A Stress Test for Climate Impacts on Water Security

Case Study from the Limari Basin in Chile

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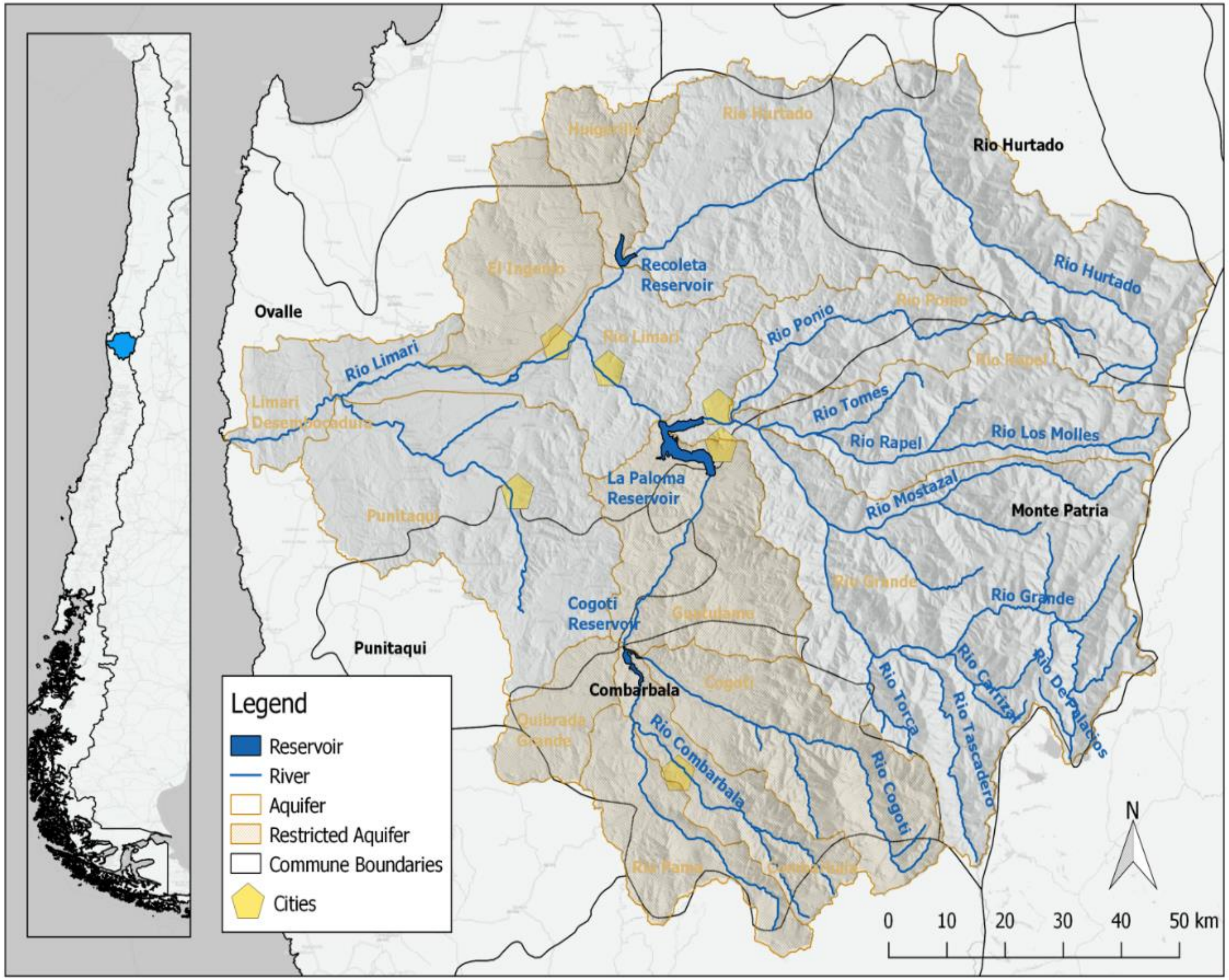
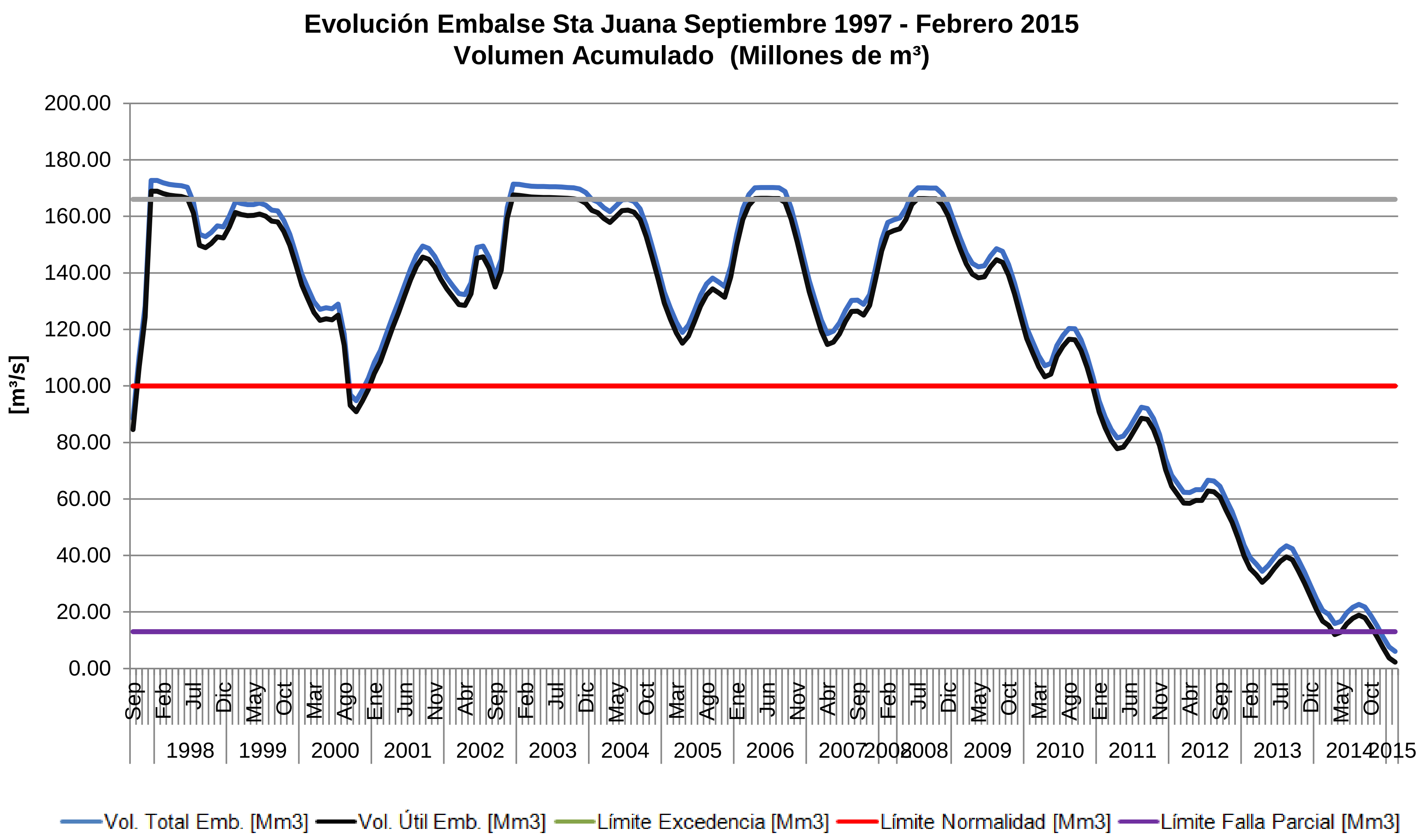
The Limarí Basin in Chile



The Limarí Basin in Chile




Occurrence of multi-year droughts



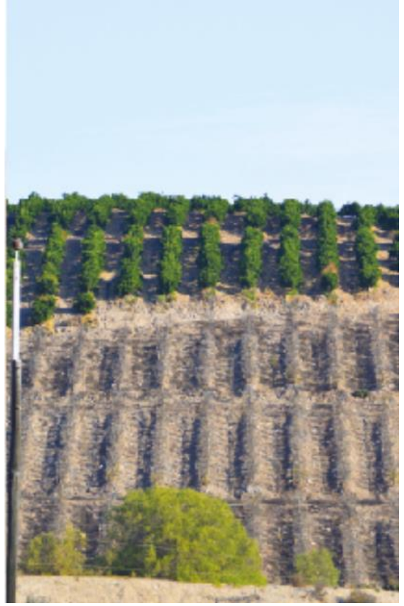
Reservoir Levels in the Chilean Atacama Region

How does a multi-year drought affect the water reservoir?

Puclaro Dam, 2009

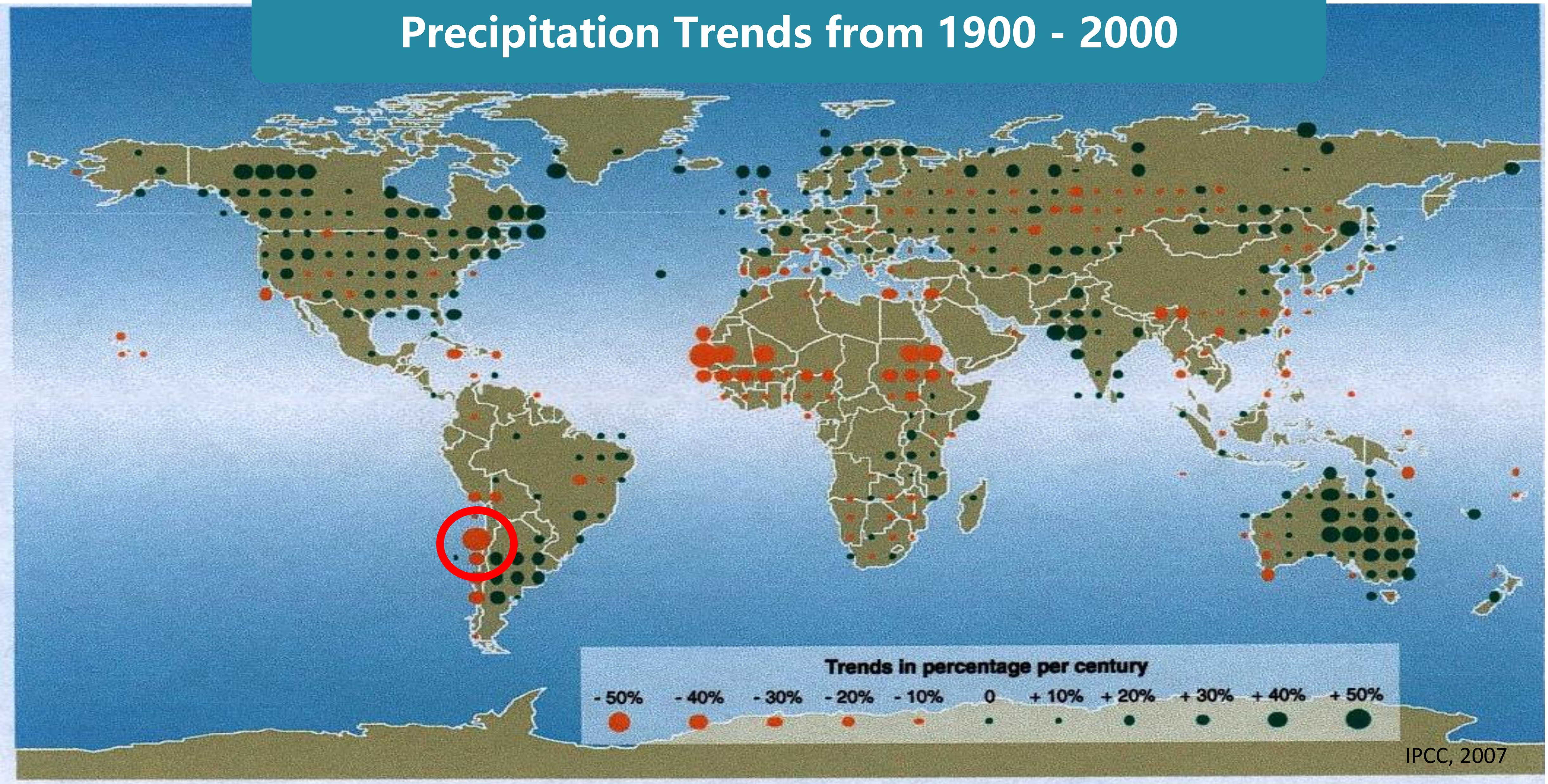
How does a multi-year drought affect the water reservoir?

How does a multi-year drought affect the agricultural production?



