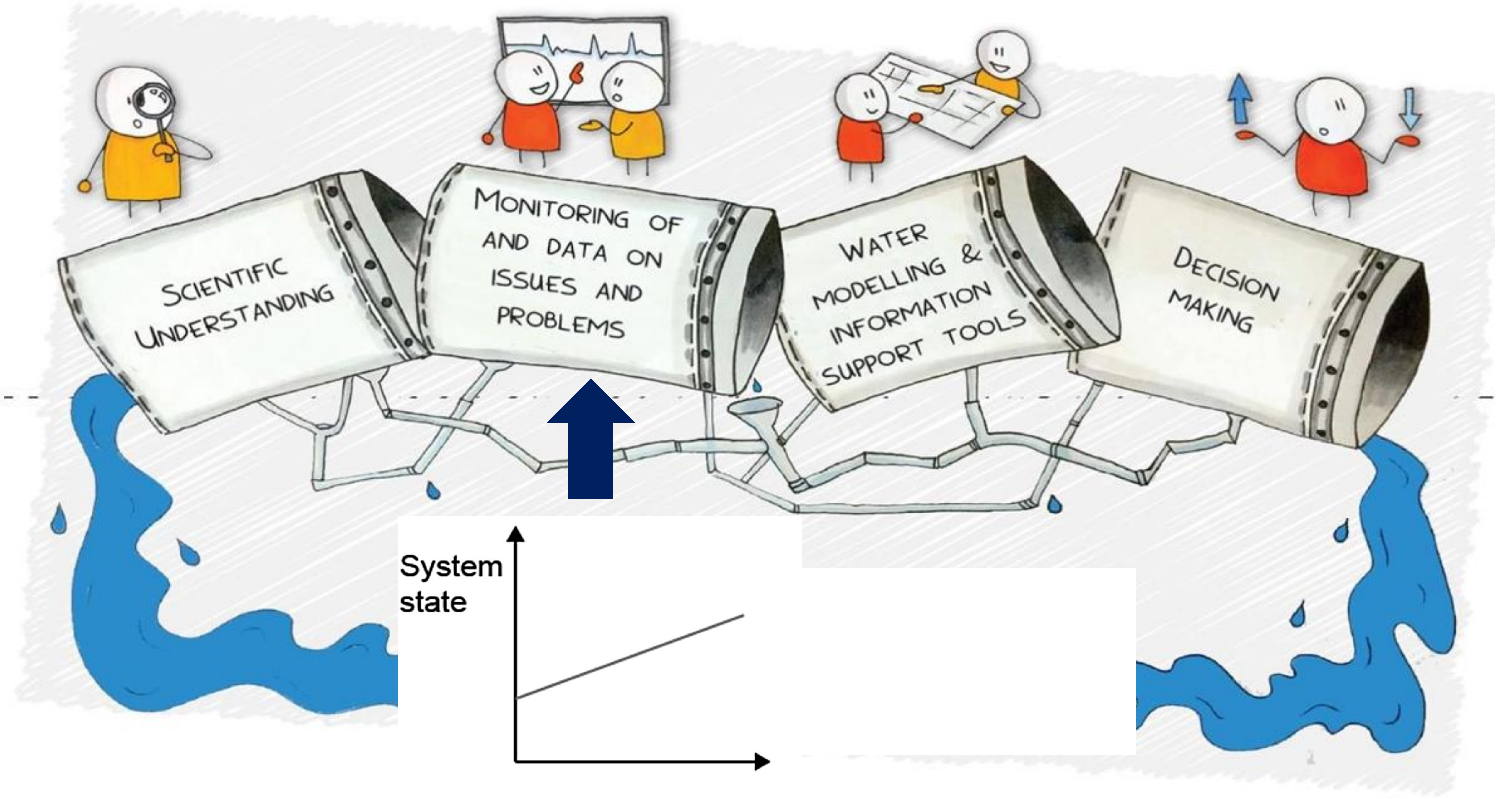
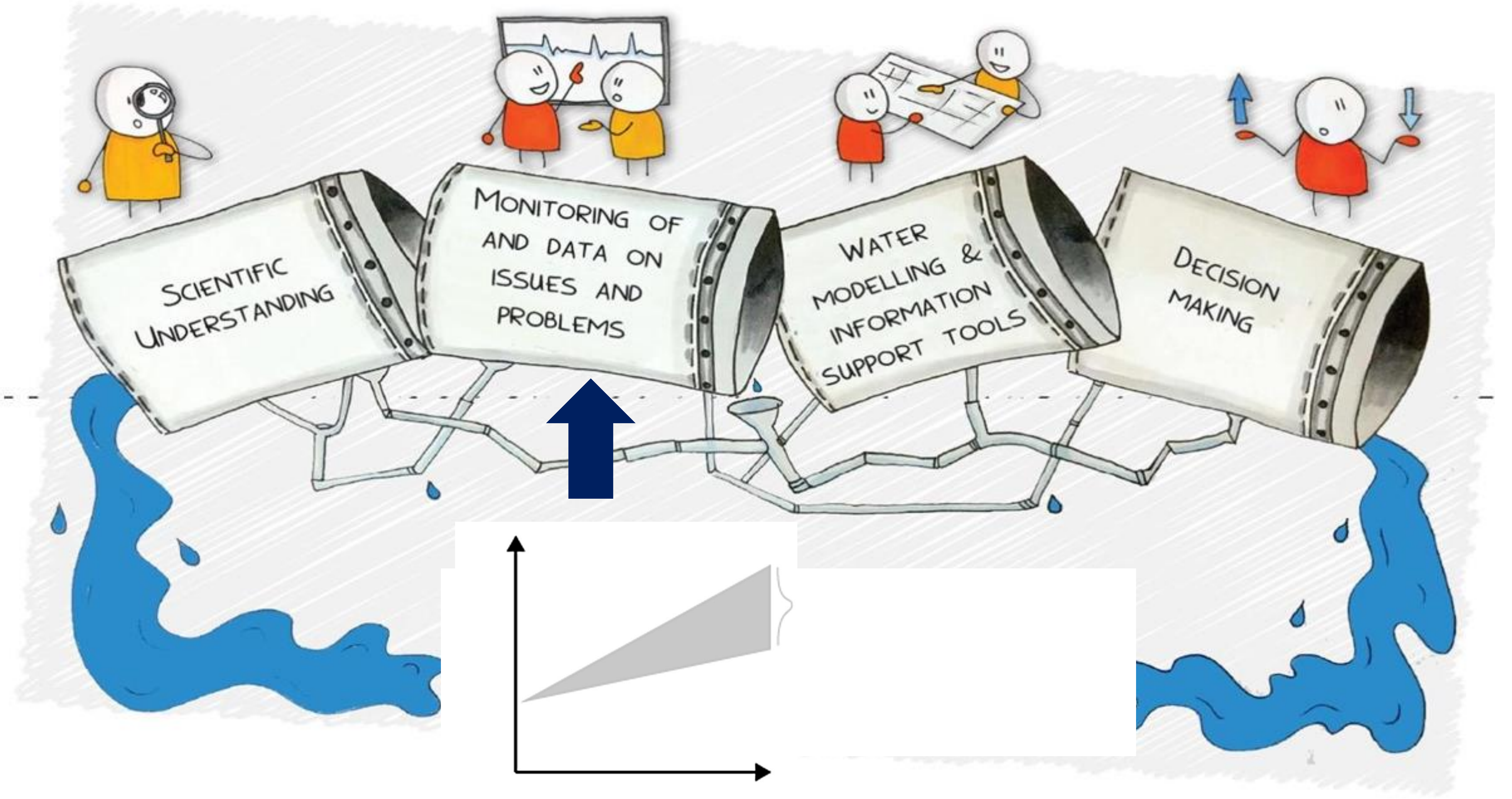
THE UNIVERSITY of ADELAIDE

TOP-DOWN AND BOTTOM-UP CLIMATE IMPACT ASSESSMENT FOR WATER SUPPLY AND RESERVOIR SYSTEMS

Holger R. Maier

School of Civil, Environmental and Mining Engineering


SCIENTIFIC UNDERSTANDING
MONITORING OF AND DATA ON ISSUES AND PROBLEMS
WATER MODELLING & INFORMATION SUPPORT TOOLS
DECISION MAKING
System state



