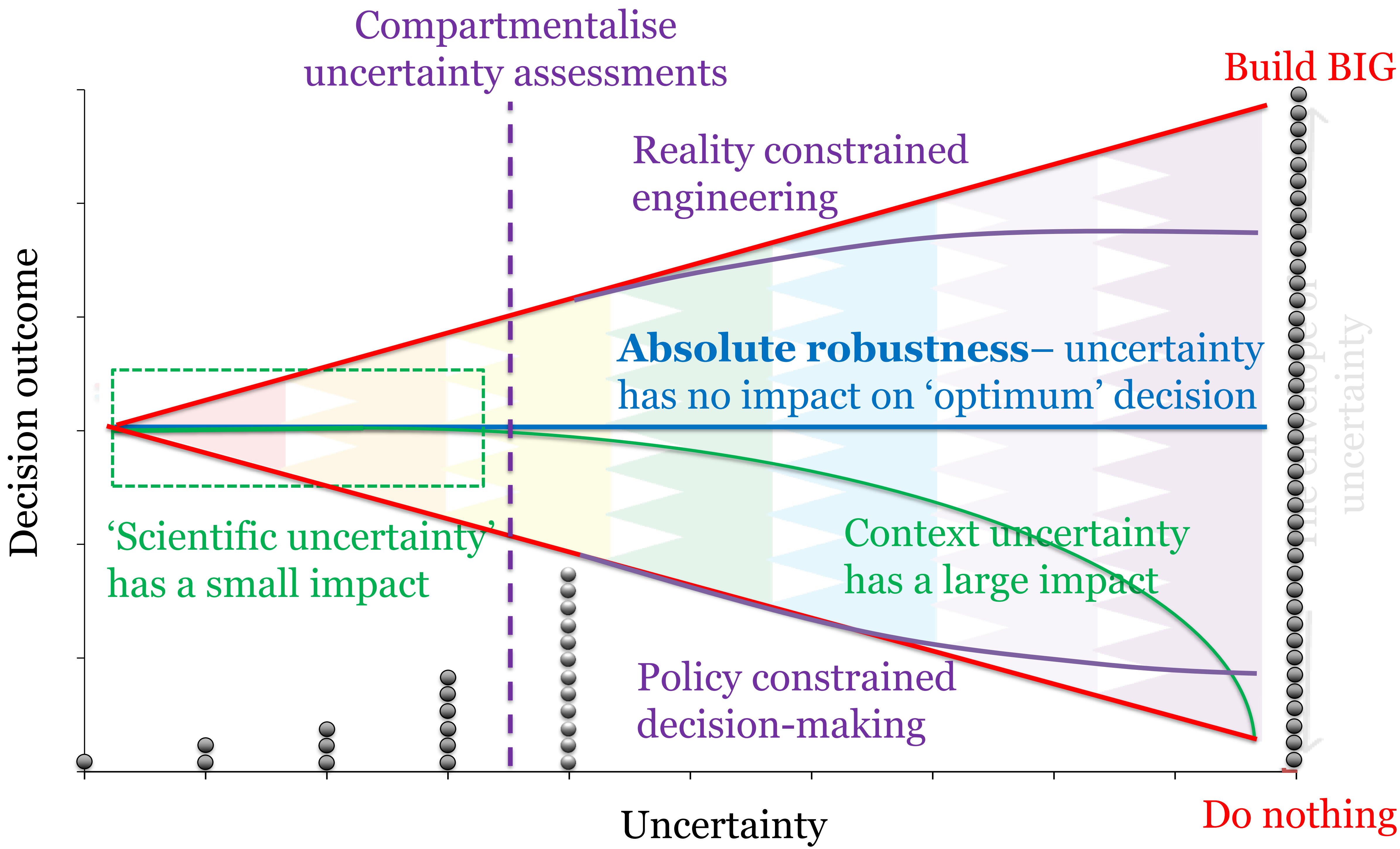
Static decision problem



Dynamic decision problem

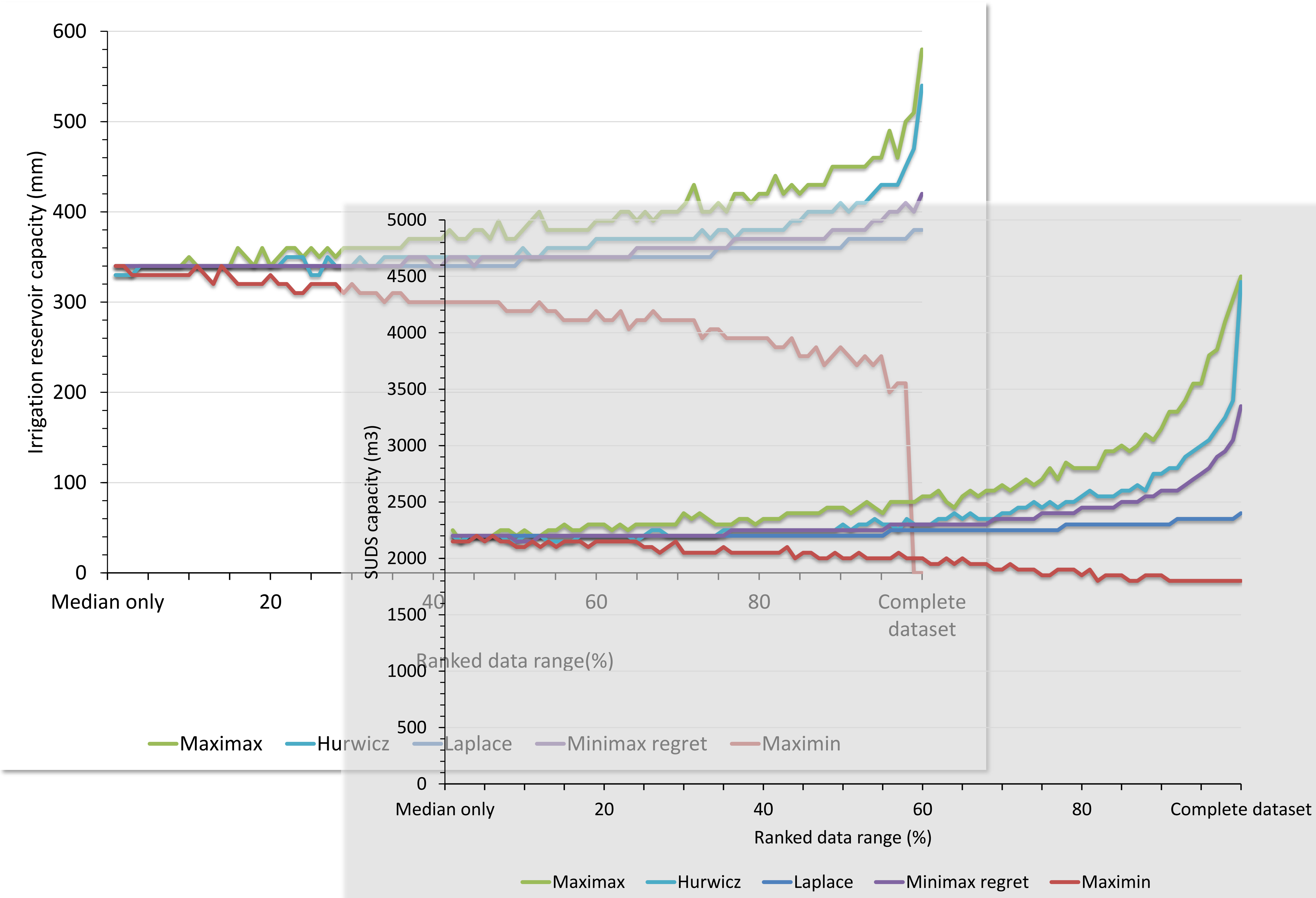


