A framework for climate change adaptation strategies acknowledging transboundary governance complexity

A case study in the Geul basin.

MSc. Thesis Presentation 21-12-2022

J.W. van der Steen

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Overview of subjects

1. Introduction and Research Gap
2. Framework and Methods
3. Adaptation Combinations
4. Inputs
   - Products
5. (Transboundary-)Governance
   - Inputs
   - Products
6. Results of the Framework
   - Systems Approach
   - Preferential Strategies
7. Discussion, Recommendations for Future Work and Conclusion

Introduction and Research Gap

A Changing Climate – Why is it relevant?

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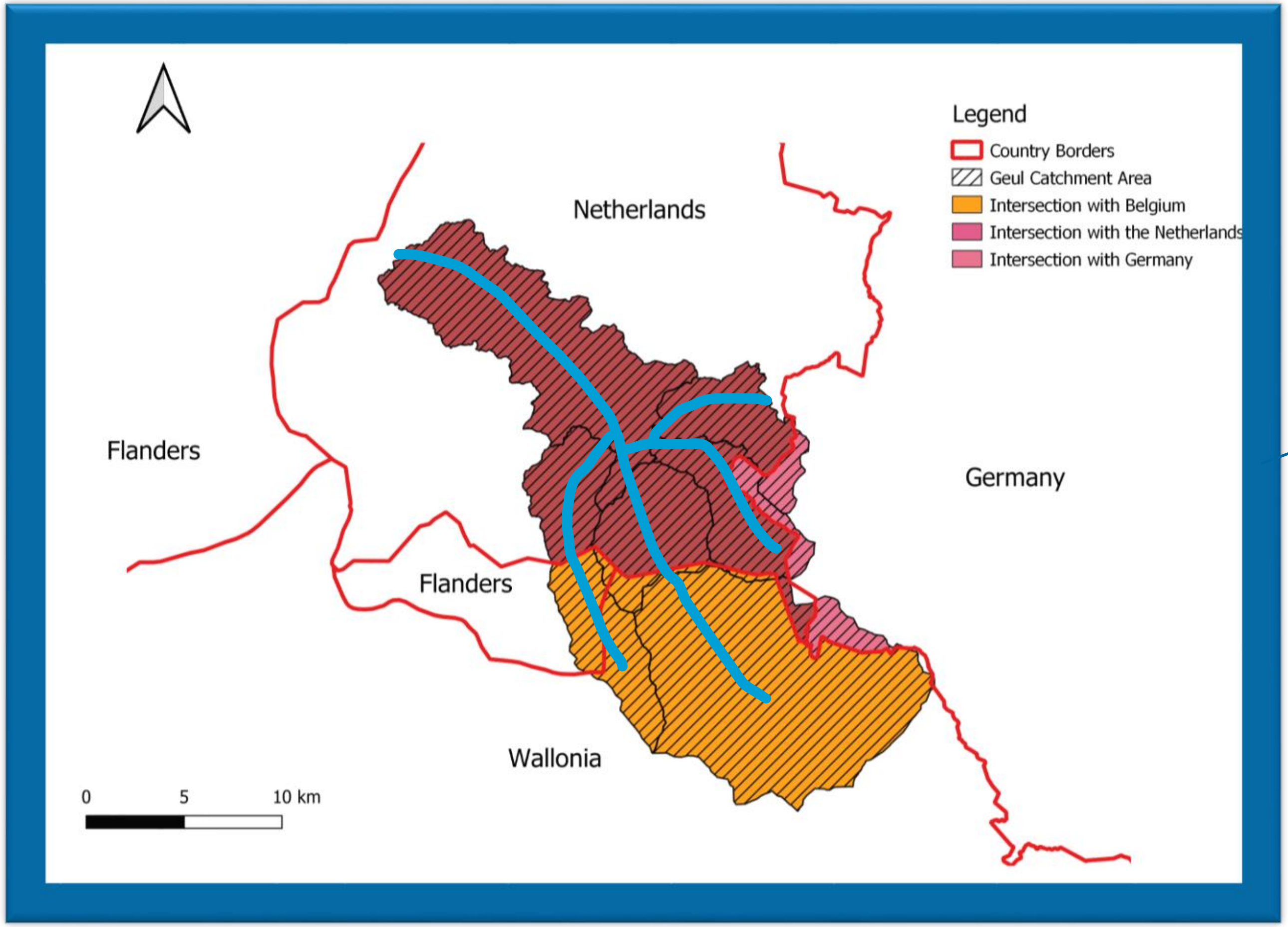
The Meuse and the Geul



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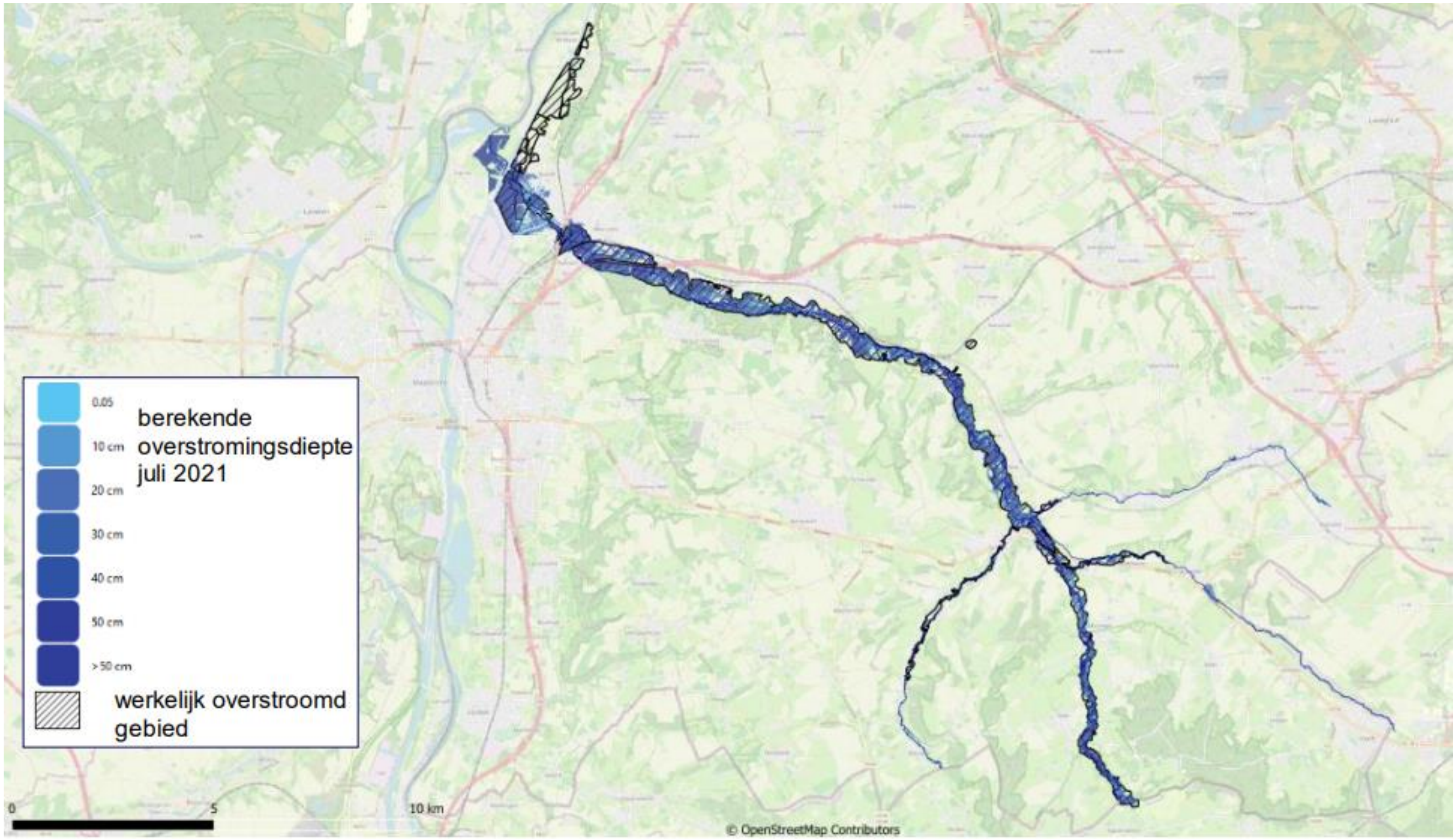
Lead up to the floods in July 2021

- Cold pit & heavy precipitation
- Historical maximum discharges
- Discharge peak Geul estimated at 130 m^3/s, capacity Valkenburg ~ 67 m^3/s
- Volume over discharge capacity 6,000,000 m^3
- Floods mainly concentrated in downstream section
- Case study focus Valkenburg



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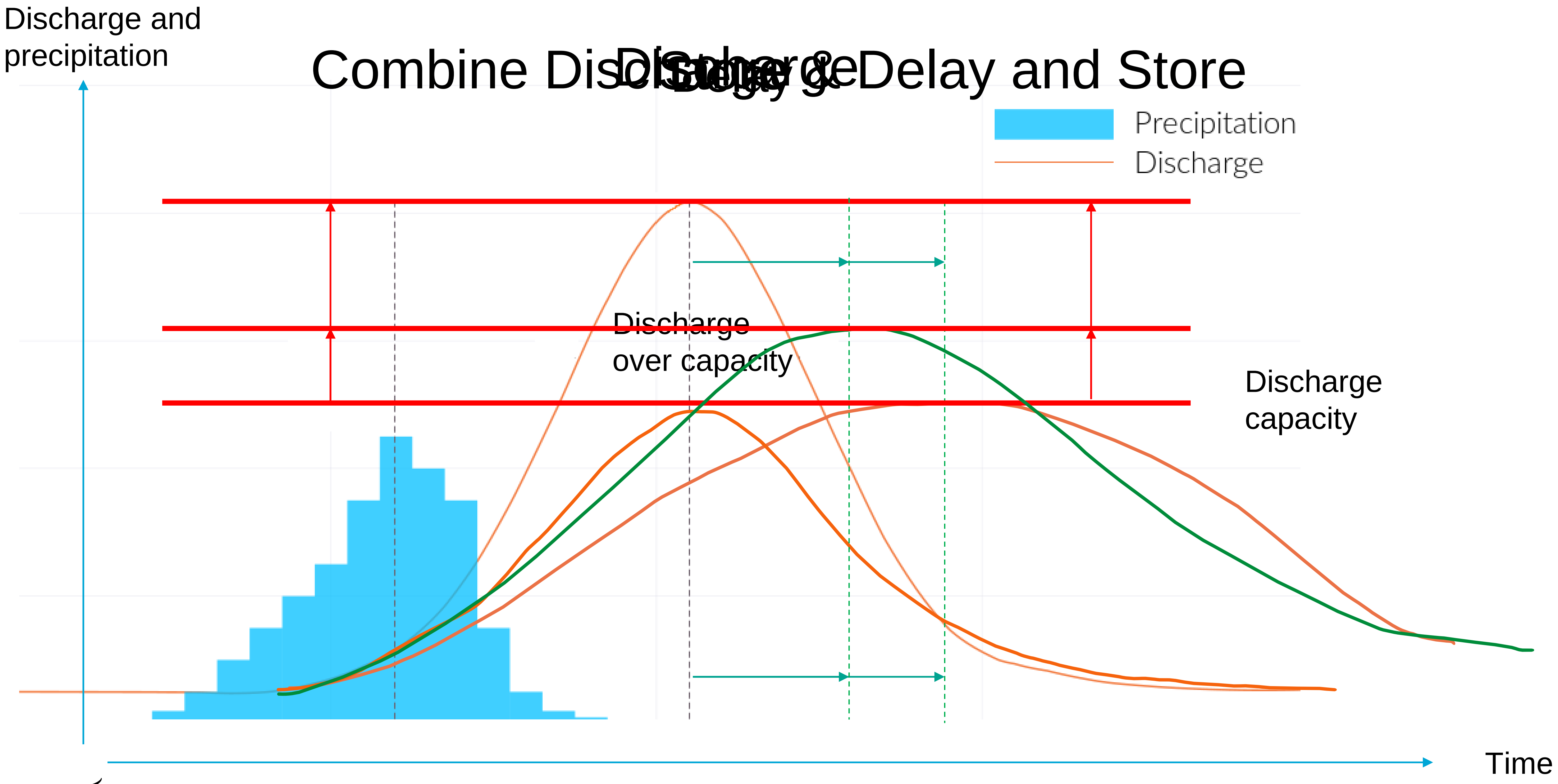
Combine Discharge Delay and Store



Flood Risk & Climate Change Adaptation

- Flood Risk = hazard x exposure x vulnerability

- Flood risk management challenges
  - (Deep) Uncertainty of extent and effects
  - Institutional and natural context
  - Adaptive capacity (natural or human)

Need for non-predefined management methods that take into account context of decision making

Why this thesis and what does it cover?

- Research gap: managing deep uncertainty while acknowledging spatial and temporal contex

Research Goal: The research goal is to find adaptation combinations and suitable locations for the Geul when acknowledging transboundary governance complexity.