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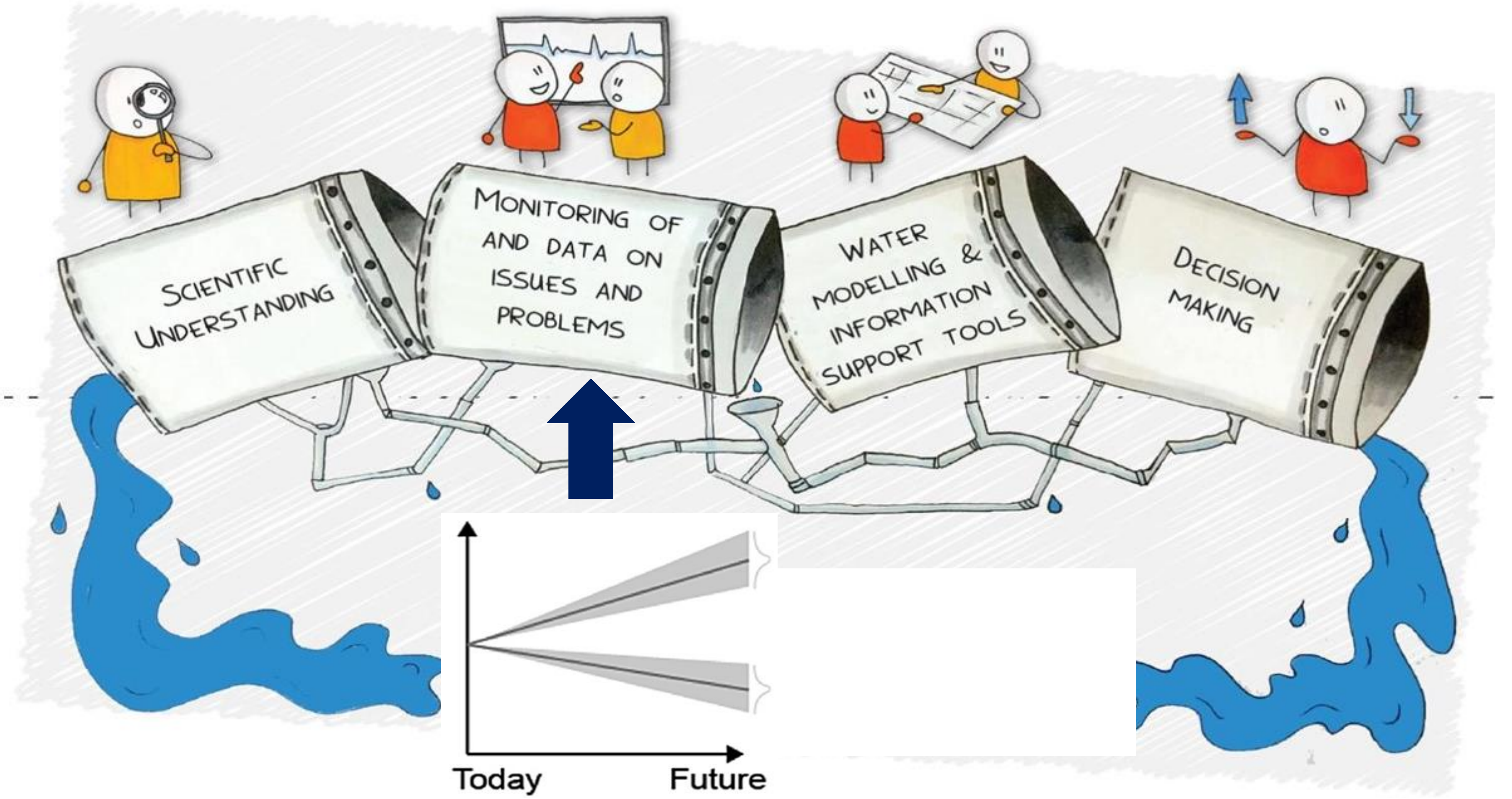
SCIENTIFIC UNDERSTANDING
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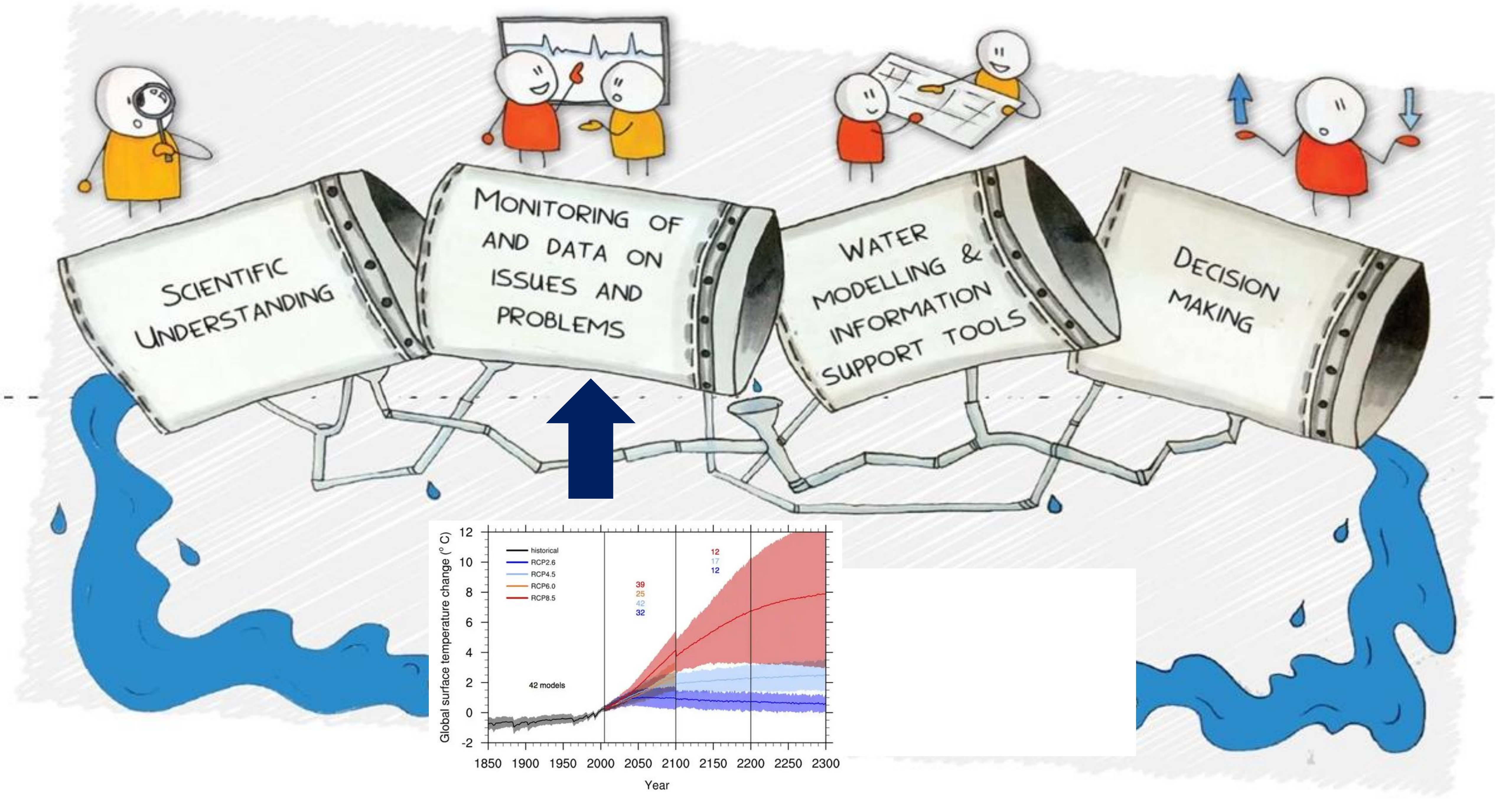
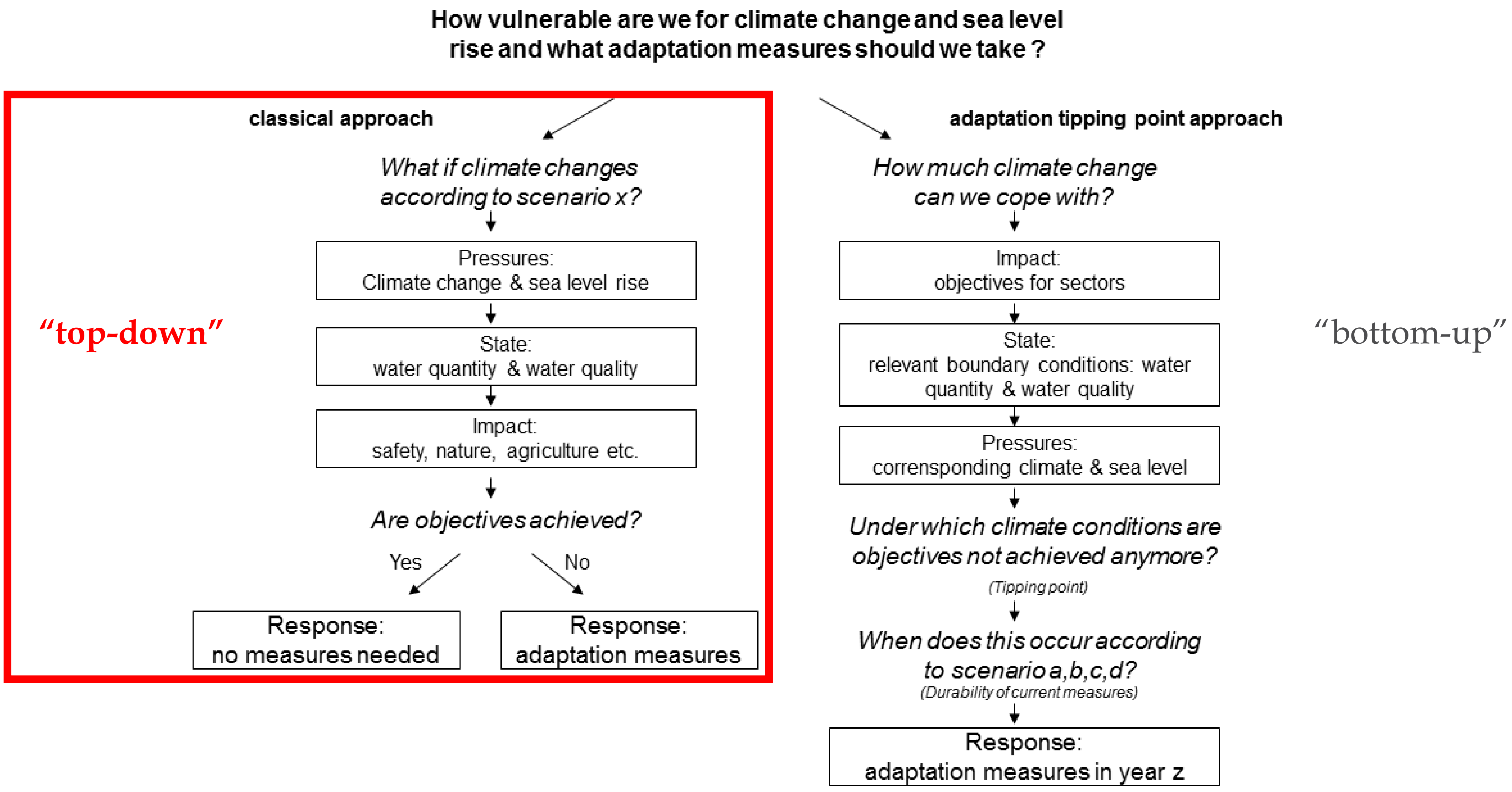
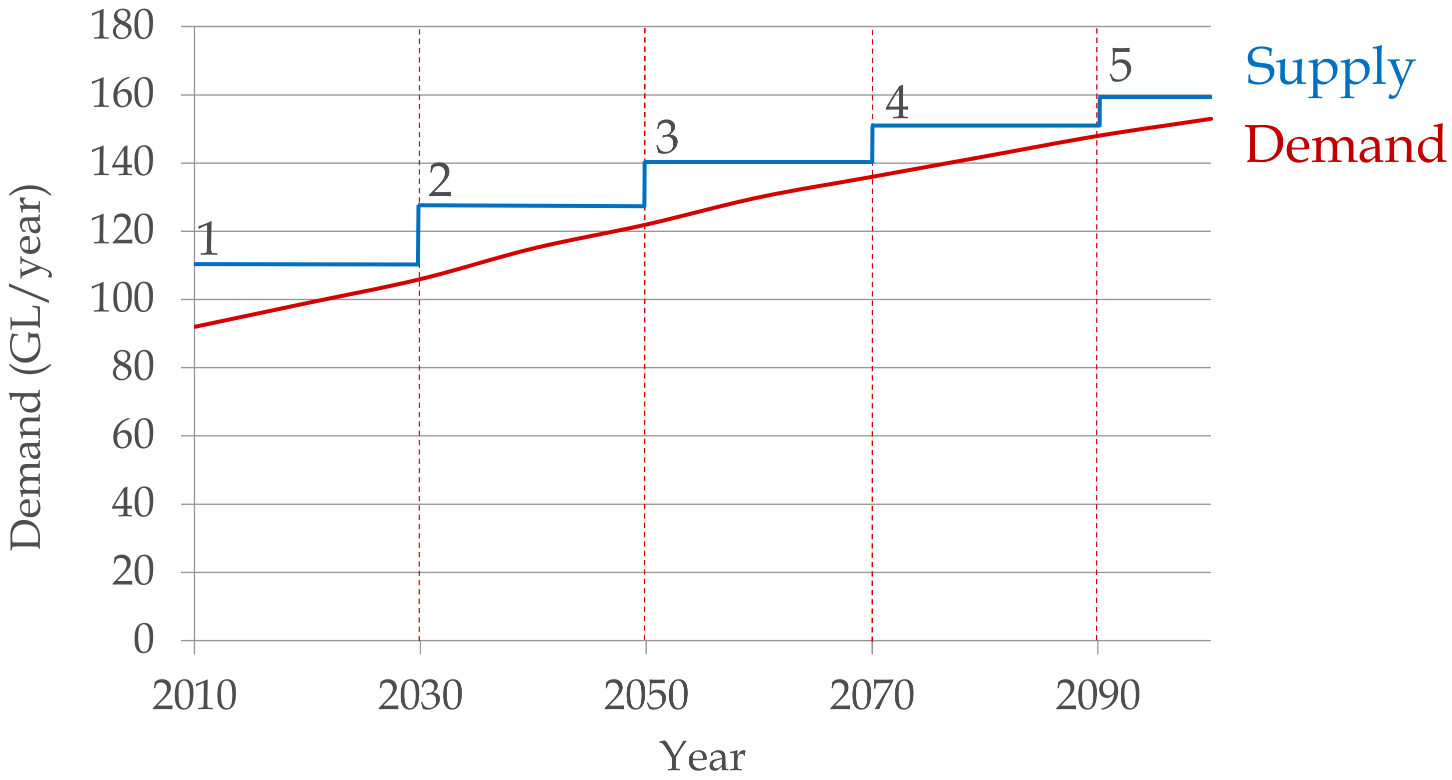
WATER MODELLING & INFORMATION SUPPORT TOOLS
DECISION MAKING
Today
Future



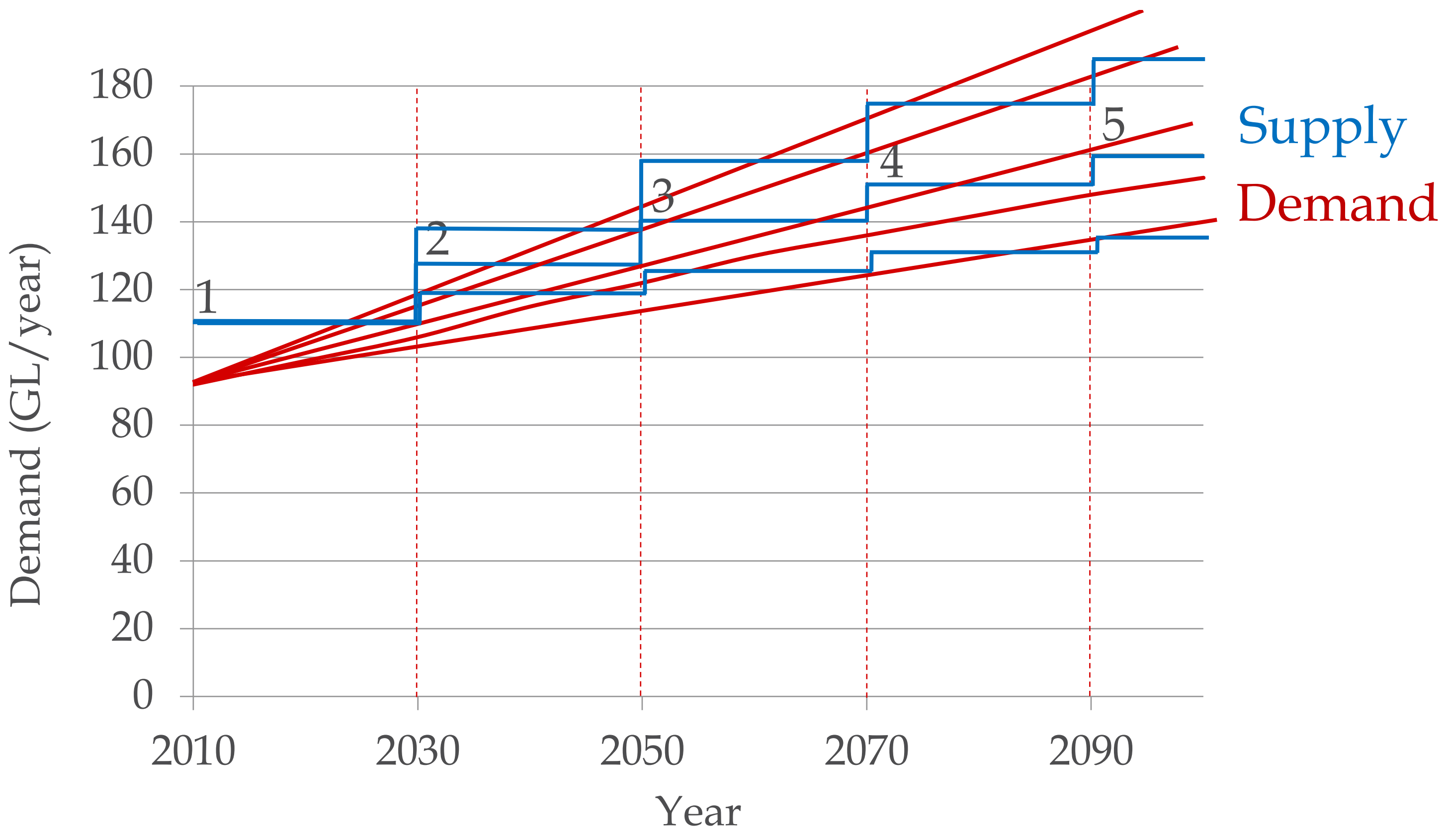
Scientific Understanding
Monitoring of and data on issues and problems
Water modelling & information support tools
Decision making
Global surface temperature change (° C)
Year
historical
RCP2.6
RCP4.5
RCP6.0
RCP8.5
42 models
39
25
42
32
12
17
12



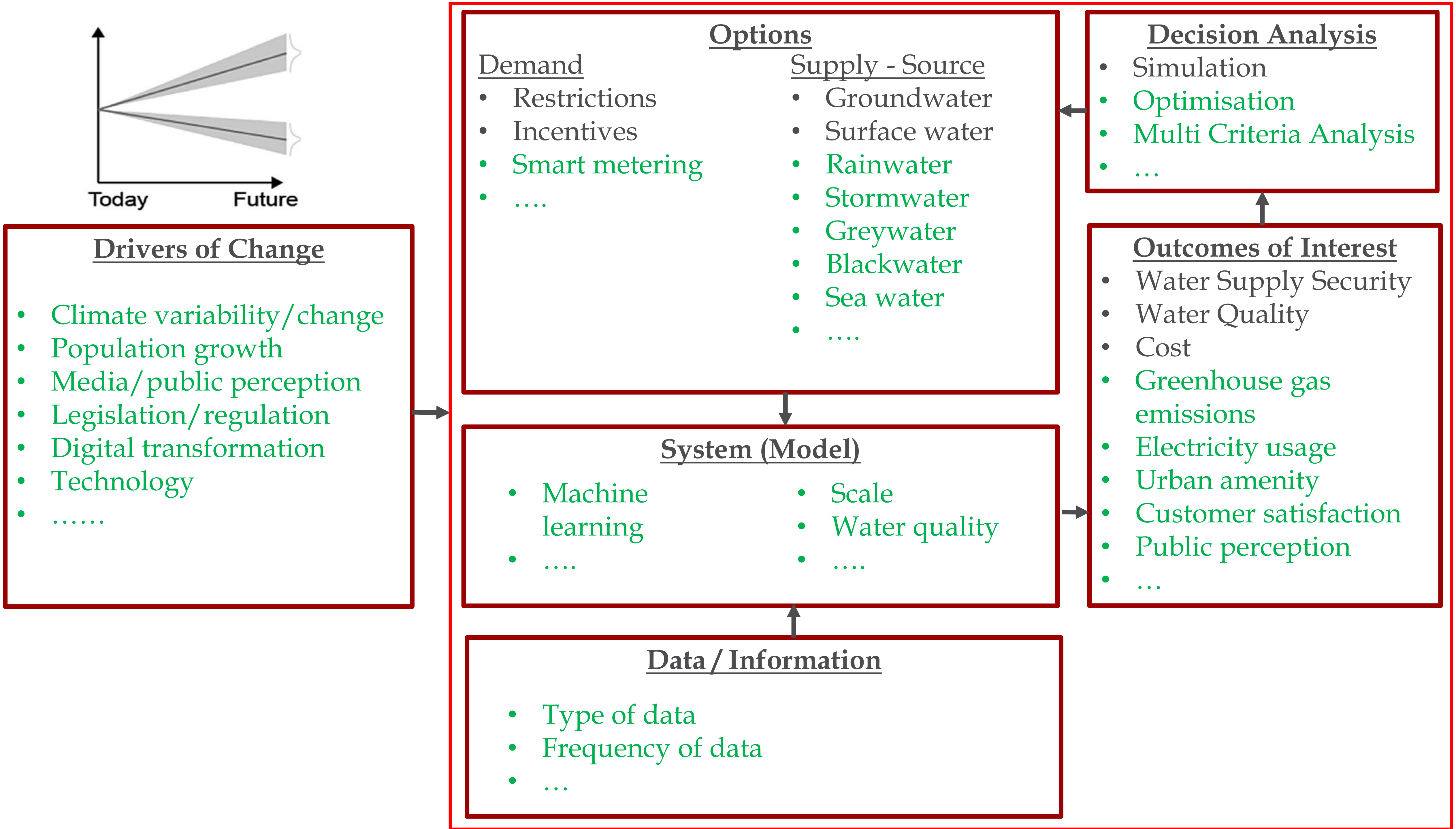
Source: Kwadijk, J.C.J., (2010). Adapting to sea level rise in the Netherlands. Interdisciplinary reviews: Climate Change.