End-to-end uncertainty-decision assessment

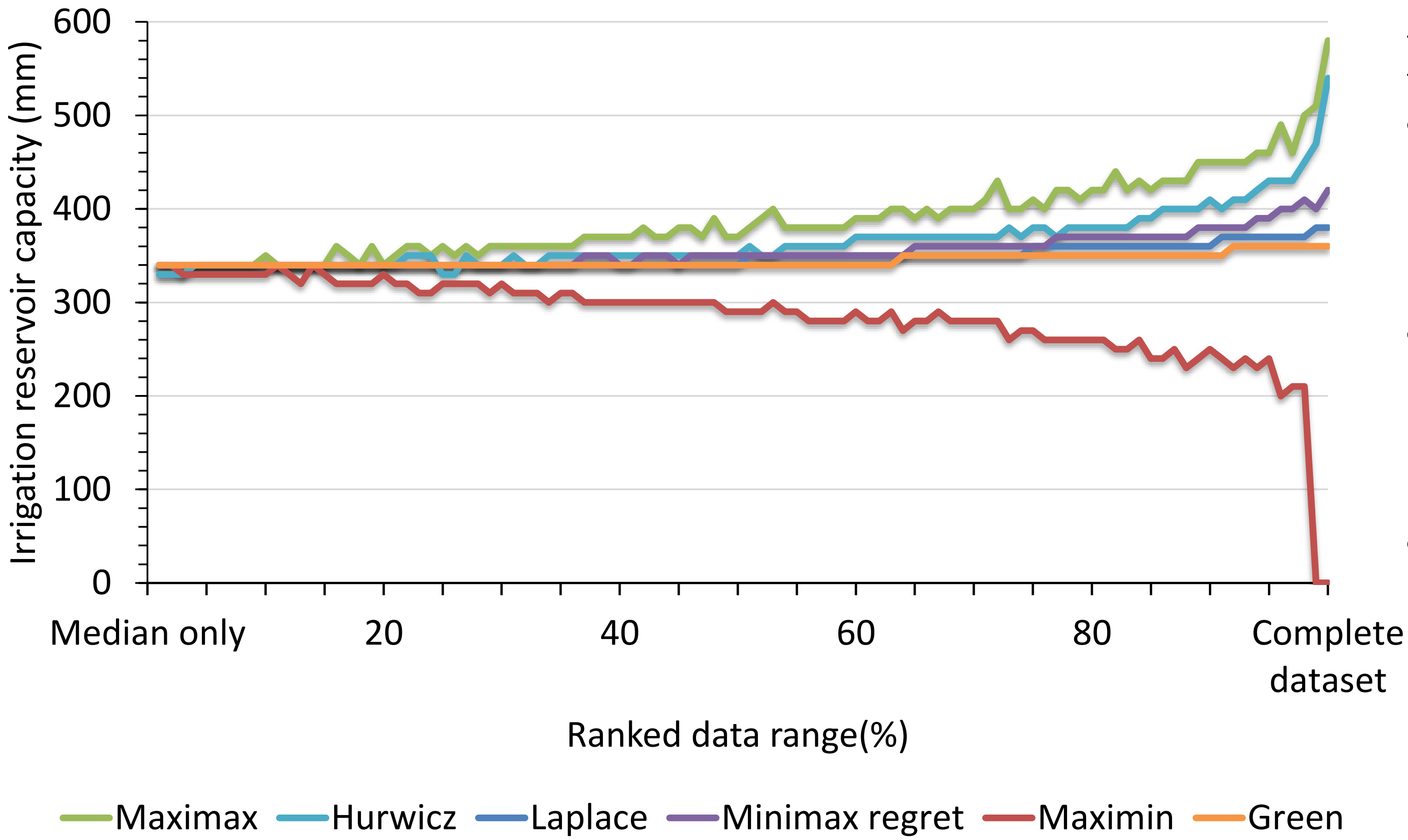


Not all uncertainty is created/treated equal

Results – empirical data (static)



Results – comparative (static and dynamic)



Key findings:

