Sebastian Dodt
Sara Khoshhal
Karma Mroueh
Shantanu Samant

Drought in California

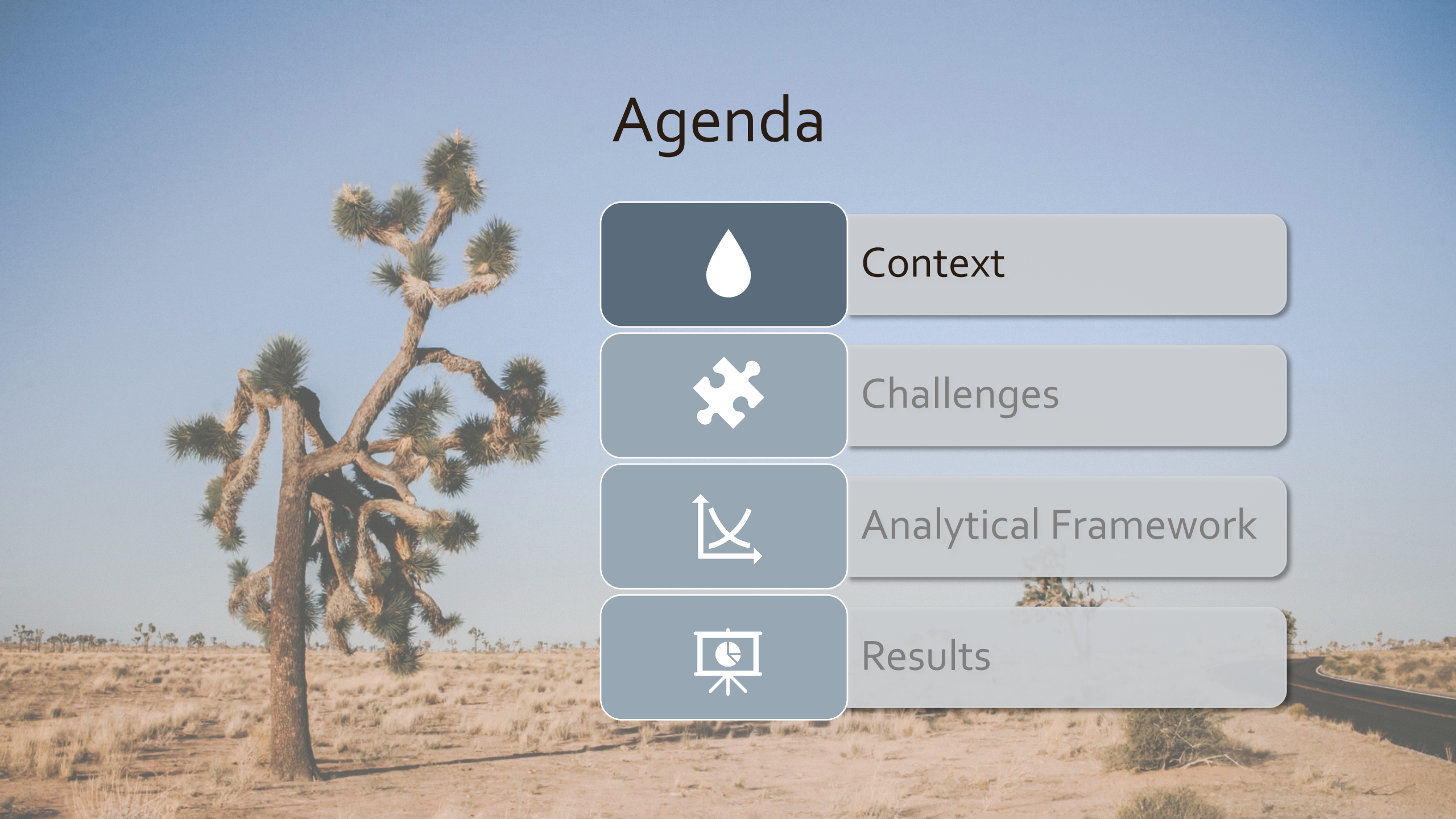
April 27, 2021

July 22, 2021

Agenda

- Context
- Challenges
- Analytical Framework
- Results

Agenda



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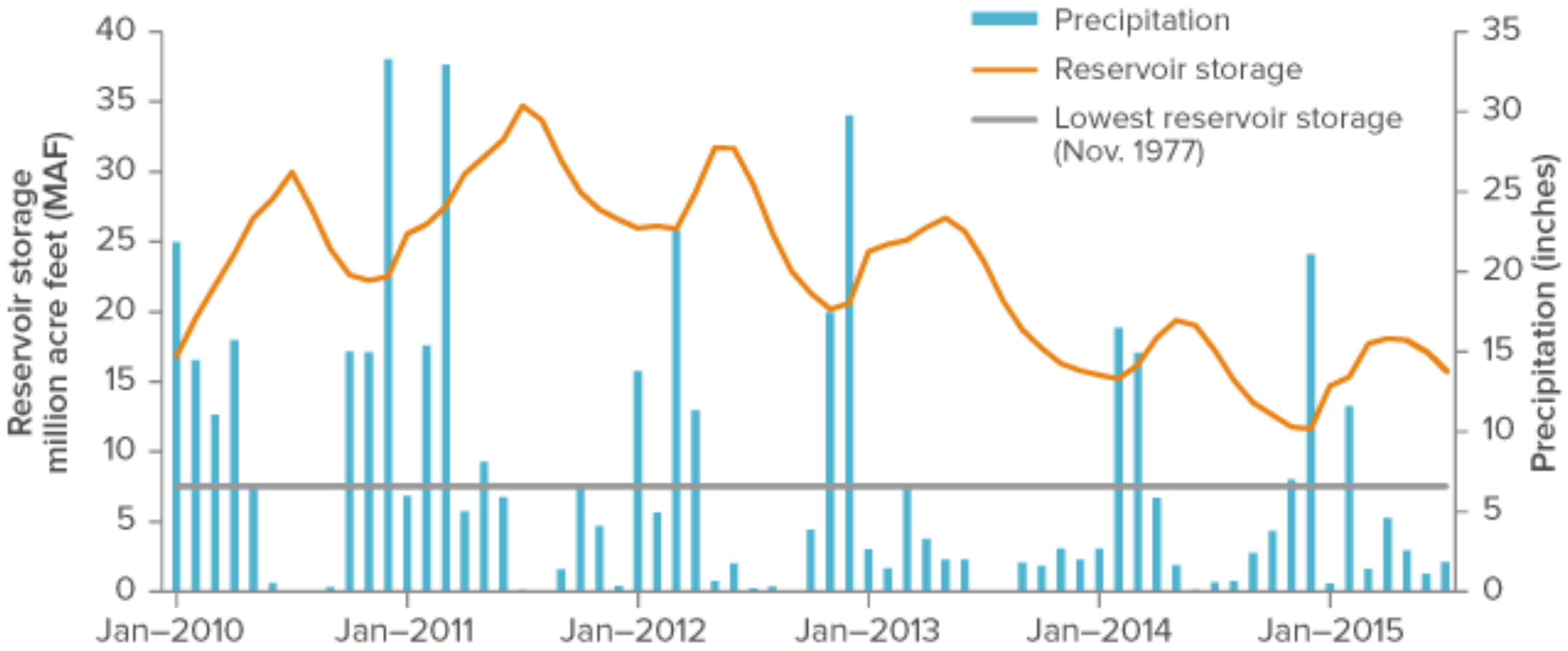
Inequality and the Drought in California

- Total direct and indirect costs of $1.7 billion
- Loss of over 14,000 jobs
- Water prices at an all-time high of $1,144.14 per acre-foot

As the drought persists, how can we mitigate its economic ramifications and equitably allocate scarce water supplies?