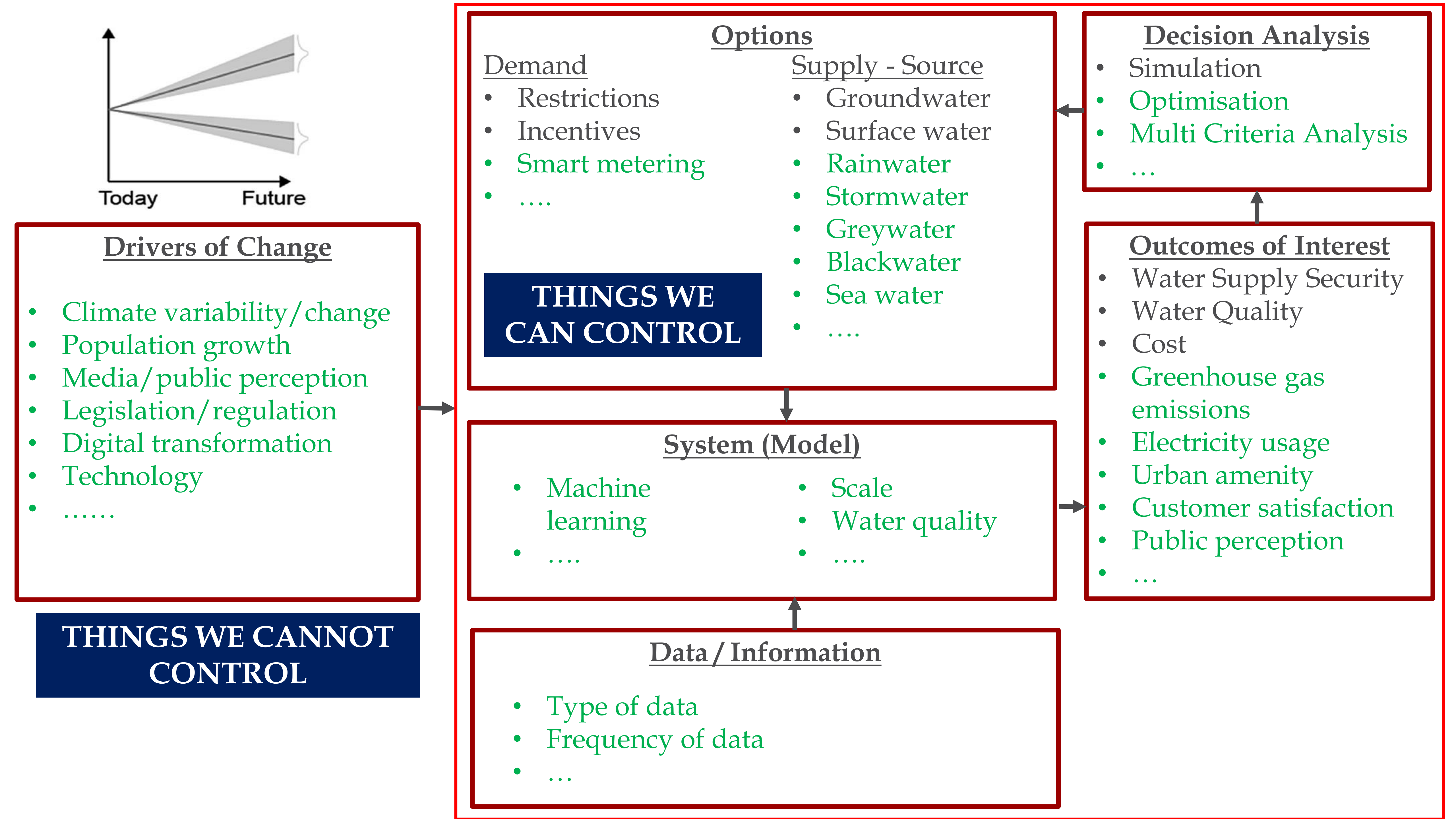


Supply
Demand
Demand (GL/year)
Year
180
160
140
120
100
80
60
40
20
0
2010
2030
2050
2070
2090
1
2
3
4
5



Supply
Demand
Demand (GL/year)
Year
0
20
40
60
80
100
120
140
160
180
2010
2030
2050
2070
2090
1
2
3
4
5


Today
Future
Drivers of Change
Climate variability/change
Population growth
Media/public perception
Legislation/regulation
Digital transformation
Technology
……
Options
Demand
Restrictions
Incentives
Smart metering
….
Supply - Source
Groundwater
Surface water
Rainwater
Stormwater
Greywater
Blackwater
Sea water
….
System (Model)
Machine learning
….
Scale
Water quality
….
Data / Information
Type of data
Frequency of data
…
Decision Analysis
Simulation
Optimisation
Multi Criteria Analysis
…
Outcomes of Interest
Water Supply Security
Water Quality
Cost
Greenhouse gas emissions
Electricity usage
Urban amenity
Customer satisfaction
Public perception
…


Today
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Drivers of Change
Climate variability/change
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……
THINGS WE CANNOT CONTROL
Options
Demand
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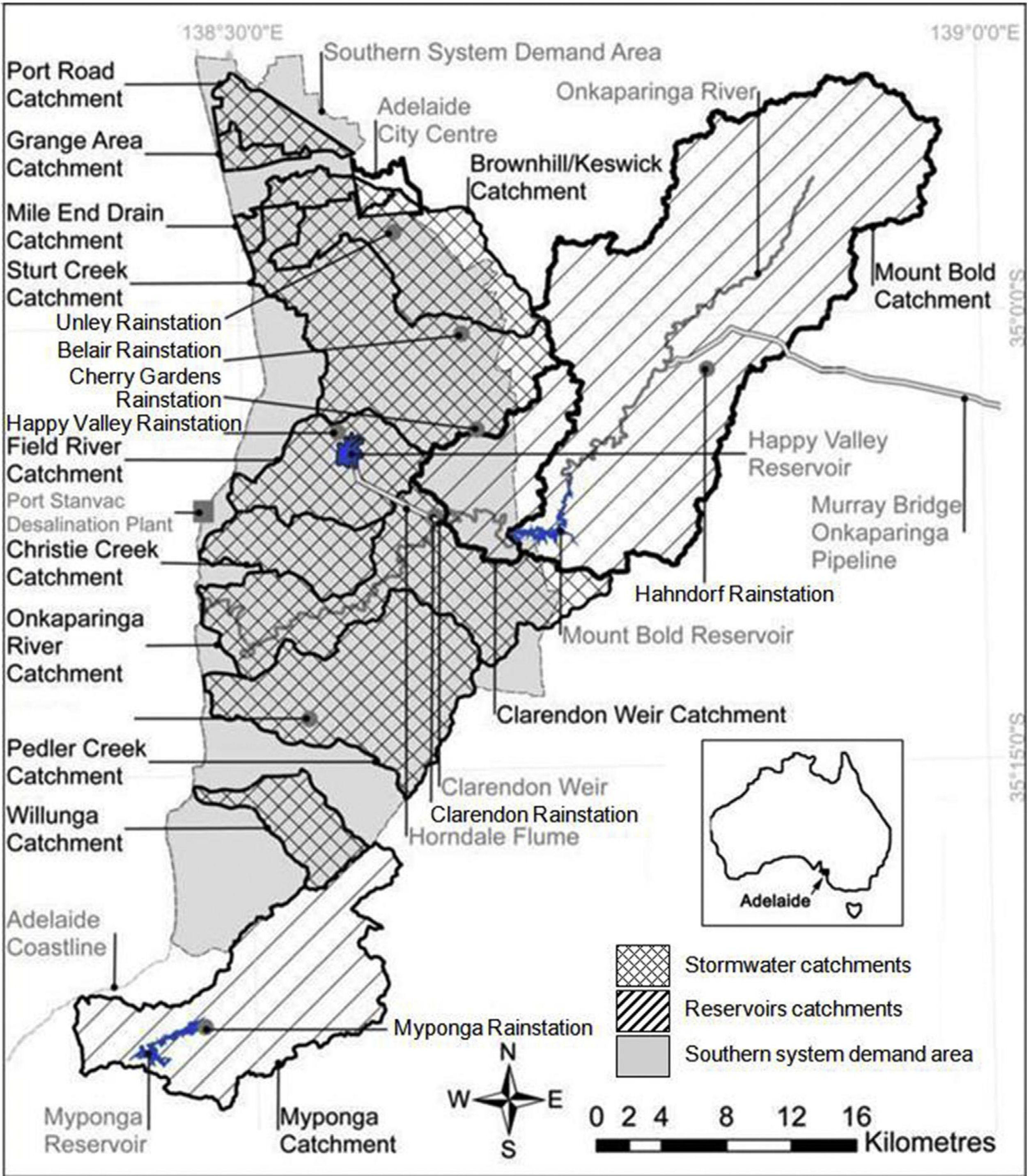
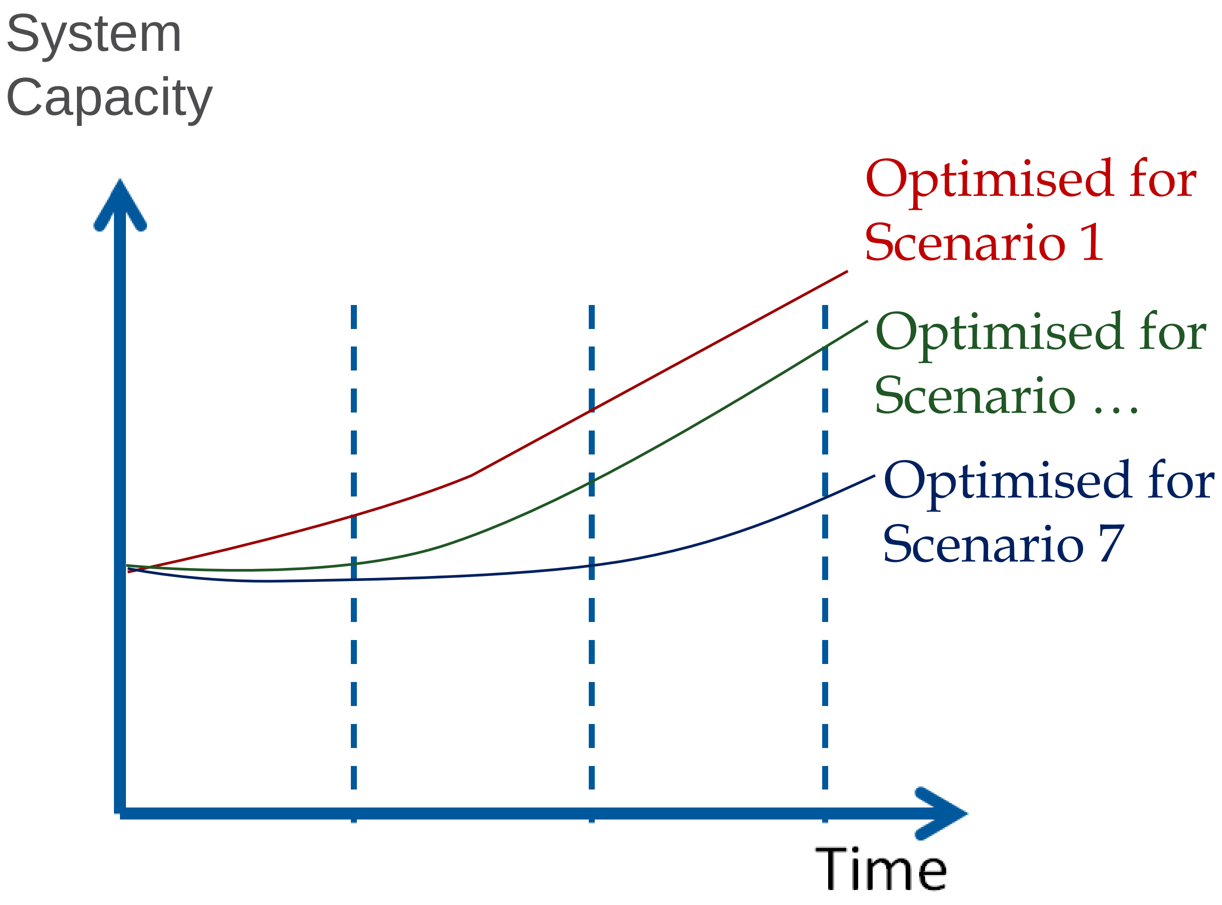
…



Scenario	Population growth	Discount rate	Climate change impact
1	Extremely low	Moderate	Least severe
2	Very low	Moderate	Mild
3	Low	Moderate	Less severe
4	Moderate	Moderate	Moderate
5	High	Moderate	Severe
6	Very high	Moderate	Very severe
7	Extremely high	Moderate	Most severe

Decision variable	Descriptions	Lower limit	Upper limit
1	50GL desalination plant implementation stage	0	5
2	100GL desalination plant implementation stage	0	5
3	50GL desalination plant expansion implementation stage	0	5
4	Household rainwater tank implementation stage	0	5
5	Household rainwater tank size (kL)	1	10
6	Brownhill & Keswick Creek stormwater harvesting scheme implementation stage	0	5
7	Sturt River stormwater harvesting scheme implementation stage	0	5
8	Field River stormwater harvesting scheme implementation stage	0	5
9	Pedler Creek stormwater harvesting scheme implementation stage	0	5

Beh E.H.Y, Maier H.R. and Dandy G.C. (2015) **Scenario driven optimal sequencing under deep uncertainty** , *Environmental Modelling and Software*, **68**, 181-195, DOI:10.1016/j.envsoft.2015.02.006