1. Solution Space
2. Governance Network
3. Preferential Strategies
4. Broader applicability

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Complexity Theory and Systems Approach

Reductionist approach

Systems approach

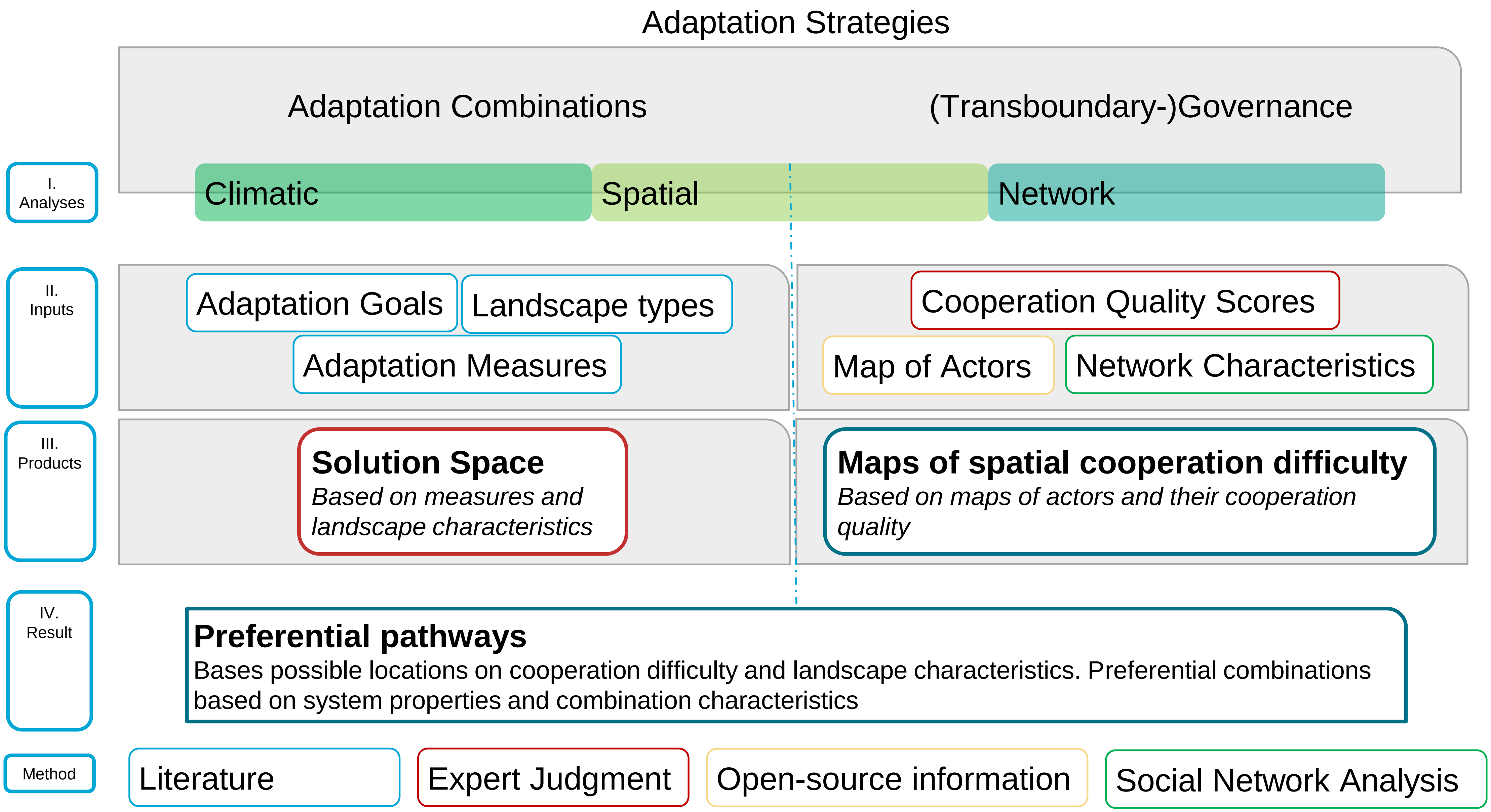
Complex systems

- Complicated Systems

  Can be very elaborate but always explained by its parts

- Emergent behavior
- Self organisation
- Multiple equilibria
- Unpredictable

Framework and Methods


Adaptation Strategies
Adaptation Combinations
(Transboundary-)Governance
I. Analyses
Climatic
Spatial
Network
II. Inputs
Adaptation Goals
Landscape types
Adaptation Measures
Cooperation Quality Scores
Map of Actors
Network Characteristics
III. Products
Solution Space
Based on measures and landscape characteristics
Maps of spatial cooperation difficulty
Based on maps of actors and their cooperation quality
IV. Result
Preferential pathways
Bases possible locations on cooperation difficulty and landscape characteristics. Preferential combinations based on system properties and combination characteristics
Method
Literature
Expert Judgment
Open-source information
Social Network Analysis

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Adaptation Combinations

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Adaptation Combinations – Inputs

Adaptation Goals

Adaptation Measures

II. Inputs

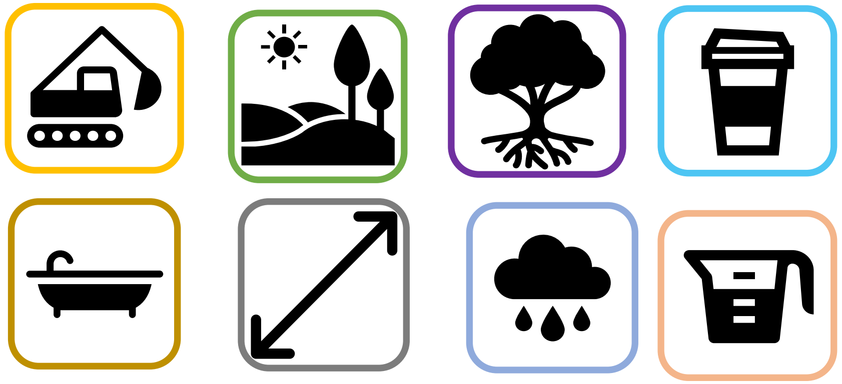
- 6,000,000 m^3over an area of 334 km^2: 17.96 millimeter at any location
- Measures from literature (Arcadis, Deltares & TU Delft)
- Recalculated to millimeters equivalent

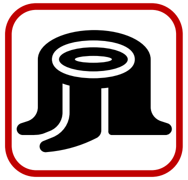
Downstream

- Emergency spillways
- Heightening quay walls
- Installing different bridges

Upstream

- Room for the river
- Planting trees
- Storages





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Adaptation Combinations – Inputs

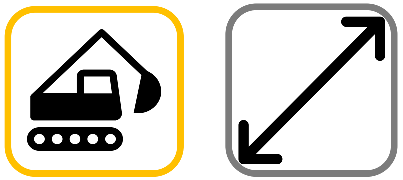
- 6,000,000 m^3 over an area of 334 km^2: 17.96 millimeter at any location
- Measures from literature (Arcadis, Deltares & TU Delft)
- Recalculated to millimeters equivalent

Downstream Infrastructure

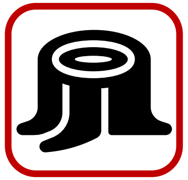
Upstream Infrastructure

Upstream Natural Retention

Room for the River



Maladaptation



Average implementation time:
DI: 13.2 years
UI: 17.9 years
UNR: 16.3 years
RR: 15.3 years

Upstream Natural Retention

Upstream Infrastructure

Upstream Infrastructure

Wetland

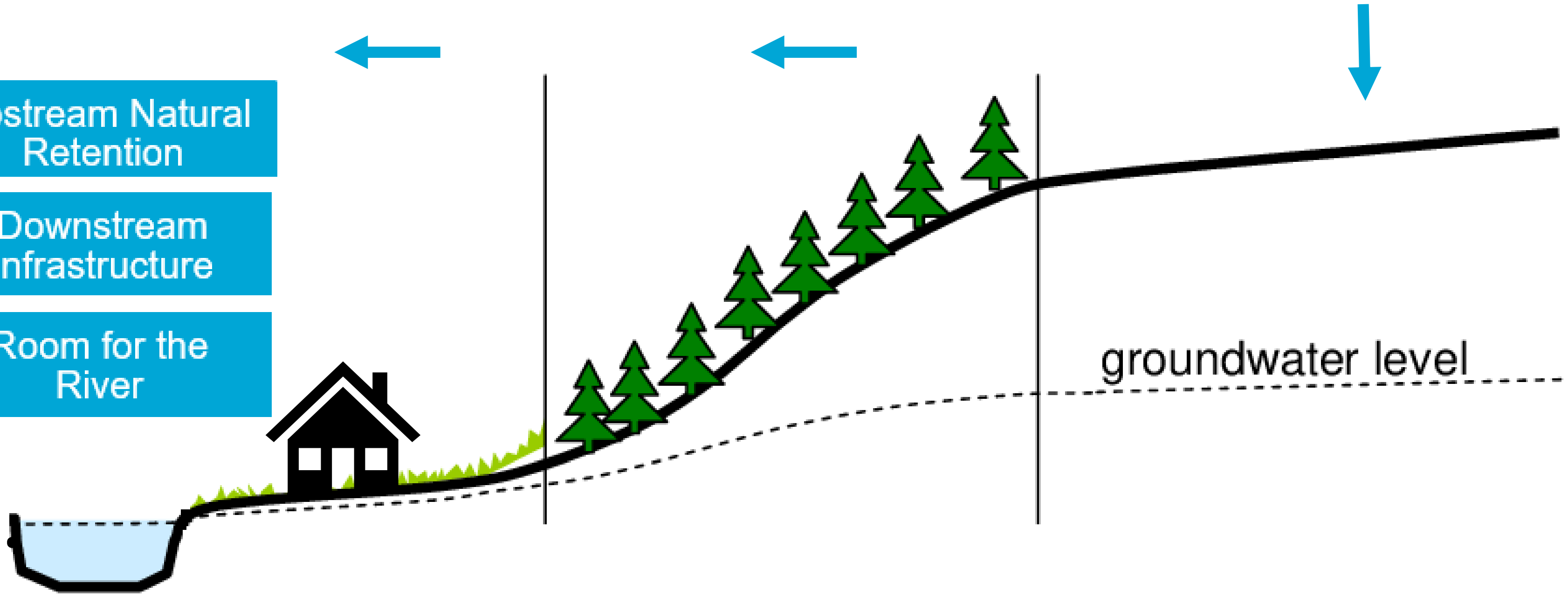
Hillslope

Plateau

Upstream Natural Retention

Downstream Infrastructure

Room for the River



Discharge

Delay/Store

Delay/Store

Store

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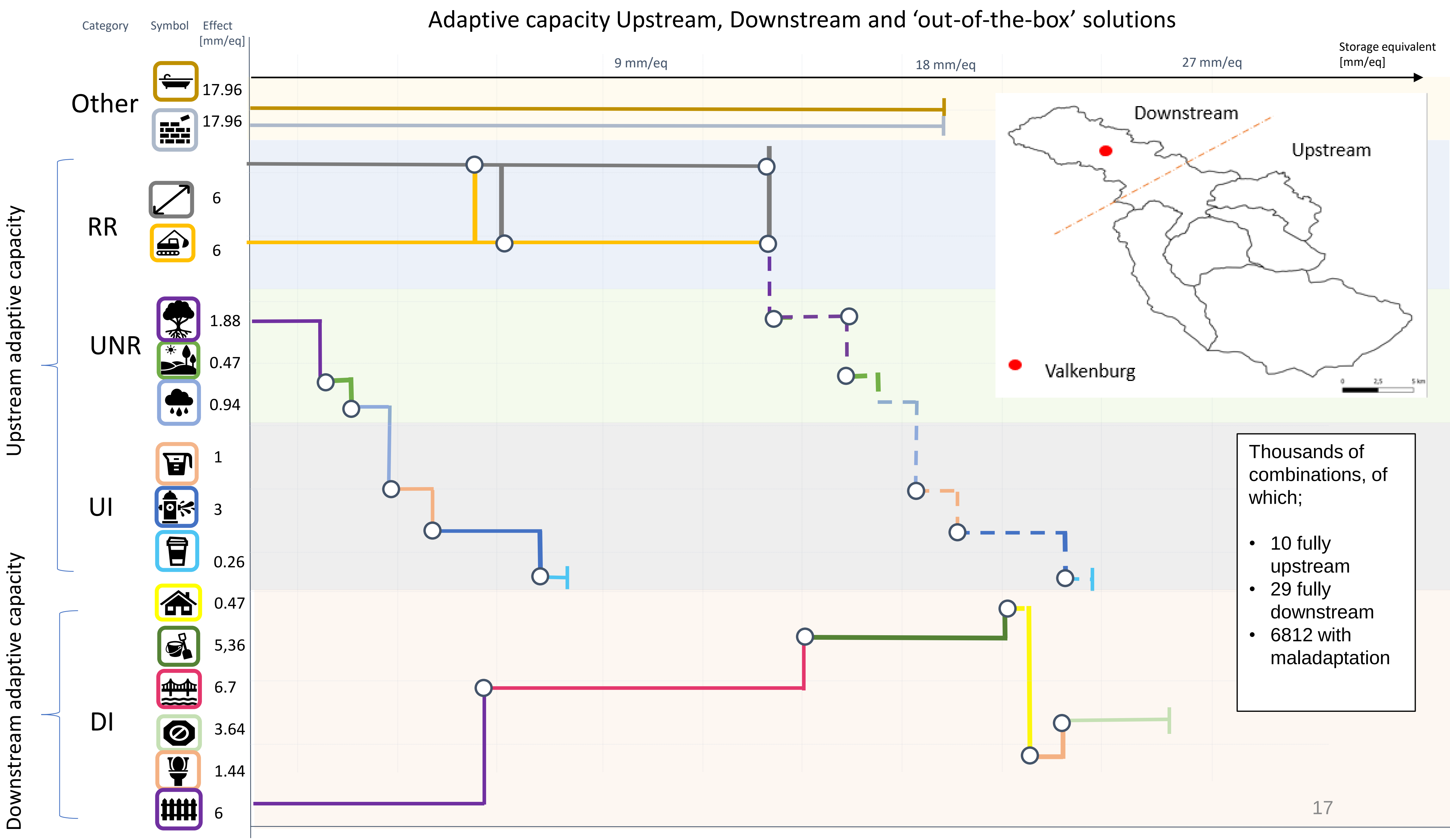