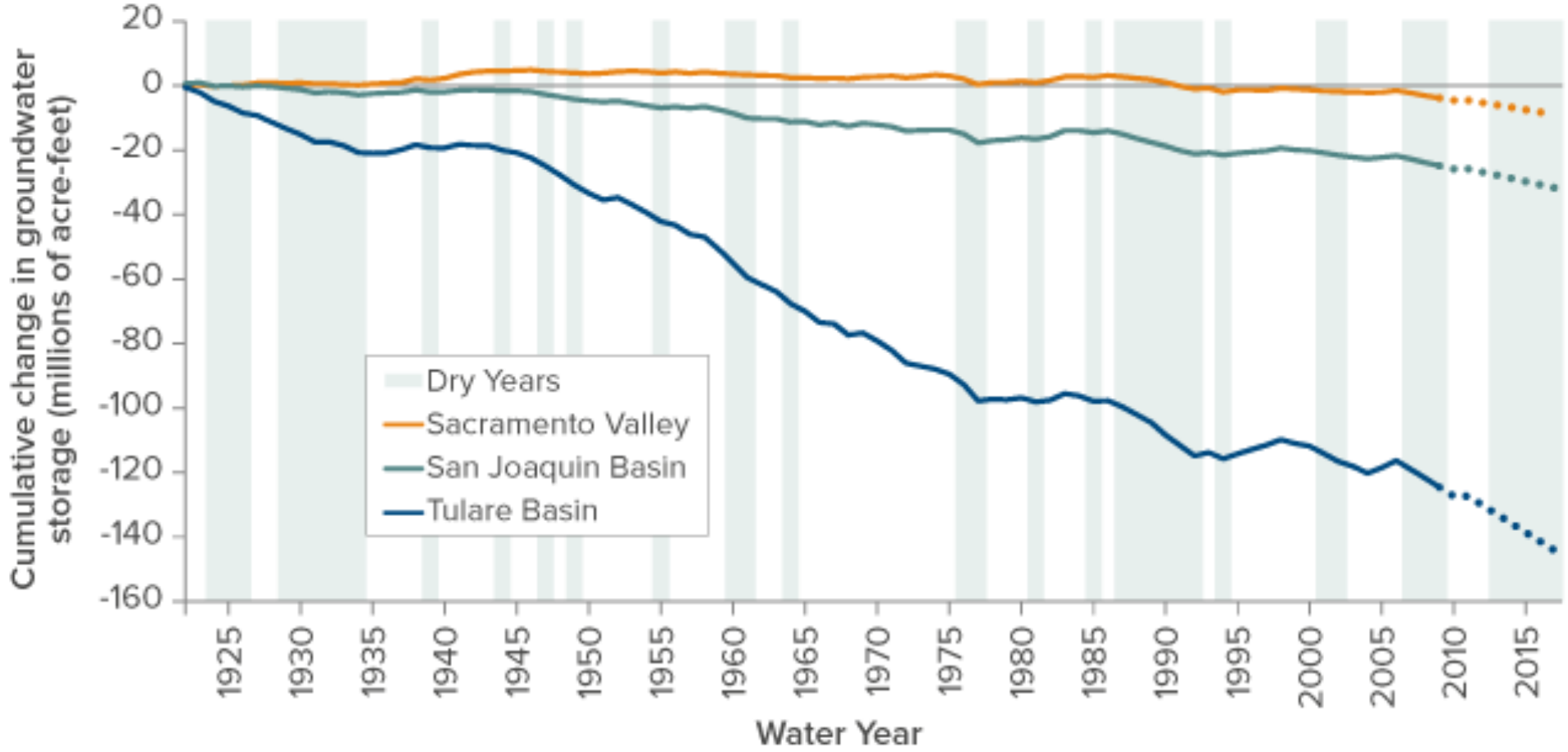
Source: Hanak, E., Mount, J., Chappelle, C., Lund, J., Melellin-Azuara, J., & Moyle, P. (2015). What If California's Drought Continues? Public Policy Institute of California.

Decrease in reservoir storage



Source: Hanak, E., Mount, J., Chappelle, C., Lund, J., Melellin-Azuara, J., & Moyle, P. (2015). What If California's Drought Continues? Public Policy Institute of California.