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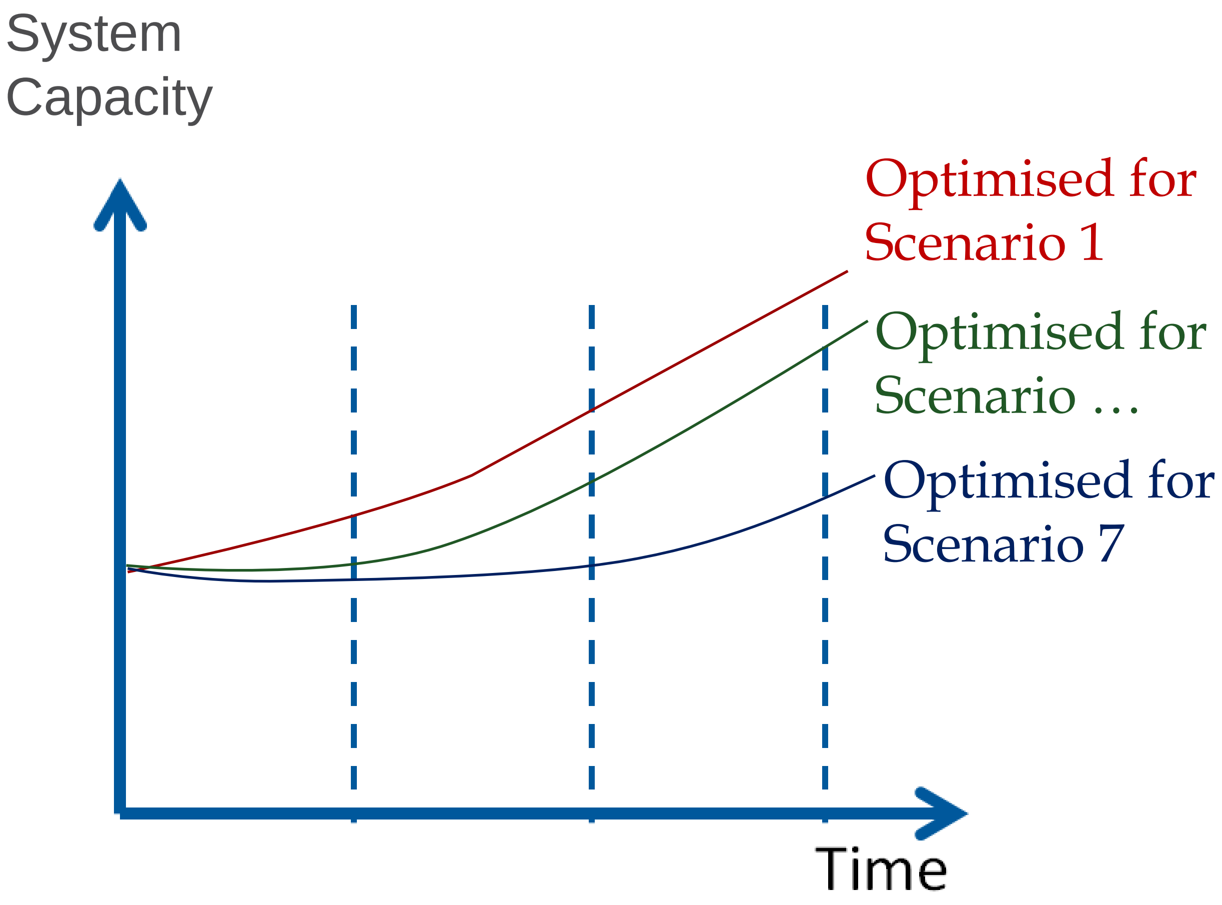
Sequence plan	Decision stage at which to implement water supply options (1 = 2010, 2 = 2020, … etc)									Present value of cost ($ million)	Present value of GHG emissions ($MtCO_2$-e)
	50GL desalination plant	50GL desalination plant	50GL desalination plant expansion	Household rainwater tank	Rainwater tank capacity (kL)	Brownhill and Keswick Creek stormwater harvesting scheme	Sturt river stormwater harvesting scheme	Field river stormwater harvesting scheme	Pedler Creek stormwater harvesting scheme		
Scenario 1											
1	2	0	0	5	1	0	0	0	0	1979.60	12.77
2	2	0	0	5	1	0	4	0	0	2022.41	12.72
3	2	0	0	5	1	1	0	0	5	2089.76	12.63
4	2	0	0	5	1	2	4	0	2	2145.18	12.55
5	2	0	0	5	1	0	2	0	1	2292.52	12.45
Scenario 2											
6	2	0	0	5	1	0	0	5	0	1995.51	13.09
7	2	0	0	5	1	0	4	0	3	2087.83	13.04
8	2	0	0	5	1	0	3	0	2	2169.69	12.98
9	2	0	0	5	1	1	0	0	1	2240.68	12.92
10	2	0	0	5	1	0	1	0	1	2415.15	12.86
•											
•											
•											
Scenario 7											
28	2	5	3	0	0	2	0	0	5	2712.53	19.15
29	2	5	3	0	0	5	0	0	2	2745.67	19.05
30	2	5	3	0	0	0	5	0	1	2829.28	18.99



Find optimal solutions for each scenario and then assess how the solutions that are optimal for a particular scenario perform under all scenarios

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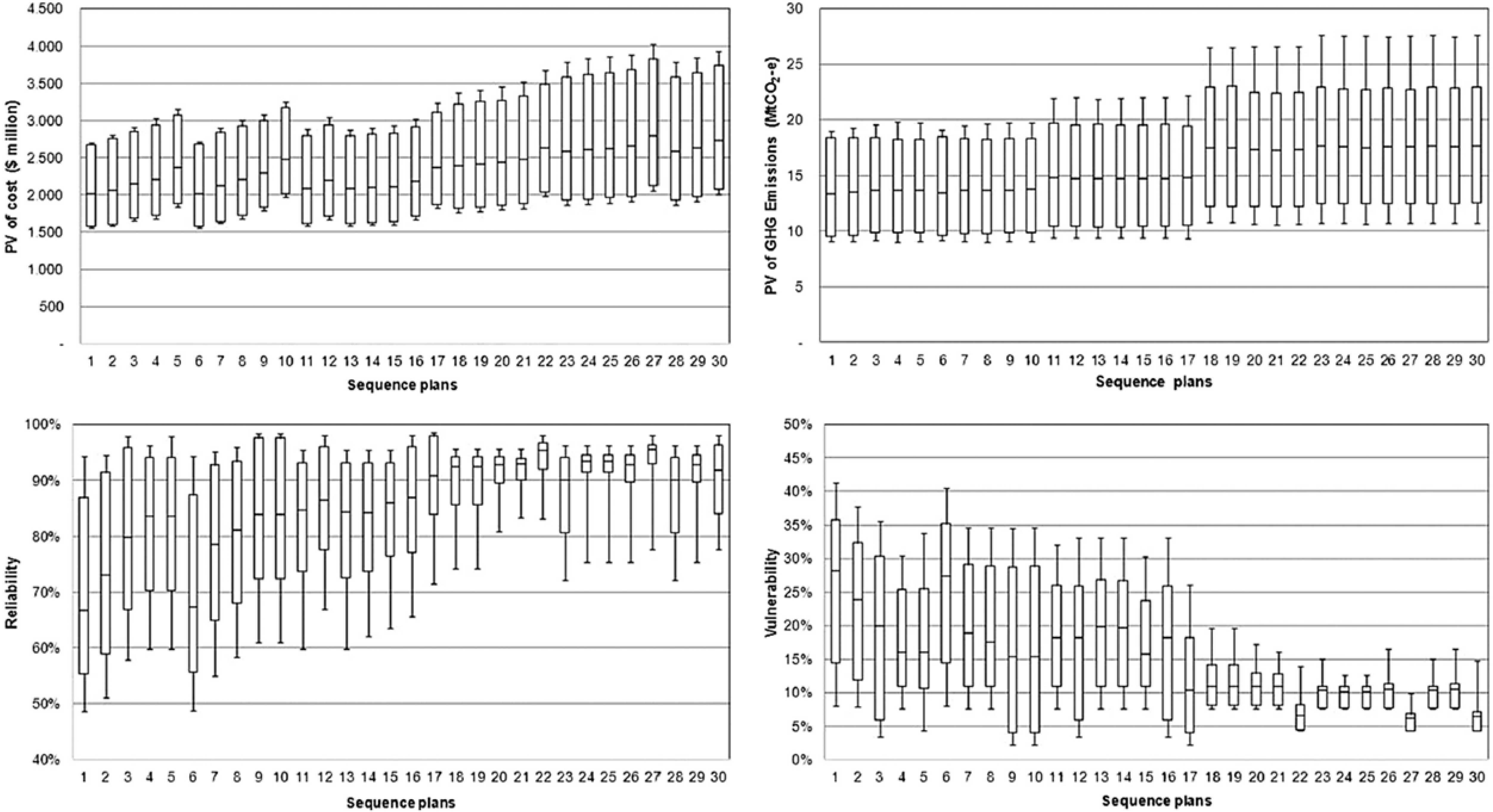

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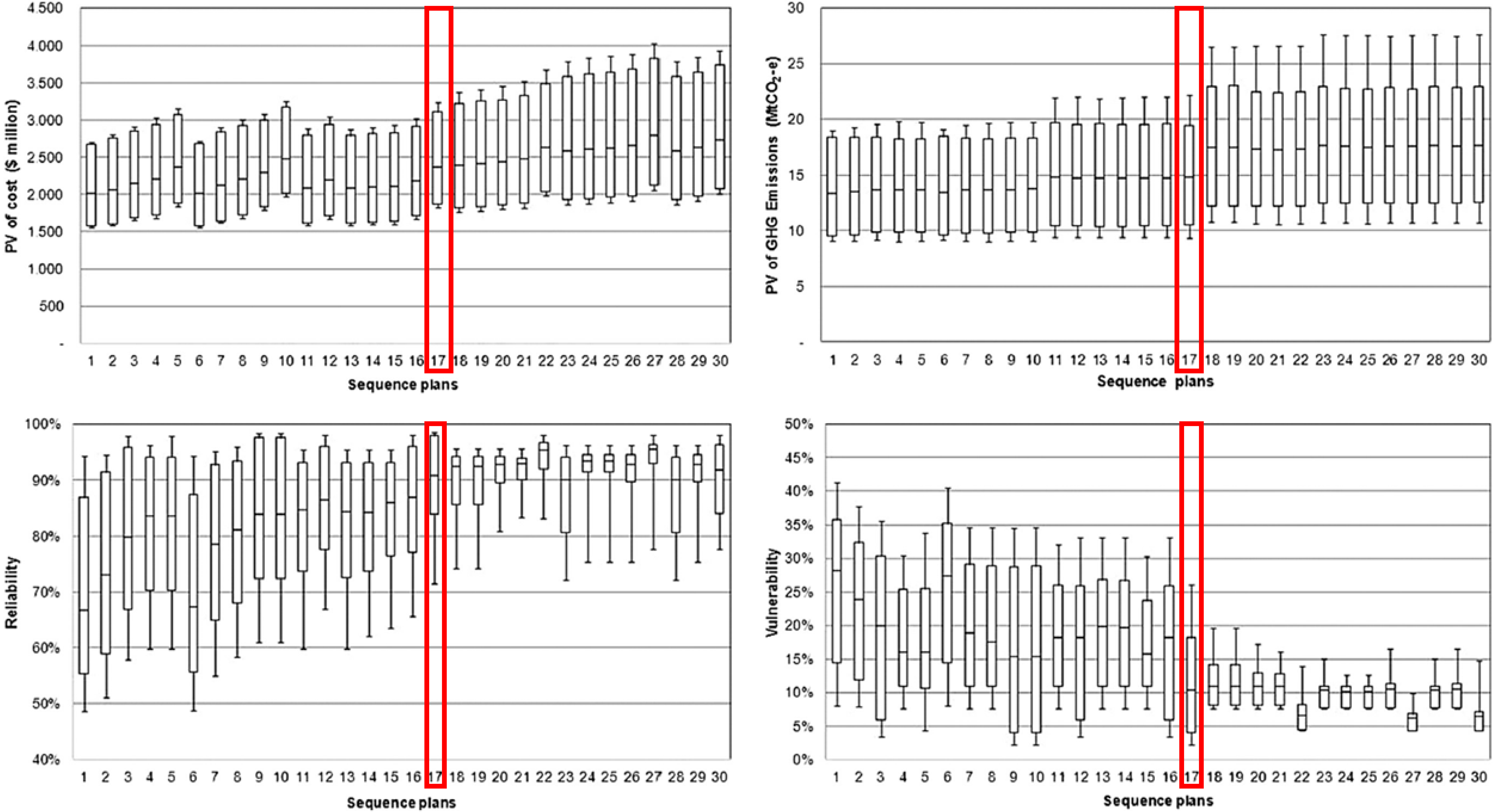

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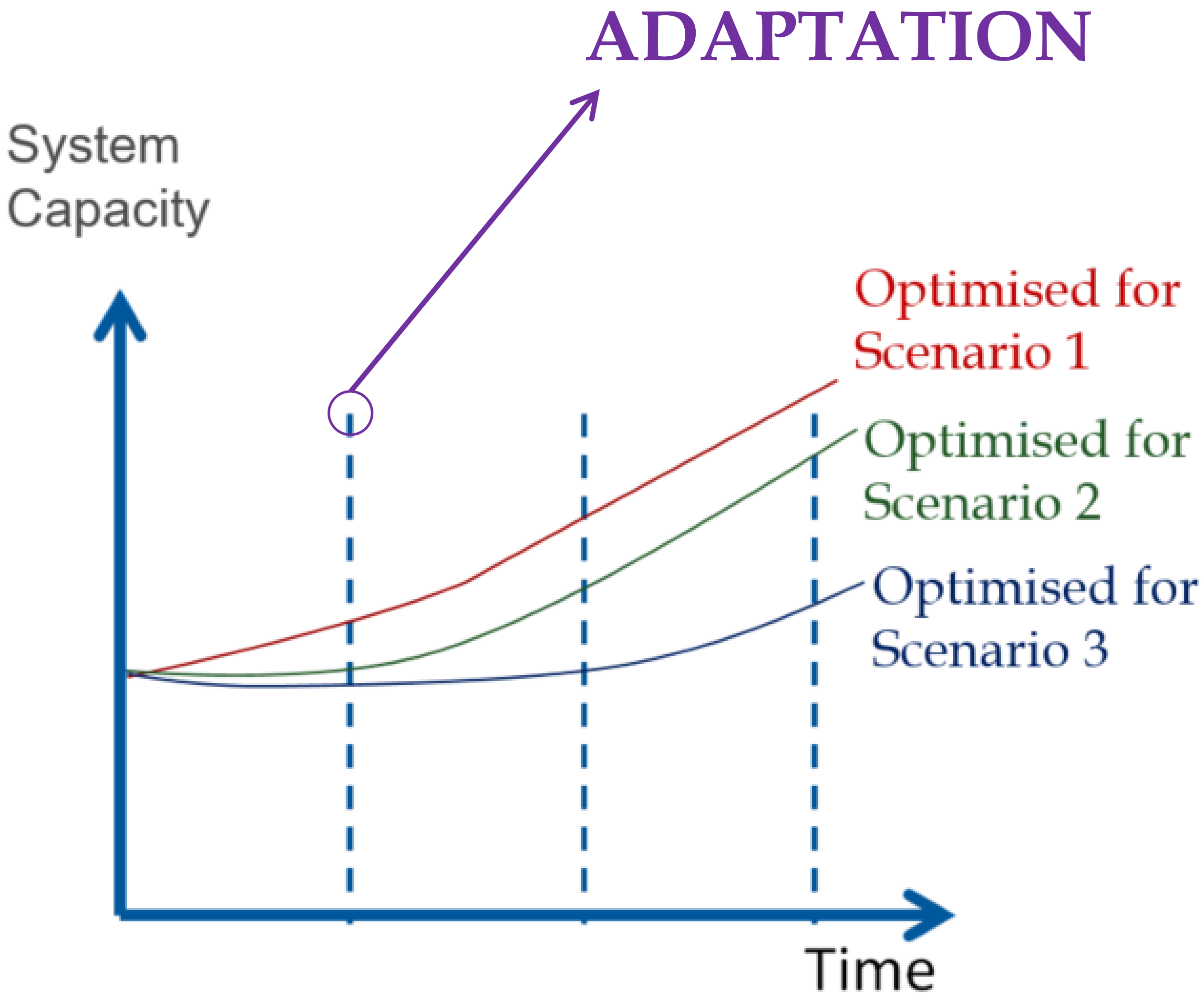