Background

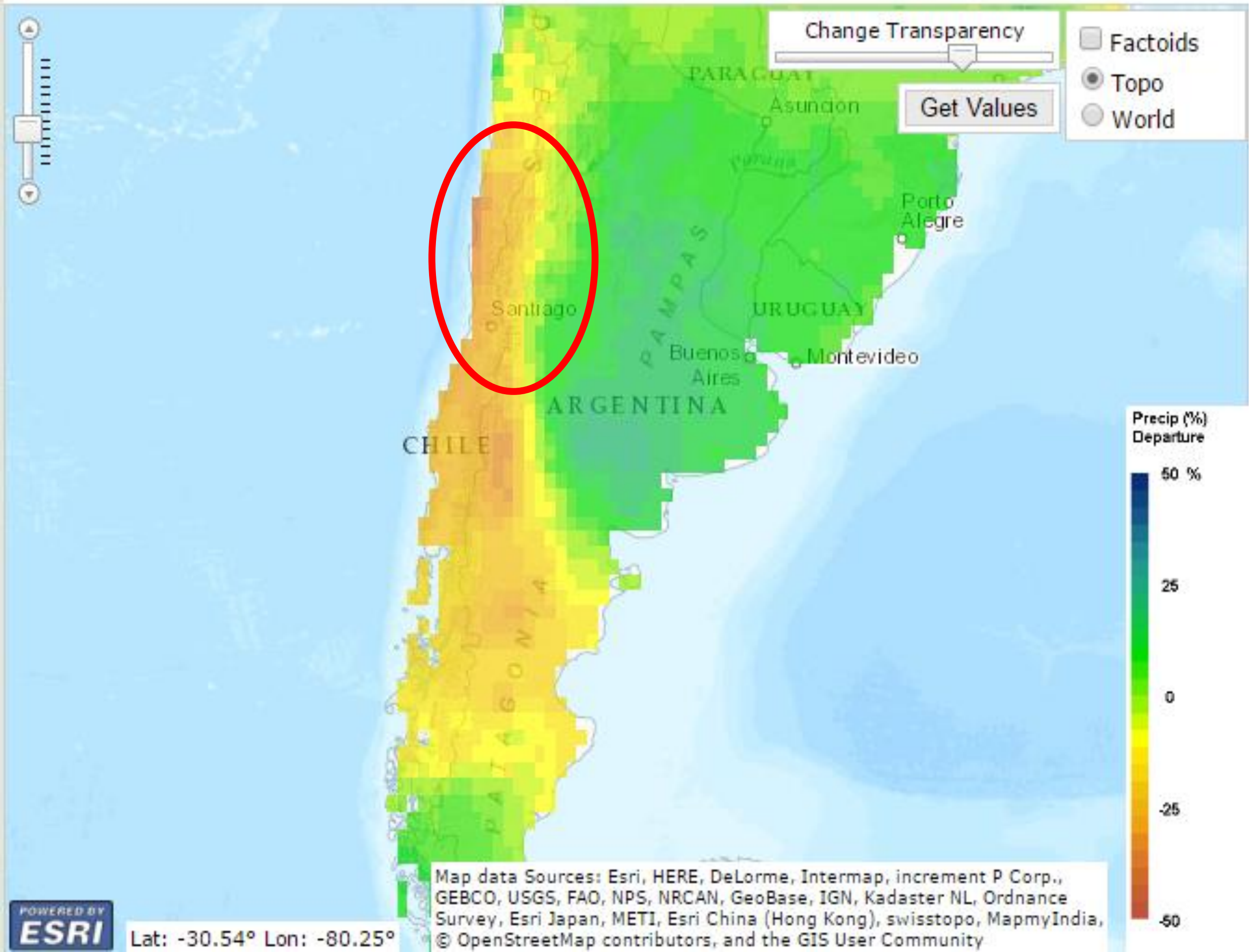
Precipitation Trends from 1900 - 2000



IPCC, 2007

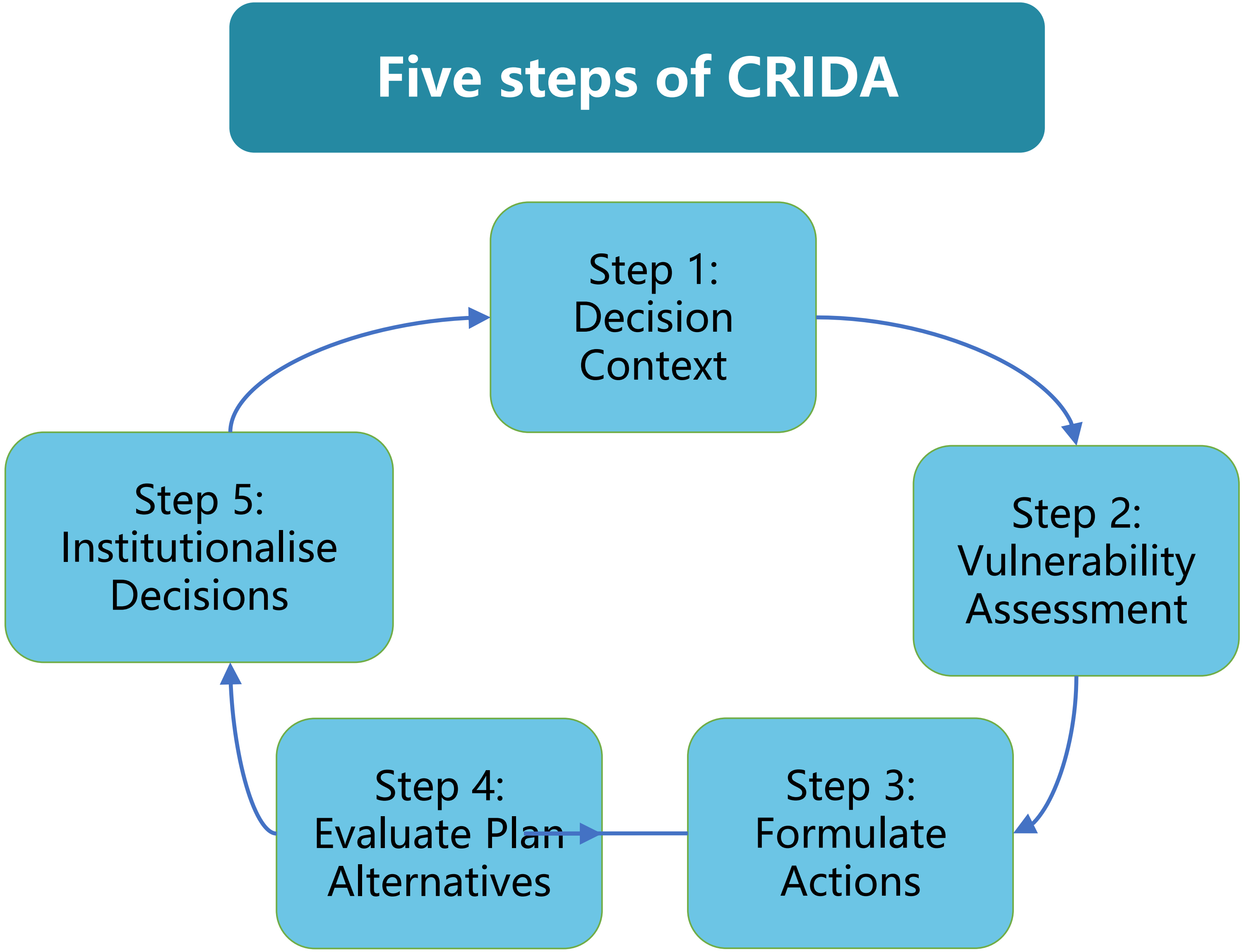
Background

Projections of Precipitation by 2080



TNC, 2017

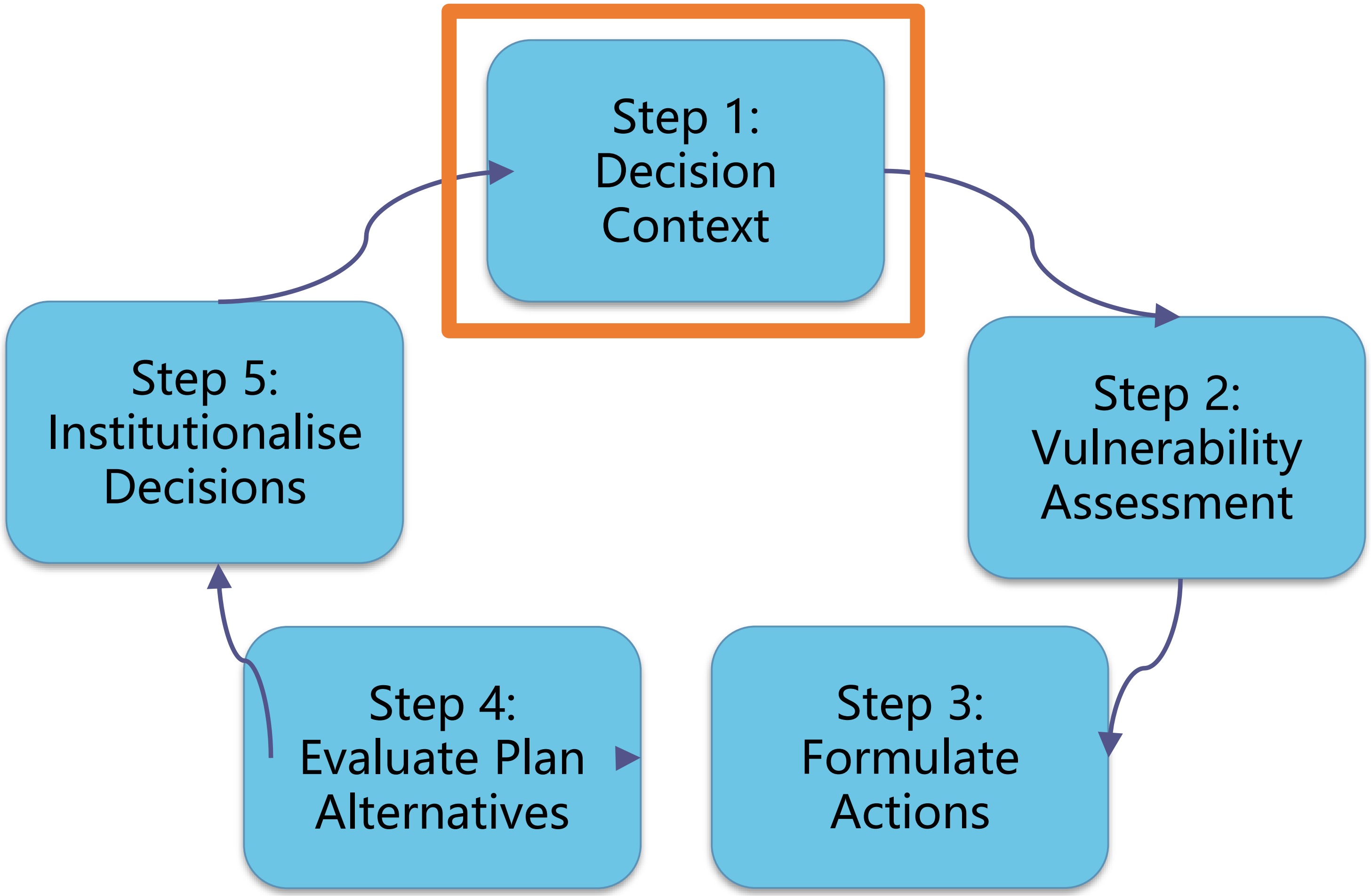
Climate Risk Informed Decision Analysis



.........to guide the analyst to *"a collaborative process for risk-informed decision making"* where complex uncertainties exists (e.g. cases considering climate change)

Climate Risk Informed Decision Analysis

Step 1: Decision Context



Climate Risk Informed Decision Analysis

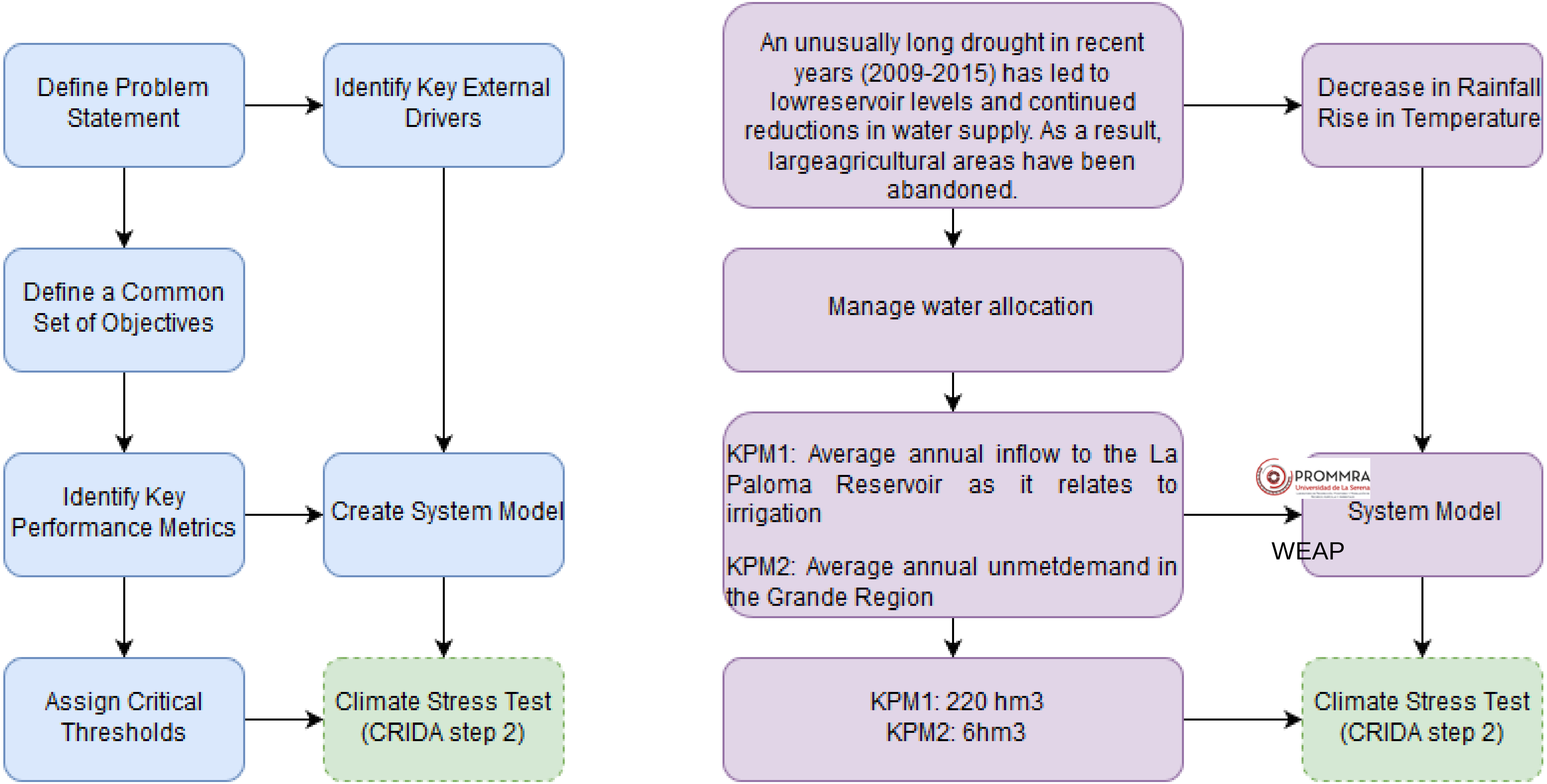
Step 1 - Define the Decision Context

CRIDA uses a **bottom-up approach**, making a stakeholder dialogue essential to:

i. **Define the water security vulnerability** for the water basin
ii. Define **sector-specific objectives** and key performance indicators
iii. Define critical **water security limits** for the indicators identified