Decrease in groundwater storage



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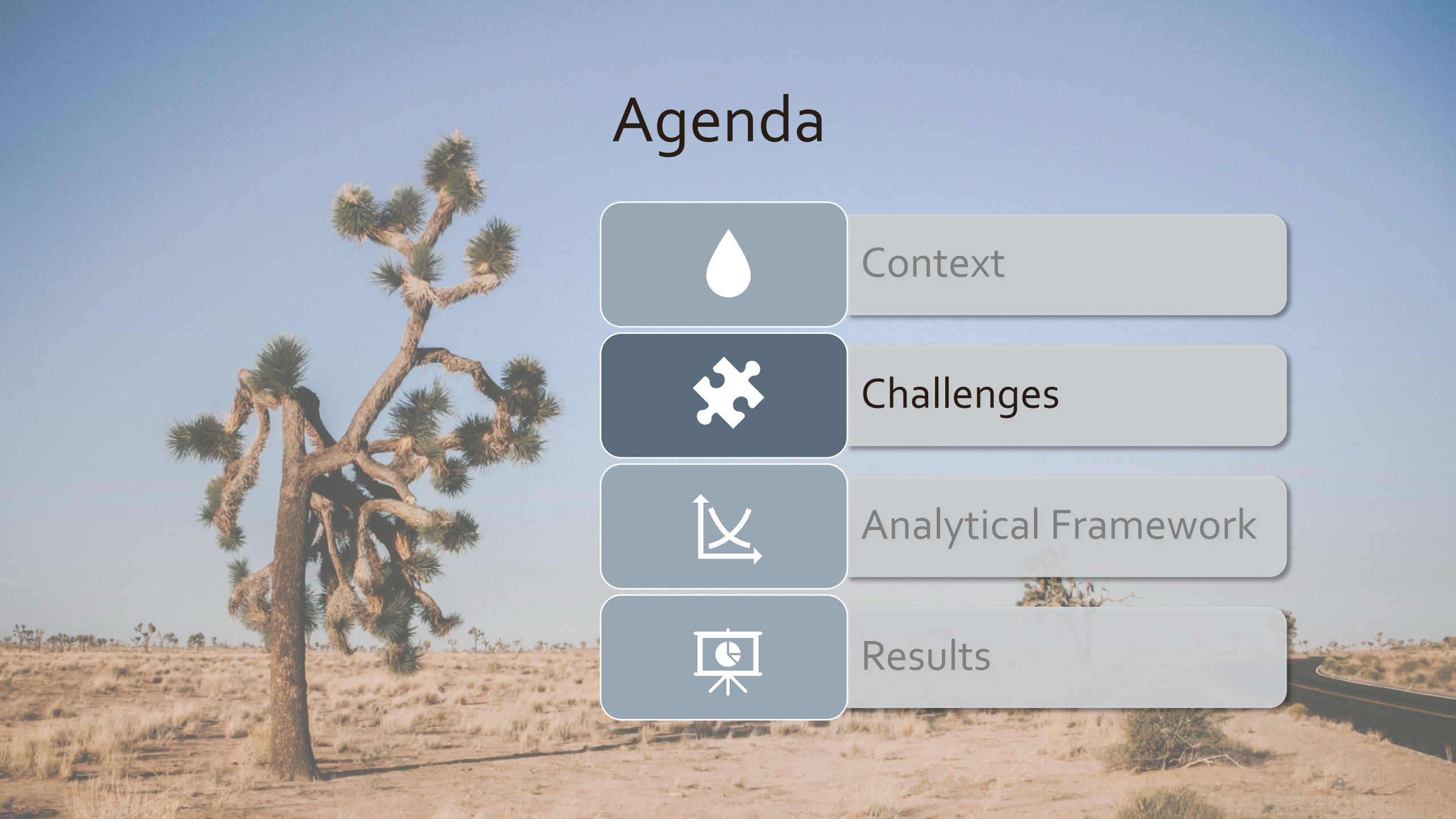
Our goal

Predict future water production

Simulate consumer demand

Determine best water price policy

Agenda



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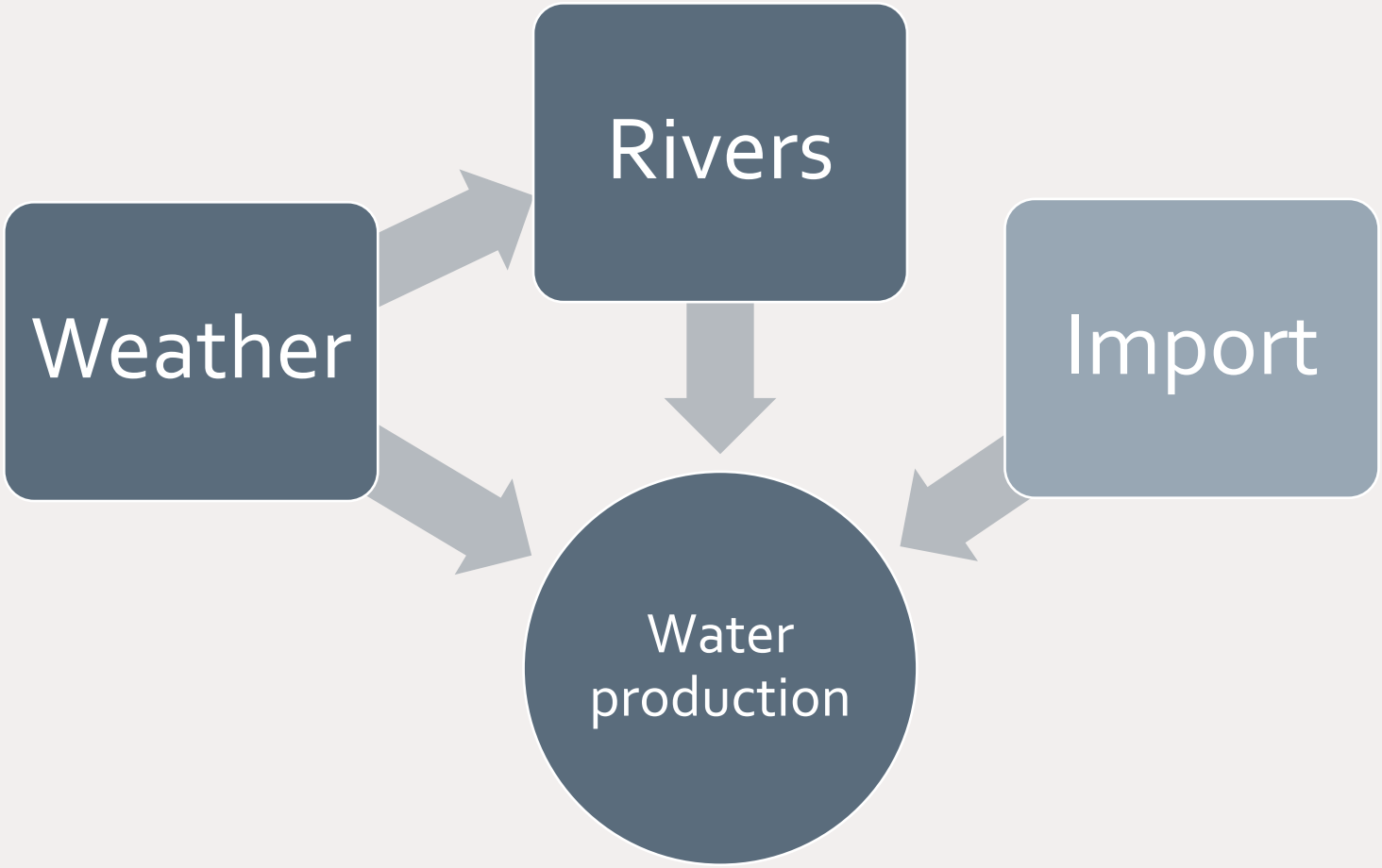
Analytical challenges

1. Understanding the causal relationships behind water production
2. Combining prediction with simulation

Image by Morgan Housal, Unsplash

Analytical challenges



Data challenges

1. Finding variables that predict water production
2. Obtaining and extracting data from weather services
3. Dealing with time-series data

Image by Morgan Housal, Unsplash

Policy challenges

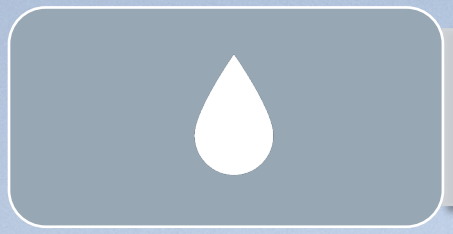
1. Defining set of possible policy responses