Adapt optimal plan at fixed time intervals, balancing robustness and flexibility

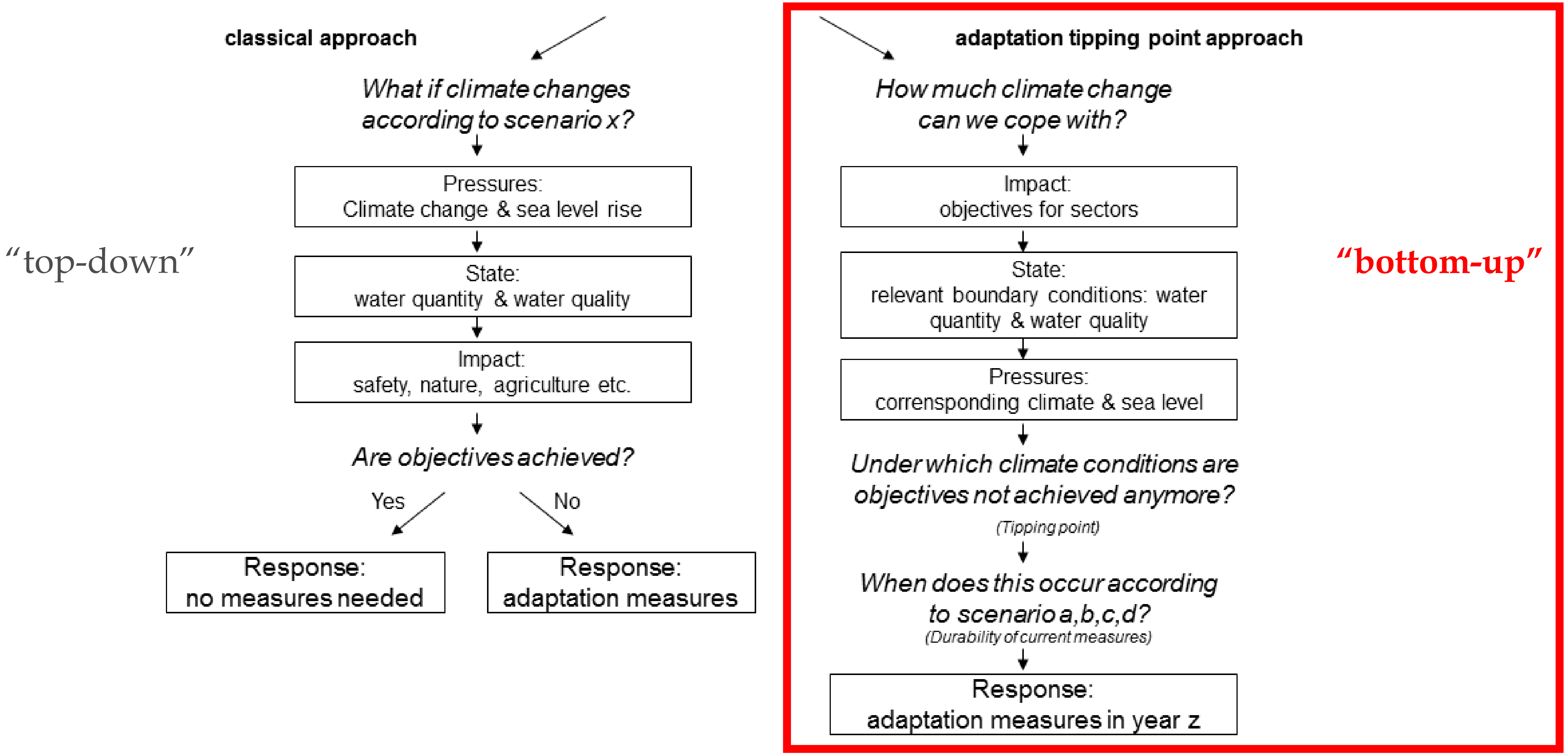
Beh E.H.Y, Maier H.R. and Dandy G.C. (2015) **Adaptive, multi-objective optimal sequencing approach for urban water supply augmentation under deep uncertainty** , *Water Resources Research*, **51(3)**, 1529-1551, DOI:10.1002/2014WR016254

Table 6. Average Performance of Systems Corresponding to the Implementation of Different Optimal Sequence Plans for Realities 1 and 2

	PV of Cost ($ million)	PV of GHG Emissions (MtCO2-e)	2010–2020 Reliability (%)	2010–2020 Vulnerability (%)	2020–2030 Reliability (%)	2020–2030 Vulnerability (%)	2030–2040 Reliability (%)	2030–2040 Vulnerability (%)	2040–2050 Reliability (%)	2040–2050 Vulnerability (%)	2050–2060 Reliability (%)	2050–2060 Vulnerability (%)
Optimal fixed plan (Scenario 1)	900.10	9.74	100	0.0	85	11.4	75	13.25	62	16.4	68	14.15
Optimal fixed plan (Scenario 2)	954.95	9.92	100	0.0	85	11.4	75	13.25	62	16.4	68	14.15
Optimal adaptive plan	1899.84	13.30	100	0.0	98	0.5	100	0.0	92	3.0	100	0.0
Optimal fixed plan (Scenario 3)	2228.51	13.57	100	0.0	100	0.0	100	0.0	92	2.95	83.5	6.35
Optimal fixed plan (Scenario 4)	2229.61	14.55	100	0.0	100	0.0	100	0.0	92	2.95	92	2.2
Optimal fixed plan (Scenario 5)	2254.22	14.60	100	0.0	100	0.0	100	0.0	92	2.95	92	2.2
Optimal fixed plan (Scenario 6)	2882.15	15.66	100	0.0	100	0.0	100	0.0	100	0.0	100	0.0
Optimal fixed plan (Scenario 7)	3187.10	16.59	100	0.0	100	0.0	100	0.0	100	0.0	100	0.0

Beh E.H.Y, Maier H.R. and Dandy G.C. (2015) **Adaptive, multi-objective optimal sequencing approach for urban water supply augmentation under deep uncertainty**, *Water Resources Research*, **51(3)**, 1529-1551, DOI:10.1002/2014WR016254

How vulnerable are we for climate change and sea level rise and what adaptation measures should we take ?



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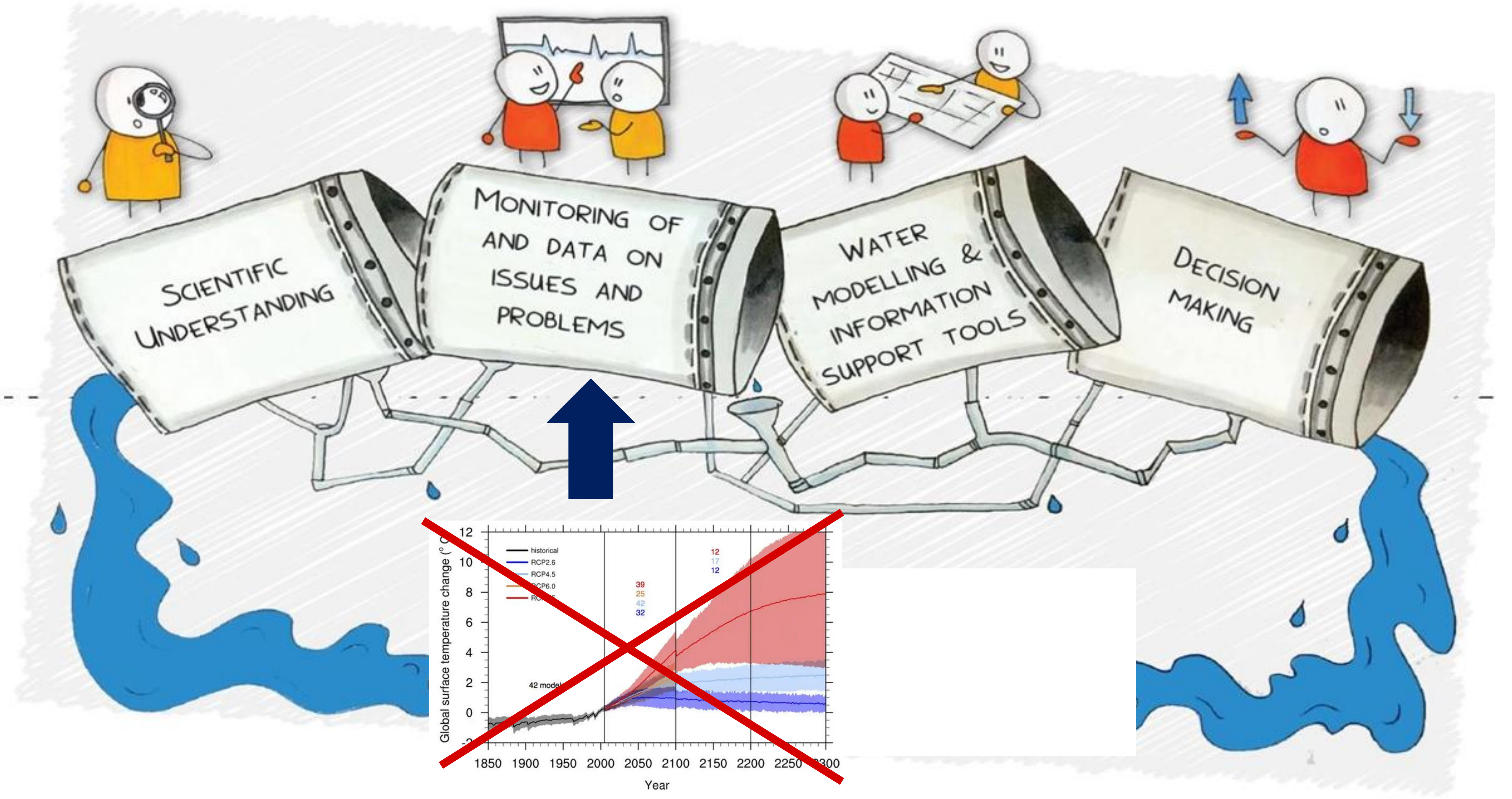
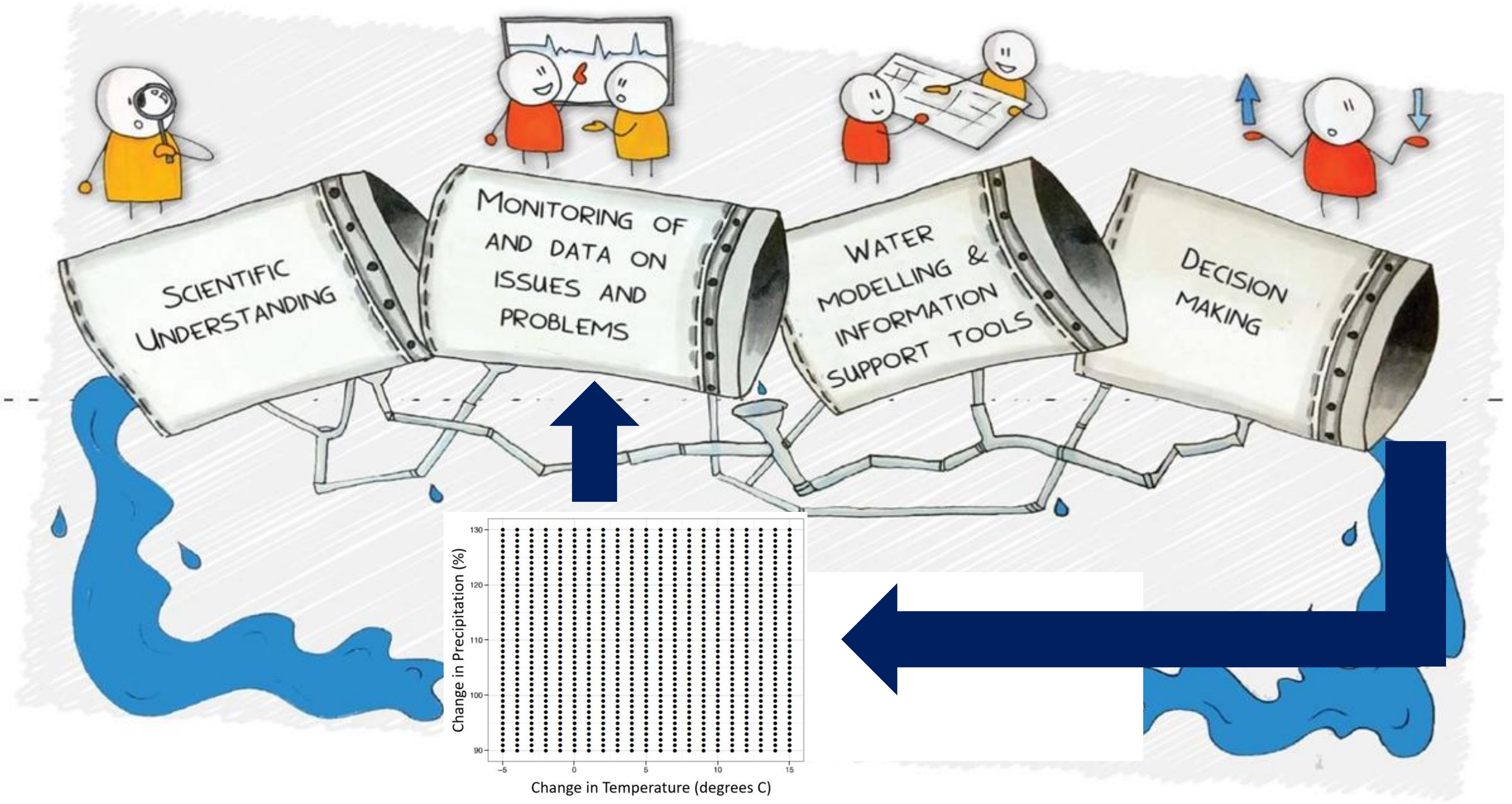


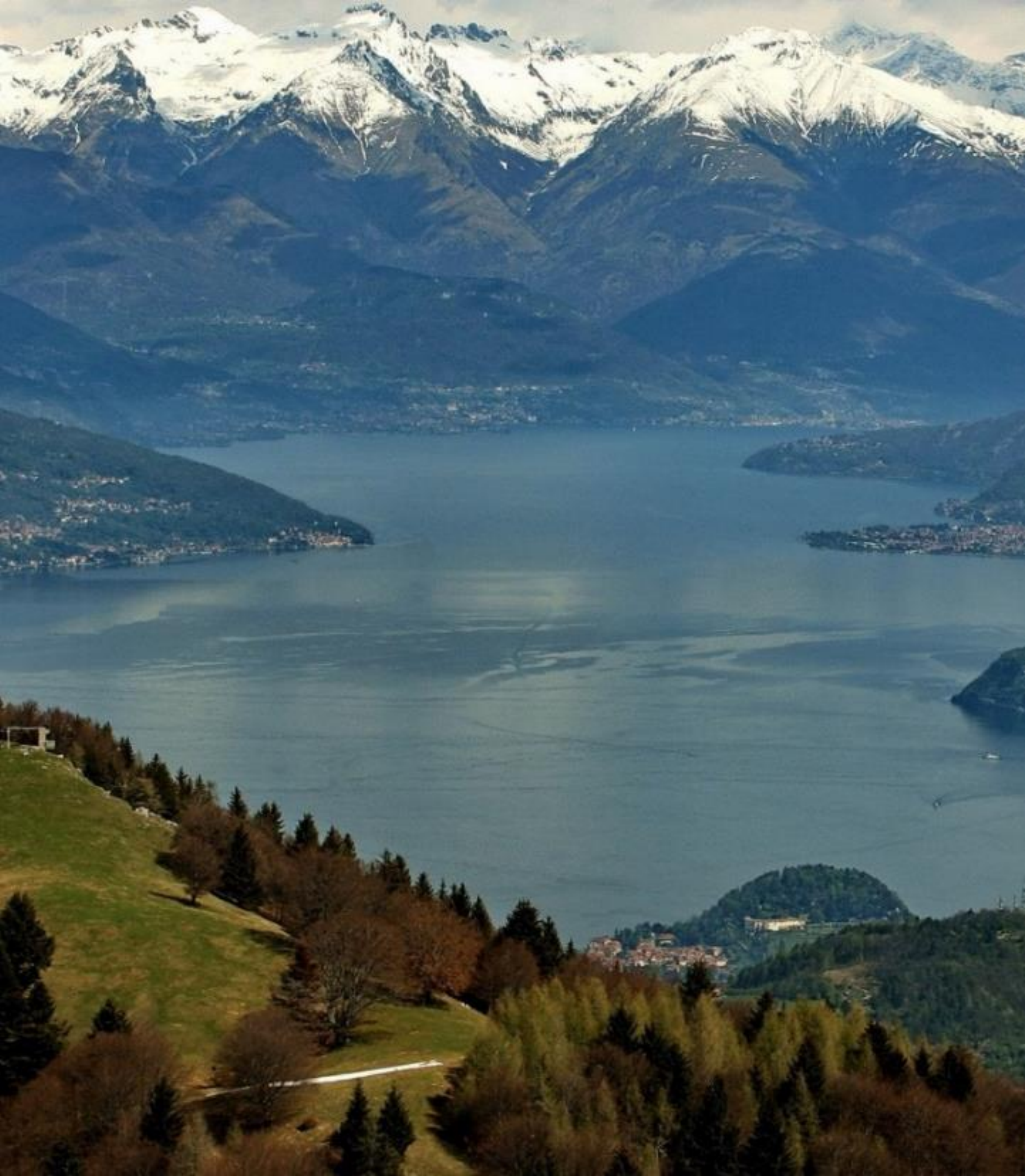
SCIENTIFIC UNDERSTANDING
MONITORING OF AND DATA ON ISSUES AND PROBLEMS
WATER MODELLING & INFORMATION SUPPORT TOOLS
DECISION MAKING
historical
RCP2.6
RCP4.5
Global surface temperature change
Year
39
25
42
32
12
17
12
1850 1900 1950 2000 2050 2100 2150 2200 2250
12 10 8 6 4 2 0