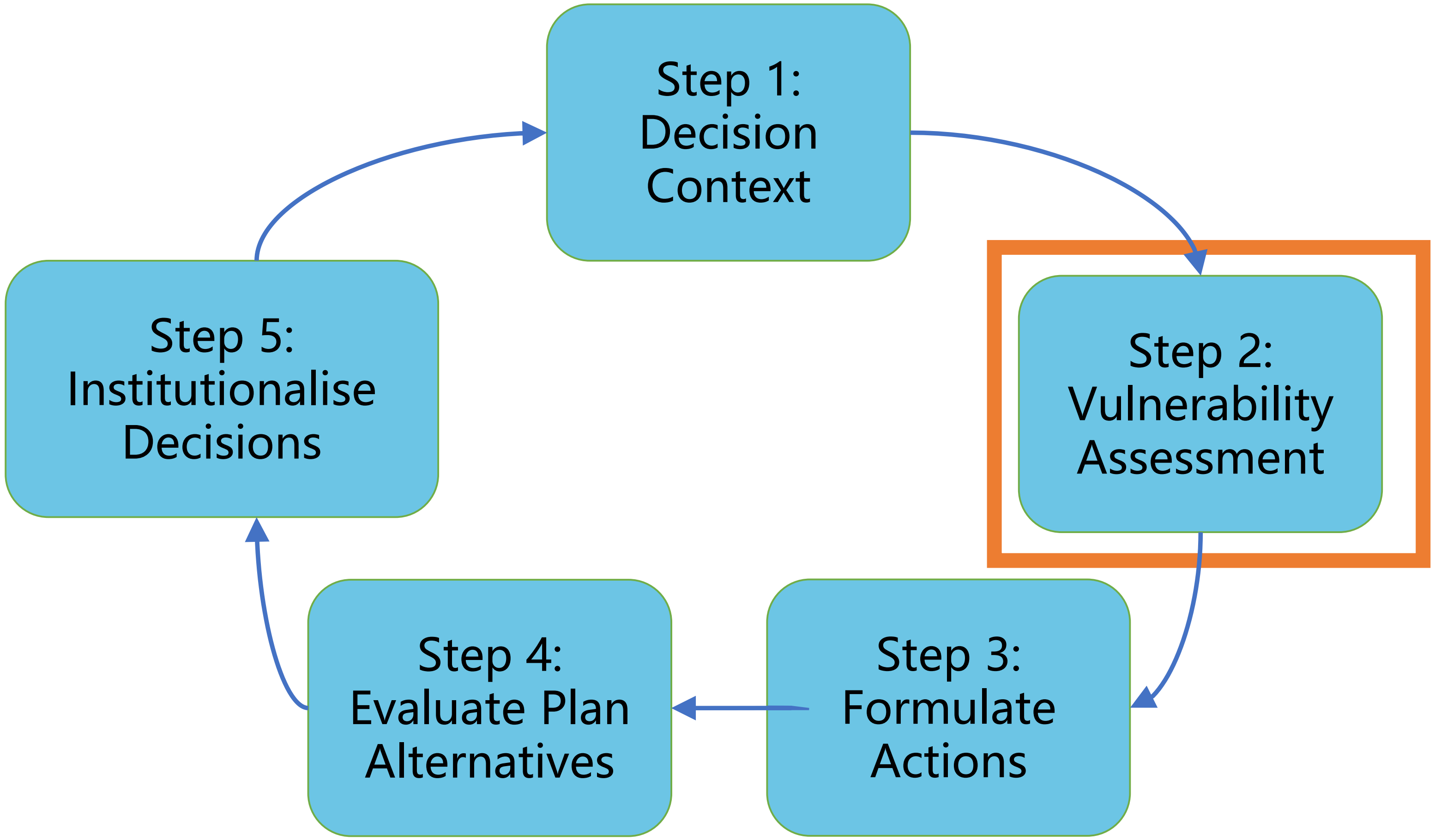
Climate Risk Informed Decision Analysis

Step 1 - Define the Decision Context



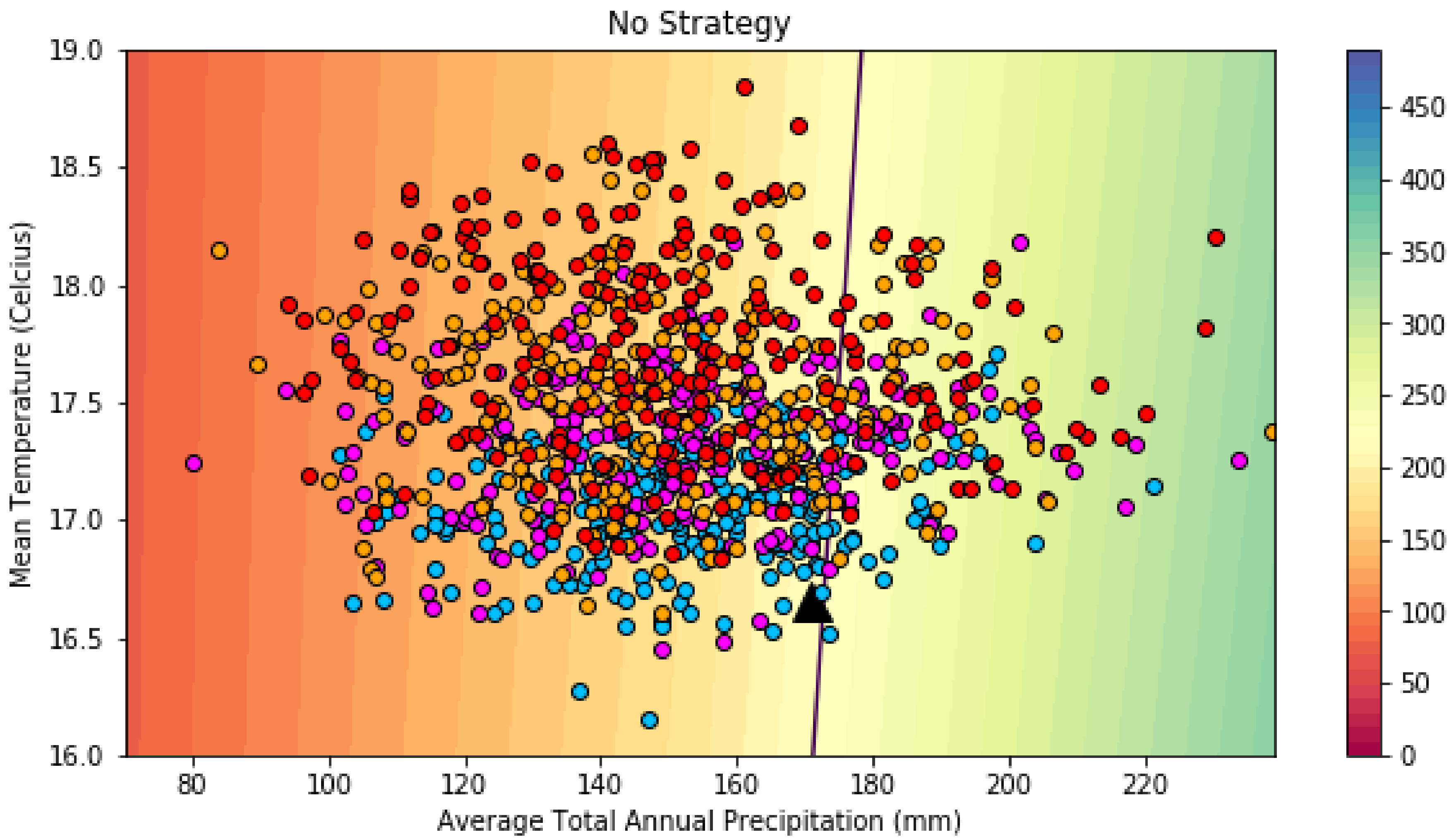
Climate Risk Informed Decision Analysis

Step 2 – Vulnerability Assessment



Step 2 – Vulnerability Assessment – Stress Test

1) Plausibility of Failure (KPM1)

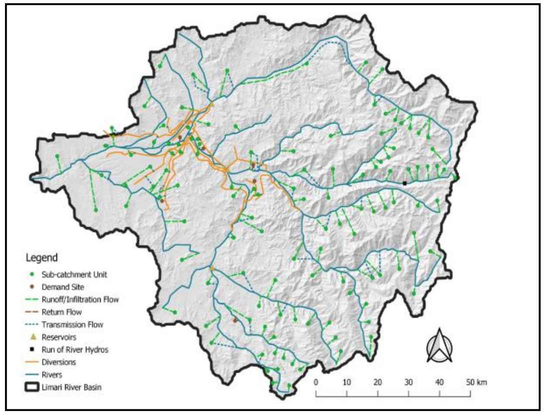


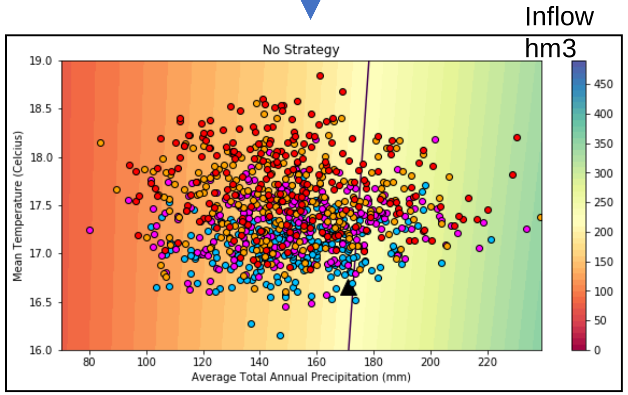
Do you consider 75% a low, medium or high probability of failure?

Step 2 – Vulnerability Assessment – Stress Test

1) Plausibility of Failure (KPM1)

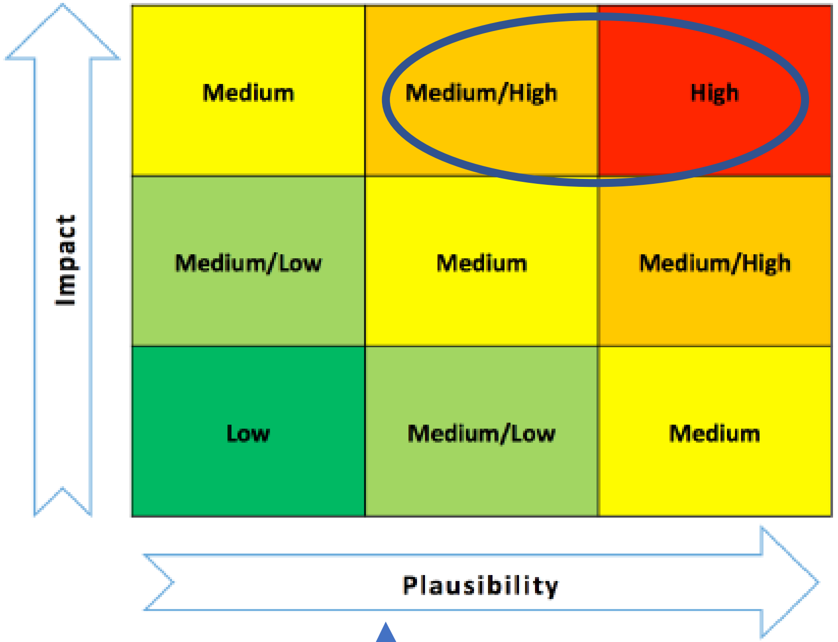
Expose the system model to progressively drier and hotter conditions (scaling and shifting of historical series).





Probability of Failure Analysis
There is a probability of 75% that the reservoir inflows fall below 220 m3 around 2035 (i.e. critical failure).

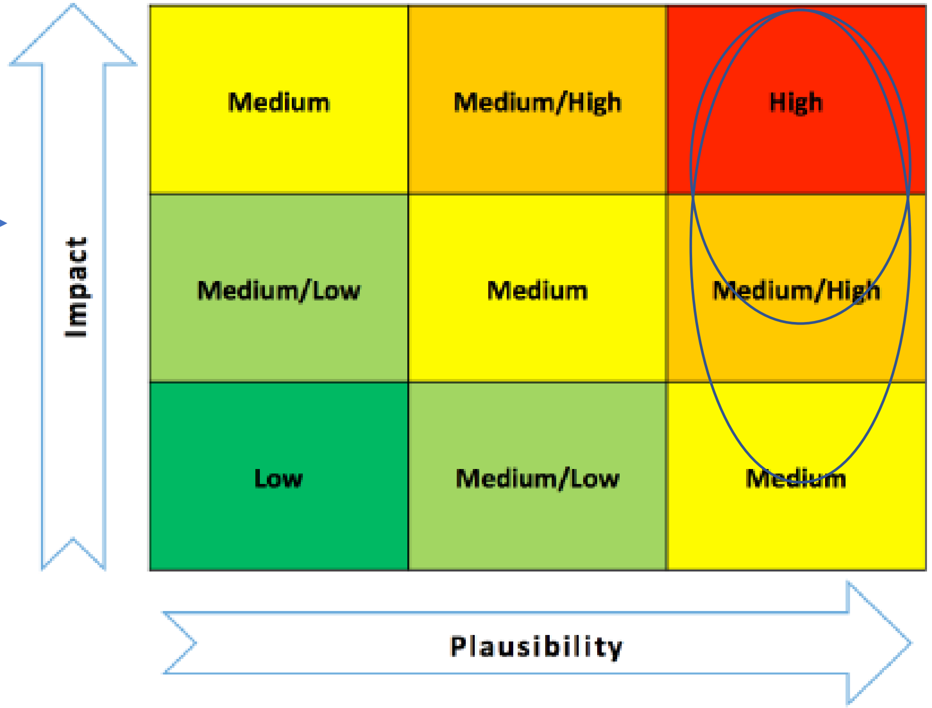
Risk Matrix



Risk Perception of stakeholders
Do you consider 75% a low, medium or high probability of failure?

Step 2 – Vulnerability Assessment – Stress Test

2) Impact of Failure (KPM1)

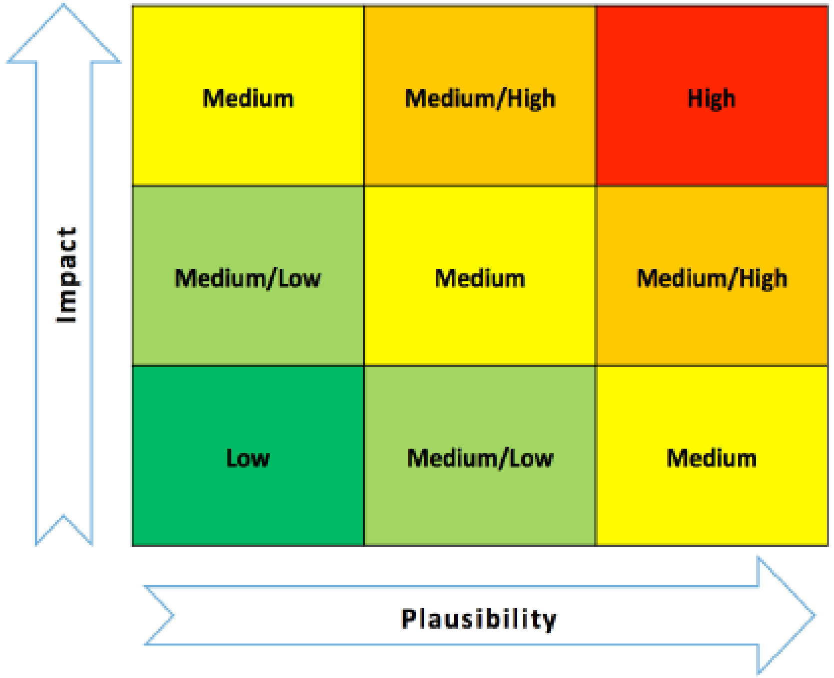


Impact of Failure Discussion
If the inflow to the reservoirs fall below 220 m3?
Would the impact be low, medium or high?

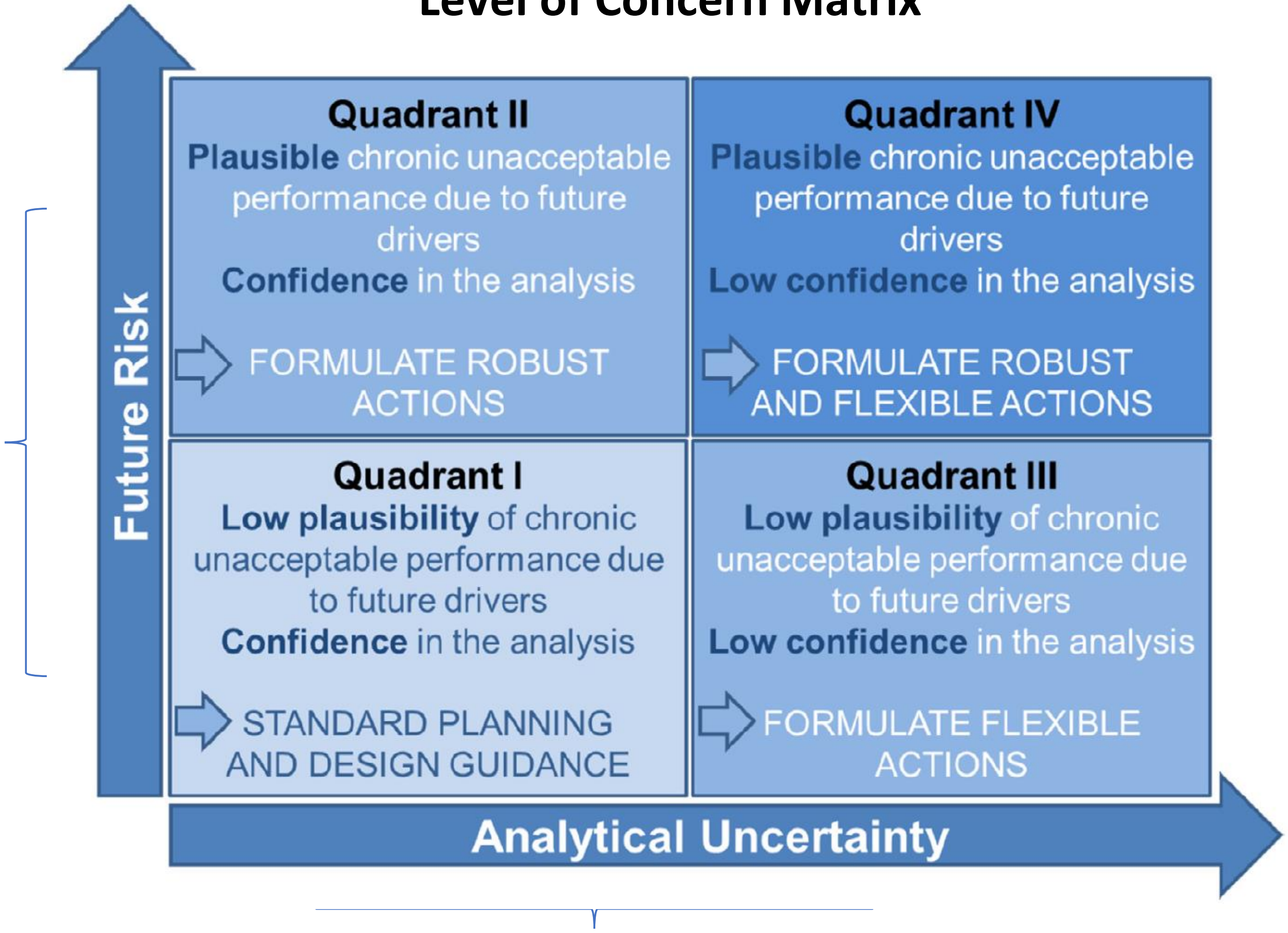
KPM: Inflow tothe Paloma Reservoir as it related to water availability					Medium-High
	STH1	STH2	STH3	STH4	
Migration	Medium	High	Medium	Medium	
Level of Poverty	Medium	High	Medium	High	
Loss in Productivity	High	High	Medium	High	