   → Focusing on price changes in a two-tier system

2. Mathematically formulating possible policies

Image by Morgan Housal, Unsplash

Agenda



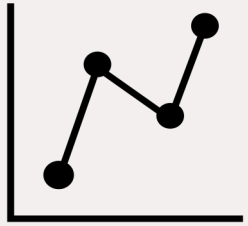
Context

Challenges

Analytical Framework

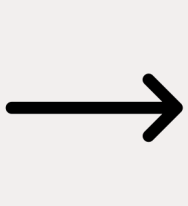
Results

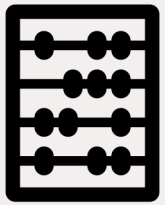
Pipeline



Predicting water production

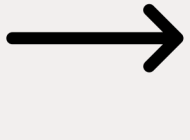
Machine Learning





Modelling consumptions and price levels

Historical data and behavior modelling

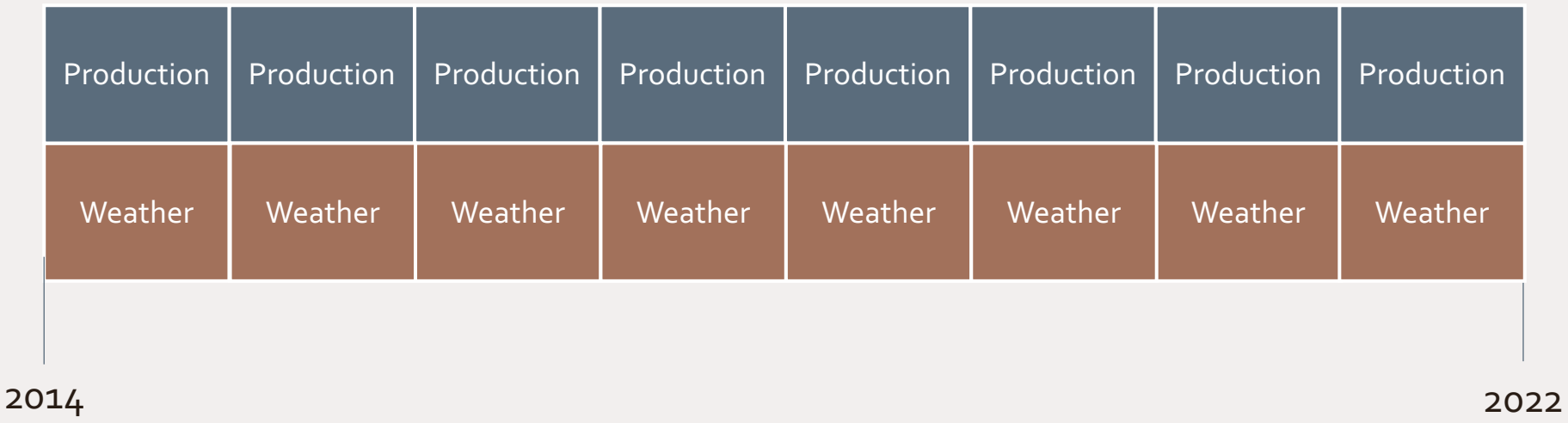


Simulating policy interventions

Simulation

Predicting water production

Predicting water production



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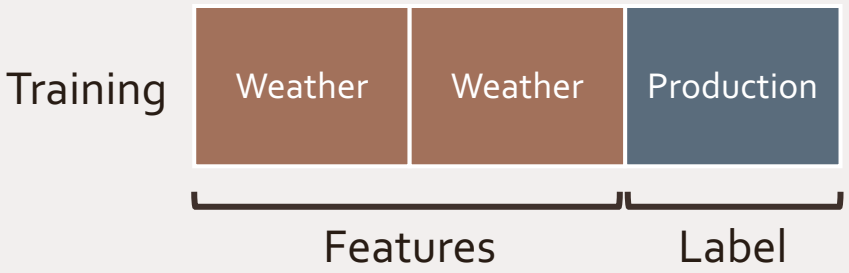