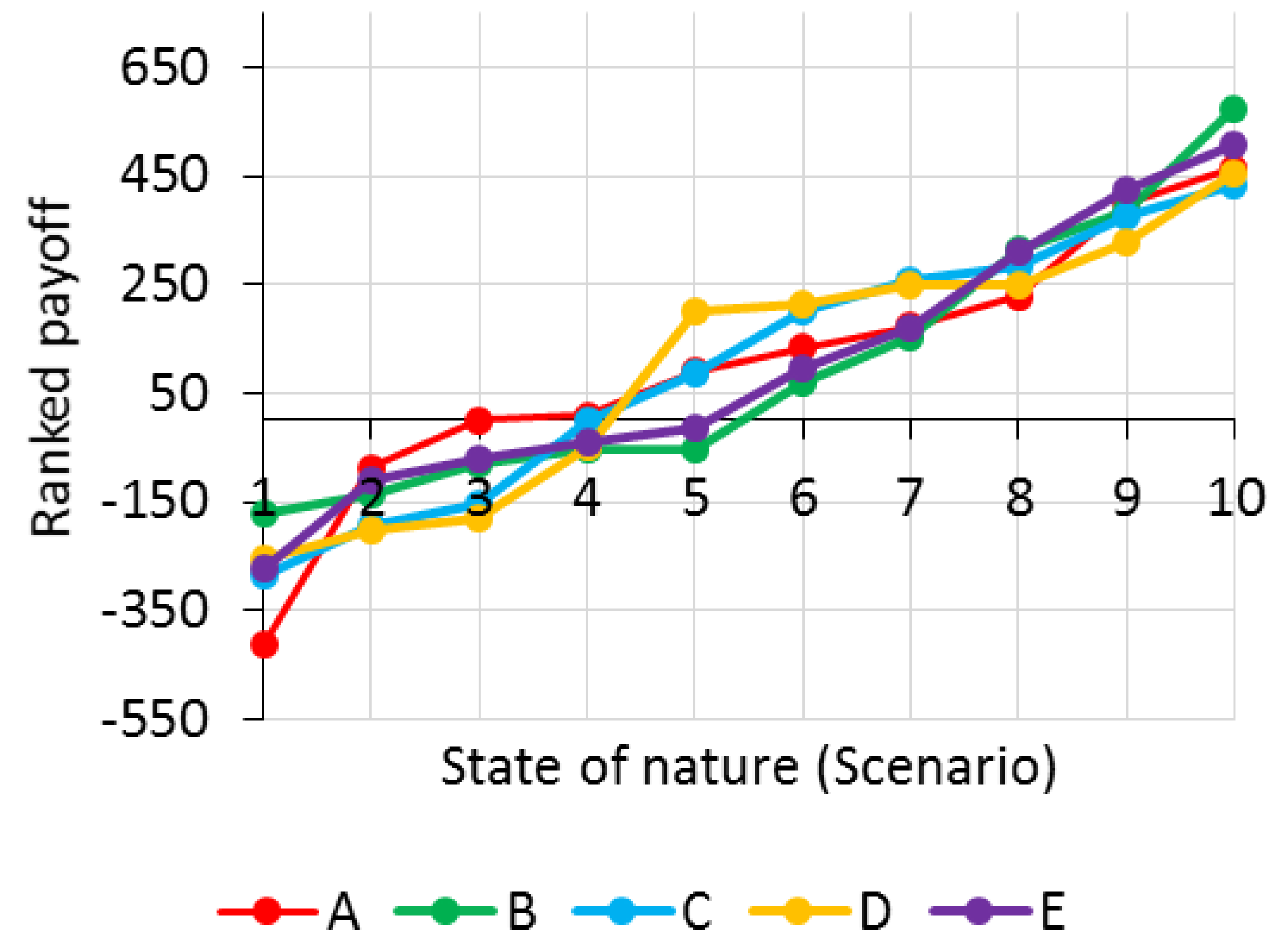
- Quantitative comparison of non-probabilistic criteria (Maximin, Minimax Regret etc.)
- 'Neutral' decision criteria produced more robust outcomes – 'stay calm/carry on'
- Observed that risk appetite dominated all other factors (emissions, downscaling etc.)

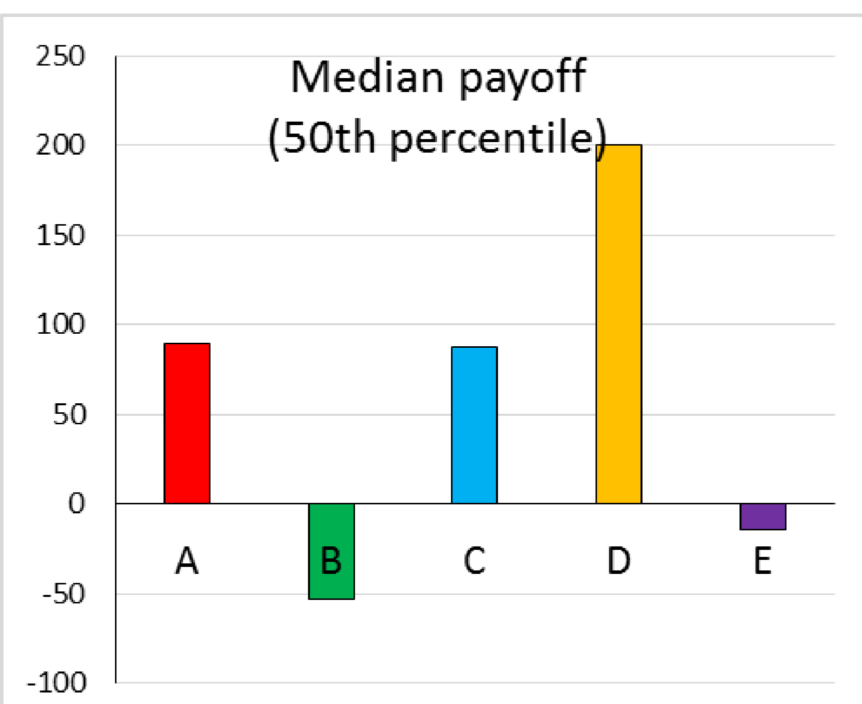
- Assets exhibited low sensitivity to climatic (precipitation) and non-climatic factors (discount)
- Result consistent across different hydrological case studies (irrigation and urban drainage) and sites
- Result consistent across static and dynamic (RO) problems