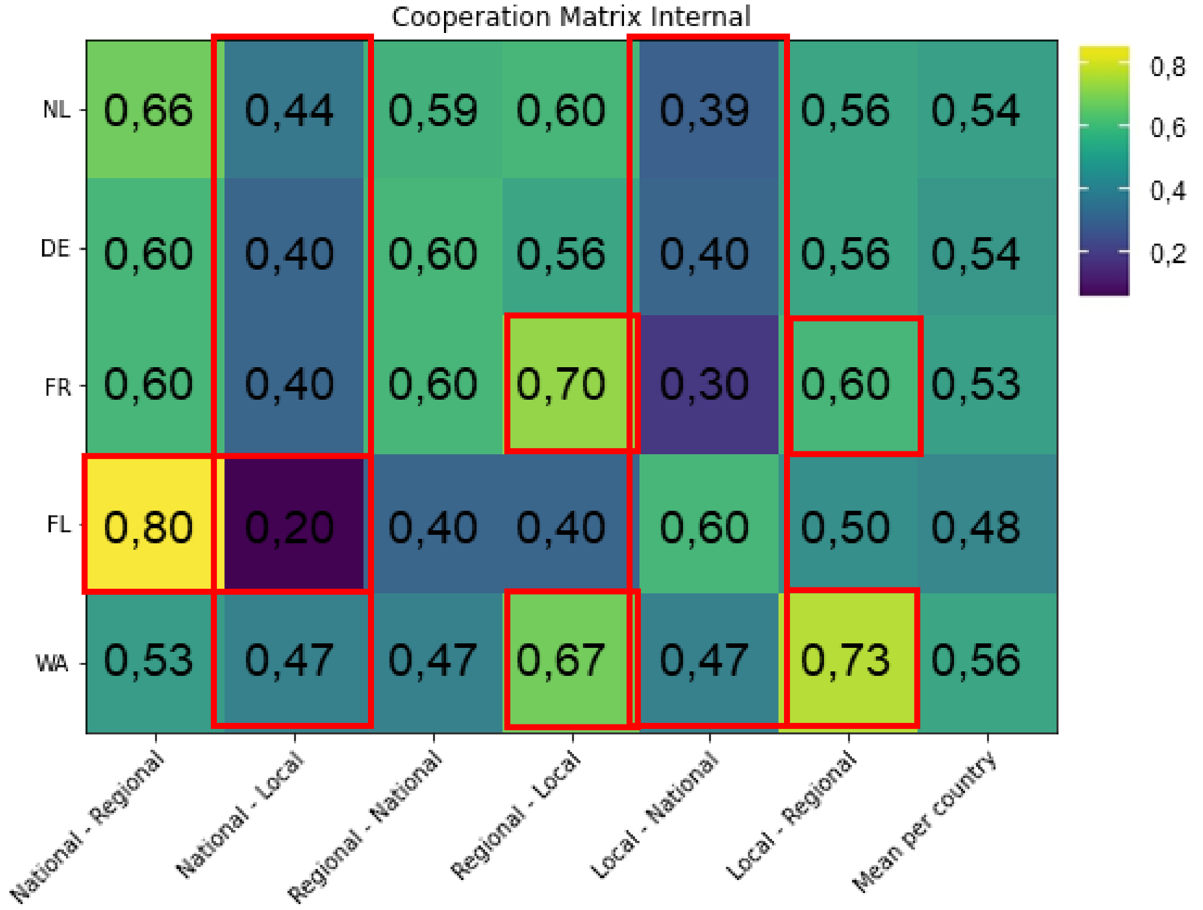
Adaptive capacity Upstream, Downstream and 'out-of-the-box' solutions
Category
Symbol
Effect [mm/eq]
9 mm/eq
18 mm/eq
27 mm/eq
Storage equivalent [mm/eq]
Other
17.96
17.96
RR
6
6
UNR
1.88
0.47
0.94
UI
1
3
0.26
DI
0.47
5,36
6.7
3.64
1.44
6
Upstream adaptive capacity
Downstream adaptive capacity
Downstream
Upstream
Valkenburg
Thousands of combinations, of which;
• 10 fully upstream
• 29 fully downstream
• 6812 with maladaptation

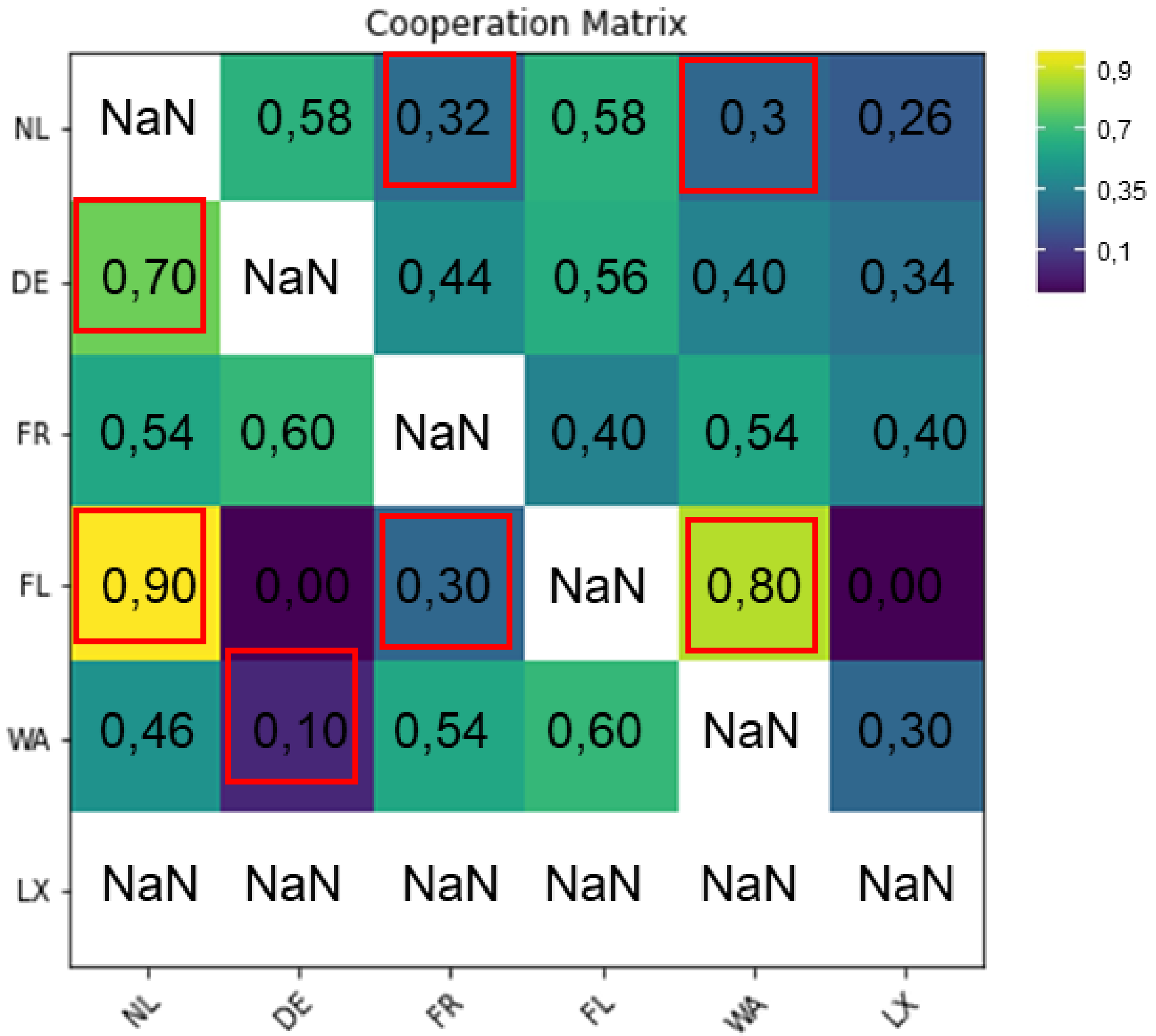
(Transboundary-)Governance

(Transboundary-)Governance

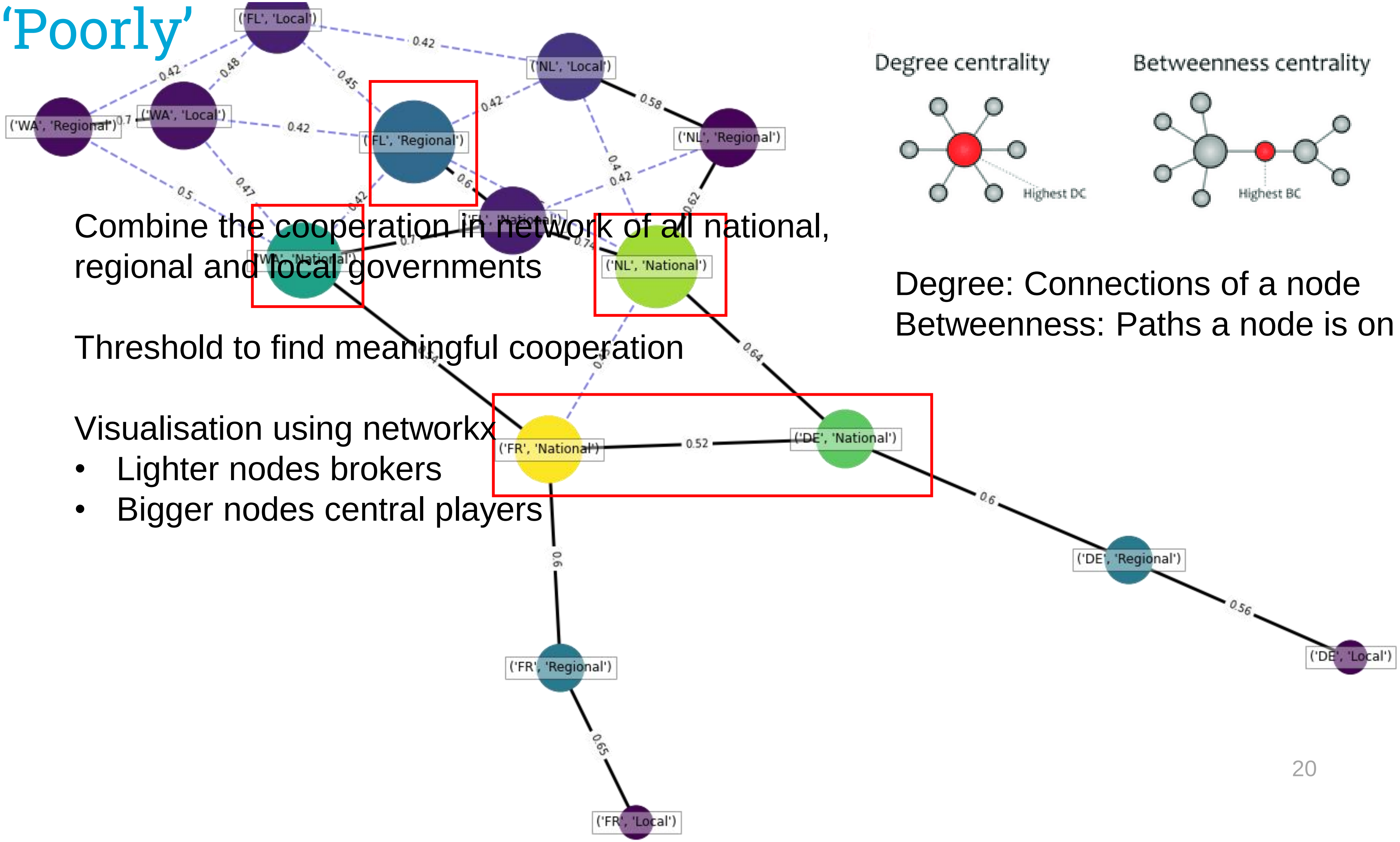
Cooperation Quality Scores

II. Inputs





Threshold ‘Poorly’



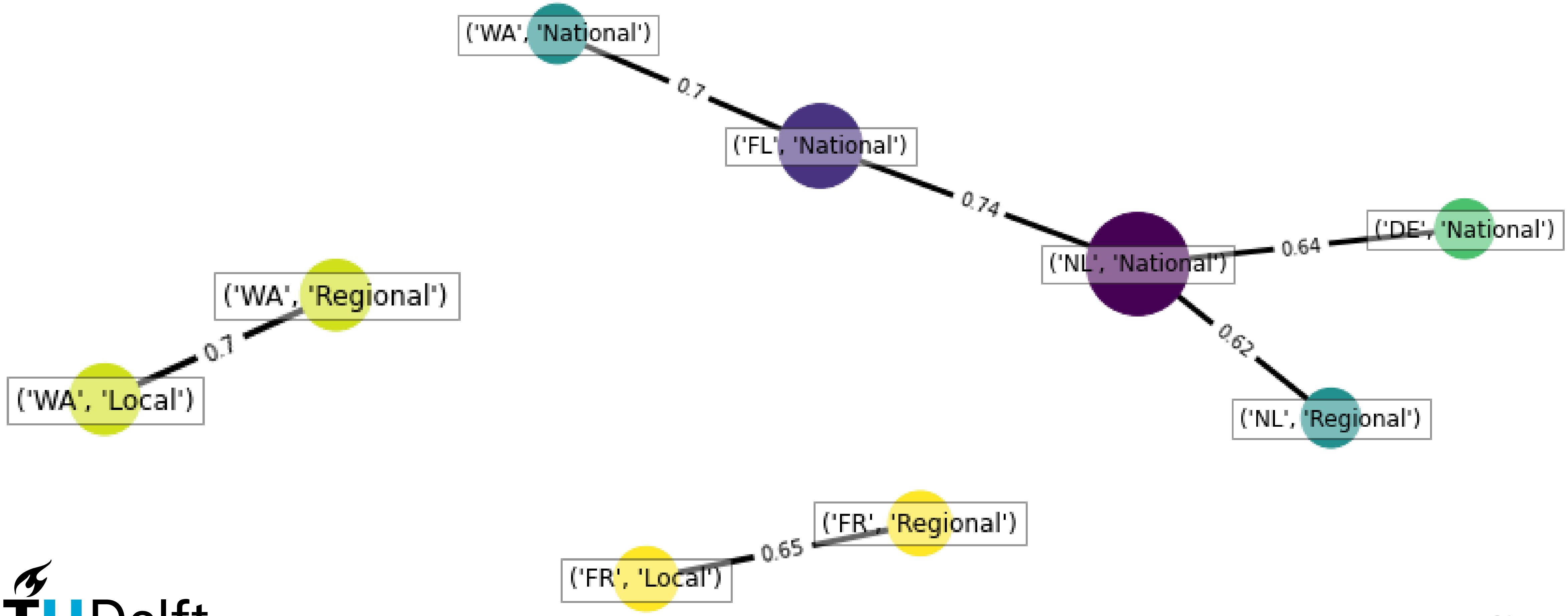
Combine the cooperation in network of all national, regional and local governments

