Decision-making under uncertainty: Robust approaches for adapting to climate change using afforestation as an example.

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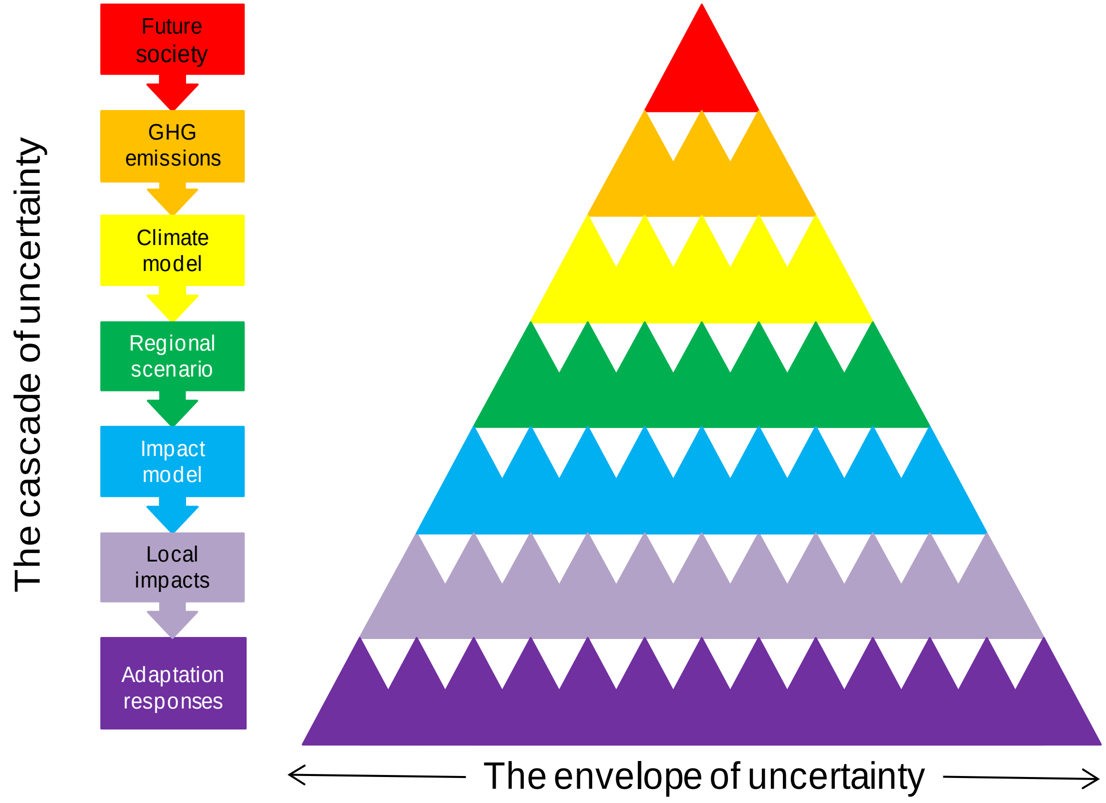
Outline

1. Uncertainty in climate change analysis
2. Robust decision-making under uncertainty
   - Real Options Analysis
   - Portfolio Analysis
   - Robust Decision-Making
3. Real-options analysis for natural flood management
4. Future directions

Climate change is uncertain

- Uncertainties in timing, magnitude and location of changes



Wilby and Dessai (2010)

- But decisions still need to be made
- ‘Robust’ under uncertainty:
  - flexible
  - reversible
  - win-wins
  - avoiding lock-in
  - soft rather than hard strategies

Long-term adaptation options

- In anticipation of climate change:

  - Decisions where adaptation requires a longer time to be fully effective (long lead time), or long life time ((partial) irreversibility)

  - E.g. flood protection schemes, river basin management, infrastructure.

  - **BUT:** Cost may be immediate and benefits uncertain.