Step 2 – Vulnerability Assessment – Level of Concern Analysis

A function of Impact and Plausibility



Level of Concern Matrix

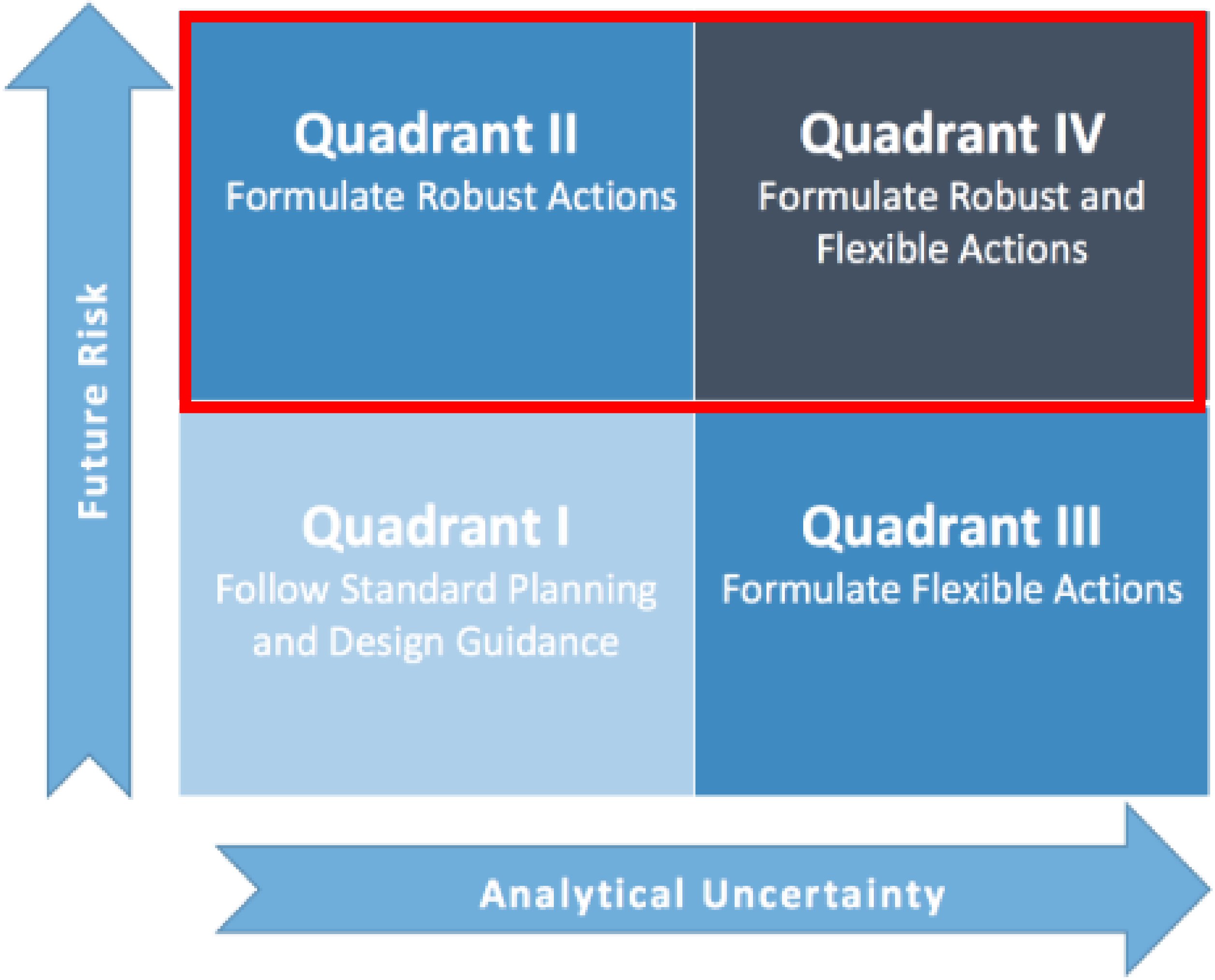


Based on the confidence in data and model

Step 2 – Vulnerability Assessment

Future Risk and Uncertainty

Medium-High Risk & Uncertainty



Critical Threshold Definition

-Agreement of studies and empirical evidence

System Model Uncertainty

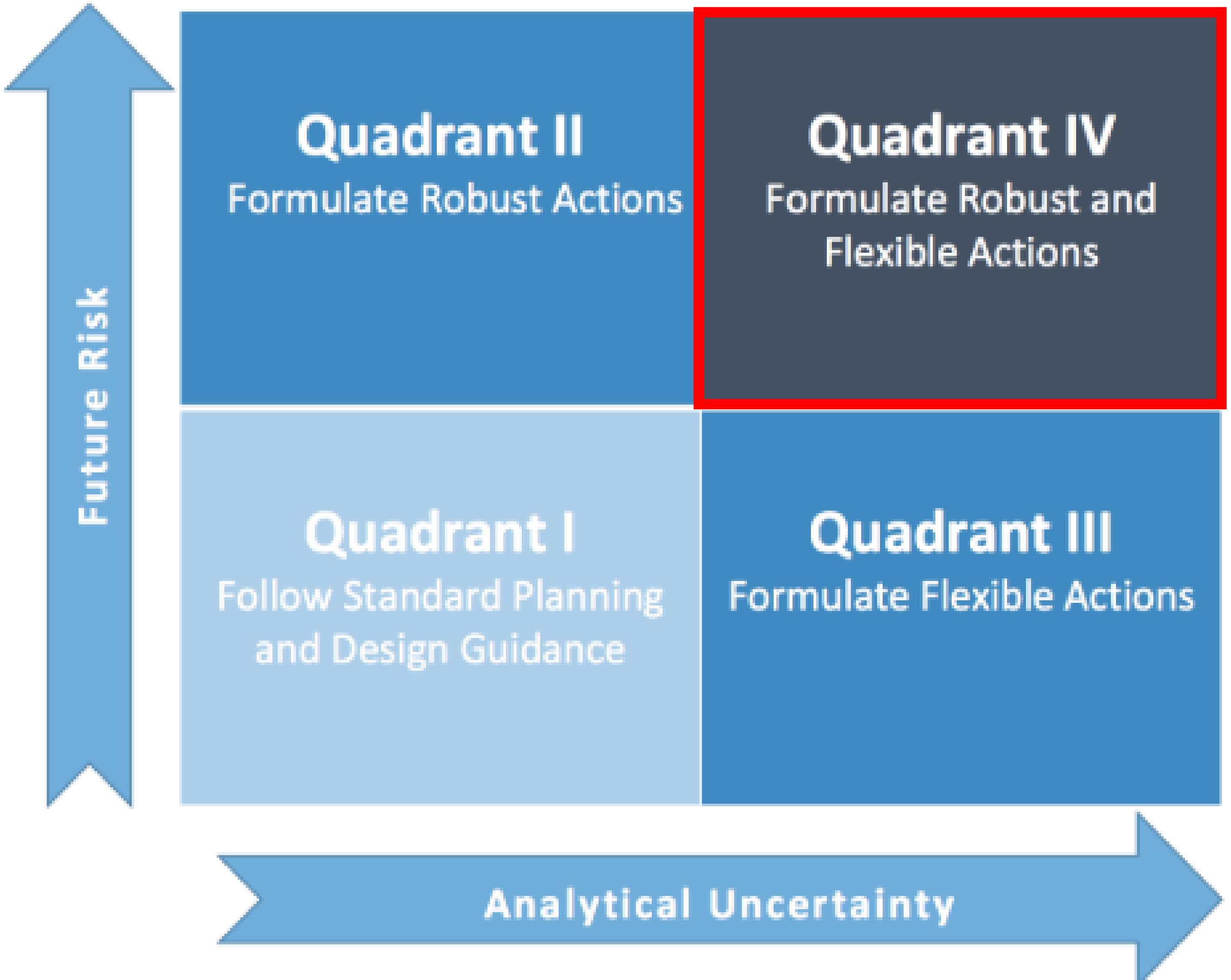
-Validation Statistics and Forecasting conditions

Uncertainty in Plausibility Assessment

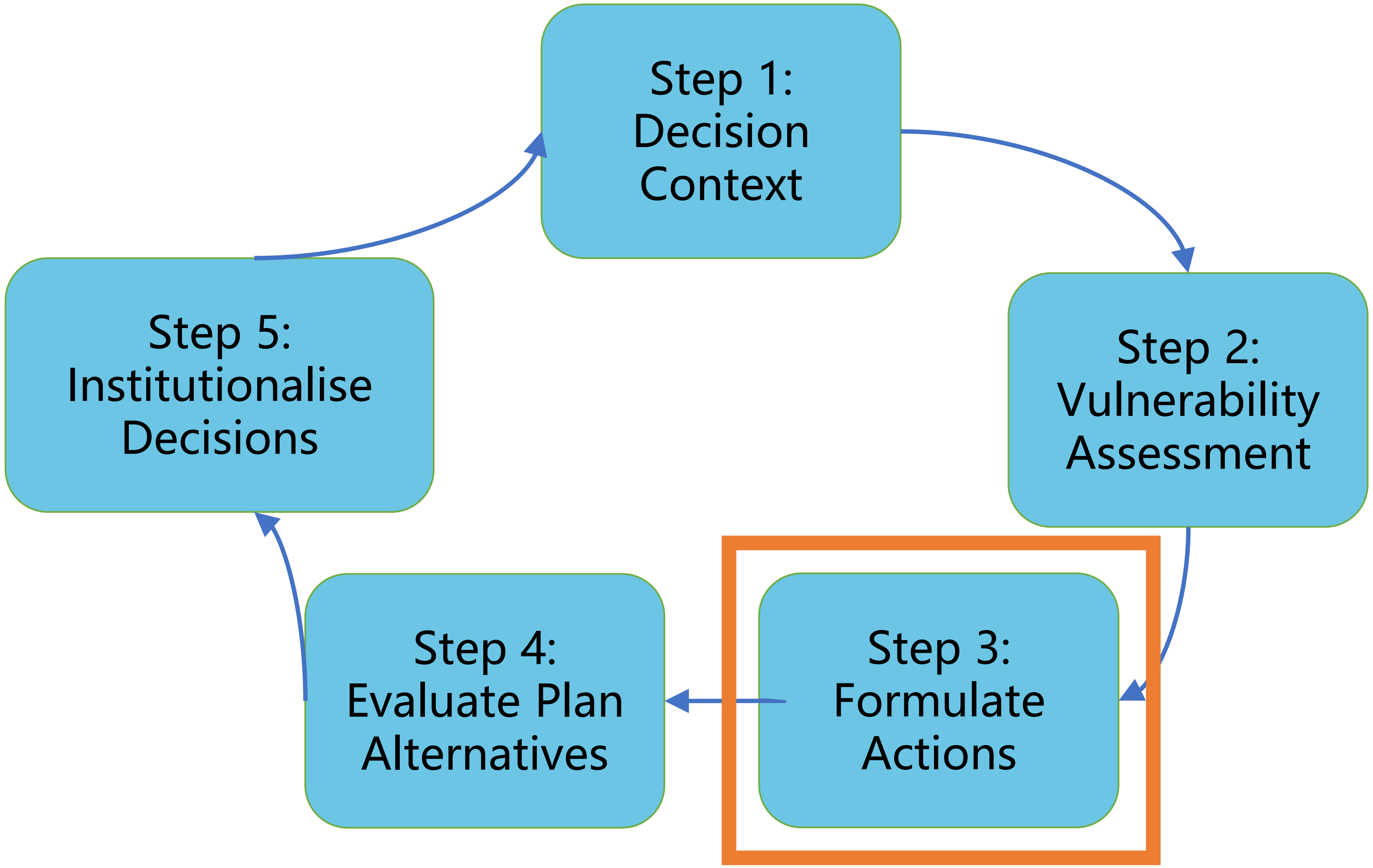
-Sensitivity

Step 2 – Vulnerability Assessment

Identify the Type of Actions



Step 3: Formulating Adaptation Strategies

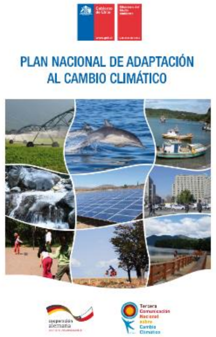


Step 3: Creating a library of Acceptable Flexible and Robust Actions

Interview & Workshop

Local Surveys

Government Plans



Impact Dimension		
Improve insurance mechanisms and monetary compensations schemes[1].	Flexible	-
Diversification of economic activities[1].	Flexible	-
Improve service for water delivery during drought[1].	Flexible	-
Plausibility Dimension		
Demand Side		
Deficit Irrigation	Flexible	D1
Reducing permanent crop acreage to annual crops with lower water requirements	Flexible	D2
• 25%		D2.1
• 50%		D2.2
• 75%		D2.3
Switching to annual crops with lower water requirements	Flexible	D3
• 25%		D3.1
• 50%		D3.2
• 75%		D3.3
Altering the Crop Schedule	Flexible	D4
Reducing plant transpiration	Flexible	D5
Switching to alternative crop cultivars[2]	Flexible	-
Improving soil quality[3]	Flexible	-
Supply Side		
Improving Irrigation Efficiency	Flexible	S1
Improving Canal Delivery Efficiency	Flexible	S2
Building Reservoirs	Robust	S3
Additional Source from waste water reuse and treatment, desalination plant or water highway	Robust	S4
• 1.5 m^3/s		S4.1
• 2 m^3/s		S4.2
• 2.5 m^3/s		S4.3
• 3 m^3/s		S4.4
Rain Water Harvesting[4]	Flexible	-
Aquifer Recharge[5]	Flexible	-
Changing water allocation rules[6]	Flexible	-

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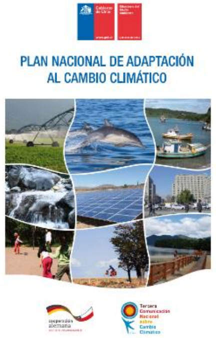

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• 2.5 m^3/s		S4.3
• 3 m^3/s		S4.4
Rain Water Harvesting[4]	Flexible	-
Aquifer Recharge[5]	Flexible	-
Changing water allocation rules[6]	Flexible	-