Threshold to find meaningful cooperation

Visualisation using networkx
- Lighter nodes brokers
- Bigger nodes central players

Degree: Connections of a node
Betweenness: Paths a node is on

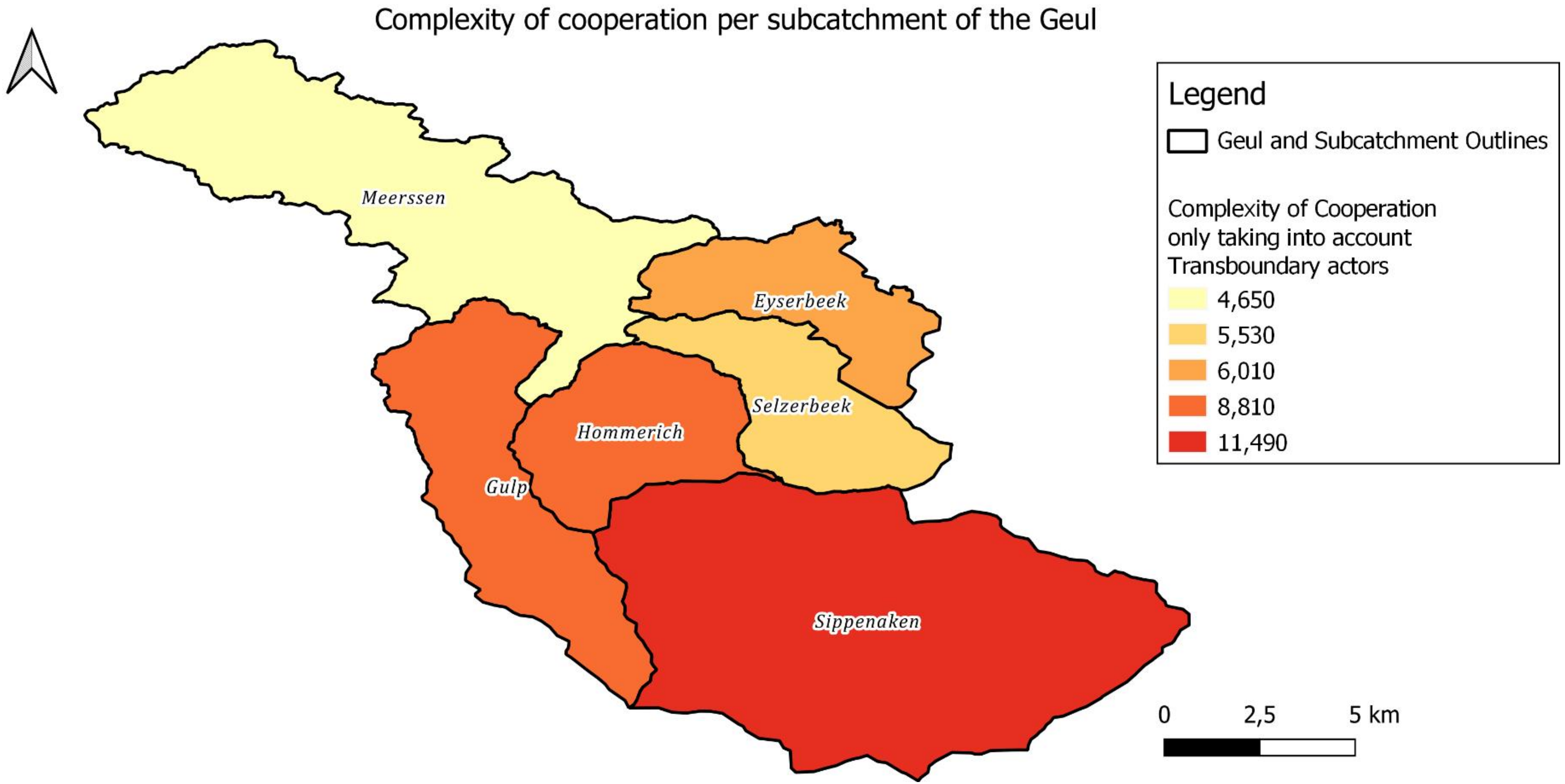
Threshold ‘Only if mutually beneficial’



(Transboundary-)Governance

Maps of spatial cooperation difficulty
Based on maps of actors and their cooperation quality

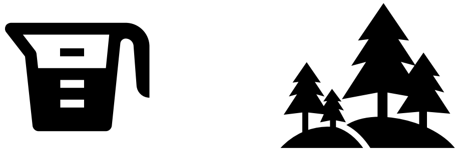
III. Products



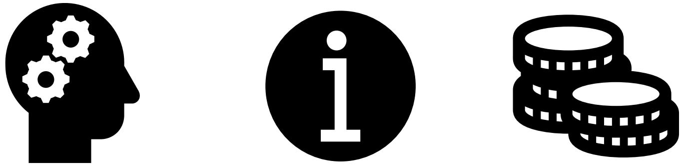
Results of the Framework

Systems approach

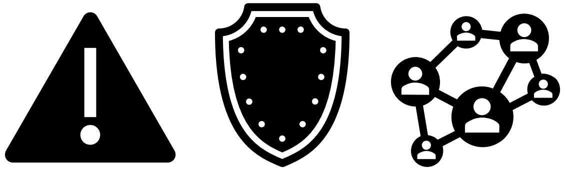
The Natural System



People



Additional policies

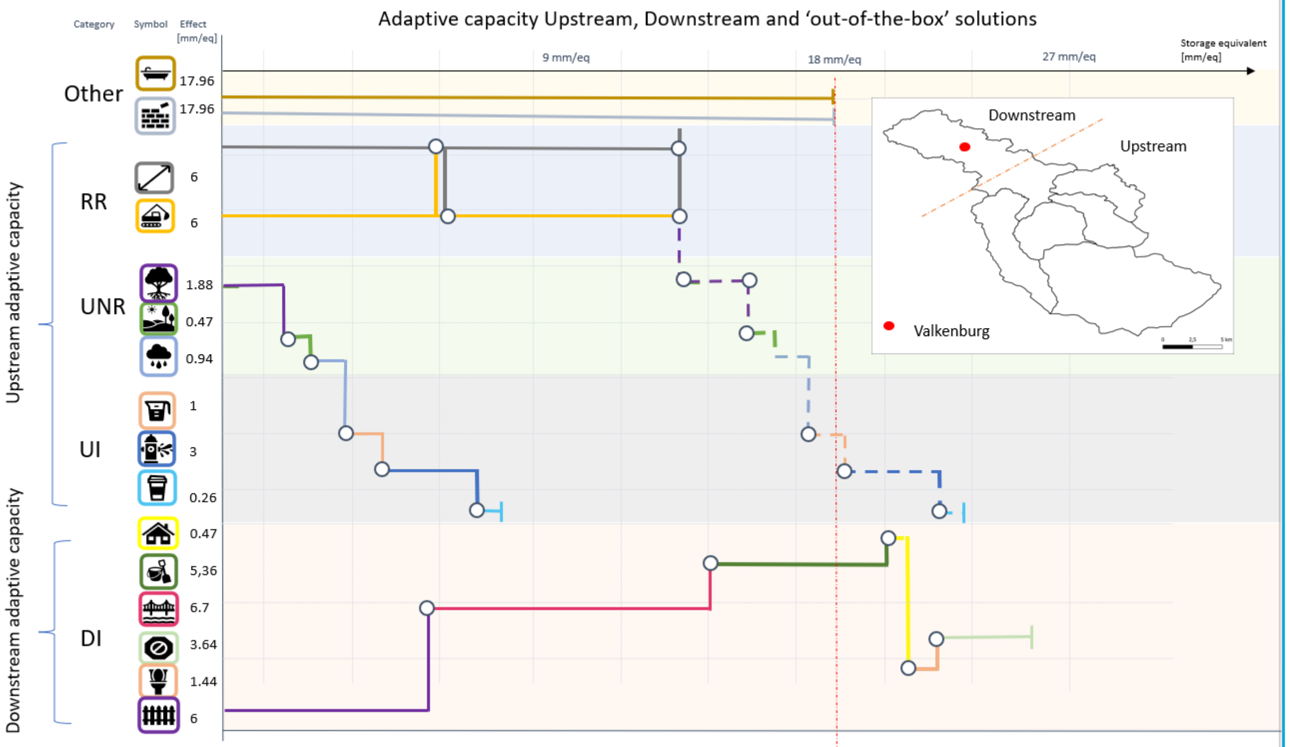


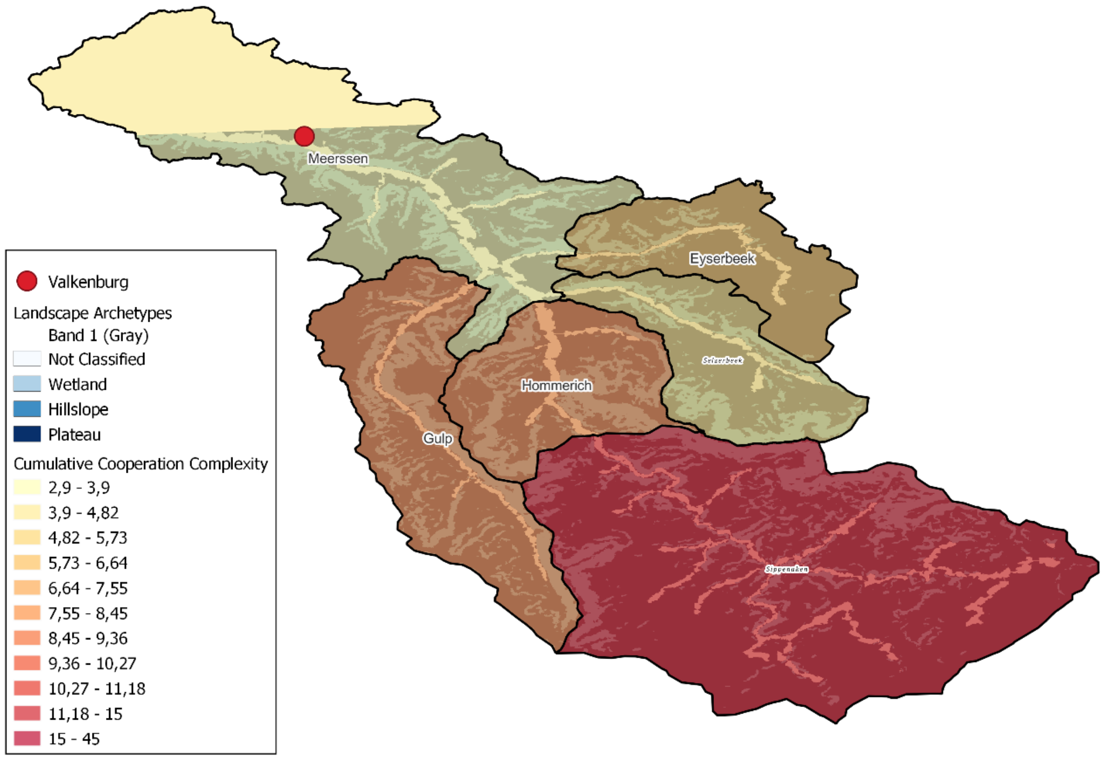
Visible, stabilizing, self-organisation, measures targeting exposure and vulnerability and supplementary policies