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Robust decision making methods

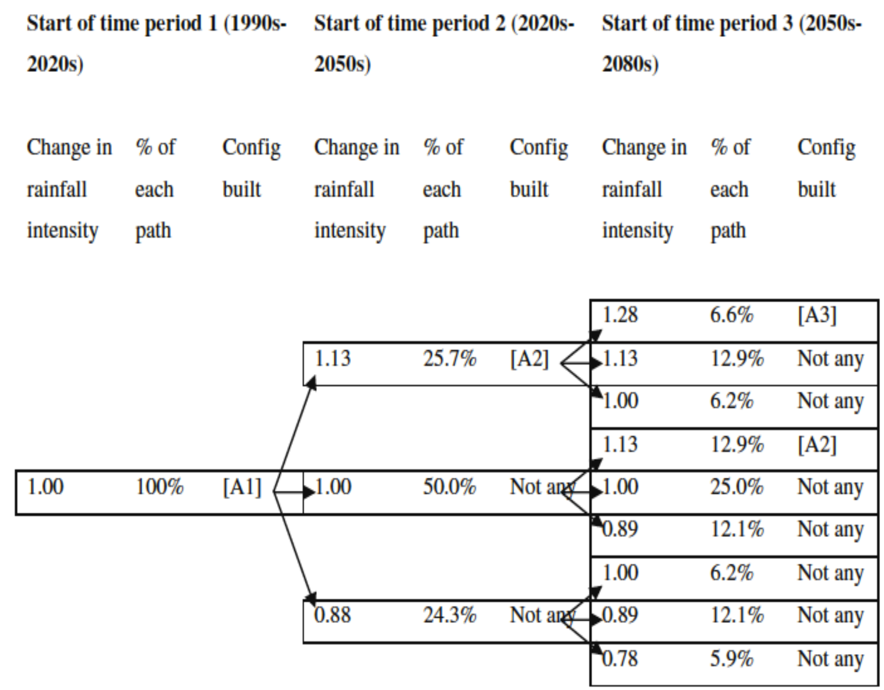
Robust approaches select projects that meet their purpose across a variety of plausible futures (Hallegatte et al., 2012).

- Robust approaches do not assume a single climate change forecast but integrate a wide range of climate scenarios through
  a. Finding the least vulnerable strategy across scenarios **(Robust Decision Making).**
  b. Diversifying adaptation options to reduce overall risk **(Portfolio Analysis).**
  c. Defining flexible, adjustable strategies **(Real Options Analysis).**

Real options analysis

- Similar to CBA but additionally values the option to wait/to be flexible depending on the uncertain parameter (climate change).
- For large (partly) irreversible investments with an opportunity cost to waiting i.e. if there is a need for action in the present
- When there is a significant chance of over- or underinvesting,
- Where uncertainty is likely to resolve over time

Scenario tree representation, including the optimal managed/adaptive strategy



Real Options Analysis (ROA) application to natural flood management in Scottish borders

- NFM involves the utilisation or restoration of ‘natural’ land cover and channel-floodplain features within catchments to increase the time to peak and reduce the height of the flood wave downstream
- Effectiveness diminishes as storm intensity increases and is more pronounced for small catchments
- Rapidly rising up policy agenda in Europe