SCIENTIFIC UNDERSTANDING
MONITORING OF AND DATA ON ISSUES AND PROBLEMS
WATER MODELLING & INFORMATION SUPPORT TOOLS
DECISION MAKING
Change in Precipitation (%)
130
120
110
100
90
-5
0
5
10
15
Change in Temperature (degrees C)

	Pipe	Reservoir
Design Variable	Flow	Volume
Design Time Period	Day	Year(s)
Critical Design Condition	Peak Day Demand (Hot Summer)	Total X-Year Inflow During Drought Period

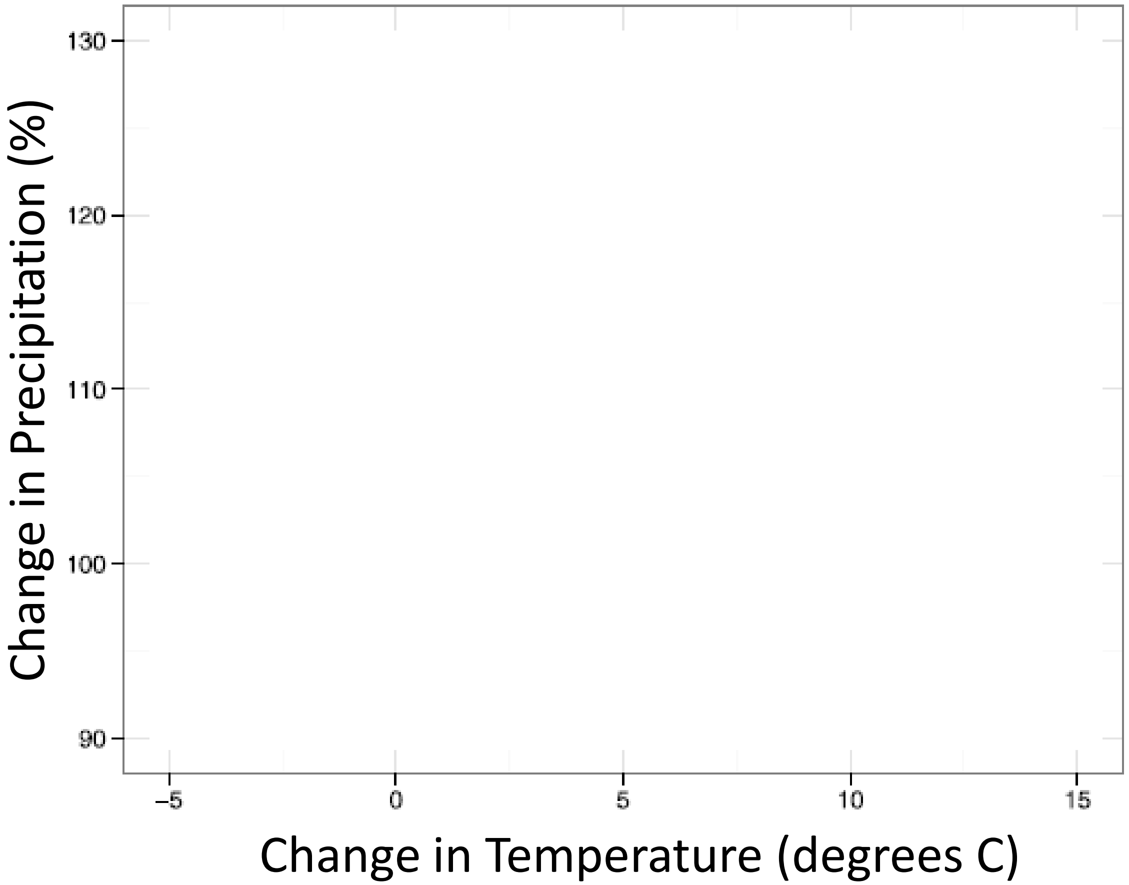
	Pipe	Reservoir
Design Variable	Flow	Volume
Design Time Period	Day	Year(s)
Critical Design Condition	Peak Day Demand (Hot Summer)	Total X-Year Inflow During Drought Period
Climate Process	Extreme Temperature	ENSO / Extreme Rainfall



Lake Como System

- Impact of climate change on:
  - Flood control
  - Irrigation
- Critical climate drivers include:
  - Change in precipitation
  - Change in temperature
- Under what climate change conditions will system fail?
- What can we do to make the system more resilient?

Lake Como: bottom-up stress testing



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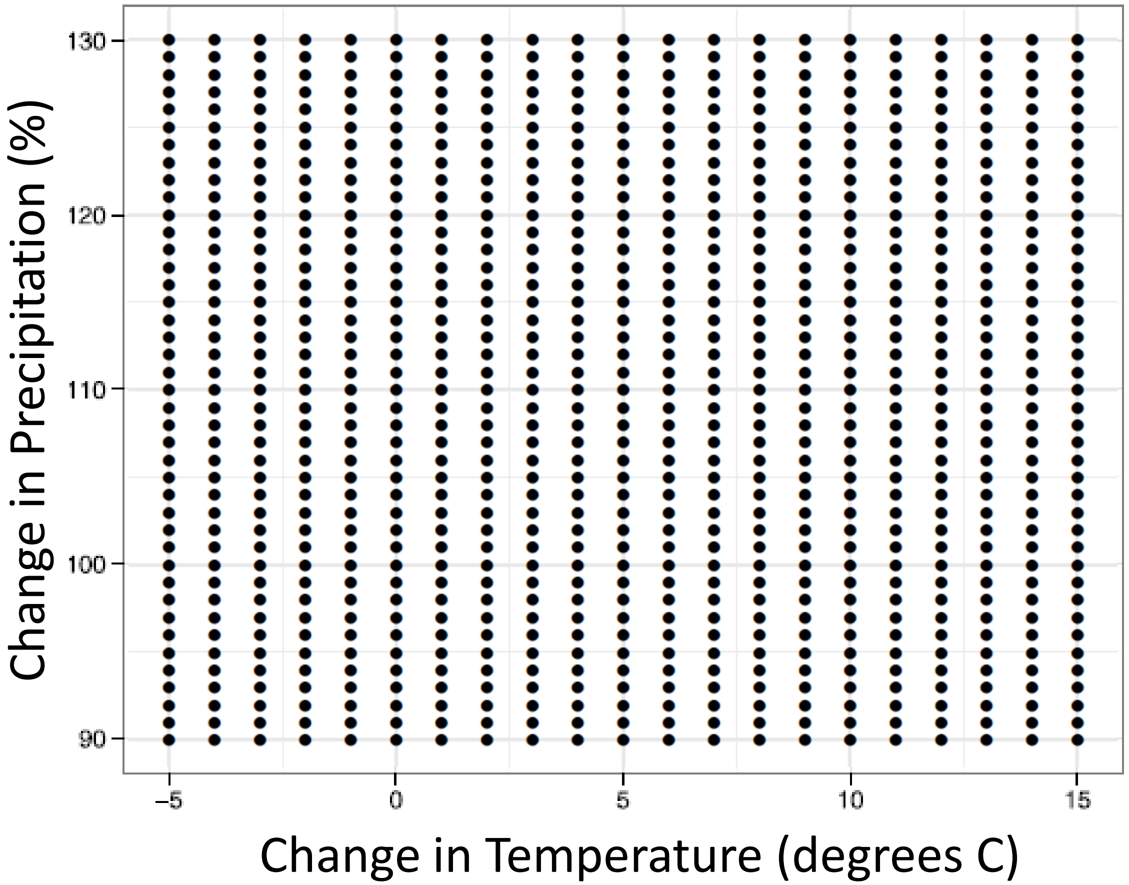

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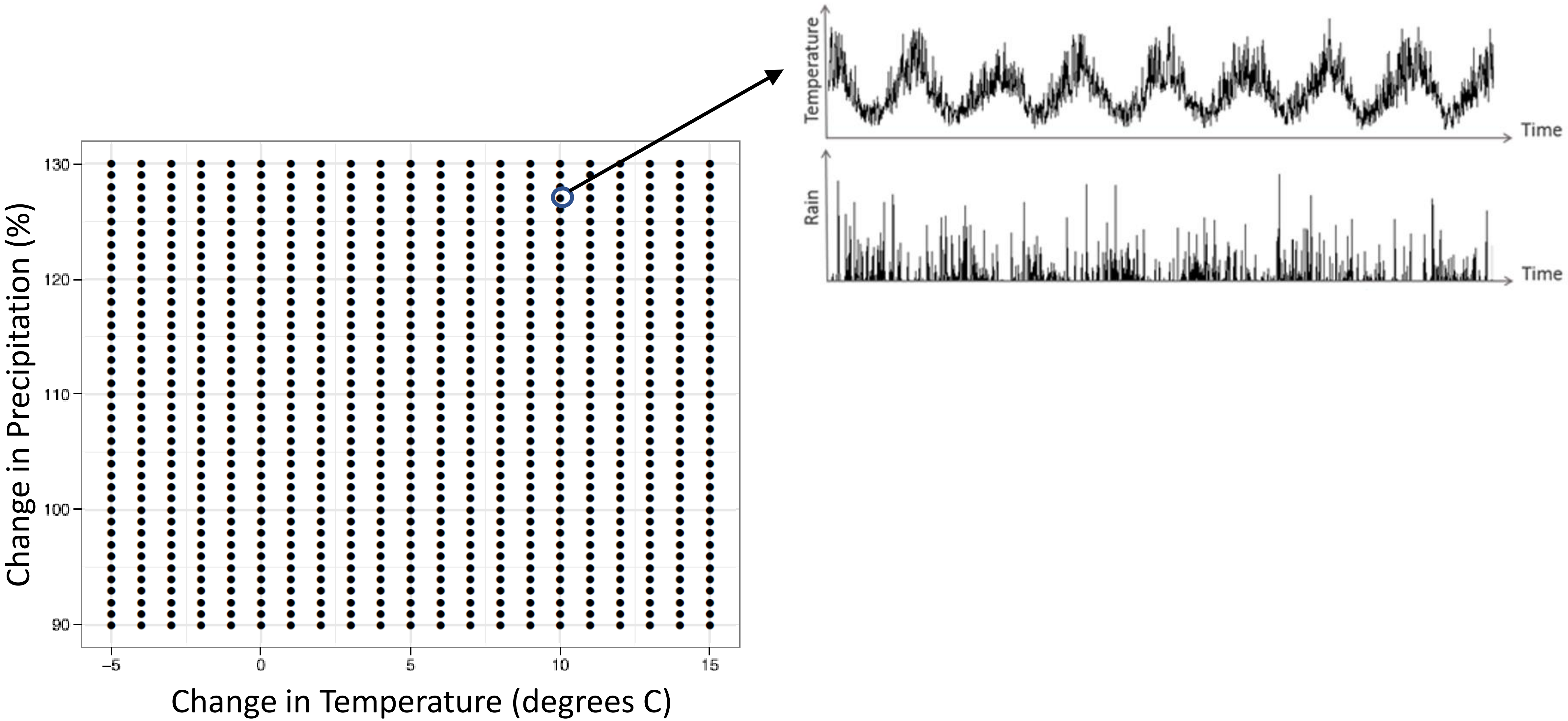

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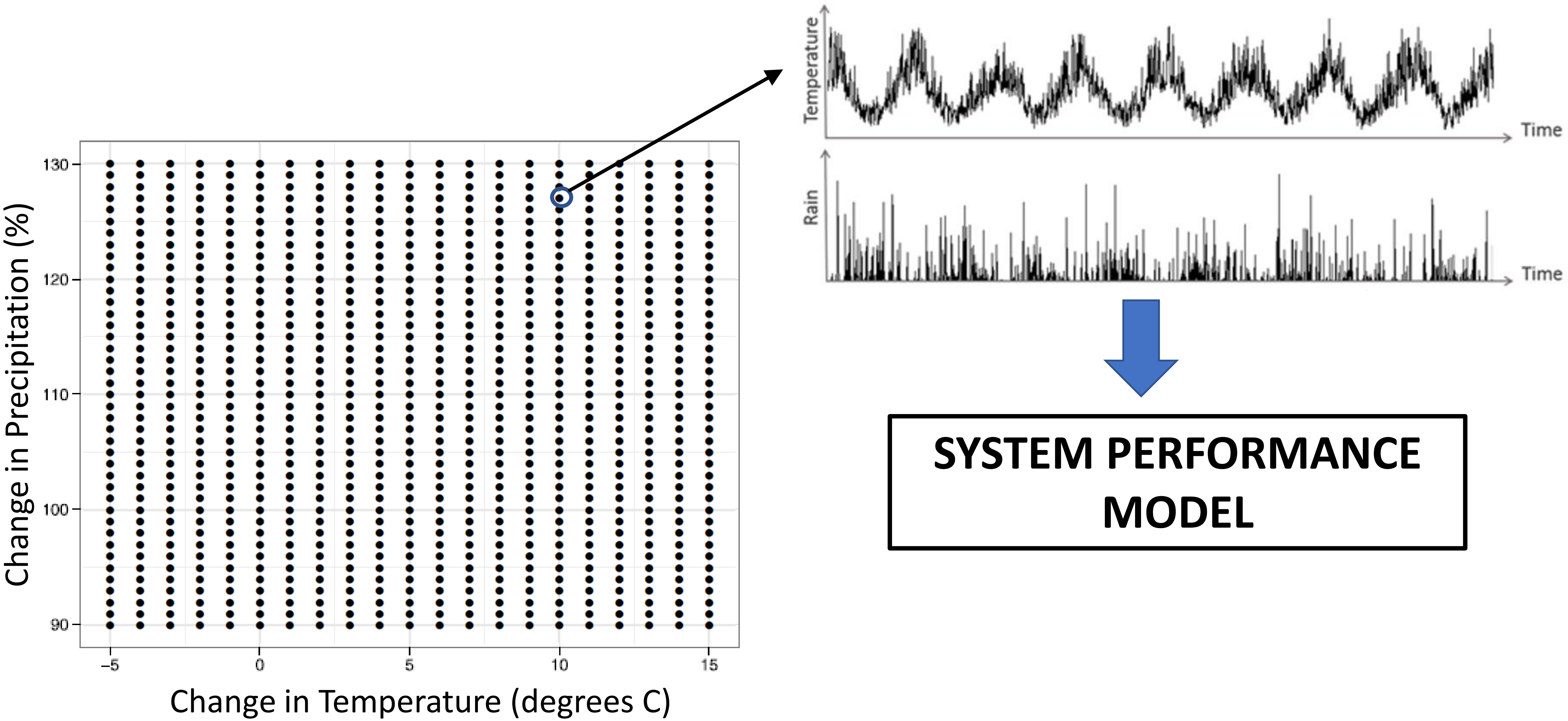