III.
Products

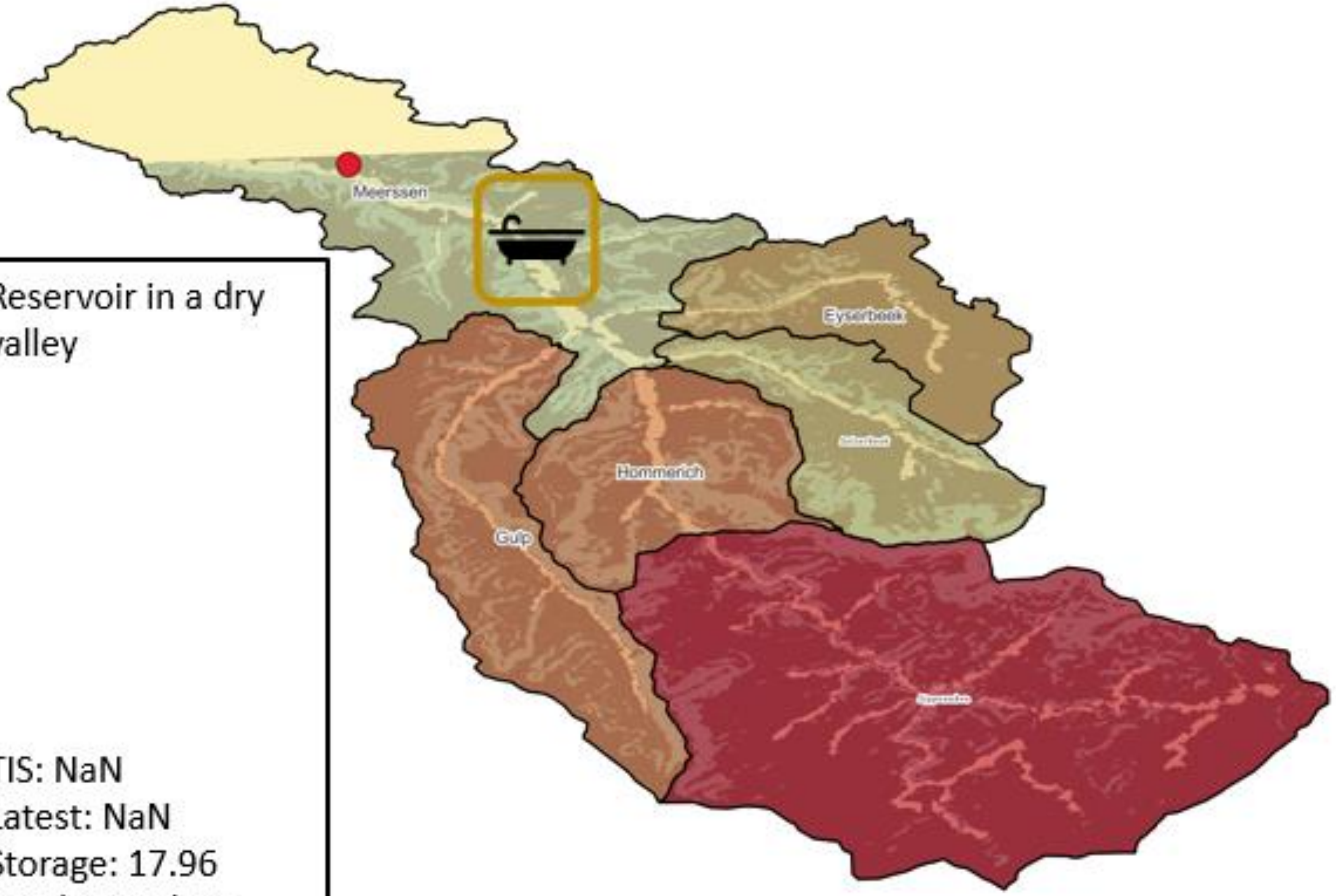
Solution Space
Based on measures and landscape characteristics

Maps of spatial cooperation difficulty
Based on maps of actors and their cooperation quality





Preferential Solutions



Reservoir in a dry valley

TIS: NaN
Latest: NaN
Storage: 17.96 mm/equivalent

Discussion, Future Recommendations and Conclusion

Discussion and recommendations for future work

Recommendations for future work

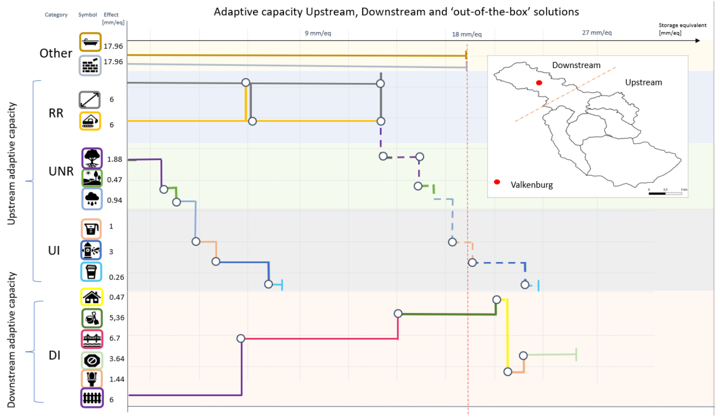
- Operationalizing network
- Cost-benefit aspect
- Using risk as a metric
- More specific analyses of actors and measures
- Applied in different contexts

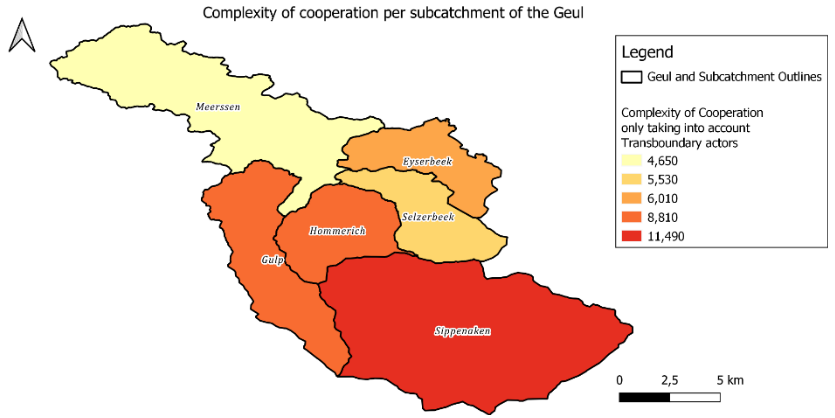
- Ethics, Methodolgy
- Transboundary cooperation harder
- Cooperation quality dependent on many factors, although not clear to what extent, they play a big role
- A lot of possibilities to adapt, even with maladaptation
- Adaptive capacity limited
- Broader policies needed
- Cooperation likely not sufficient for adaptation measures
- Can be applied broader but needs local information.
- Able to produce insight with relatively little information

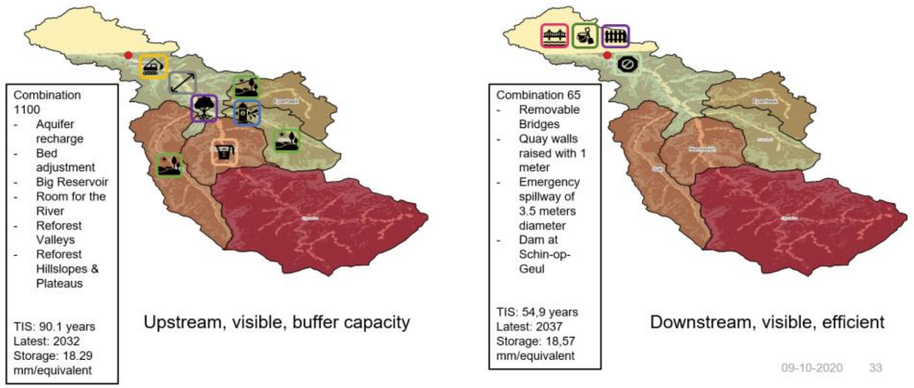
Conclusion

Research Goal: The research goal is to find <u>adaptation combinations</u> and <u>suitable locations</u> for the Geul when <u>acknowledging transboundary governance complexity</u>.

1. Which combinations of measures can help adapt to fluvial flooding risk in the Geul?
2. In implementing these measures, which administrative actors are involved, and how is the quality of their cooperation?
3. Which adaptation combinations are suited and would be preferential for the Geul catchment?
4. How does the Framework developed in this thesis perform and can it be applied broader?







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Overheden kunnen schade door weersextremen niet langer voorkomen. Om de overlast te beperken, moeten individuele bewoners ook zelf een steentje bijdragen.

Unie van Waterschappen over eindrapport Beleidstafel Hoogwater en Wateroverlast (19-12-2022)

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Thank you for your attention!

You are welcome to ask questions.

Jan

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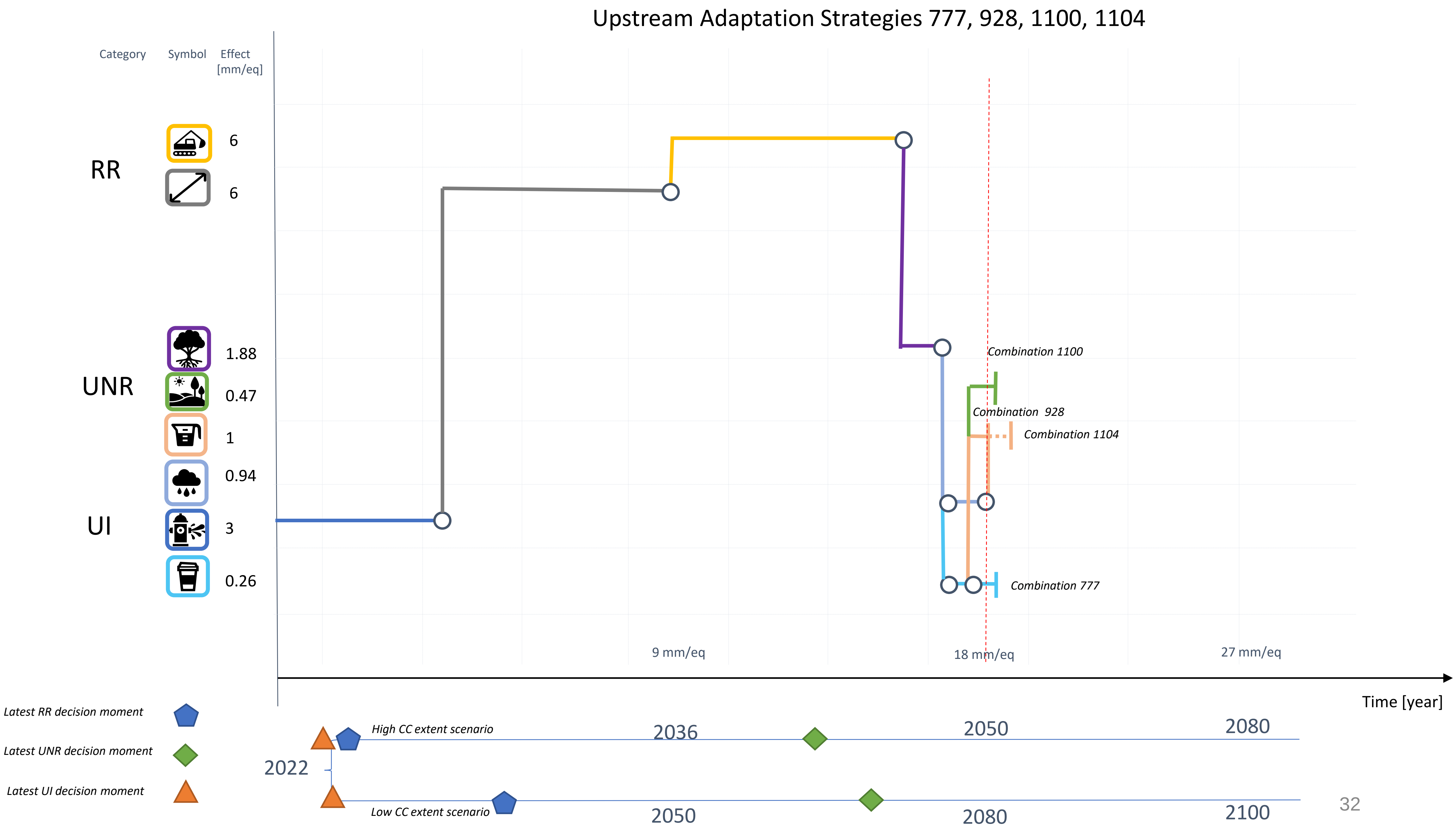


Upstream Adaptation Strategies 777, 928, 1100, 1104
Category
Symbol
Effect [mm/eq]
RR
6
6
UNR
1.88
0.47
1
0.94
UI
3
0.26
Combination 1100
Combination 928
Combination 1104
Combination 777
9 mm/eq
18 mm/eq
27 mm/eq
Time [year]
Latest RR decision moment
Latest UNR decision moment
Latest UI decision moment
High CC extent scenario
2022
2036
2050
2080
Low CC extent scenario
2050
2080
2100

Methods

Open-source information

- Map of actors using borders
- Map of subcatchments for broader applicability assessment

Social Network Analysis

- Network characteristics of the full network
- Network characteristics when thresholds are applied

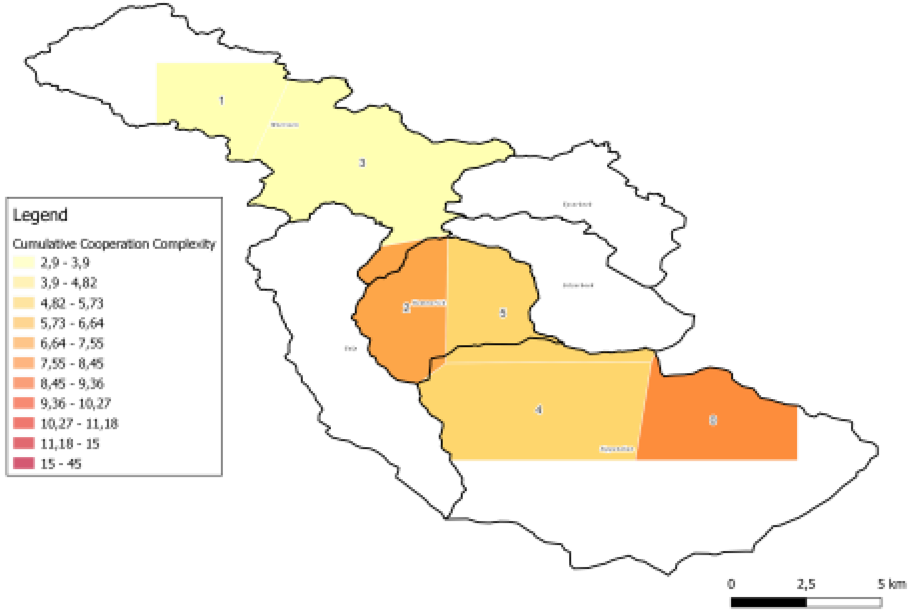
Literature

- Measures in the Geul
- Climate change in the area of interest
- Landscapes in the area of interest