Popular Actions

- Building more Dams
- Ground Water Recharge
- Improving Irrigation Efficiency

Step 3: Testing the effectiveness of each action

Impact Dimension		
Improve insurance mechanisms and monetary compensations schemes[1].	Flexible	-
Diversification of economic activities[1].	Flexible	-
Improve service for water delivery during drought[1].	Flexible	-
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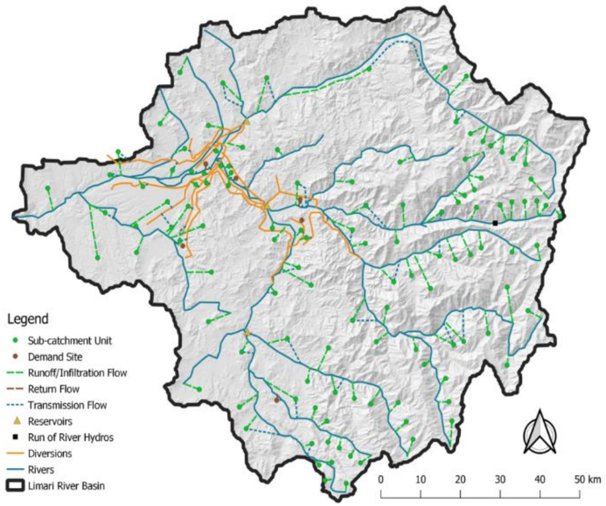
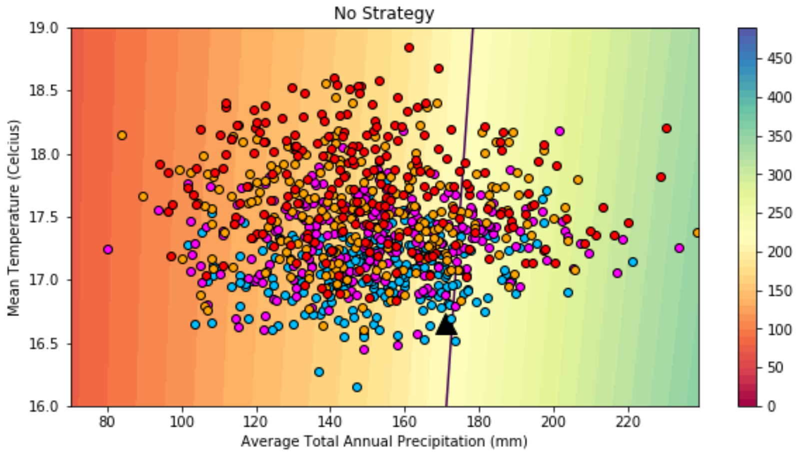
Rain Water Harvesting[4]	Flexible	-
Aquifer Recharge[5]	Flexible	-
Changing water allocation rules[6]	Flexible	-

Incorporate each action into the system model



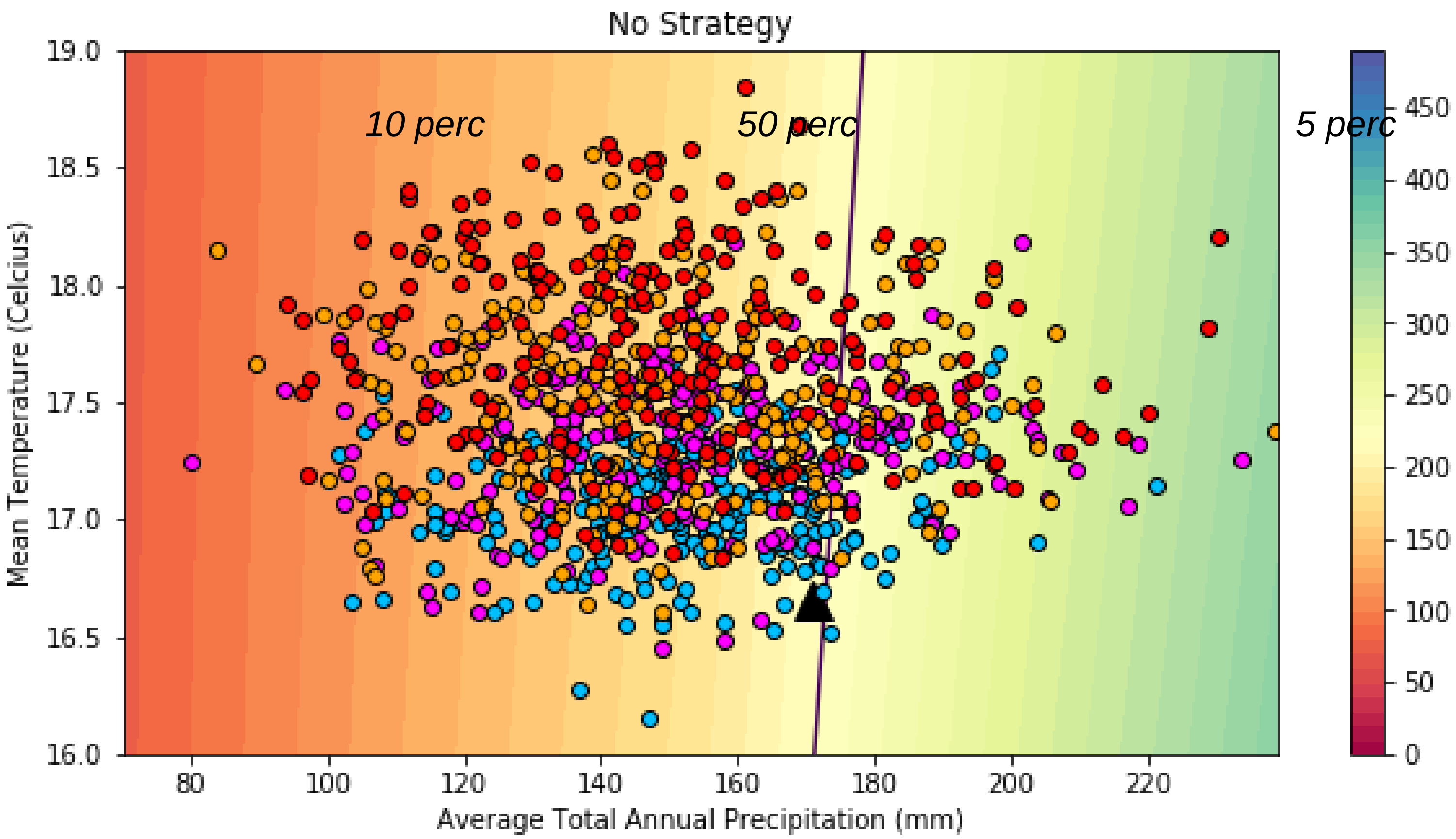
Repeat the plausibility of failure analysis



An effective action is one that reduces the plausibiltiy of failure in the future.

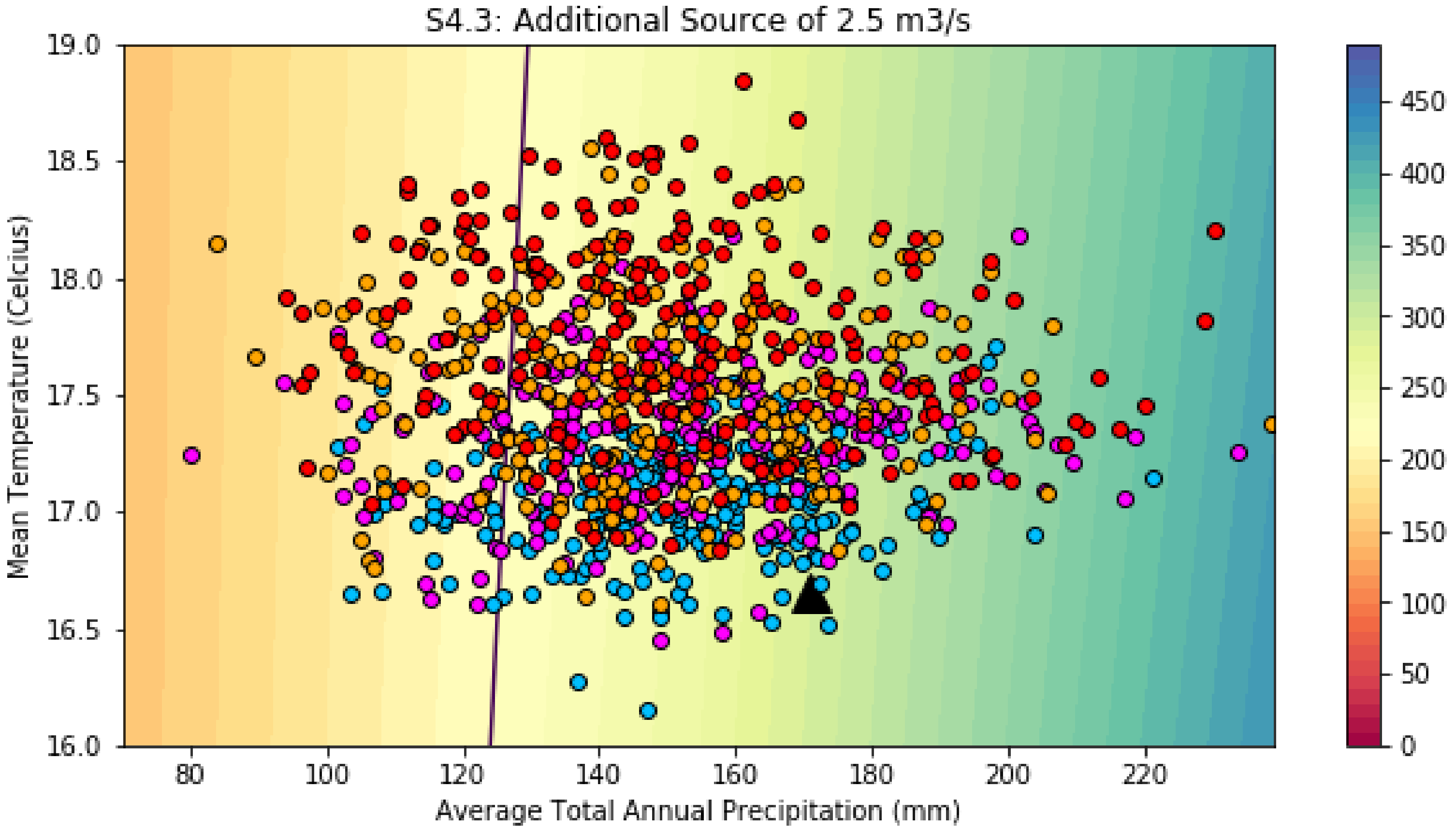
Step 3: Closer look into effectiveness of strategies

KPM1 : Total Annual Inflow to the La Paloma Reservoir



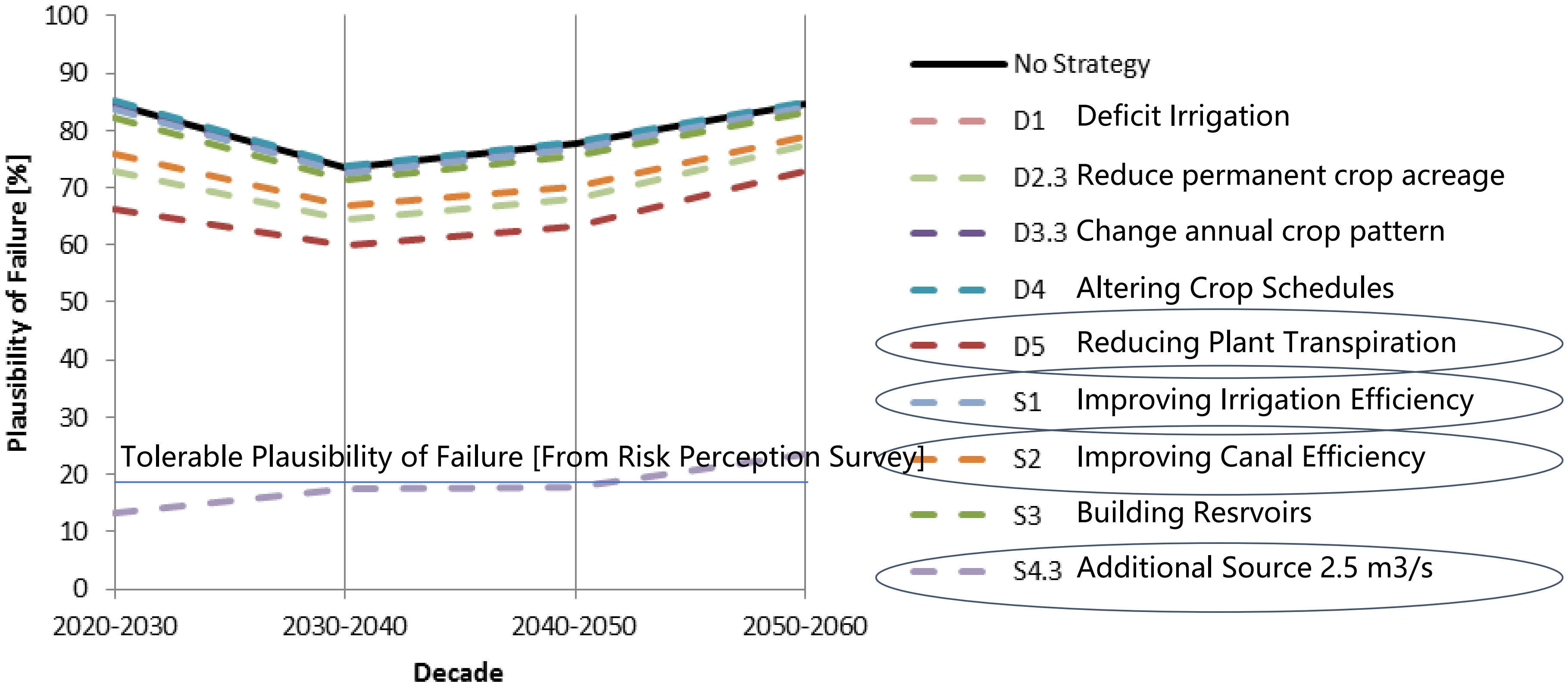
Step 3: Formulate Robust and Flexible Solutions

KPM1 : Total Annual Inflow to the La Paloma Reservoir



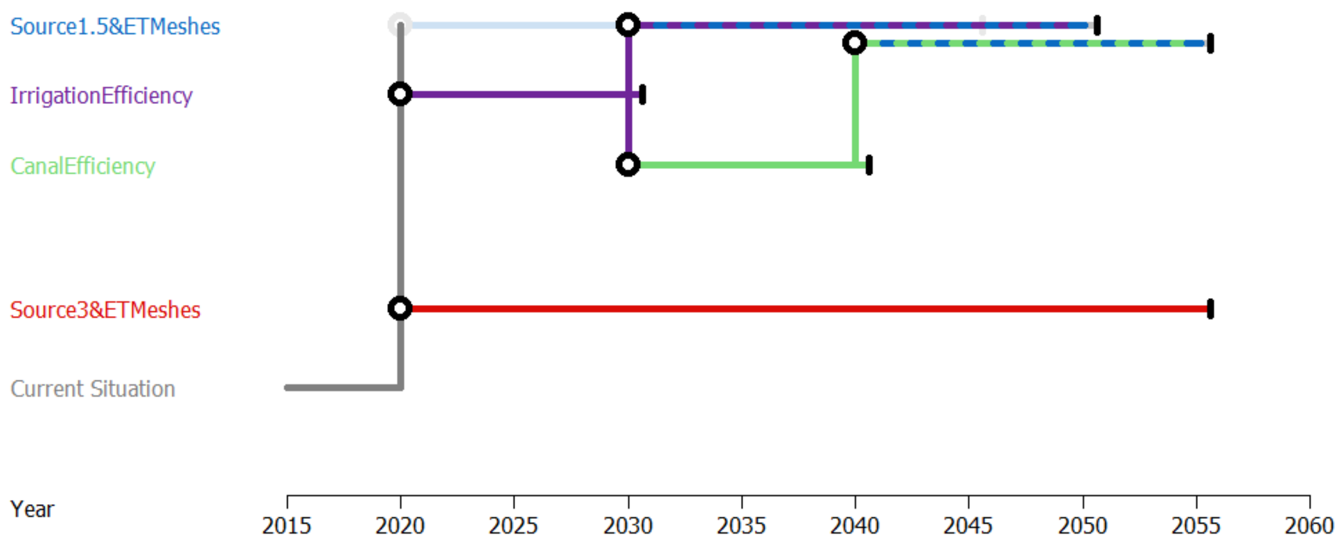
Step 3: Effectiveness of strategies by decade