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Research Question

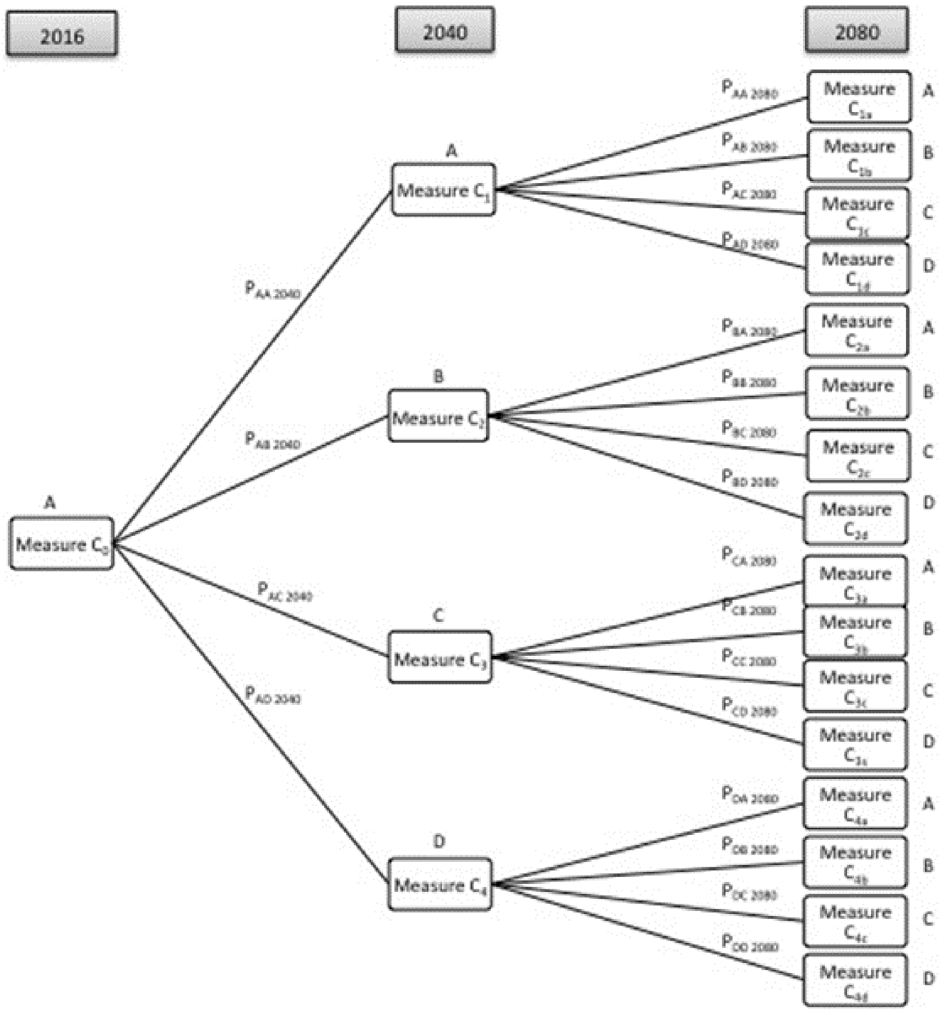
- how to sequence the flood risk management measure so that it prevents flooding in a 1 in 20 year rainfall event in a way that minimises the expected life-time cost of the system

- In this case the flood risk management measure is the hectares of trees planted

- The aim is to avoid both under and over-investment, which either results in a flood protection standard below the 1/20 year flood event or flood regulation capacity above the required standard

ROA steps

- Specify the decision-tree
- Identify the potential options
- Formulate the optimisation objective
- Solve the optimisation problem