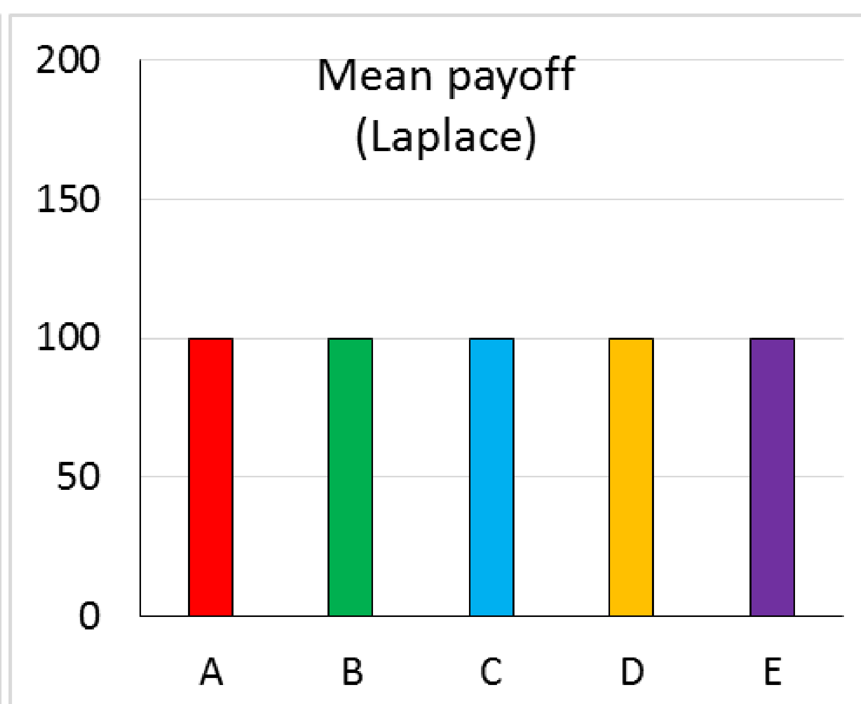
Criteria	Real Options - Absolute robustness RMSE							
	Static	Delay	Aban	Expan	Contr	Intens	Shut	Trans
Laplace	11.3	9.90	6.16	6.16	14.18	15.59	5.57	12.29
Maximin	55.8	51.95	57.61	57.12	53.75	52.73	59.30	55.60
Maximax	66.0	67.45	64.40	67.19	67.93	67.32	64.84	66.33
Minimax	21.9	20.49	15.13	21.31	24.66	26.33	14.66	23.45
Hurwicz	48.8	43.08	42.45	42.45	51.80	50.16	43.99	49.15
Green	12.2	11.87	8.25	10.63	15.03	15.91	7.28	13.45