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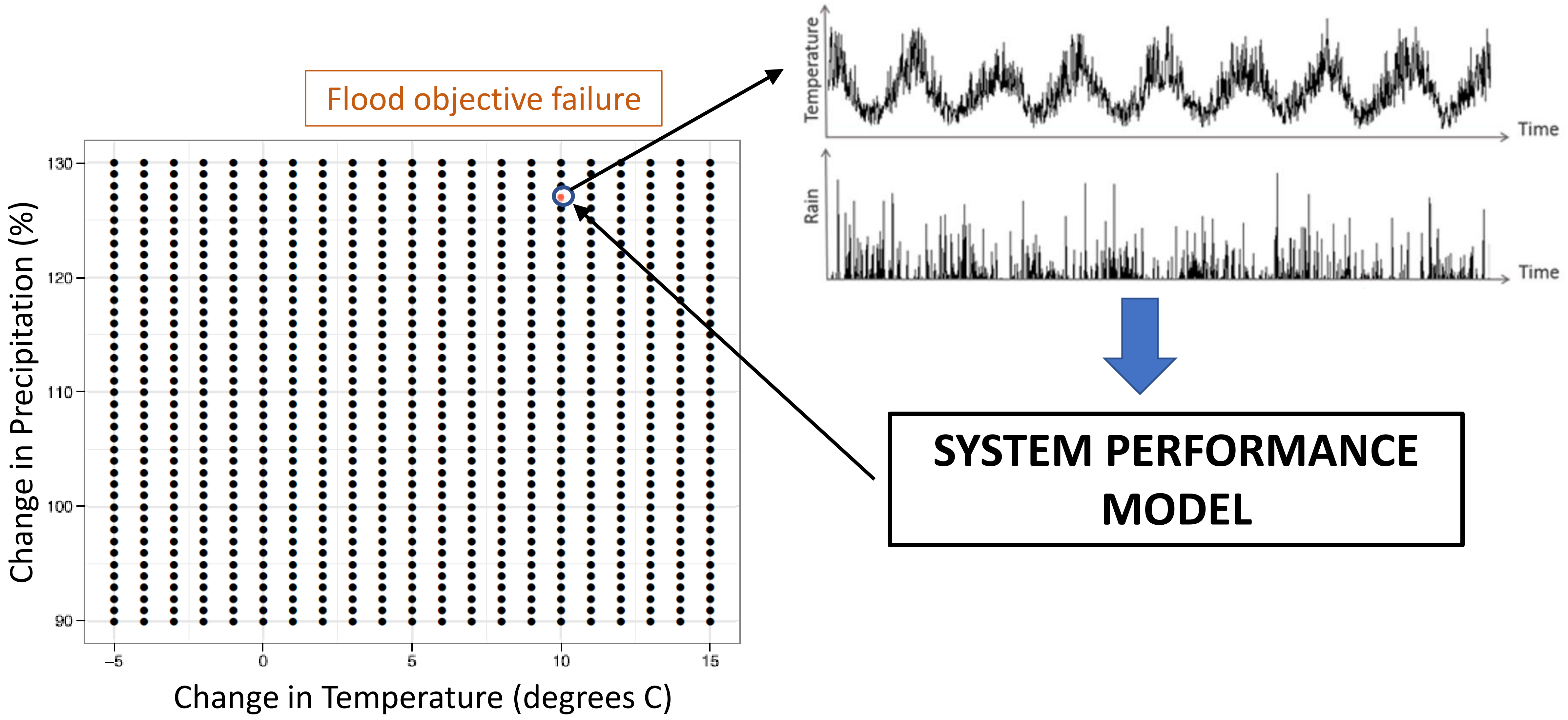

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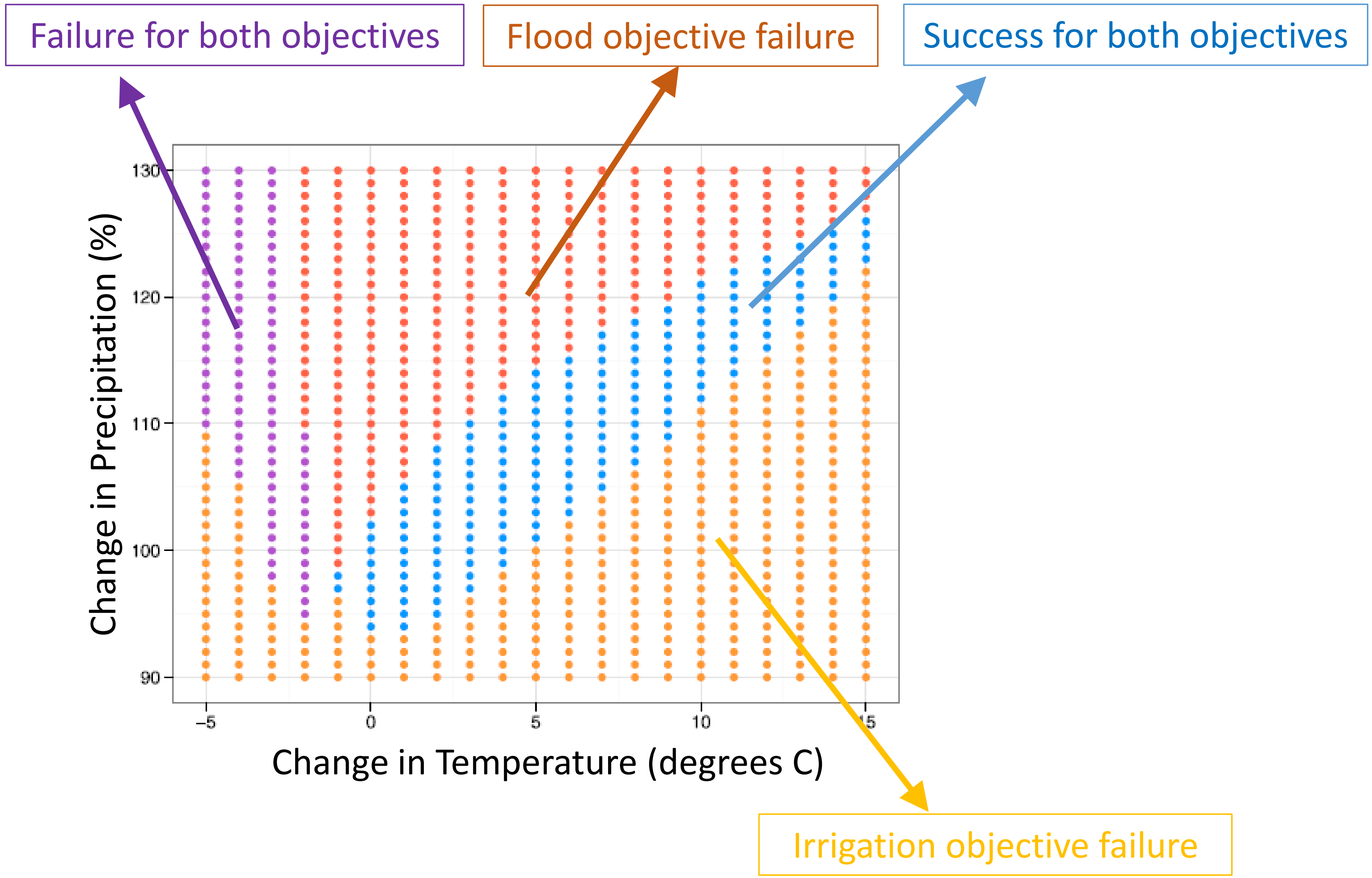

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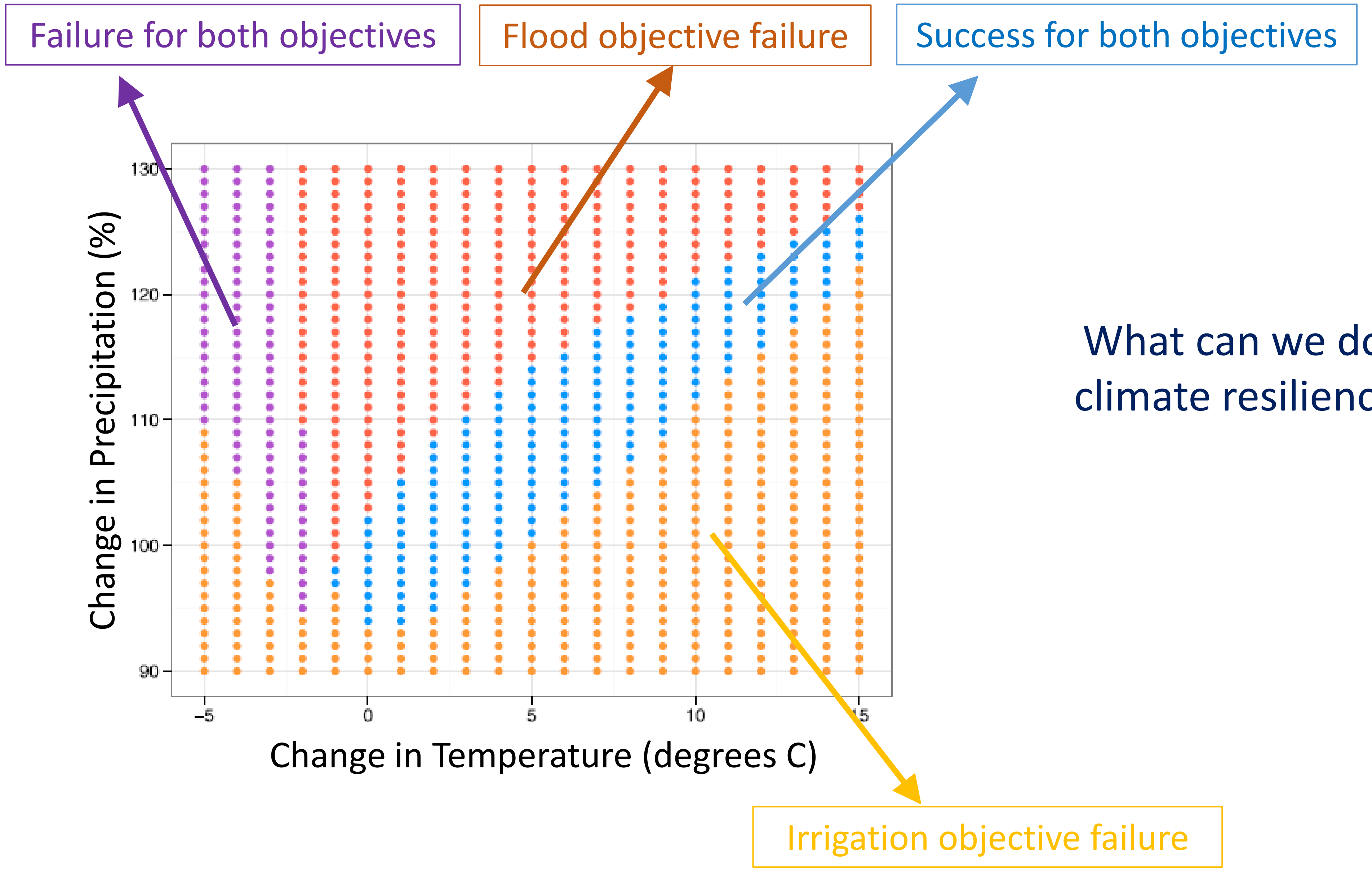
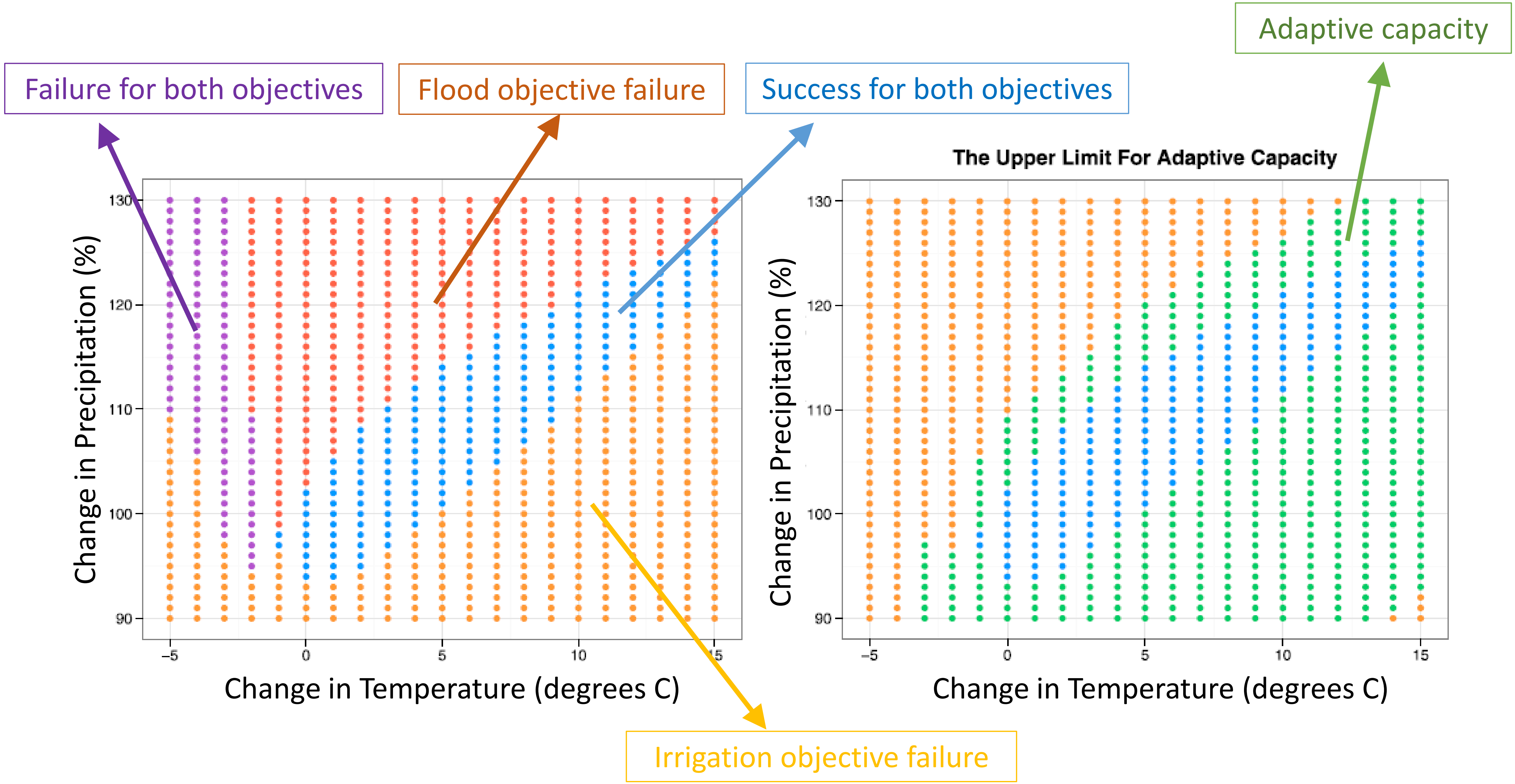


What can we do to increase the climate resilience of the system?

Lake Como: bottom-up stress testing



How "likely" is it that the conditions that cause system failure will occur?