2016
2040
2080
A
Measure C0
P AA 2040
P AB 2040
P AC 2040
P AD 2040
A
Measure C1
B
Measure C2
C
Measure C3
D
Measure C4
P AA 2080
P AB 2080
P AC 2080
P AD 2080
P BA 2080
P BB 2080
P BC 2080
P BD 2080
P CA 2080
P CB 2080
P CC 2080
P CD 2080
P DA 2080
P DB 2080
P DC 2080
P DD 2080
Measure C1a
A
Measure C1b
B
Measure C1c
C
Measure C1d
D
Measure C2a
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Measure C2b
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Measure C2c
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Measure C2d
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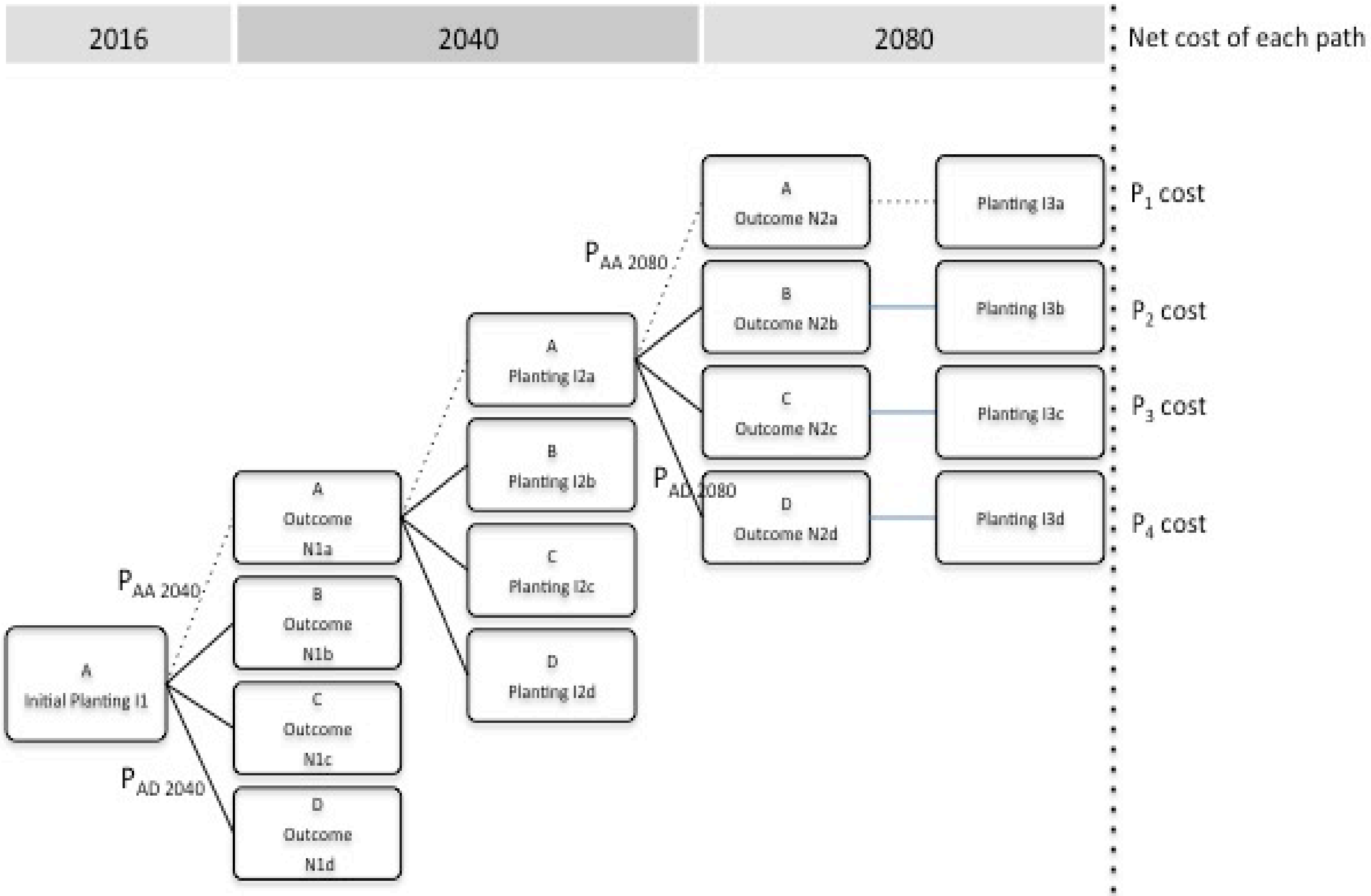
Measure C3a
A
Measure C3b
B
Measure C3c
C
Measure C3s
D
Measure C4a
A
Measure C4b
B
Measure C4c
C
Measure C4d
D

Data

- Use the underlying distribution of the UKCP09 climate change data (Murphy et al., 2009).
- Weather generator and random number sampling to produce long time series of statistically plausible daily and hourly weather data.
- Hydrological model
- Chose medium climate scenario (likely to be conservative)

Solve the optimisation problem

- Can be solved by dynamic (stochastic) programming
- Simplified version using backward induction in spreadsheet
- Costs = cost of planting and maintenance, opportunity cost of alternative land use (sheep)
- Damage cost = cost of a 1/20 RP flood event.