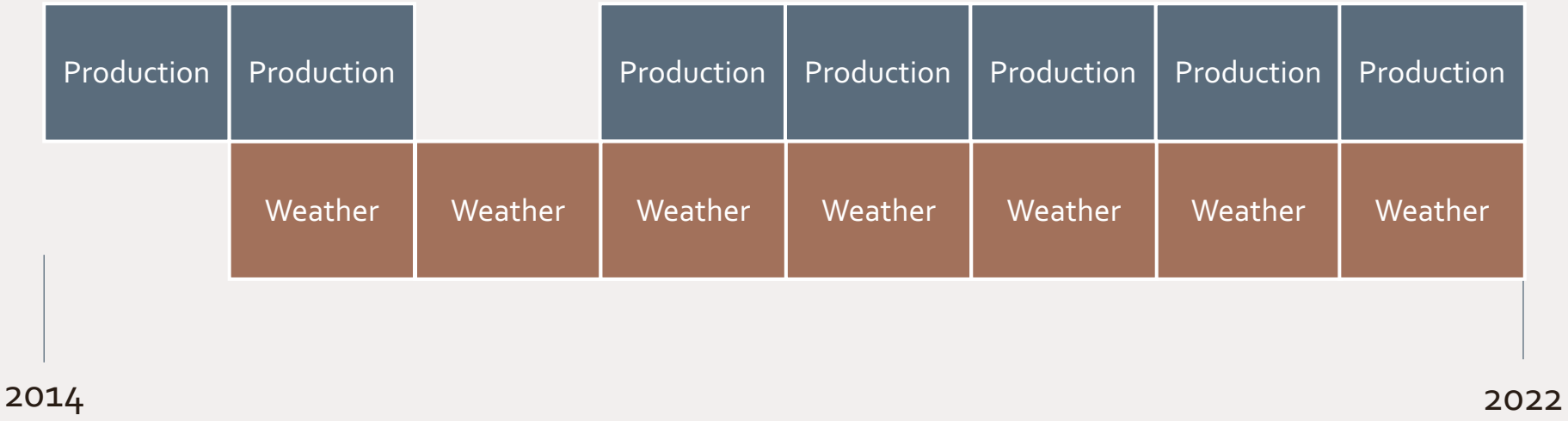

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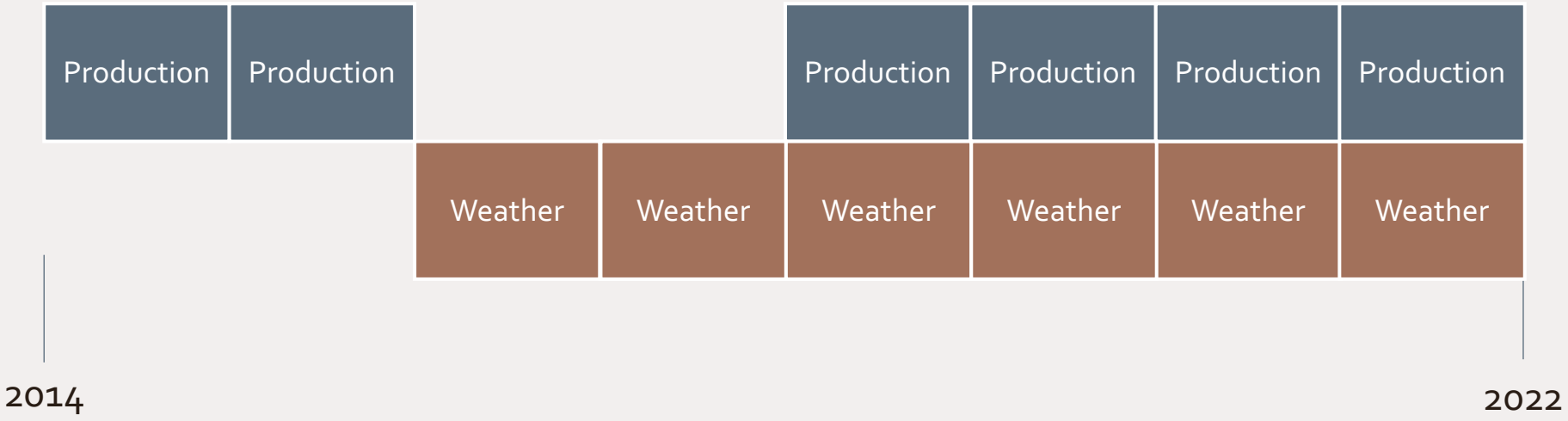

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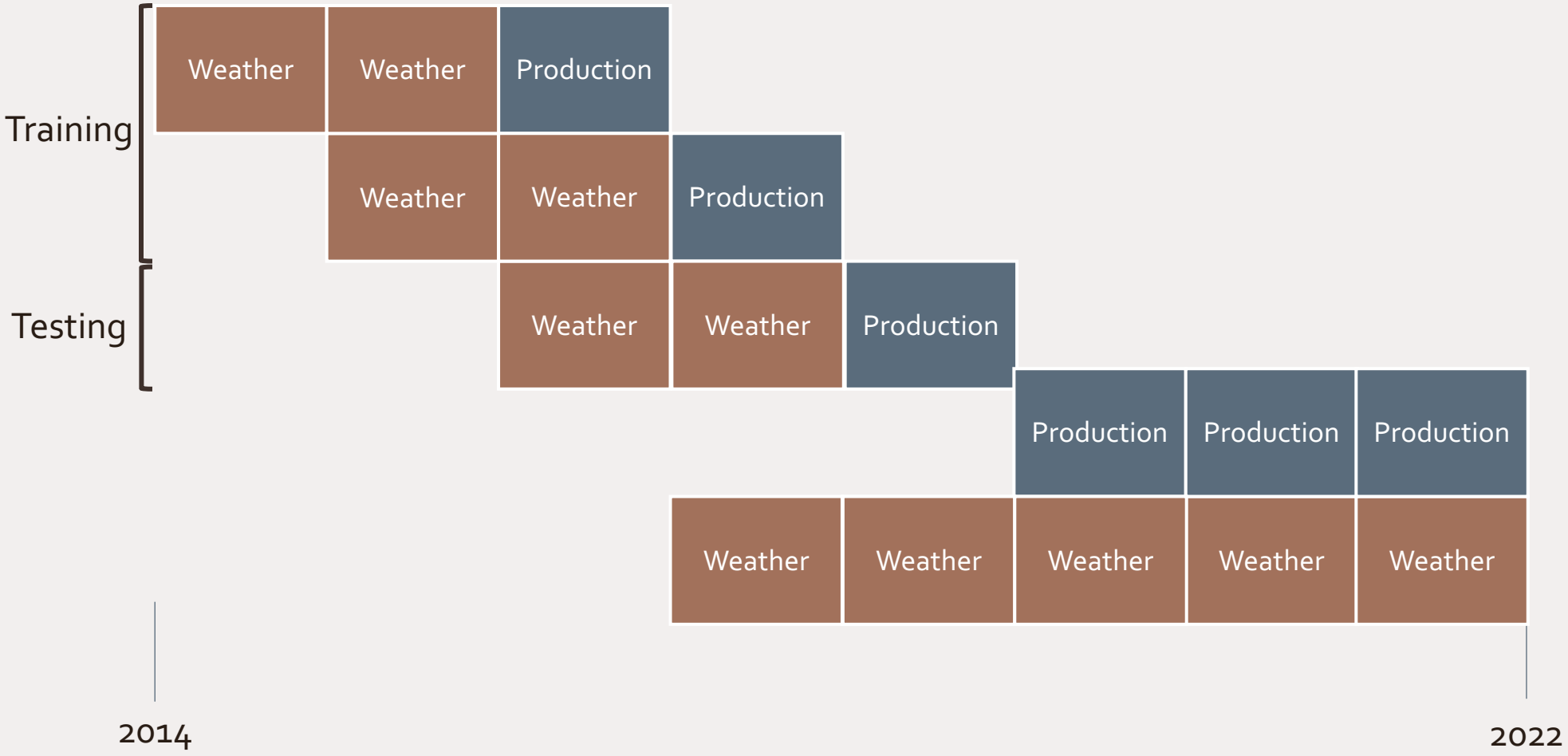