KPM1 : Total Annual Inflow to the La Paloma Reservoir

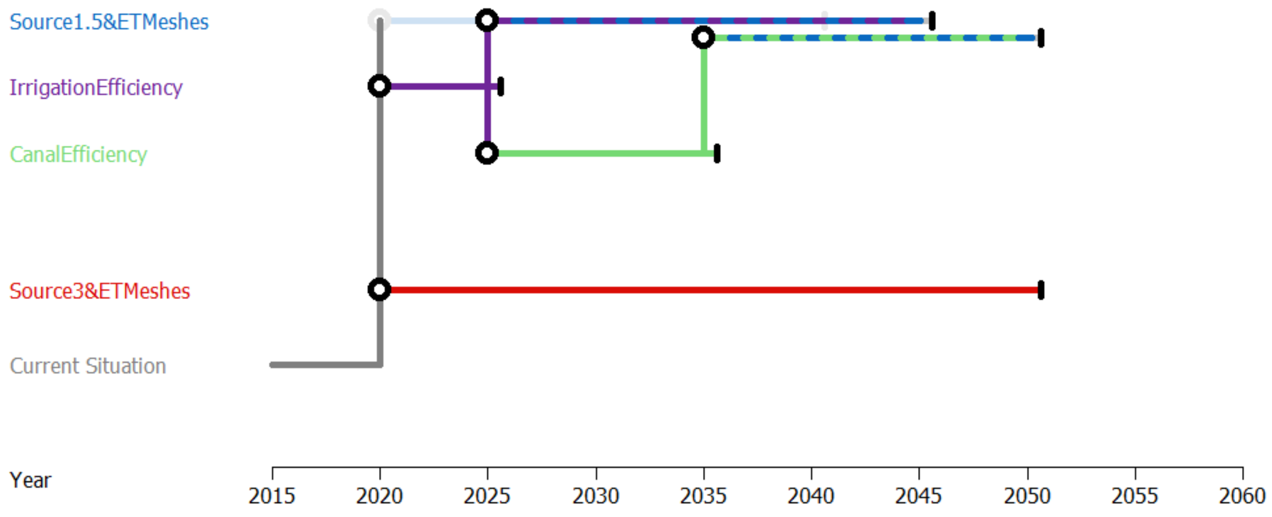


Step 3: Adaptation Strategy Pathways

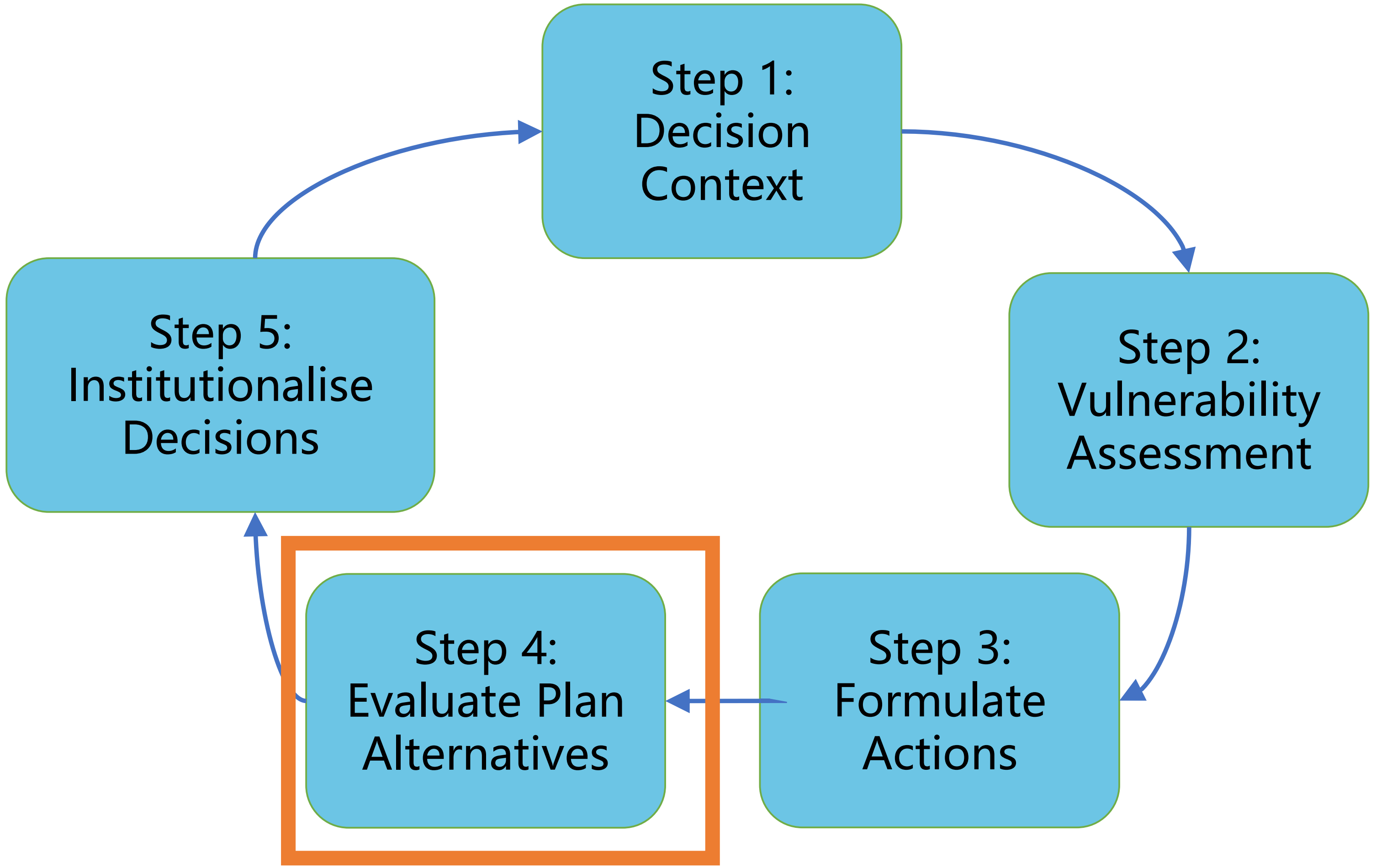
50th Percentile Trend



10th Percentile Trend



Next Steps……



Step 1: Decision Context
Step 2: Vulnerability Assessment
Step 3: Formulate Actions
Step 4: Evaluate Plan Alternatives
Step 5: Institutionalise Decisions

Step 4 Evaluation of pathways

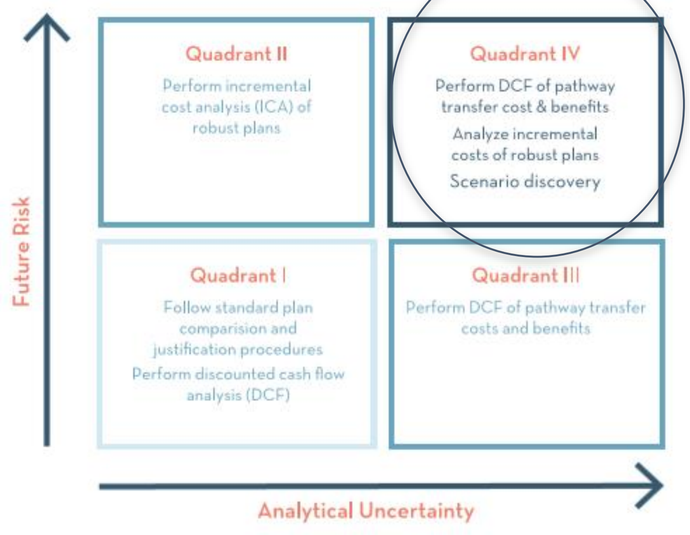
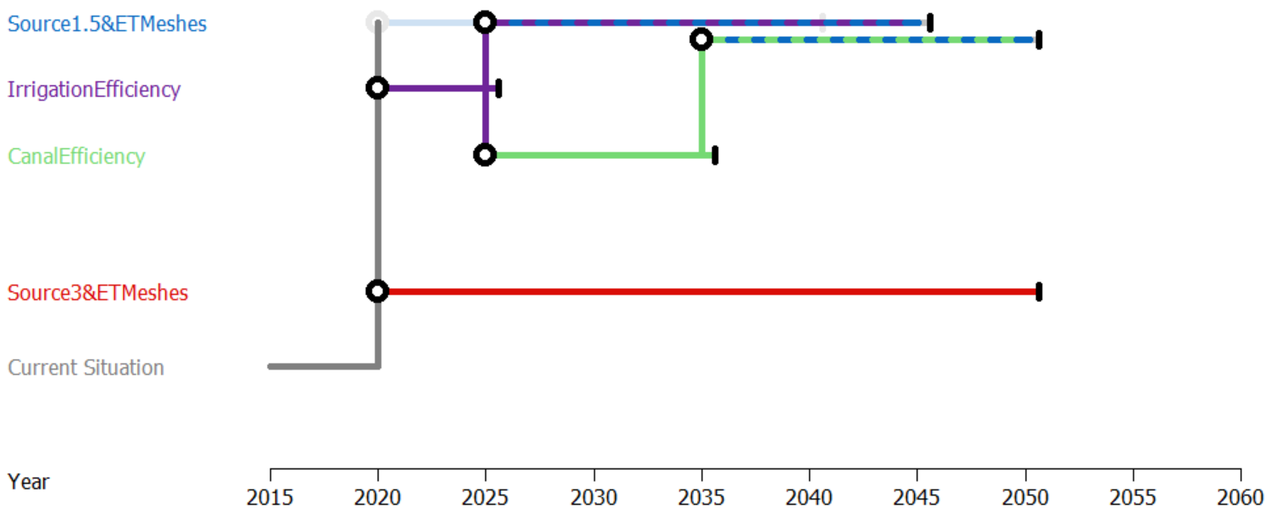


Figure 4.1. The decision matrix for comparing and justifying plans based on uncertainties in impacts and analysis.



2. Quantify Total Costs per Pathway

(green)	enter value	Total agricultural area	64000.00	ha
(light blue)	cell referenced value - do not change (always double check)	Total canal network length	700	km
(orange)	calculated value - do not change (always double-check)	Percent agric area in Grande	30%	<< to be confirmed
(light orange)	calculated value - do not change (always double-check)			

	Measures	Itemized Costs	Value	Unit	Cost per Unit	Unit	Total Cost per Unit ($)	Unit	Type of Cost	Initial Costs ($)	Recurrent Costs (
Pathway 0	Additional Source - Wastewater Treatment and Reuse 1.5m³/s	initial investment/cost for plant construction	1.50	m3/s	16,900,000.00	$/(m3/s)	25,350,000.00	$	Initial Cost	25,350,000.00	-
		initial investment/cost of main trunk pipeline	13.50	km	27,000.00	$/km	364,500.00	$	Initial Cost	364,500.00	-
		annual operation & maintenance (O&M) costs - treatment plant	47,304,000.00	m3/yr	0.12	$/(m3/s)	5,865,696.00	$/year	Recurrent Cost	-	5,865,696.
	Reducing Crop Evapotranspiration (Meshes/Screens)	cost of meshes	19,200.00	ha	1,700.00	$/ha	32,640,000.00	$	Initial Cost	32,640,000.00	-
		installation of meshes	19,200.00	ha	229.00	$/ha	4,396,800.00	$	Initial Cost	4,396,800.00	-
		annual O&M costs	19,200.00	ha	567.00	$/ha/yr	10,886,400.00	$/year	Recurrent Cost	-	10,886,400.
									TOTAL COSTS	-62,751,300.00	-16,752,096.
									TOTAL COSTS (Millions)	-62.75	-16.7

Step 4

3.4. Summarize Benefits

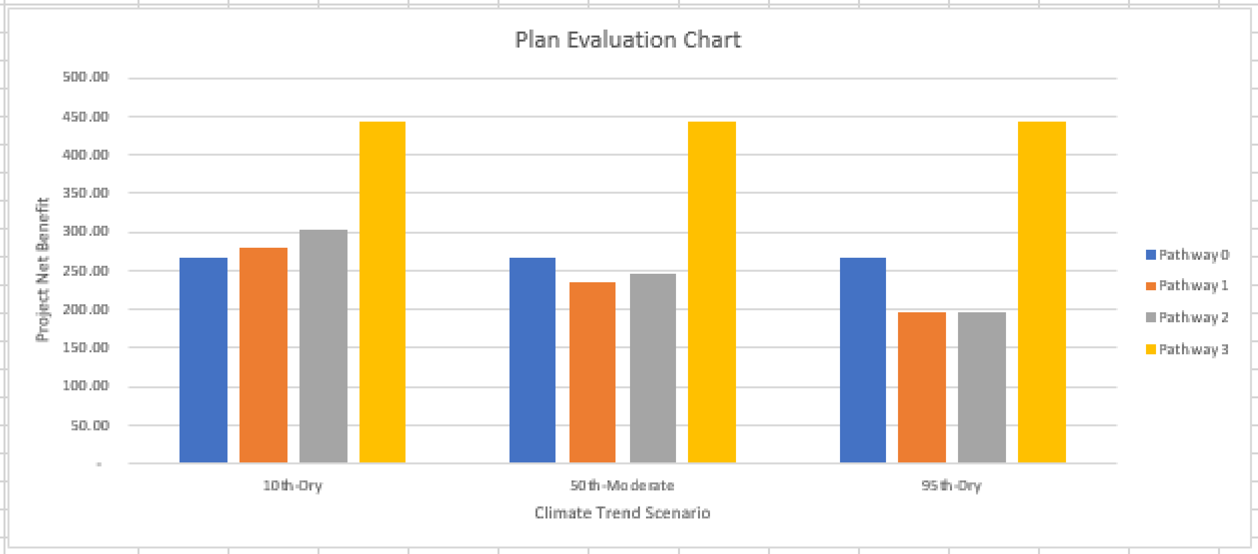
(green)	enter value
(light blue)	cell referenced value - do not change (always double check)
(orange)	calculated value - do not change (always double-check)

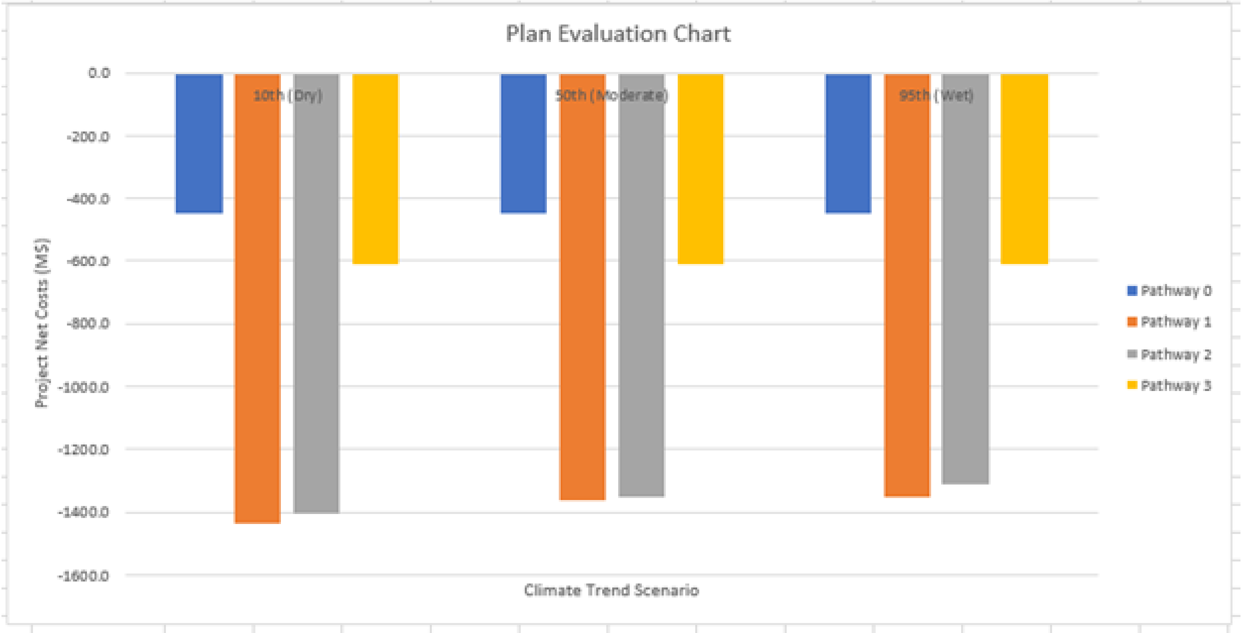
Table 3.1. - Summary Benefits per Climate Scenario