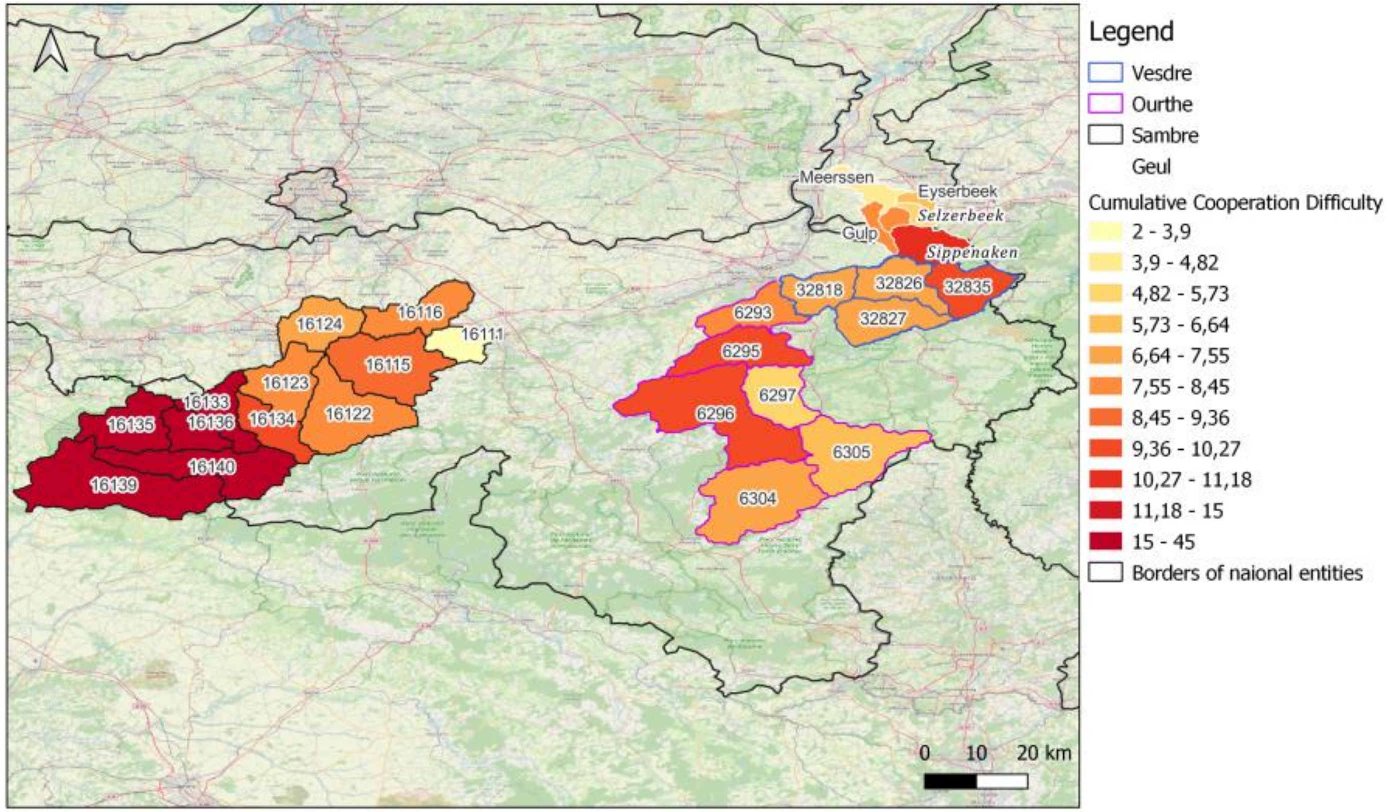
Expert Judgment

- Cooperation quality scores
- Estimation of implementation time of different categories of measures

Broader applicability



Spatial Complexity maps for the Vesdre, Ourthe, Sambre and Geul tributaries



Category & N	Index	Measures	Storage	TIS	LIT
Most Efficient	0	Removable Bridges, Quay walls raised with 1 meter, Bed adjustment	18.7	46.9	2035
-	4	Removable Bridges, Room for the River, Bed adjustment	18.7	47.9	
	5	Room for the River, Quay walls raised with 1 meter, Bed adjustment	18	47.9	
Upstream	1474	Aquifer recharge, Bed adjustment, Rainwater retention upstream, Room for the River, Reforest Valleys, Reforest Hill slopes & Plateaus	18.29	92.8	2034
10	1100	Aquifer recharge, Big reservoir, Bed adjustment, Room for the River, Reforest Valleys, Reforest Hill slopes & Plateaus	18.35	92.8	
Downstream	63	Removable Bridges, Quay walls raised with 1 meter, Emergency spillway of 3.5 meters diameter, Use of old sewer pipe as spillway	18.57	52.8	2037
29	65	Removable Bridges, Quay walls raised with 1 meter, Emergency pipe spillway of 3.5 meters diameter, Dam at Schin-op-Geul	18.57	54.9	
	67	Removable Bridges, Quay walls raised with 1 meter, Emergency pipe spillway of 3.5 meters diameter, Diverting urban rainwater	20.7	52.8	
With Maladaptation	496	Decrease in forest, Removable Bridges, Quay walls raised with 1 meter, Room for the River, Reforest Valleys	19.5	58	2034
6812	500	Decrease in forest, Removable Bridges, Quay walls raised with 1 meter, emergency pipe spillway of 3.5 meters diameter, Dam at Schin-op-Geul	18.38	54.9	2037
Alternative options	-	Quay walls of 2.5 meters	17.96	-	2
	-	Reservoir in a dry valley	17.96	-	

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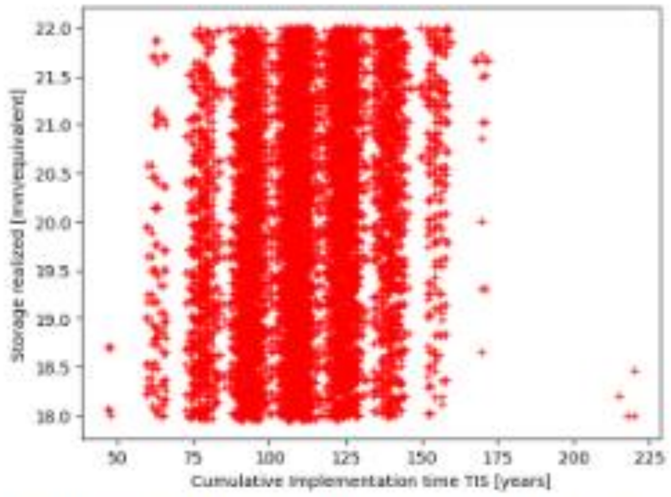
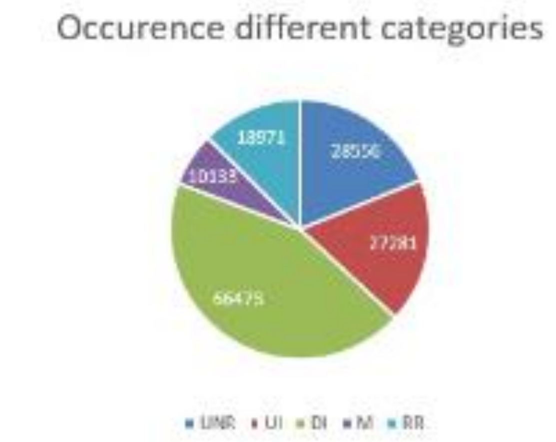
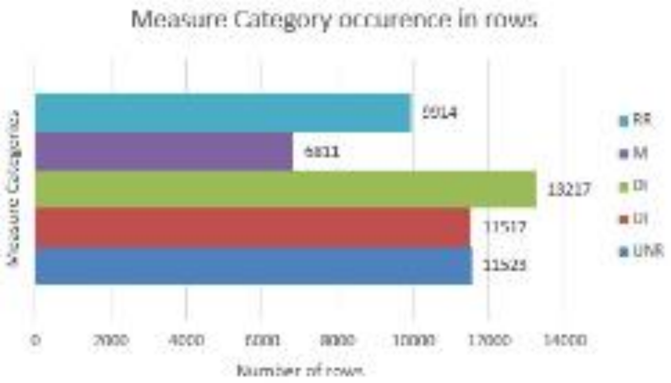
Solution space metrics



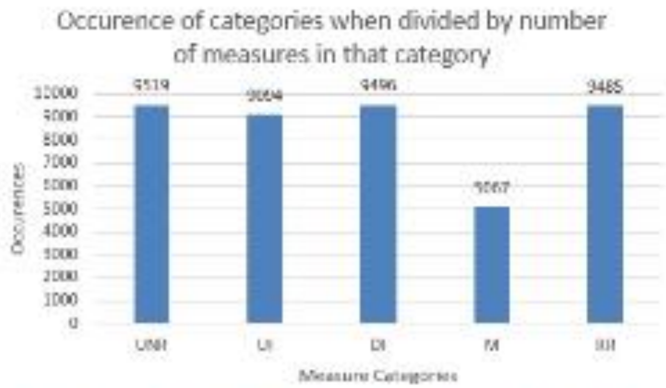
(a) Number of actions per category in the solution space



(b) Actions per category in the solution space divided by the number of measures in that category



(c) Number of actions per category in the solution space



(d) Actions per category in the solution space divided by the number of measures in that category

Example of the solution space

	A1	A2	A3	A4	A5	A6	A7	A8	Wet Constraint	#Actions	DI	UI	UNR	M	RR	TIS	LIT
1	RemBr	QuayOne	Tunnel3.5	Done	Done	Done	Done	Done	18.060	3	NaN	NaN	3.0	NaN	NaN	15.3	2034.7
2	RemBr	QuayOne	Bedupstr	Done	Done	Done	Done	Done	18.701	3	NaN	NaN	2.0	NaN	1.0	31.6	2033.7
3	RemBr	QuayNotch	Tunnel3.5	Done	Done	Done	Done	Done	18.860	3	NaN	NaN	3.0	NaN	NaN	15.3	2034.7
4	RemBr	QuayNotch	Bedupstr	Done	Done	Done	Done	Done	19.501	3	NaN	NaN	2.0	NaN	1.0	31.6	2033.7
5	RemBr	Tunnel3.5	Bedupstr	Done	Done	Done	Done	Done	18.061	3	NaN	NaN	2.0	NaN	1.0	31.6	2033.7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
100	Aquifer	BigRes	ForestDEC	RemBr	QuayOne	Tunnel3.5	ReforestV	Done	21.740	7	1.0	2.0	3.0	1.0	NaN	46.4	2032.1
101	Aquifer	BigRes	ForestDEC	RemBr	Tunnel3.5	Bedupstr	ReforestV	Done	21.741	7	1.0	2.0	2.0	1.0	1.0	62.7	2032.1
102	Aquifer	BigRes	ForestDEC	QuayOne	QuayNotch	Tunnel3.5	ReforestV	Done	21.840	7	1.0	2.0	3.0	1.0	NaN	46.4	2032.1
103	Aquifer	BigRes	ForestDEC	QuayOne	Tunnel3.5	Bedupstr	ReforestV	Done	21.041	7	1.0	2.0	2.0	1.0	1.0	62.7	2032.1
104	Aquifer	BigRes	ForestDEC	QuayNotch	Tunnel3.5	Bedupstr	ReforestV	Done	21.841	7	1.0	2.0	2.0	1.0	1.0	62.7	2032.1

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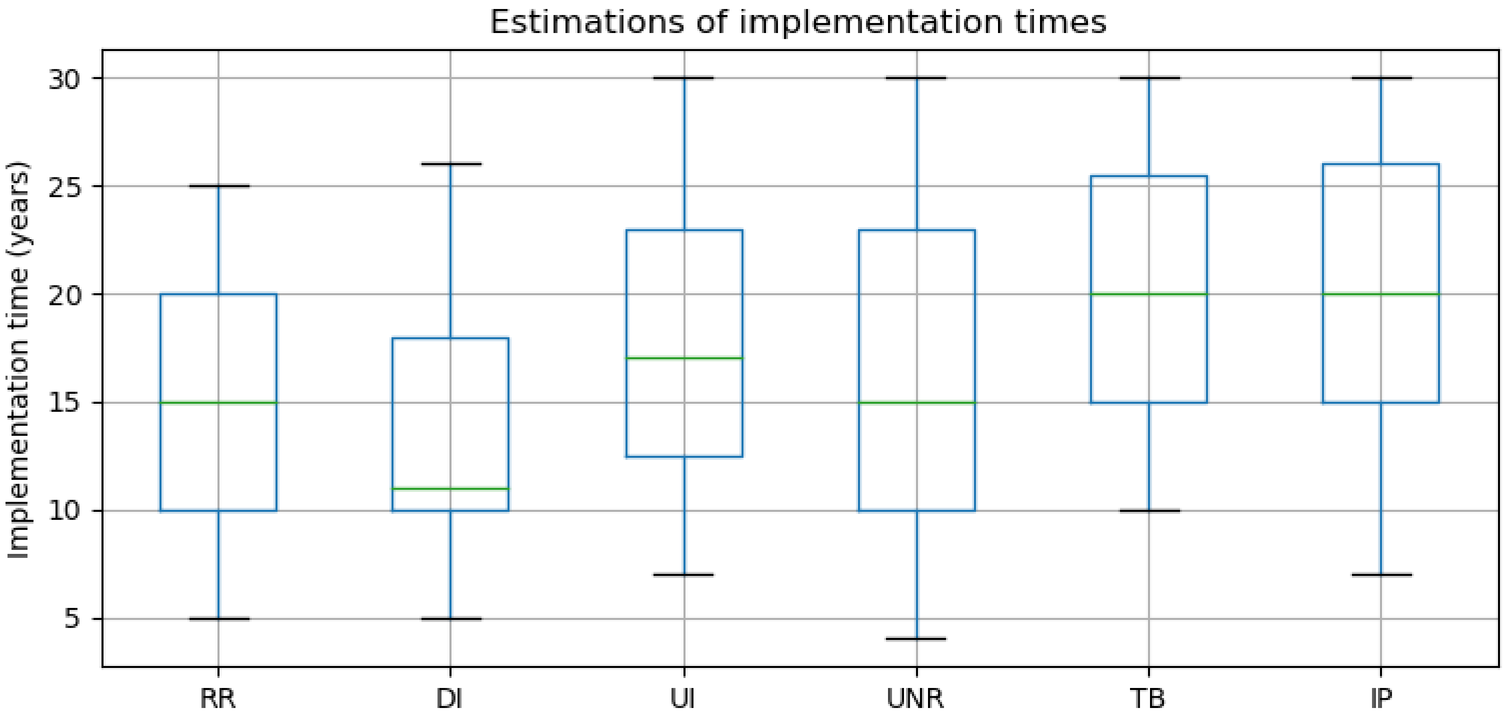
Implementation times