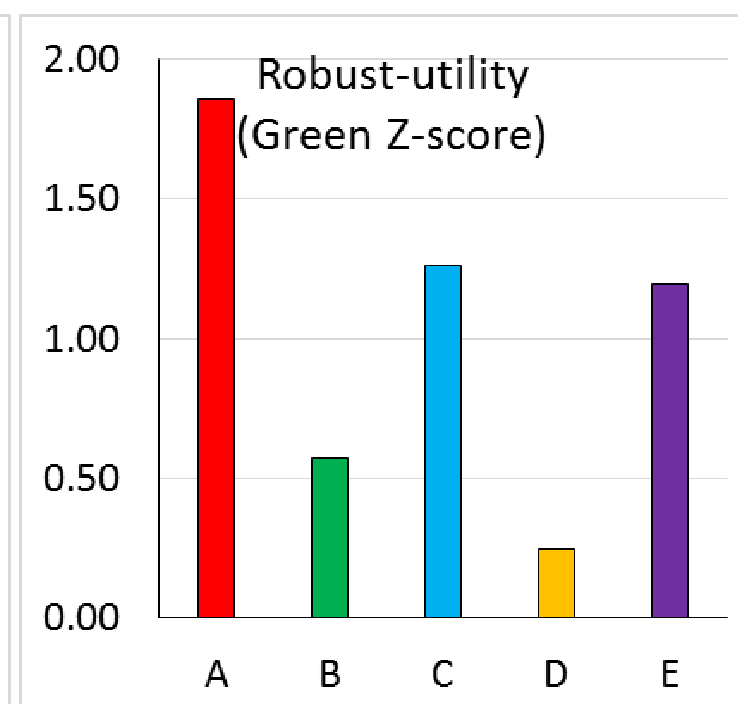
Results – synthetic data

		Option				
		A	**B**	**C**	**D**	**E**
Scenario	**1**	-412.55	-169.75	-283.93	-256.62	-271.10
	2	-88.07	-137.78	-194.72	-203.42	-108.33
	3	1.09	-80.36	-153.50	-180.89	-70.54
	4	9.78	-53.57	-0.32	-48.41	-39.45
	5	89.12	-52.93	87.59	200.30	-14.88
	6	134.68	69.89	198.38	213.61	94.71
	7	172.63	152.22	255.78	246.67	168.24
	8	227.71	315.42	281.93	250.34	310.63
	9	400.54	385.58	377.78	326.13	422.71
	10	465.06	571.28	430.99	452.30	508.01