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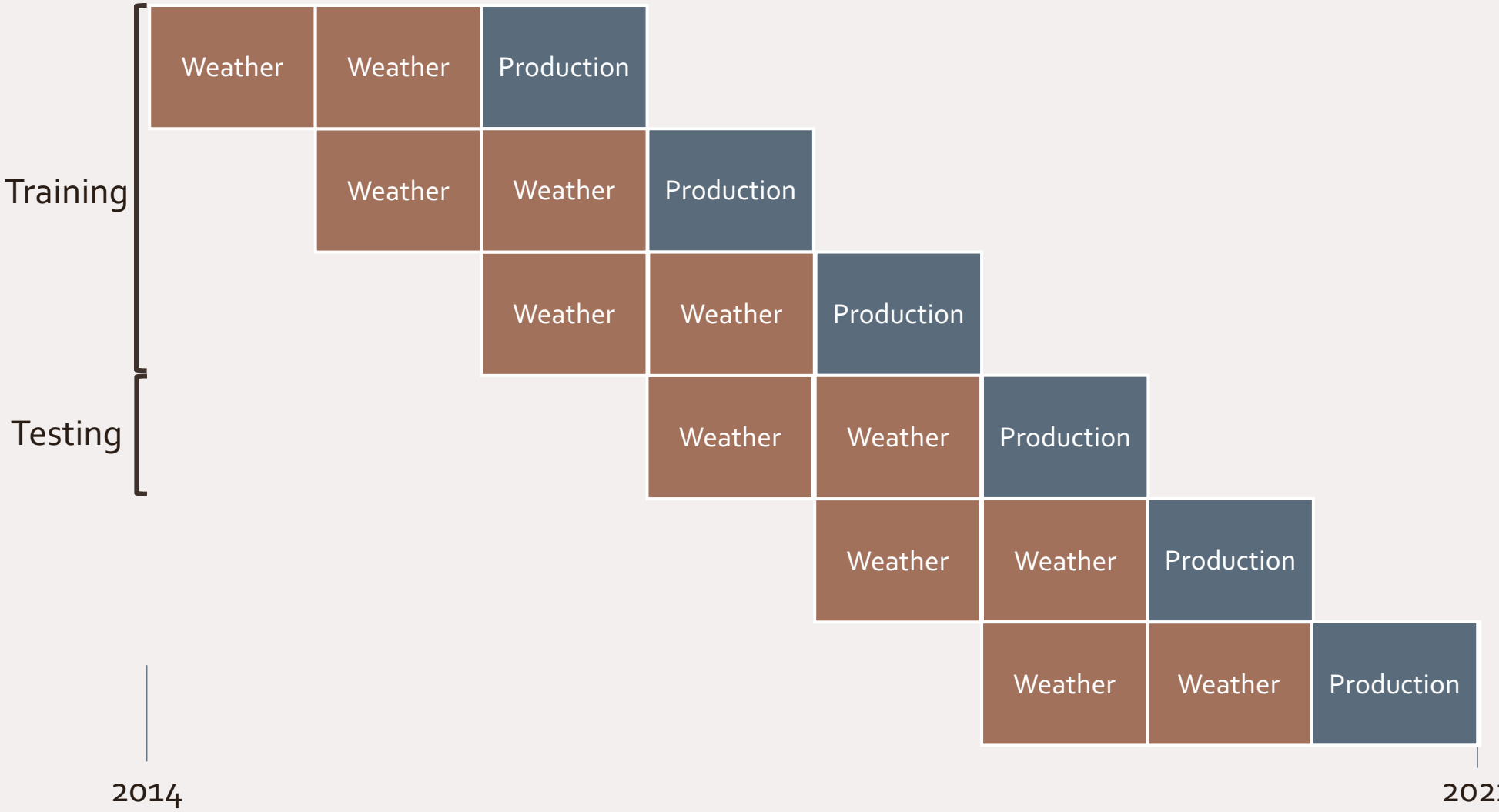

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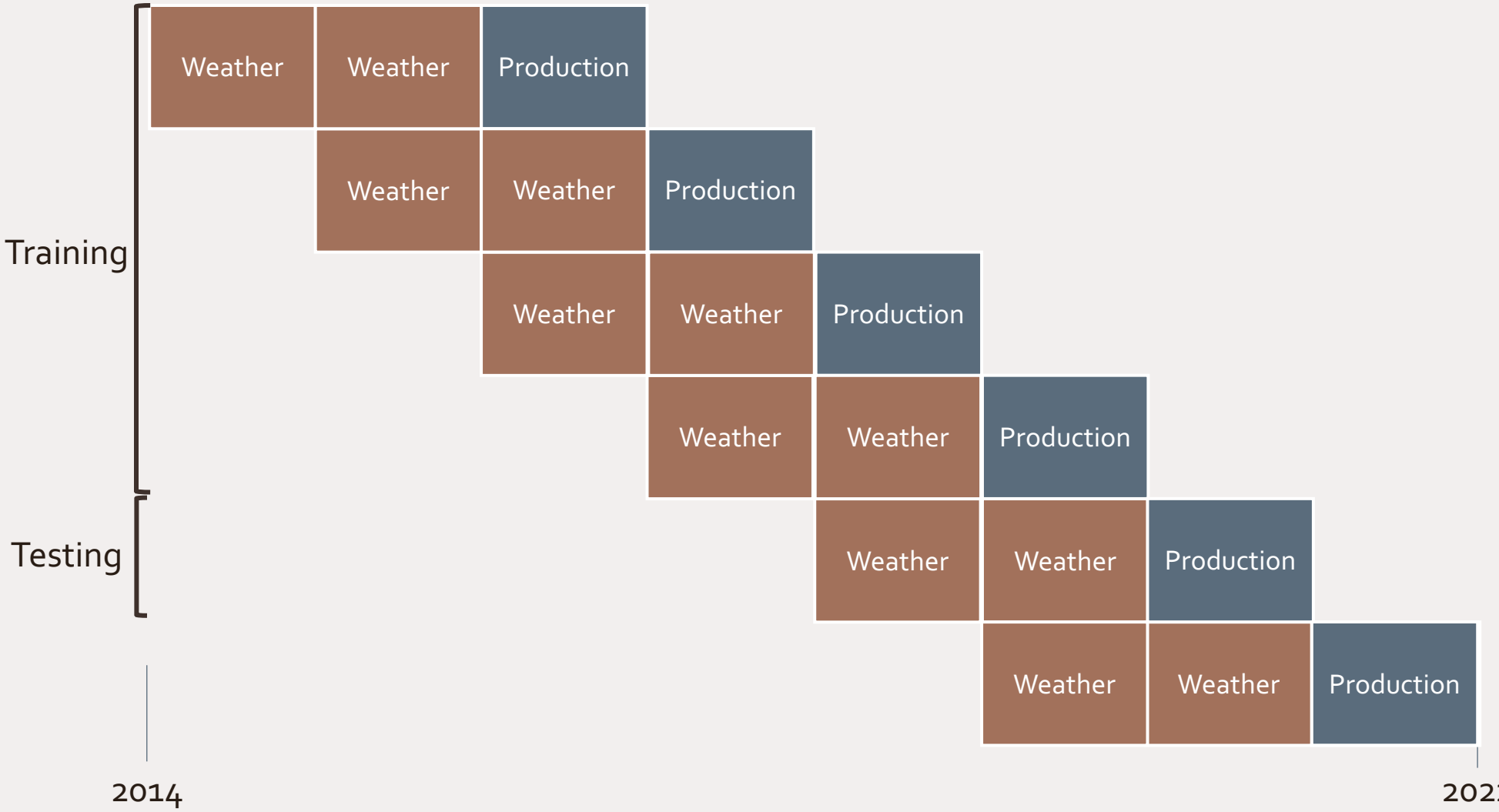