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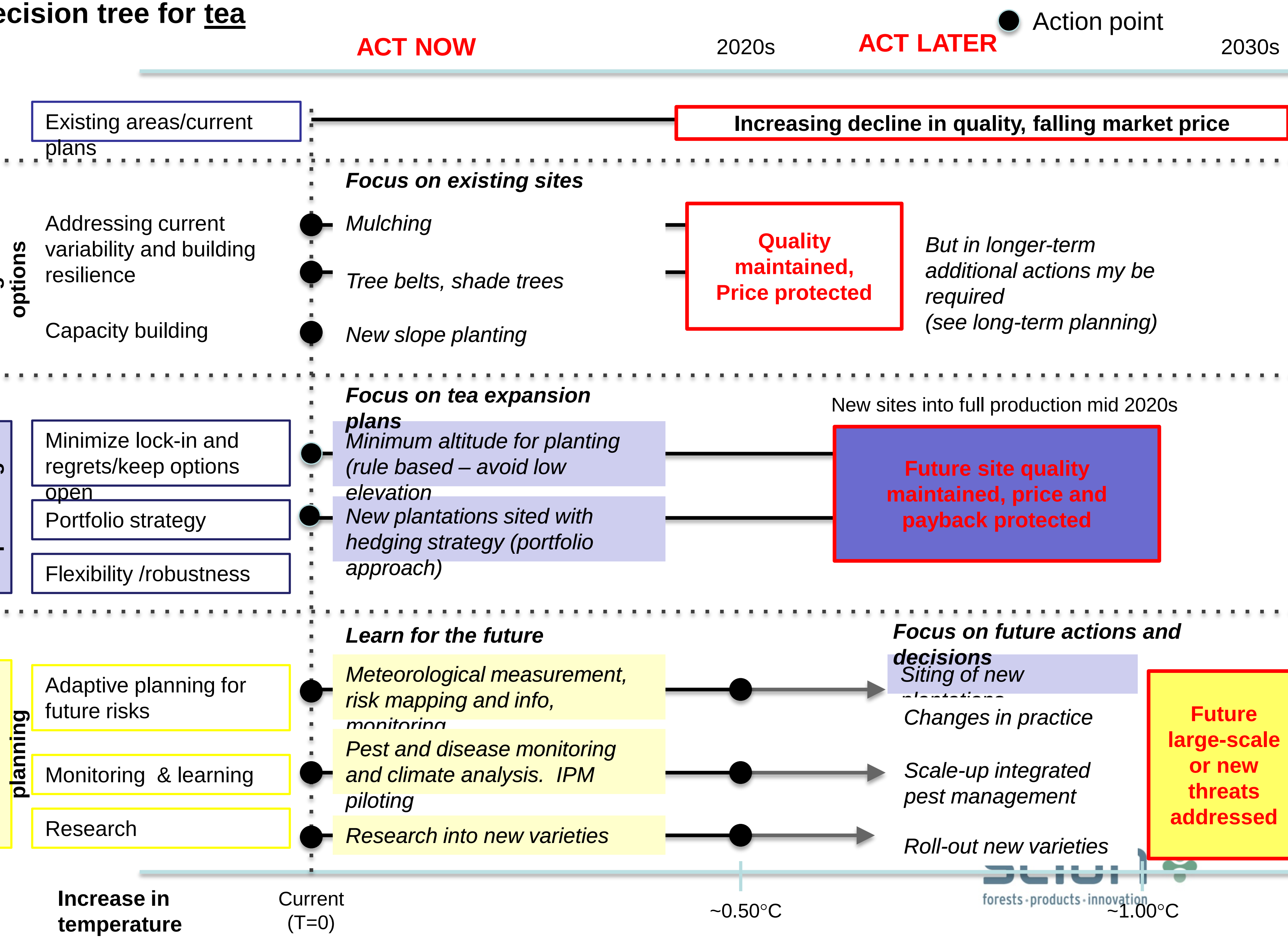
Results

- The cost of the expected flexible strategy is shown to be about 65 % cheaper (£5.3 mil) than the worst case strategy, (£15.6m), i.e. planting for the worst case outcome in 2016
- Results are driven by the high maintenance cost within the system relative to the damage cost for most configurations.
- Could add additional decision nodes allowing for more frequent planting - but would significantly increase the complexity
- Didn’t include ecosystem service benefits which would likely shift the decision towards earlier investment

- More conceptual application for policy-making?

ecision tree for tea



Related reading

- Dittrich, R, Ball, T., Butler, A., Moran, D. 2016. Economic appraisal of afforestation for flood management under climate change and associated benefits. *Working paper.* Edinburgh: SRUC.
- Dittrich, R., Wreford, A., Butler, A., Moran, D (2016).The impact of flood action groups on the uptake of flood management measures. *Climatic Change* DOI 10.1007/s10584-016-1752-8
- Dittrich, R., Wreford, A., Moran, D. 2016. A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward? *Ecological Economics,* 122**,** 79–89

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