	Benefits per Climate Scenario		
Pathway	10th-Dry	50th-Moderate	95th-Dry
Pathway 0	266.28	266.28	266.28
Pathway 1	280.09	234.58	195.33
Pathway 2	302.09	245.47	196.63
Pathway 3	443.80	443.80	443.80

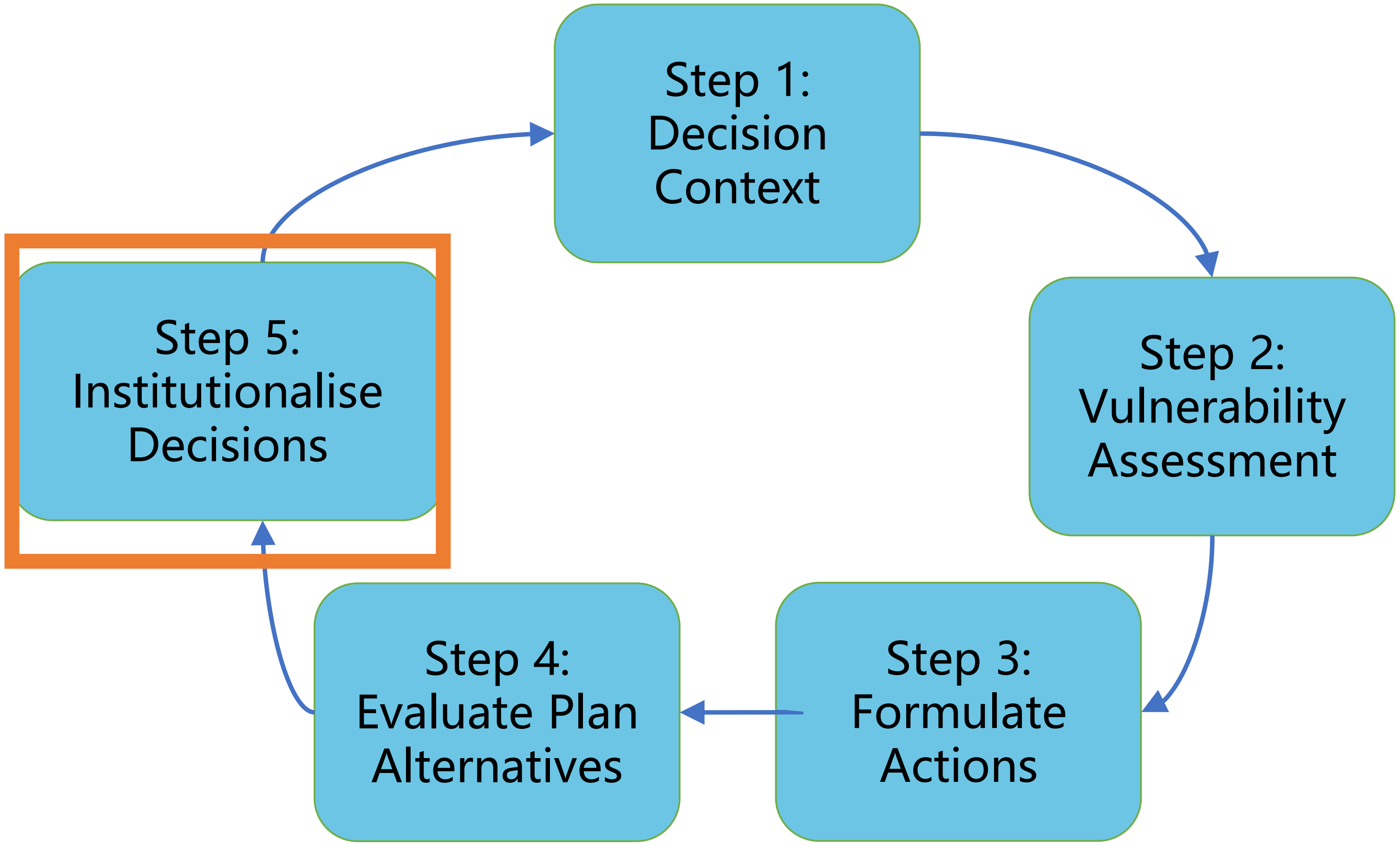
Table 3.2. - "Winner" Per Climate Scenario

Climate Scenario	Vinning Pathwa	Benefit Value
10th Percentile (Dry)	Pathway 3	443.80
50th Percentile (Mod)	Pathway 3	443.80
95th Percentile (Wet)	Pathway 3	443.80





Step 5 Institutionalize decision

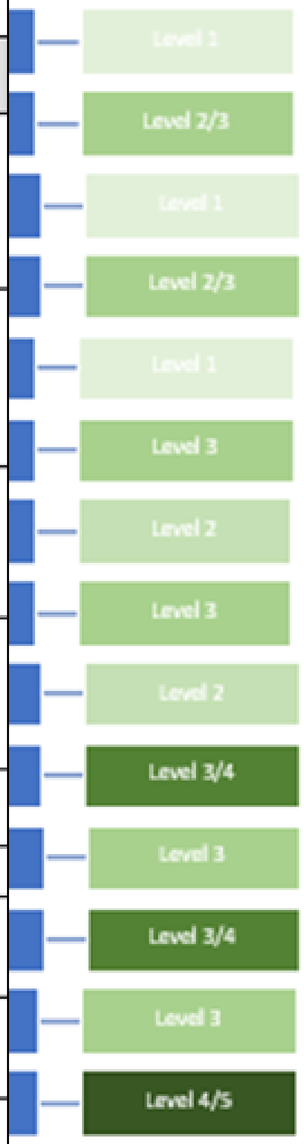


Implementation analysis using ISA (in progress)

- **Step 0**: Identify institutional an
economic structures
- **Step 1**: Pinpoint which structur
to change
- **Step 2**: Define how structure n
change
- **Step 3**. Identify which actors ha
ability to change structures
- **Step 4**.Determine governance
complexity

Table 1: Institutional and Socio-Cultural Analysis Framework (Steps 1 -4)

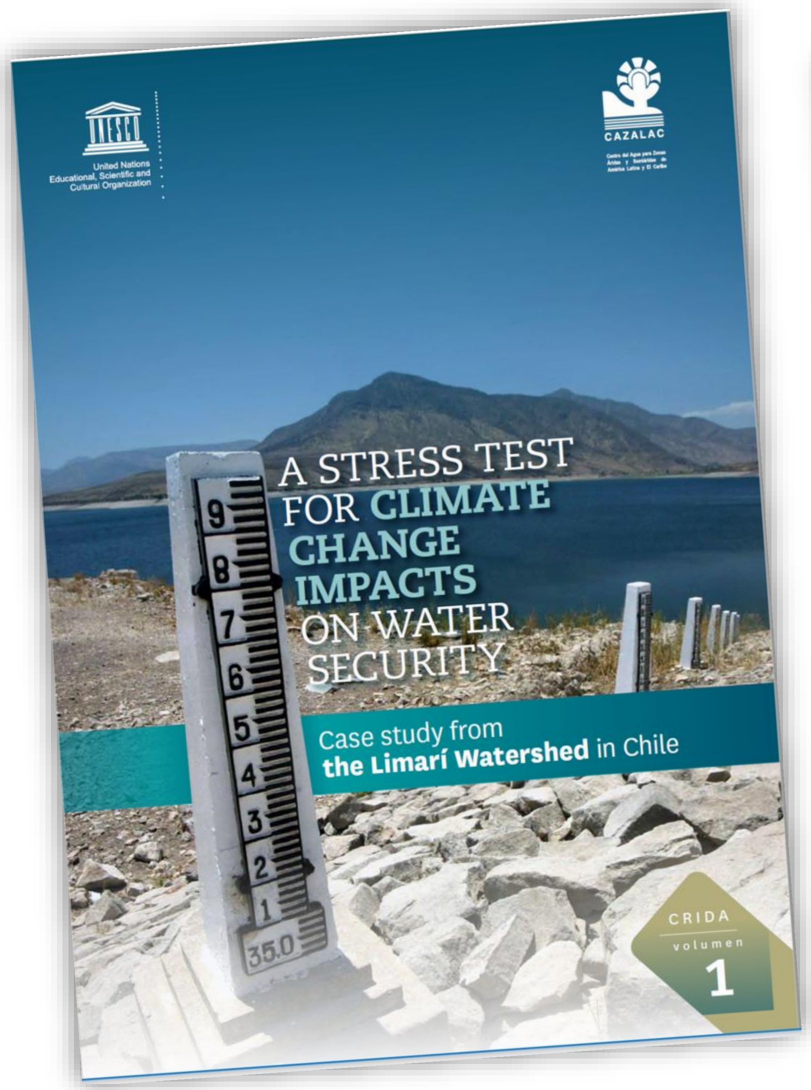
Measure/Pathway	[Step 1] Institutional or socio-economic barriers that need to change or be removed in order to support implementation of each measure	[Step 2] Actions that can be taken to change structures or remove the identified barriers
Additional source-wastewater treatment and reuse (2-3m³/s)	Legal restriction/manual: treated grey water can be used for irrigation but only for trees, parks and recreational areas and fruit production **(Institutional –Legislation/Policy)**	Local authority could relax restrictions on use of greywater which would allow farmers to use it more freely
	It is likely that under current conditions, private funding is the most likely method for funding small-scale measures **(Institutional - Budget)**	Develop local small-scale agreement between farmers and local drinking water providers; with shared economic profit
	Small farmers have limited resources and apply for government subsidies from Irrigation National Commission (CNR)) and INDAP (National Institute for Small Agricultural Development) **(Institutional - Budget)**	Explore public-private partnerships as funding mechanism for larger scale infrastructure
	INDAP provides funding for small farmers to achieve agricultural goals and for improving local conditions but not for irrigation **(Institutional - Budget)**	Regional government to provide more subsidies and subsidies specifically for irrigation
	People (farmers and consumers) are concerned regarding use of treated wastewater for crops and don't trust the quality **(Social - Beliefs)**	Local government could increase required level of water treatment to increase trust in water quality
	Consumers don't like to use products irrigated with treated wastewater **(Social - Beliefs)**	Change perception of grey water so that people are more comfortable and accepting of its use.
	When water is available in La Paloma reservoir, it is generally used for permanent crops. However, when there is a drought, people reduce permanent area so need less water **(Social - Practices)**	Encourage the use of alternative sources of water, not only during droughts AND Proactively establish greywater infrastructure so that it is available when needed
	Only a few farmers are currently using treated wastewater **(Social - Awareness).** This is linked to a lack of trust in water quality; a lack of necessity and limited proof/evidence of its success	Change perception of grey water, increase awareness of how it can be used
	Some research has been conducted in the region by a construction company which was hired by CRDP. It was completed four years ago, and costs could have changed since **(Social - Knowledge)**	Undertake more studies and pilot projects

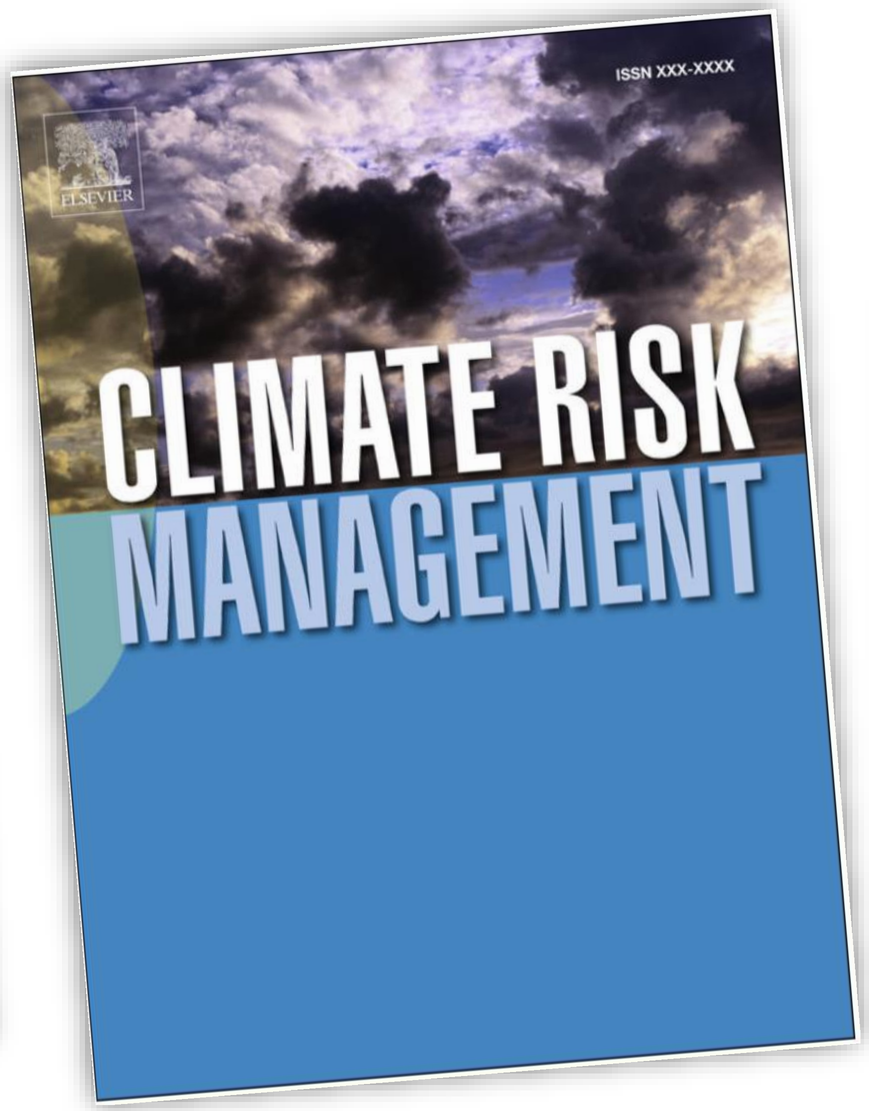


Case Study Conclusion

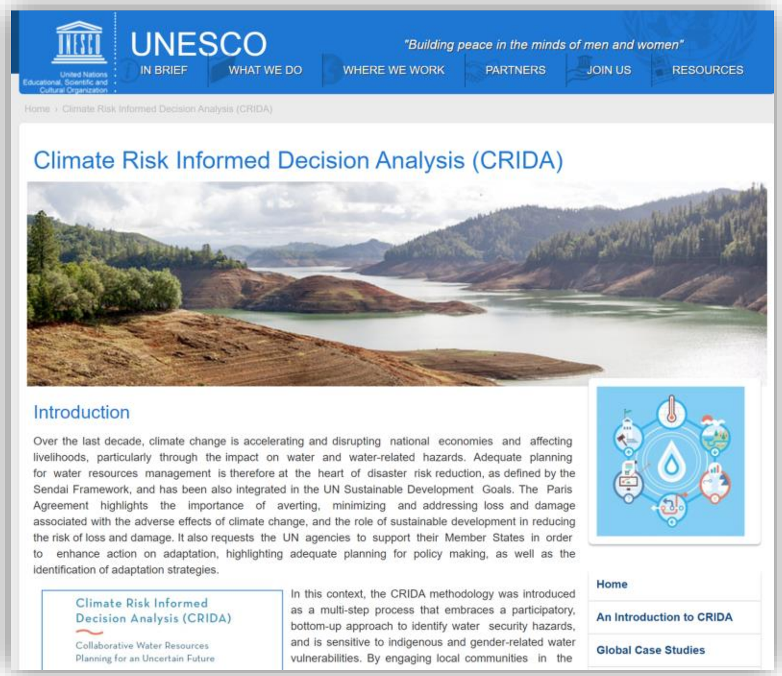
- Adaptation Strategies:
    - Only a "Proof of concept"
        - Not all strategies are tested
        - Groundwater could not be modelled in this application which is an important water source for the most vulnerable in the basin (rural settlements).
    - Reservoirs may not be the best solution
    - An additional source (i.e. desalination or water highway) may be required if current water use is to be sustainable.
- Current situation is already very stressed obscuring effects of measures.
- Economic and Implementation analysis no conclusions yet (work in progress)