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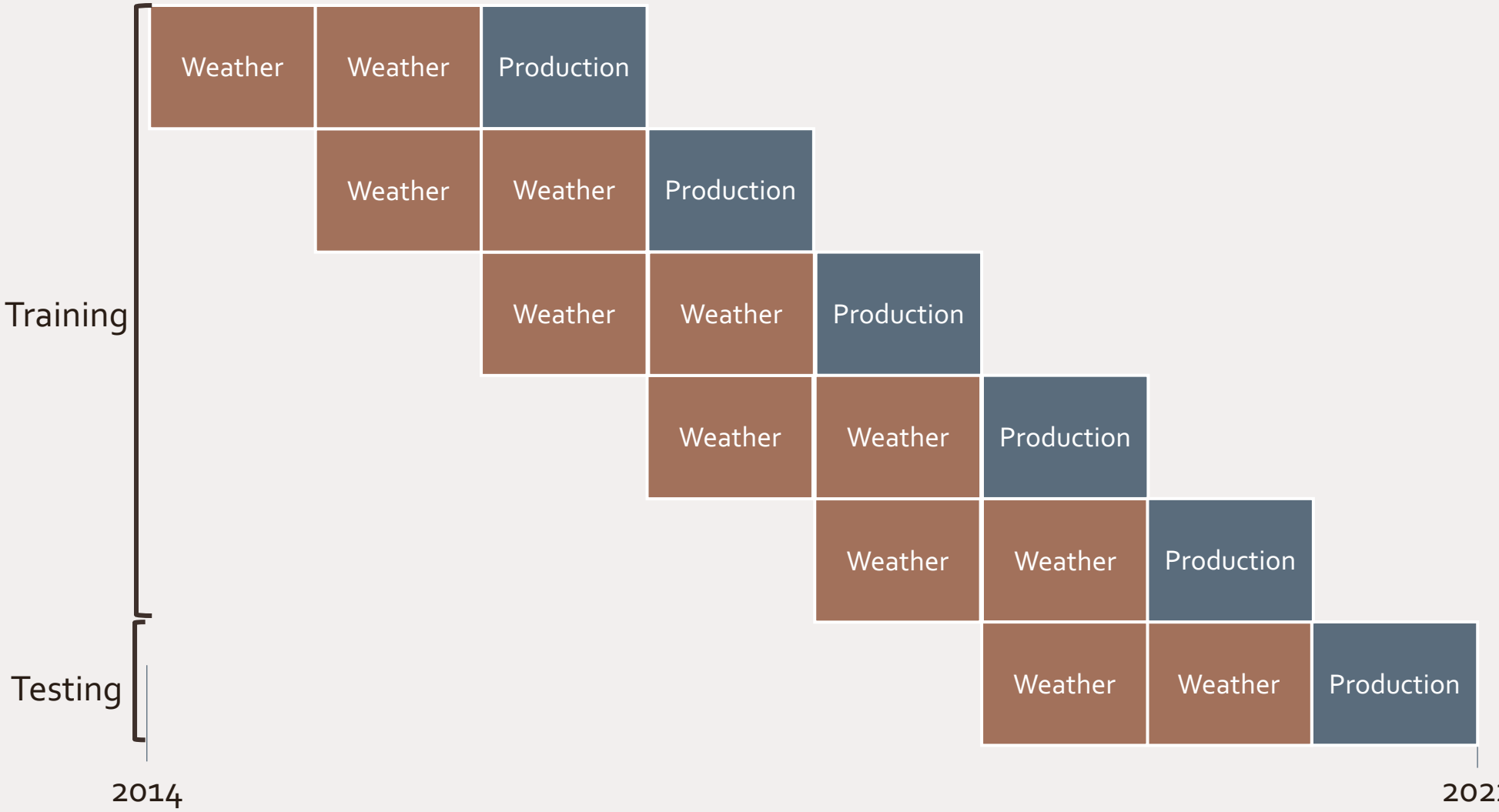

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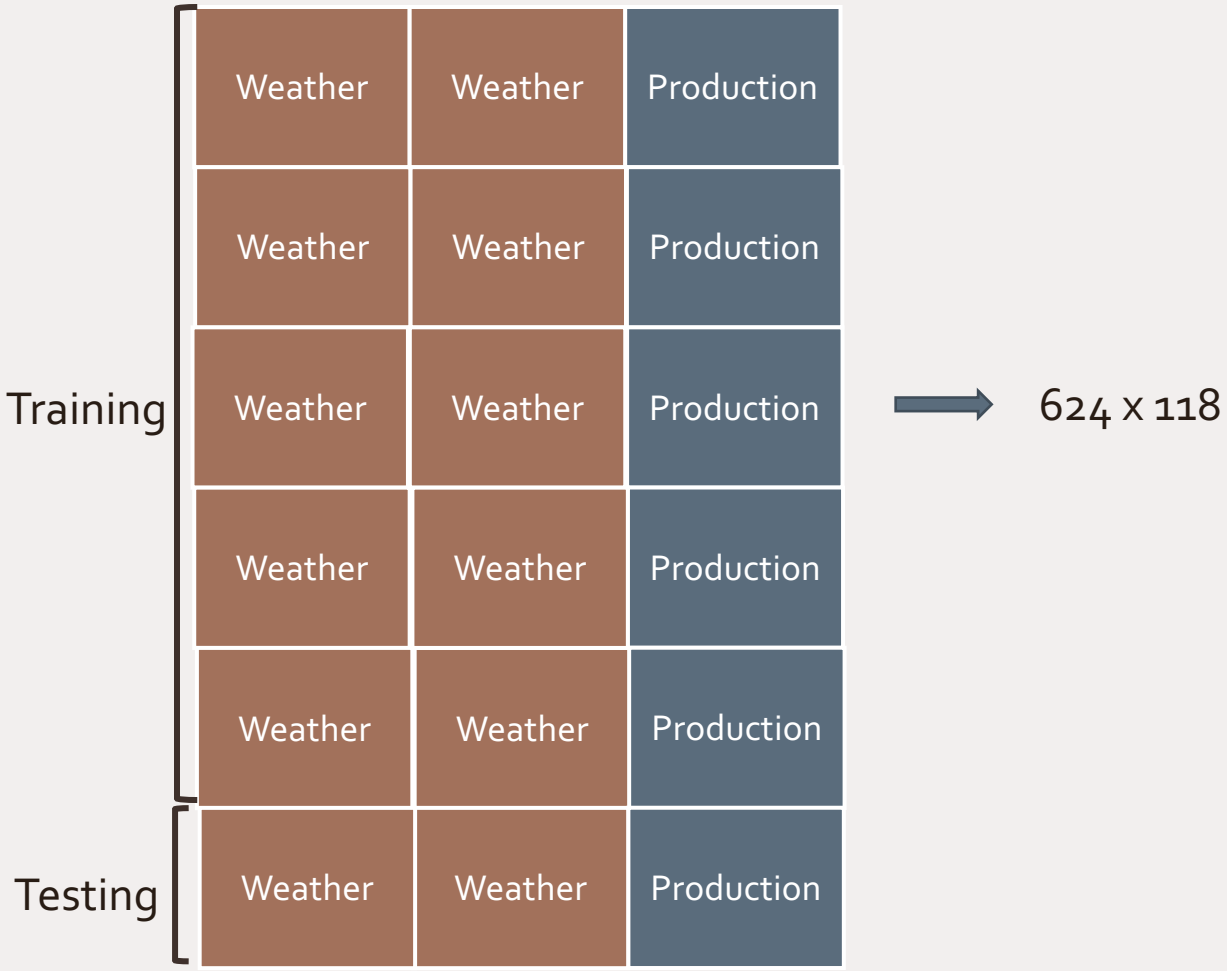