Metric	RR	DI	UI	UNR	TB	IP
5% interval mean	8.5	7.2	10.7	9.9	13.1	14.0
Estimation mean	15.3	13.2	17.9	16.3	20.2	20.2
95% interval mean	23.9	18.5	25.0	22.5	26.9	28.0
Estimation median	15.0	11.0	17.0	15.0	20.0	20.0
N	26.0	24.0	26.0	26.0	17.0	20.0

Actors in the Geul

Sub-catchm	Total Actors	I-N	I-L	I-R	T-N	T-R	T-L	Countries
Sippenaeken	18	0	0	0	4	4	7	BE, DE
Selzerbeek	10	1	2	2	2	2	1	DE, NL
Meerssen	10	1	7	2	0	0	0	NL
Hommerich	14	1	2	2	3	4	2	BE, NL
Gulp	14	1	2	2	3	4	2	BE, NL
Eyserbeek	11	1	3	2	2	2	1	DE, NL

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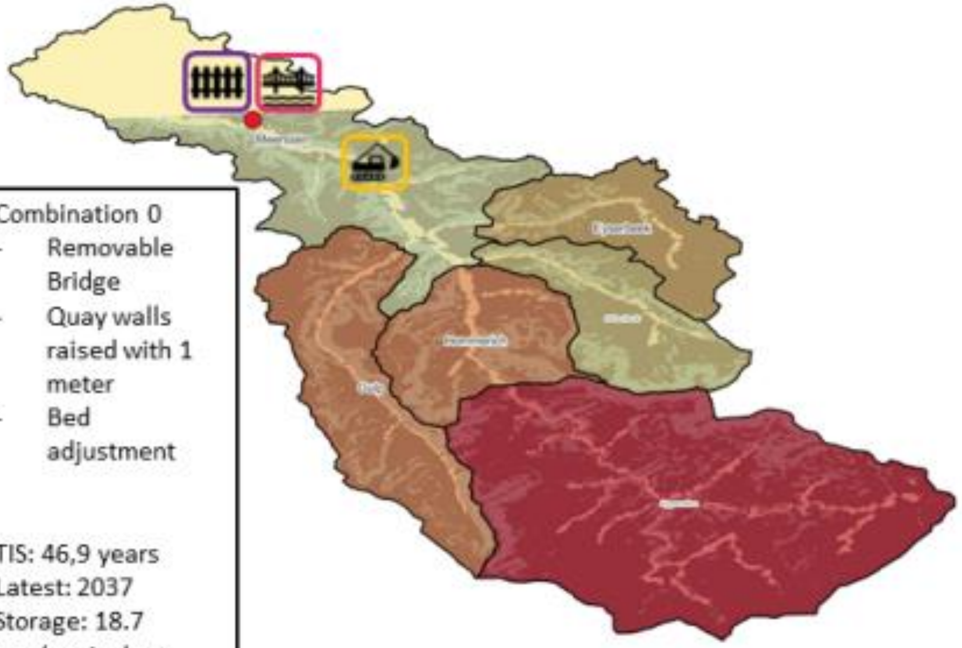
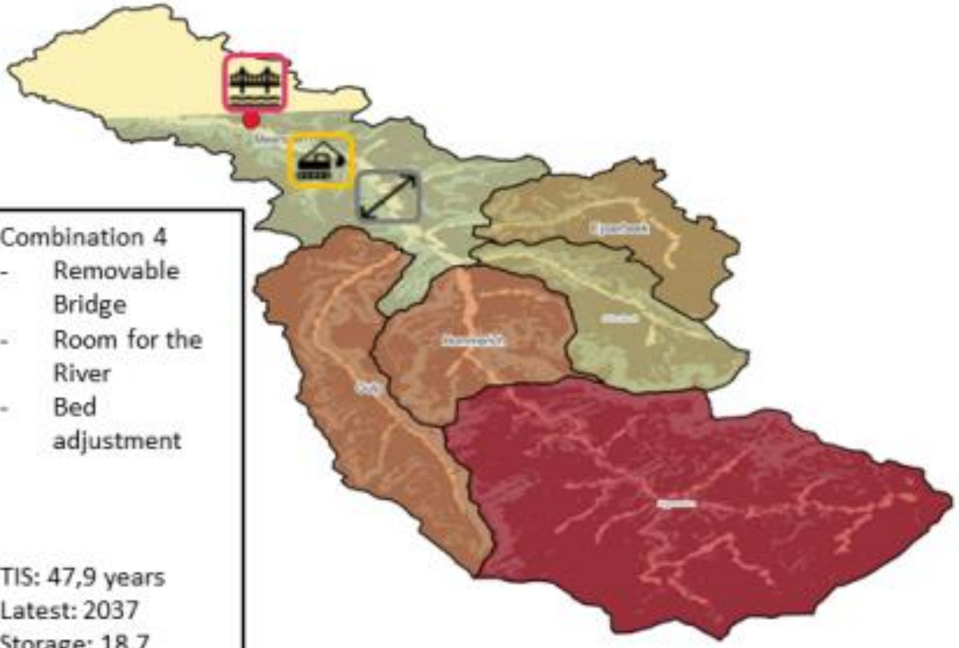
Efficient strategies



Combination 0
- Removable Bridge
- Quay walls raised with 1 meter
- Bed adjustment

TIS: 46,9 years
Latest: 2037
Storage: 18.7 mm/equivalent



Combination 4
- Removable Bridge
- Room for the River
- Bed adjustment

TIS: 47,9 years
Latest: 2037
Storage: 18.7 mm/equivalent

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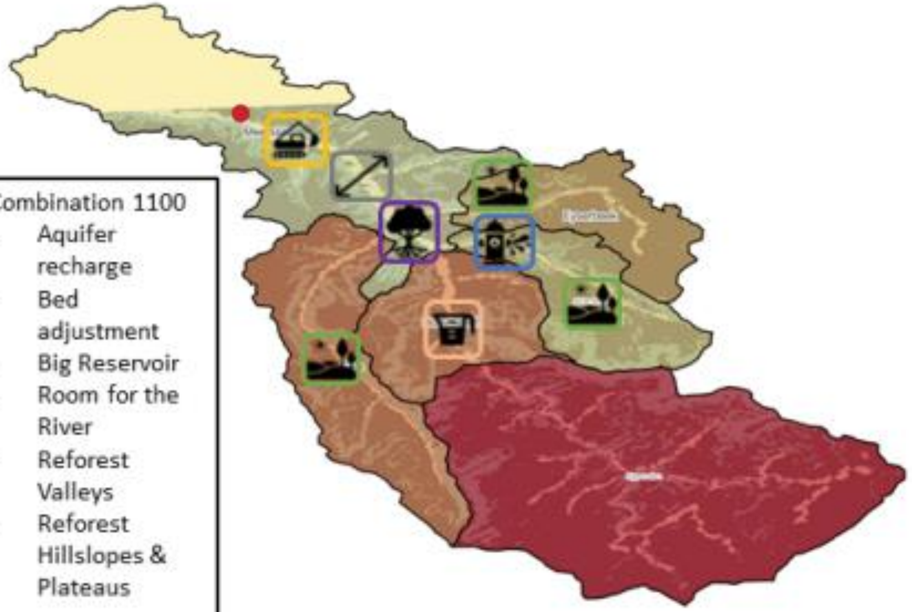
Upstream strategies

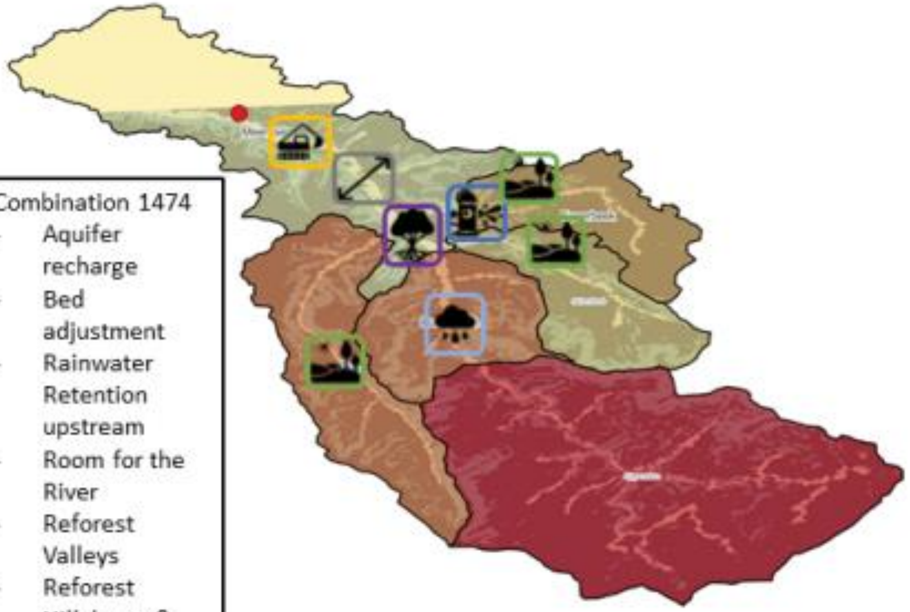
Combination 1100
- Aquifer recharge
- Bed adjustment
- Big Reservoir
- Room for the River
- Reforest Valleys
- Reforest Hillslopes & Plateaus

TIS: 90.1 years
Latest: 2032
Storage: 18.29 mm/equivalent



Combination 1474
- Aquifer recharge
- Bed adjustment
- Rainwater Retention upstream
- Room for the River
- Reforest Valleys
- Reforest Hillslopes & Plateaus

TIS: 90.1 years
Latest: 2032
Storage: 18.29 mm/equivalent



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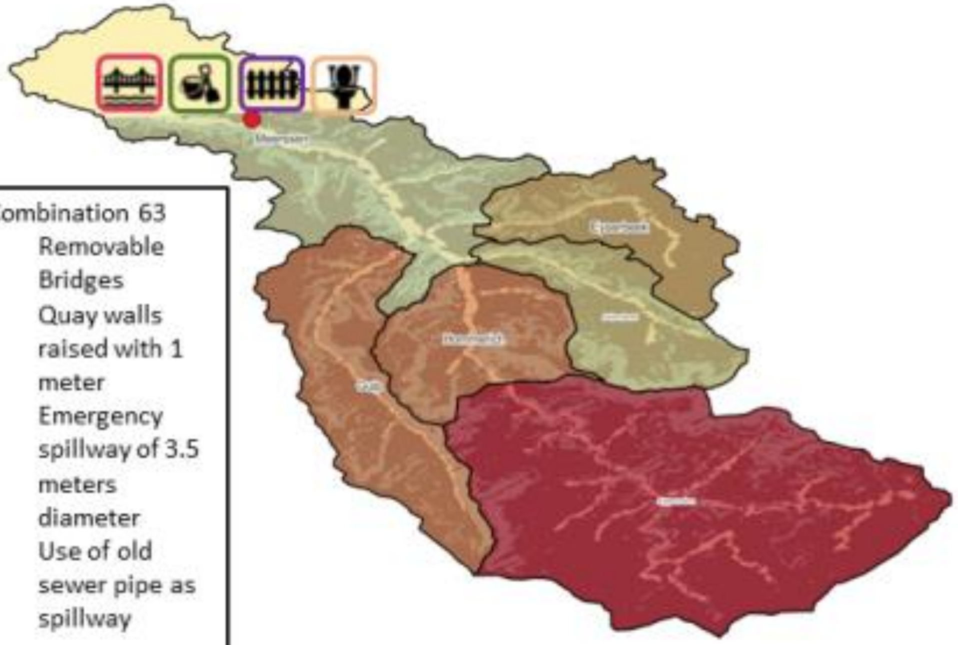
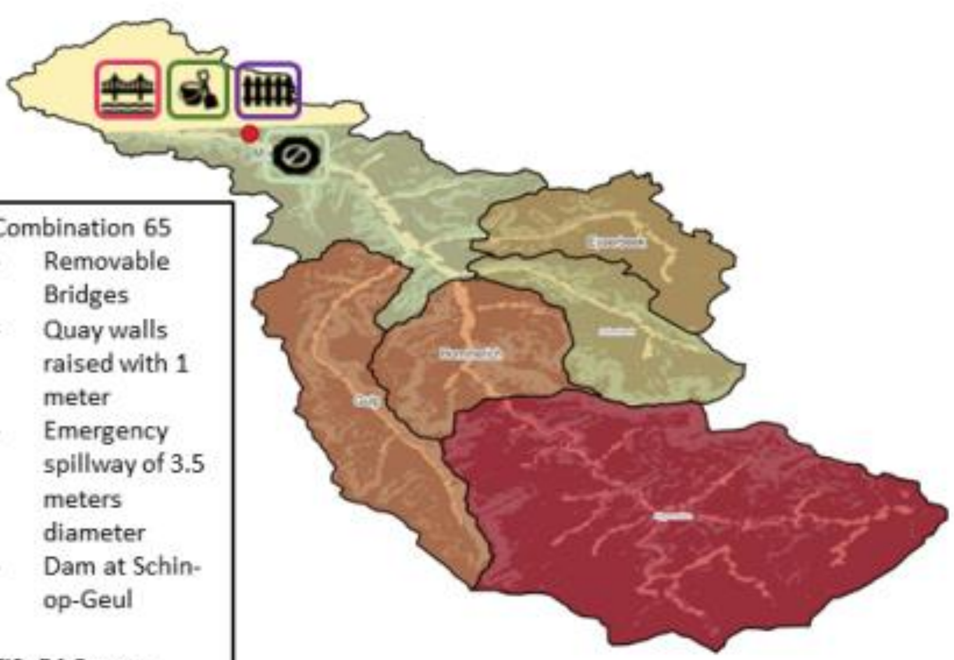
Downstream strategies