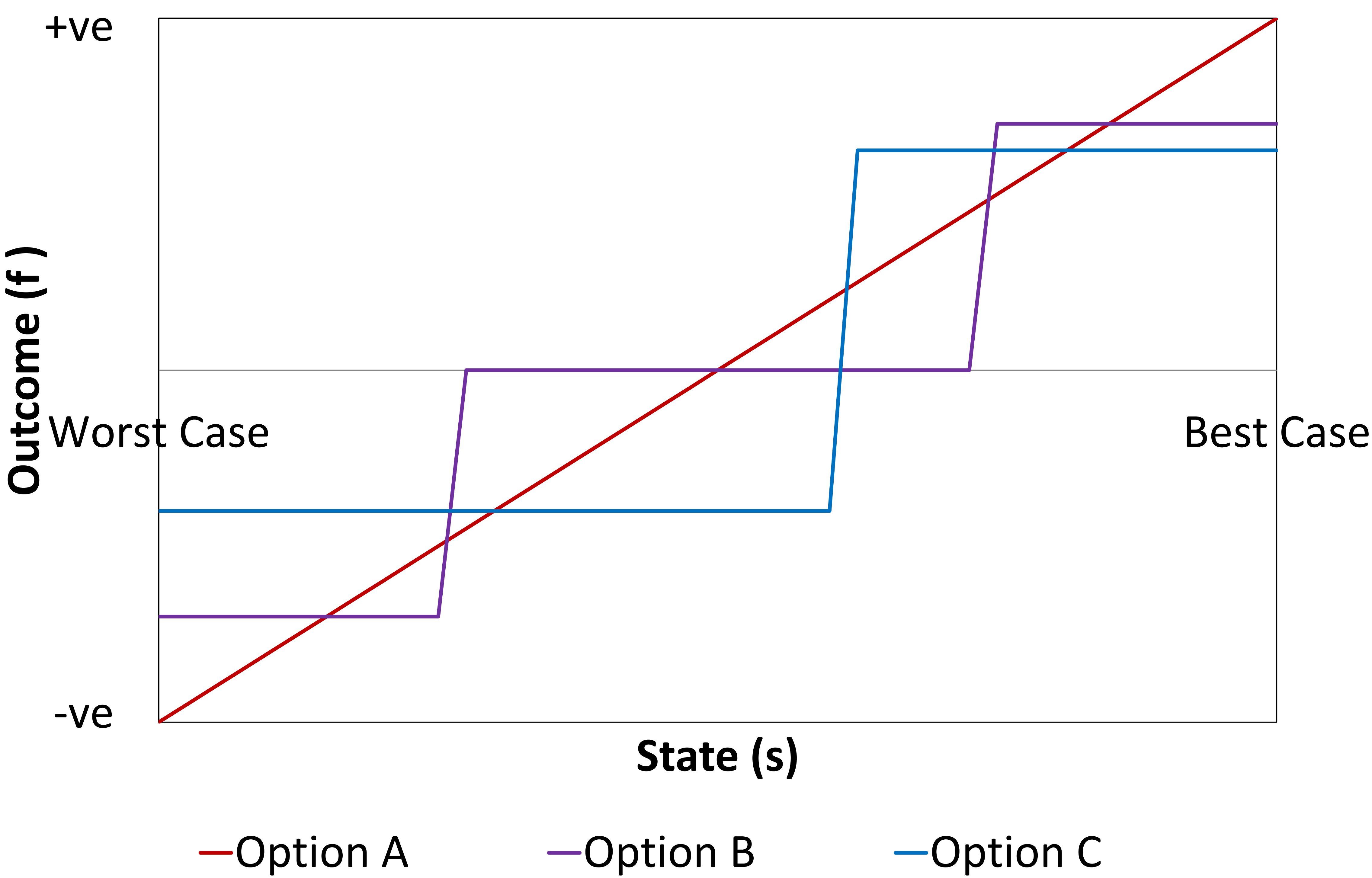






Try it yourself

Q) Do you prefer Option A, B or C?



Robust-utility (Green Z-score)

$$z = \max_{d \epsilon D}\Big((\alpha.A) - ((1-\alpha).B)\Big)d$$

$$A = \left(\frac{(a)d - \min_{d \epsilon D}(a)d}{\max_{d \epsilon D}(a)d - \min_{d \epsilon D}(a)d}\right)$$

$$B = \left(\frac{(b)d - \min_{d \epsilon D}(b)d}{\max_{d \epsilon D}(b)d - \min_{d \epsilon D}(b)\,d}\right)$$

$$a = \sum_{s=1}^{n}\left(\frac{((f)s - \chi)}{\left(\max_{s \epsilon S}(f)s - \chi\right)}\right)$$

$$b = \sum_{s=1}^{n}\left(\frac{((f)s - t)}{\left(\min_{s \epsilon S}(f)s - t\right)}\right)$$

$$\chi = \left(\max_{s=n} f - \left(\left(\max_{s \epsilon S}(f)s - \min_{s \epsilon S}(f)s\right).\left(\frac{\beta}{100}\right)\right)\right)$$

Where

z = decision outcome
d = option/s
α = coefficient of optimism (0-1)
f = outcome
n = number of states
β = coefficient of robustness (0-100)
t = threshold (e.g. 0)
s = state

Advantages:

- Exploratory decision tool
- Accommodate a range of risk appetites
- Incorporate threshold concepts
- Supports static and adaptive decision making
- Does not rely on probabilities
- Highly reproducible from small sub samples
- Can be easily integrated with more advanced techniques
- Easy to implement/tailor

Green and Weatherhead, 2014

Decision making under uncertainty

Q) How should we adapt to future climate change uncertainty?

A) Ensure your proposed solution is:

1. **Resistant** (so you avoid the worst case scenario, options are often big and expensive)
2. **Robust** (so the option performs reasonably well, regardless of what happens, can inhibit risk appetite)
3. **Resilient** (so people and systems can recover quickly, not always socially acceptable)
4. **Flexible** (so the system can adapt if things go wrong, often depends on continuous monitoring and maintenance)

*Note, these approaches are not mutually exclusive

Q) How should we measure progress towards the above?

A) TBC

Future work

- Develop and refine techniques for measuring asset robustness and resilience to climatic and non-climatic pressures
- Validate robust-utility criterion against additional case studies and decision problems
- Compare and integrate robust-utility criterion with more advanced methods (e.g. RDM, Info-Gap etc.)
- Evaluate the relative impact of climatic (emission scenario, GCM, downscaling) and contextual sources of uncertainty (risk appetite, bias)
- Develop a conceptual framework to compare methods in terms of appropriateness and suitability