Further Reading

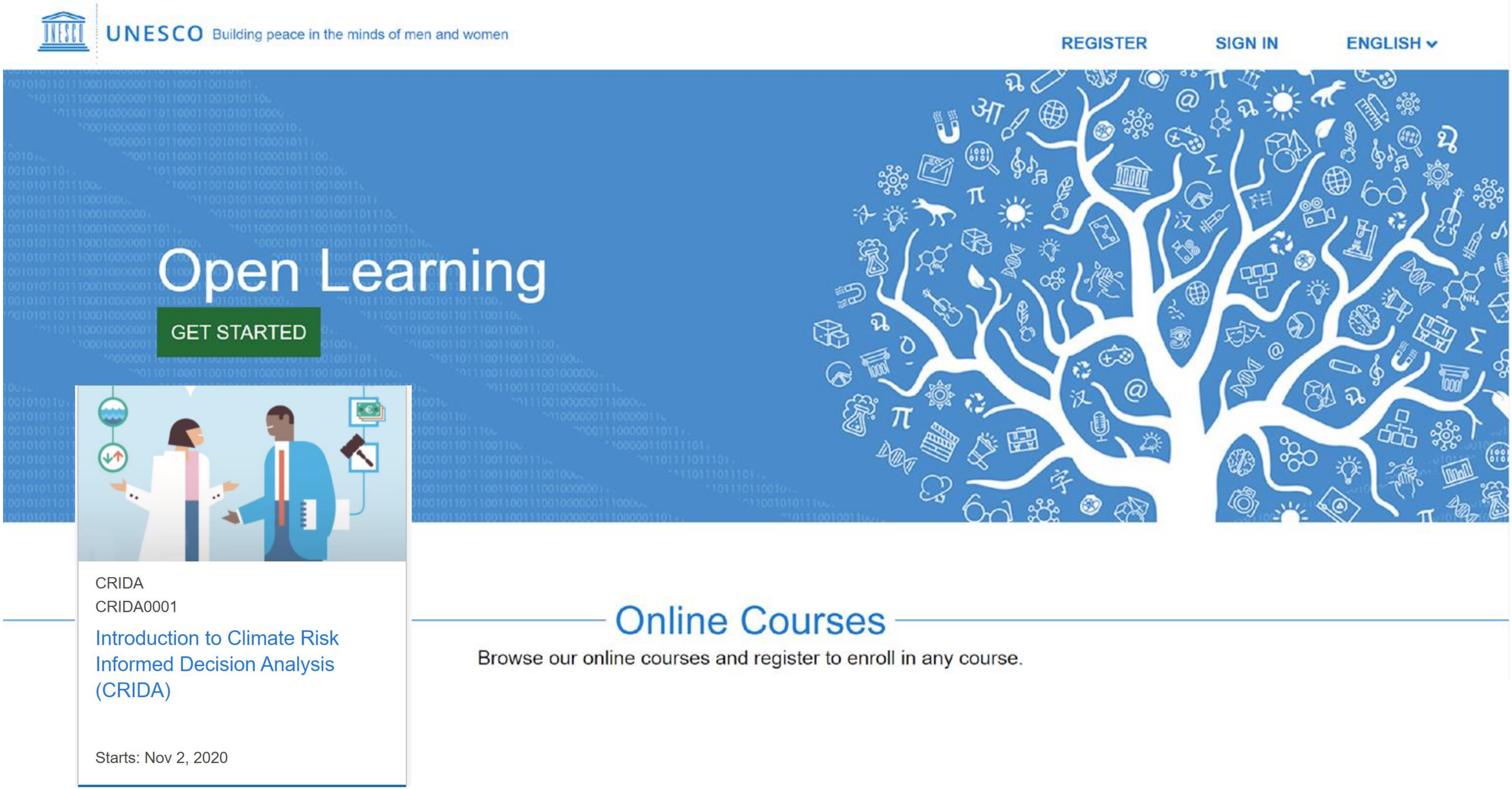




https://en.unesco.org/crida

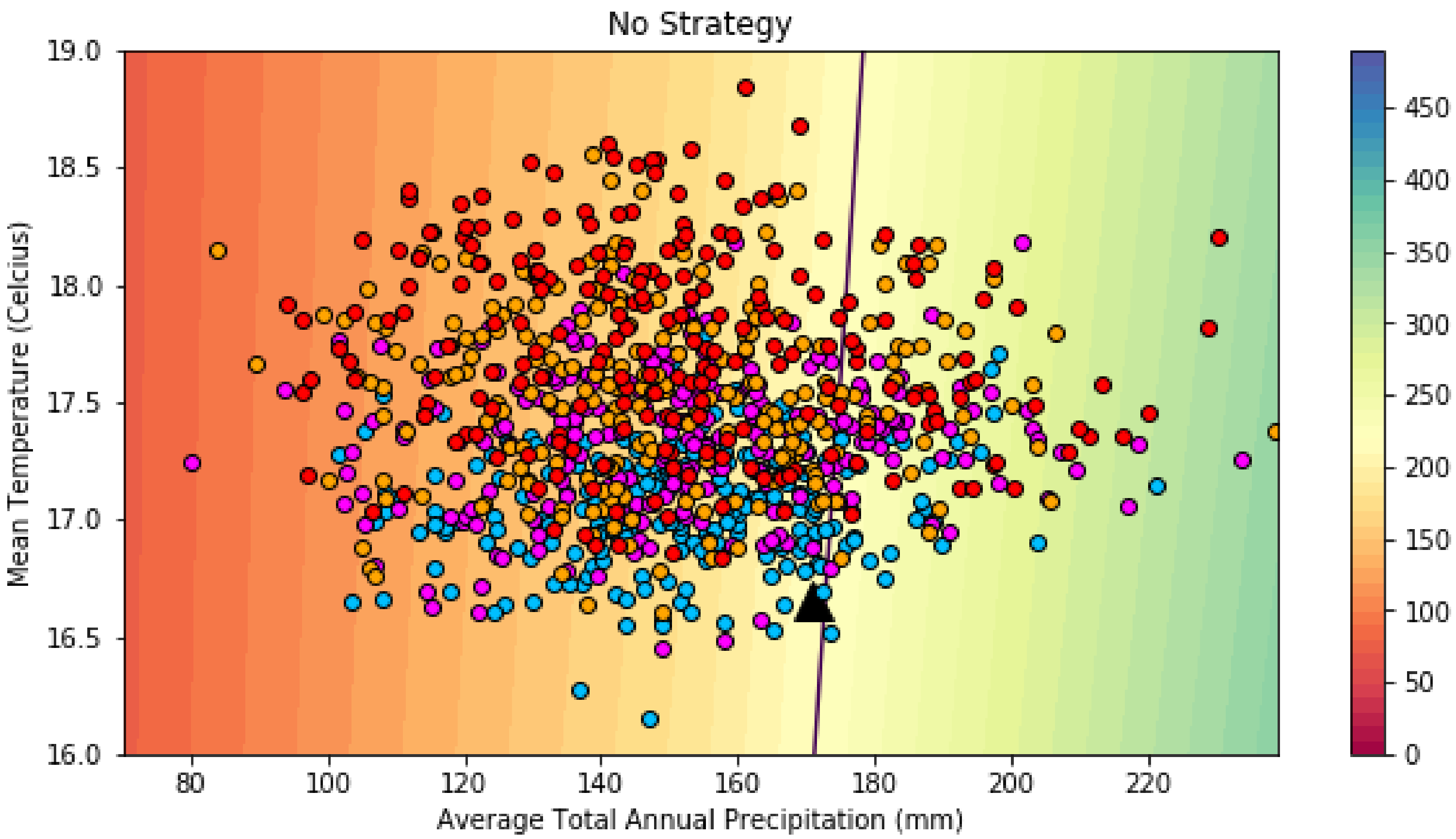


Online training course on CRIDA



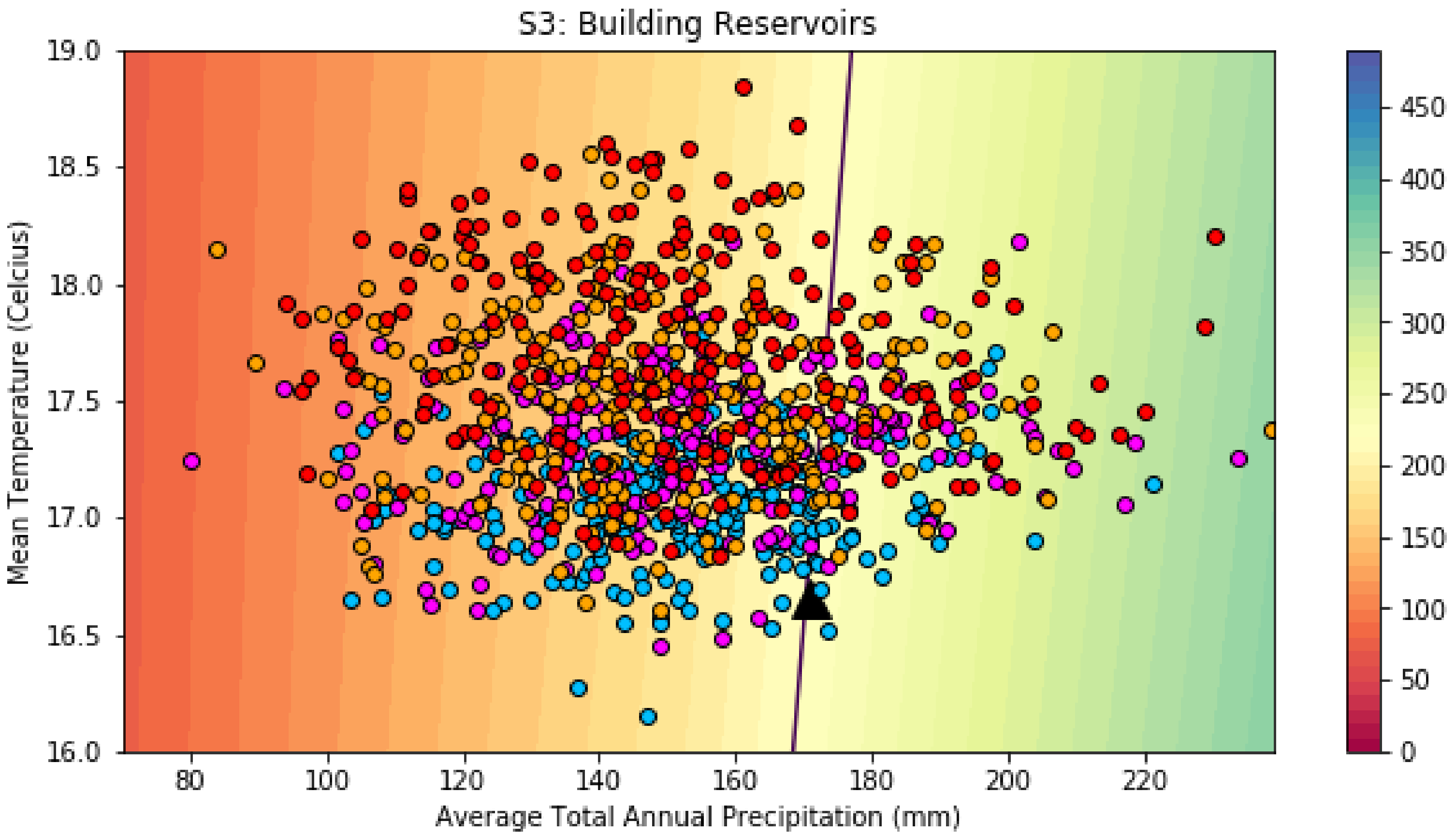
Step 3: Formulate Robust and Flexible Solutions

KPM1 : Total Annual Inflow to the La Paloma Reservoir



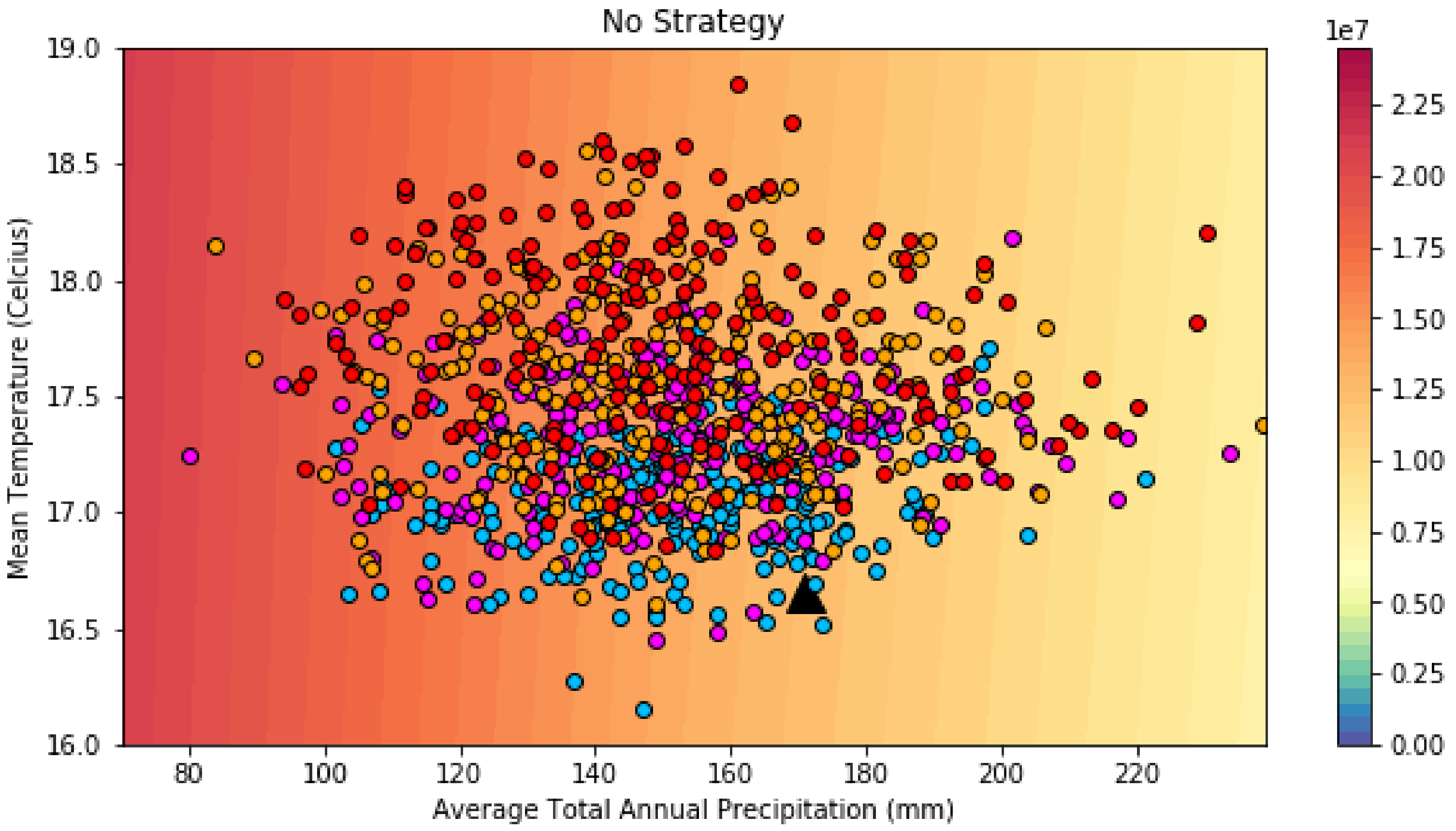
Step 3: Formulate Robust and Flexible Solutions

KPM1 : Total Annual Inflow to the La Paloma Reservoir



Step 3: Formulate Robust and Flexible Solutions

KPM2 : Average Annual Unmet Demand in the Grande Region



Step 3: Formulate Robust and Flexible Solutions

KPM2 : Average Annual Unmet Demand in the Grande Region