Combination 63
- Removable Bridges
- Quay walls raised with 1 meter
- Emergency spillway of 3.5 meters diameter
- Use of old sewer pipe as spillway

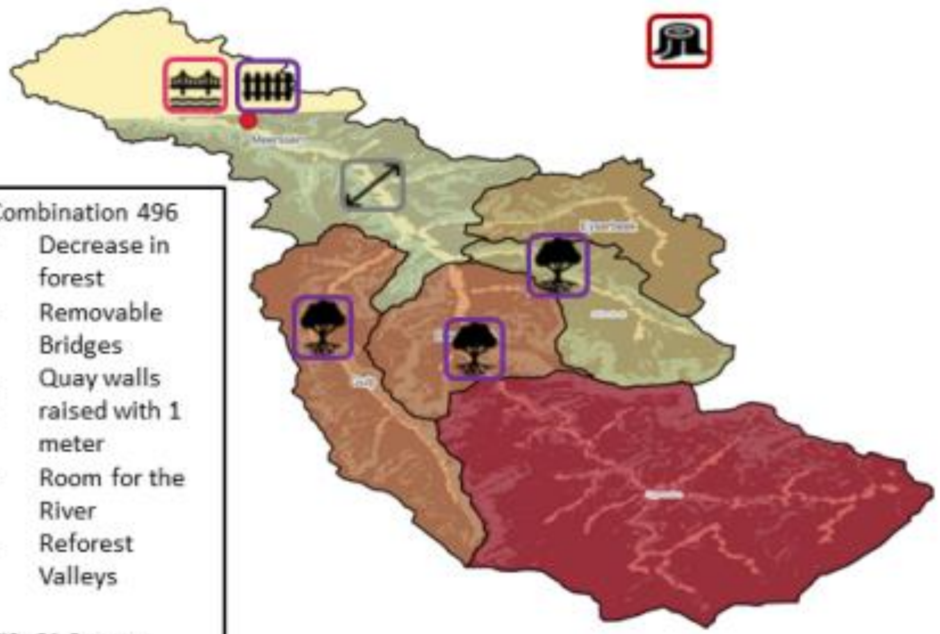
TIS: 52,8 years
Latest: 2037
Storage: 18,57 mm/equivalent



Combination 65
- Removable Bridges
- Quay walls raised with 1 meter
- Emergency spillway of 3.5 meters diameter
- Dam at Schin-op-Geul

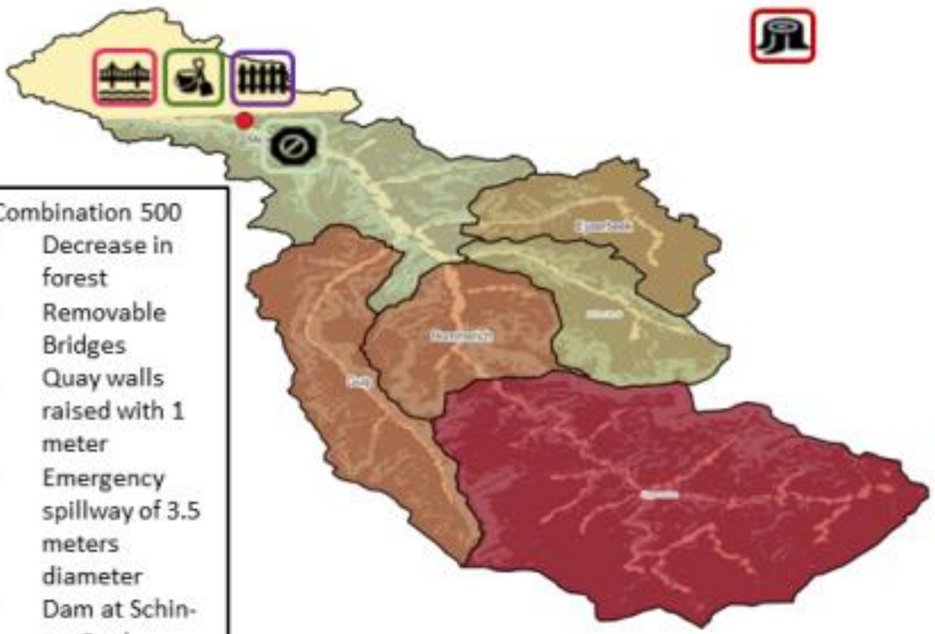
TIS: 54,9 years
Latest: 2037
Storage: 18,57 mm/equivalent

Maladaptation strategies



Combination 496
- Decrease in forest
- Removable Bridges
- Quay walls
- raised with 1 meter
- Room for the River
- Reforest Valleys

TIS: 61,2 years
Latest: 2032
Storage: 19,5 mm/equivalent

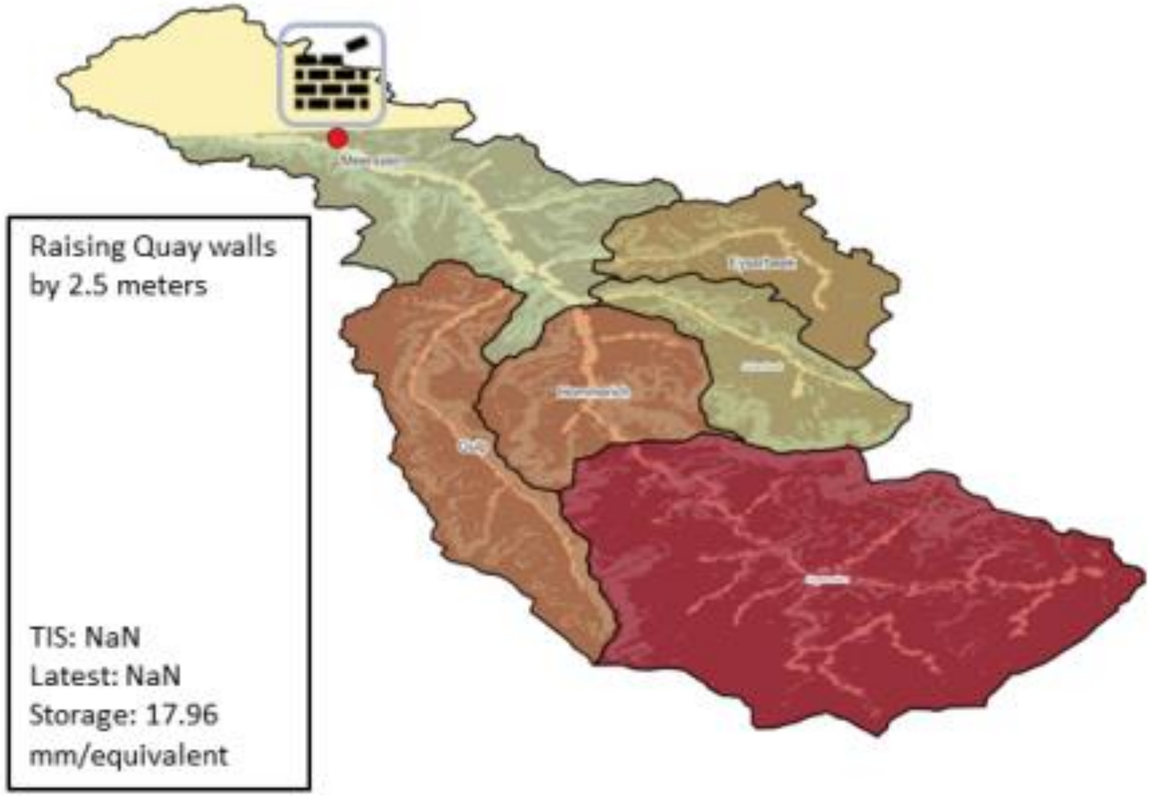


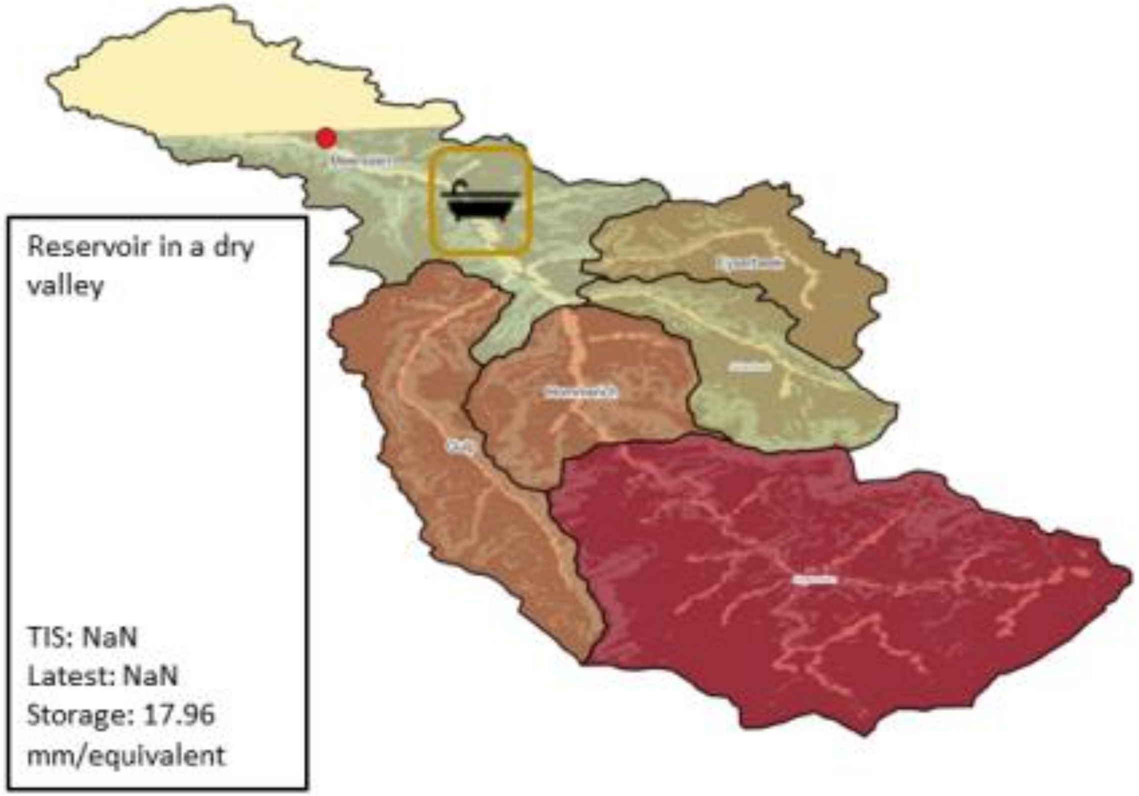
Combination 500
- Decrease in forest
- Removable Bridges
- Quay walls raised with 1 meter
- Emergency spillway of 3.5 meters diameter
- Dam at Schin-op-Geul

TIS: 60,1 years
Latest: 2037
Storage: 18,38 mm/equivalent

TU Delft

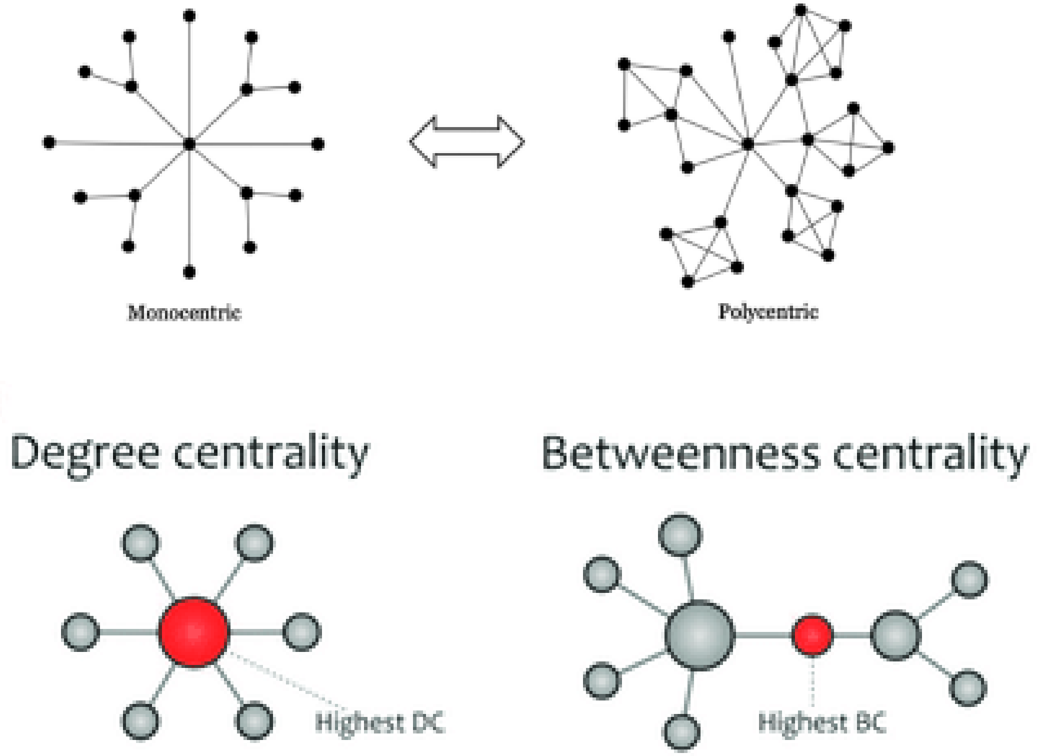
Alternative strategies





- National results and cooperation between countries extrapolated
- Thresholds for meaningful cooperation (0.2, 0.4, 0.6)

- Social Network Analysis applied to networks
  - Density
  - Degree (centrality)
  - Betweenness (centrality)
  - Average path length



Threshold 0.2