Table 1. GCM-RCM Combinations of Climate Models

Model Reference #	GCM	RCM	RCP
1	CM5 (CNRM CERFACS)	CCLM4 (CLMcom)	4.5
2	CM5 (CNRM CERFACS)	CCLM4 (CLMcom)	8.5
3	CM5 (CNRM CERFACS)	RCA4	4.5
4	CM5 (CNRM CERFACS)	RCA4	8.5
5	EARTH (ICEC)	CCLM4 (CLMcom)	4.5
6	EARTH (ICEC)	CCLM4 (CLMcom)	8.5
7	EARTH (ICEC)	HIRHAM5 (DMI)	4.5
8	EARTH (ICEC)	HIRHAM5 (DMI)	8.5
9	EARTH (ICEC)	RACMO22E (KNMI)	4.5
10	EARTH (ICEC)	RACMO22E (KNMI)	8.5
11	EARTH (ICEC)	RCA4	2.6
12	EARTH (ICEC)	RCA4	4.5
13	EARTH (ICEC)	RCA4	8.5
14	ESM LR (MPI)	REMO 2009 (MPI)	4.5
15	CanESM2 (CCCma)	RCA4	4.5
16	CanESM2 (CCCma)	RCA4	8.5
17	MIROC	RCA4	4.5
18	MIROC	RCA4	8.5
19	NCC	RCA4	4.5
20	NCC	RCA4	8.5
21	NOAA	RCA4	4.5
22	NOAA	RCA4	8.5

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3	CM5 (CNRM CERFACS)	RCA4	4.5
4	CM5 (CNRM CERFACS)	RCA4	8.5
5	EARTH (ICEC)	CCLM4 (CLMcom)	4.5
6	EARTH (ICEC)	CCLM4 (CLMcom)	8.5
7	EARTH (ICEC)	HIRHAM5 (DMI)	4.5
8	EARTH (ICEC)	HIRHAM5 (DMI)	8.5
9	EARTH (ICEC)	RACMO22E (KNMI)	4.5
10	EARTH (ICEC)	RACMO22E (KNMI)	8.5
11	EARTH (ICEC)	RCA4	2.6
12	EARTH (ICEC)	RCA4	4.5
13	EARTH (ICEC)	RCA4	8.5
14	ESM LR (MPI)	REMO 2009 (MPI)	4.5
15	CanESM2 (CCCma)	RCA4	4.5
16	CanESM2 (CCCma)	RCA4	8.5
17	MIROC	RCA4	4.5
18	MIROC	RCA4	8.5
19	NCC	RCA4	4.5
20	NCC	RCA4	8.5
21	NOAA	RCA4	4.5
22	NOAA	RCA4	8.5

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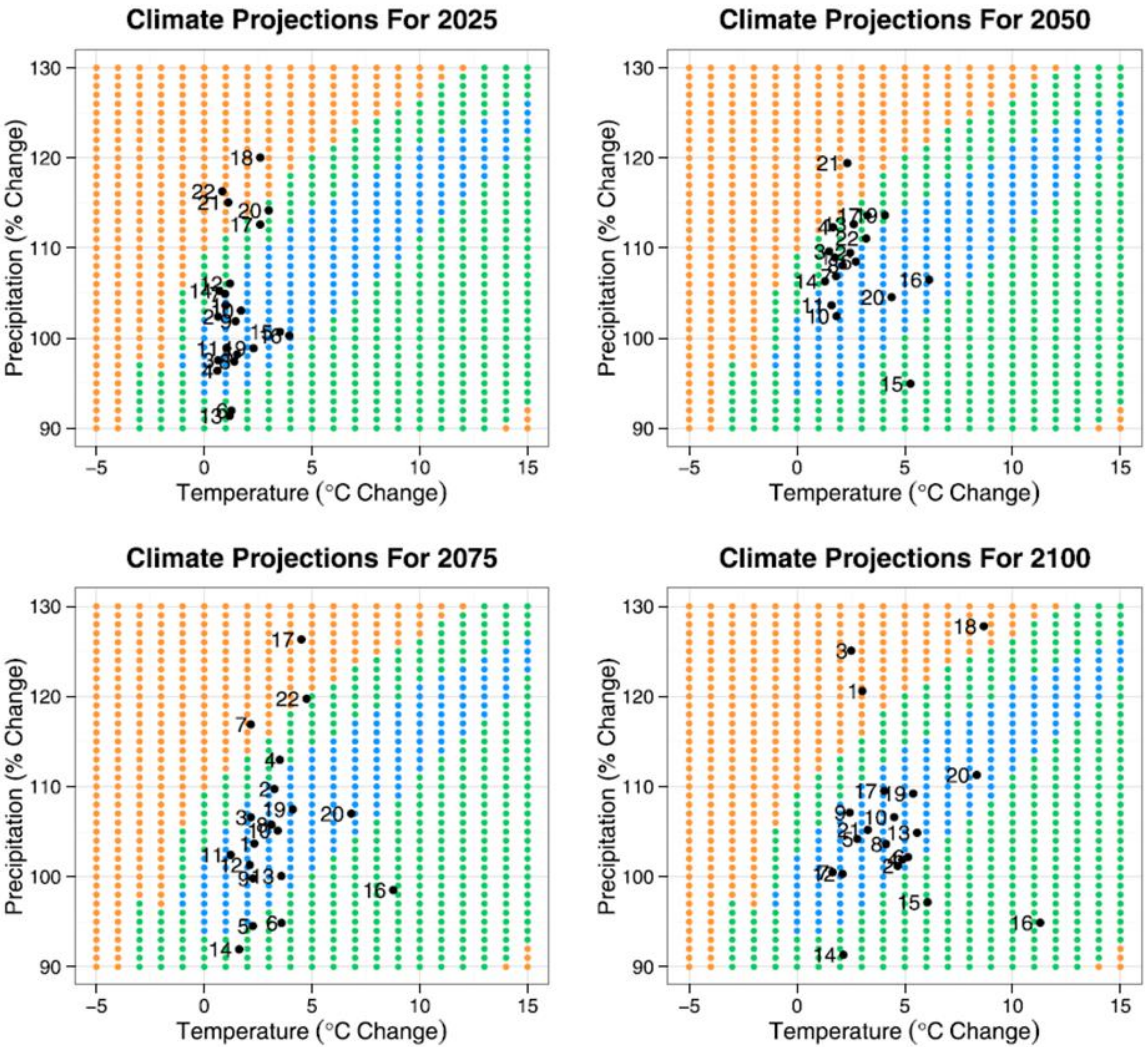

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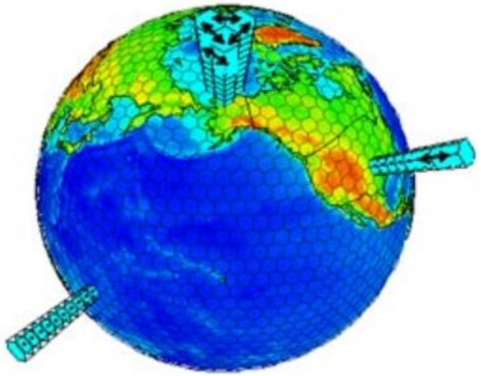
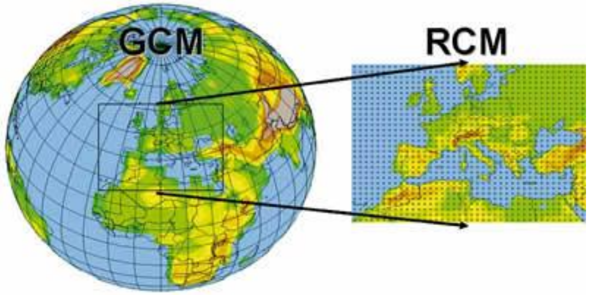
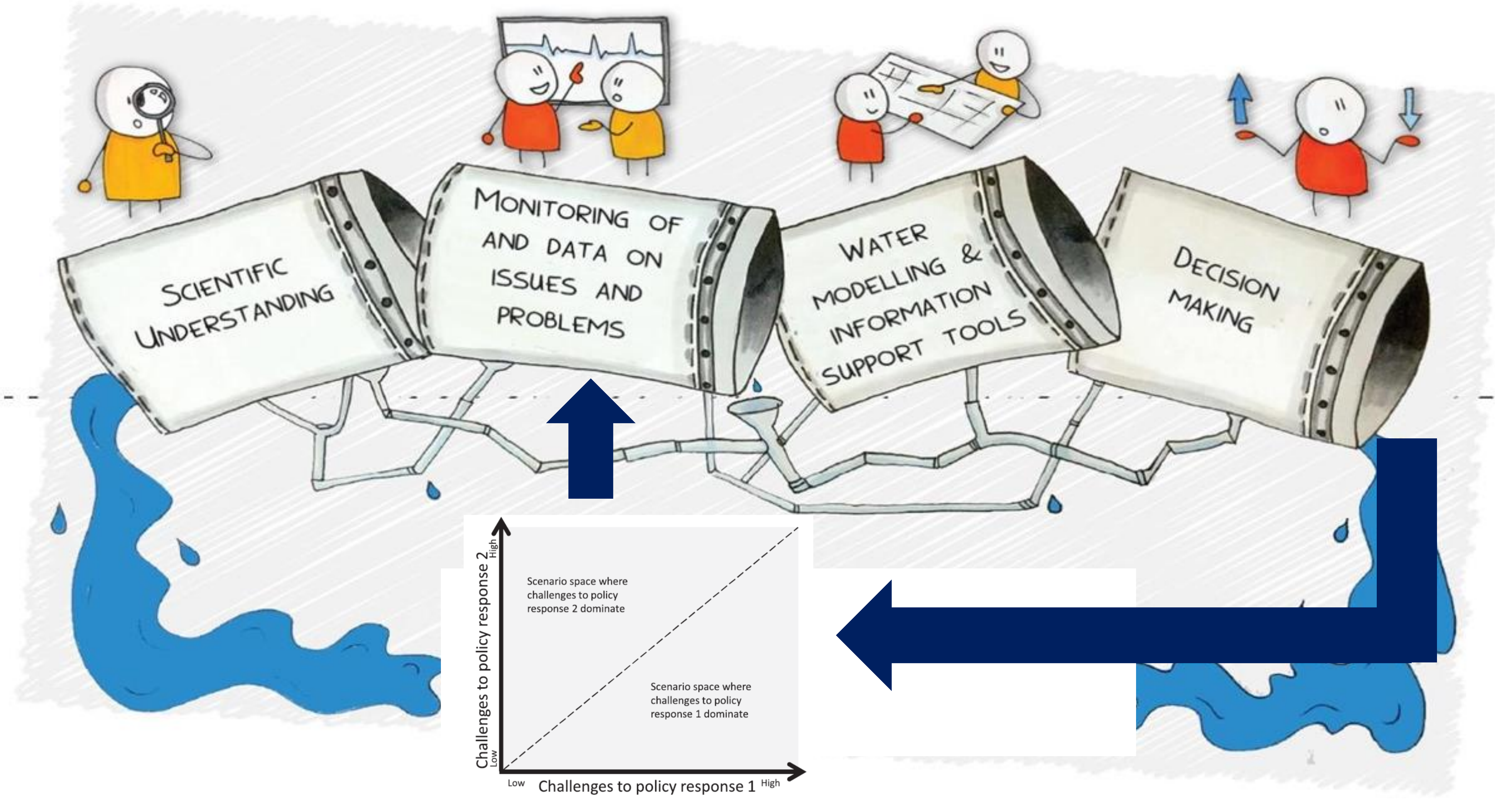


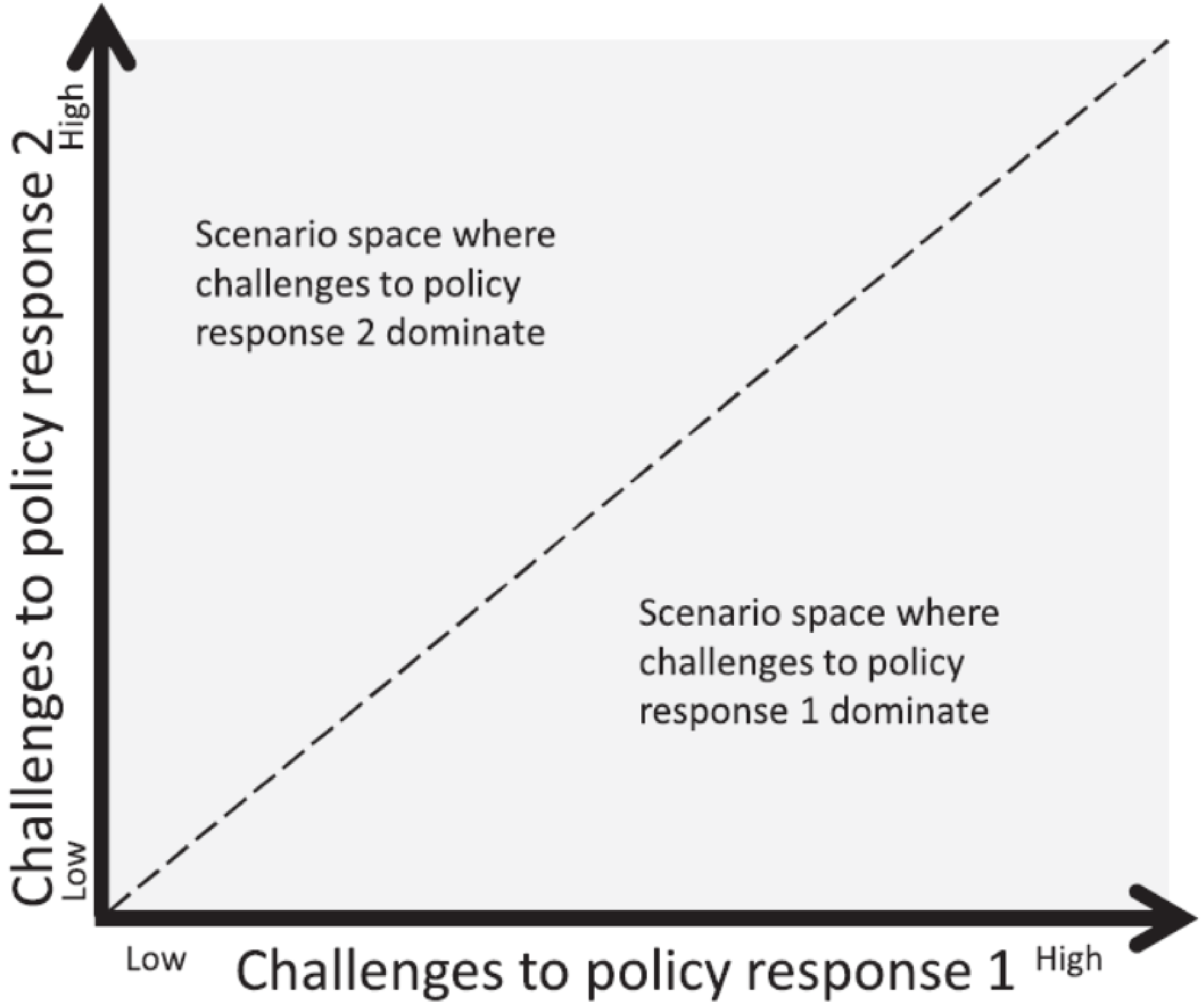


*fore*SIGHT – Systems Insights from Generation of Hydroclimatic Timeseries

Download now at: https://CRAN.R-project.org/package=foreSIGHT



SCIENTIFIC UNDERSTANDING
MONITORING OF AND DATA ON ISSUES AND PROBLEMS
WATER MODELLING & INFORMATION SUPPORT TOOLS
DECISION MAKING
Scenario space where challenges to policy response 2 dominate
Scenario space where challenges to policy response 1 dominate
Challenges to policy response 2
Challenges to policy response 1
Low
High
Low
High



Riddell G.A., van Delden H., Maier H.R, Zecchin A.C. (2019) **Exploratory scenario analysis for disaster risk reduction: Considering alternative pathways in disaster risk assessment** , *International Journal of Disaster Risk Reduction*, **39,** 101230.