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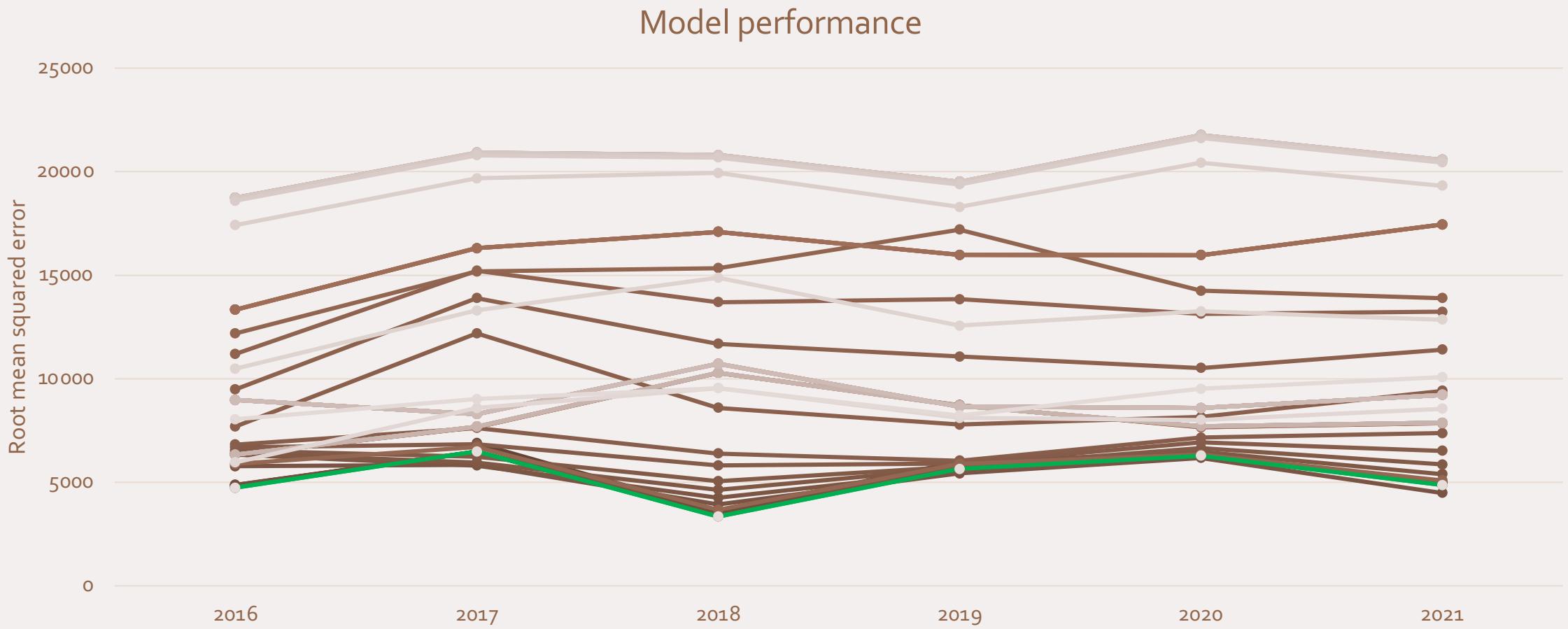

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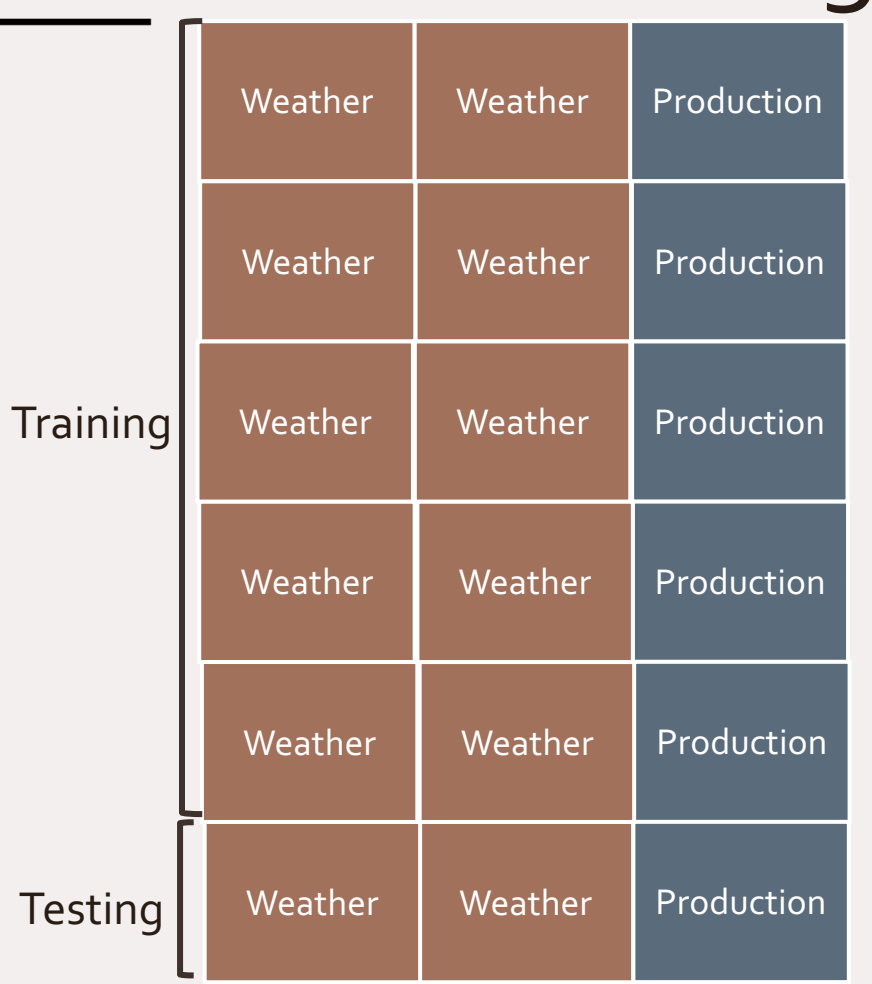
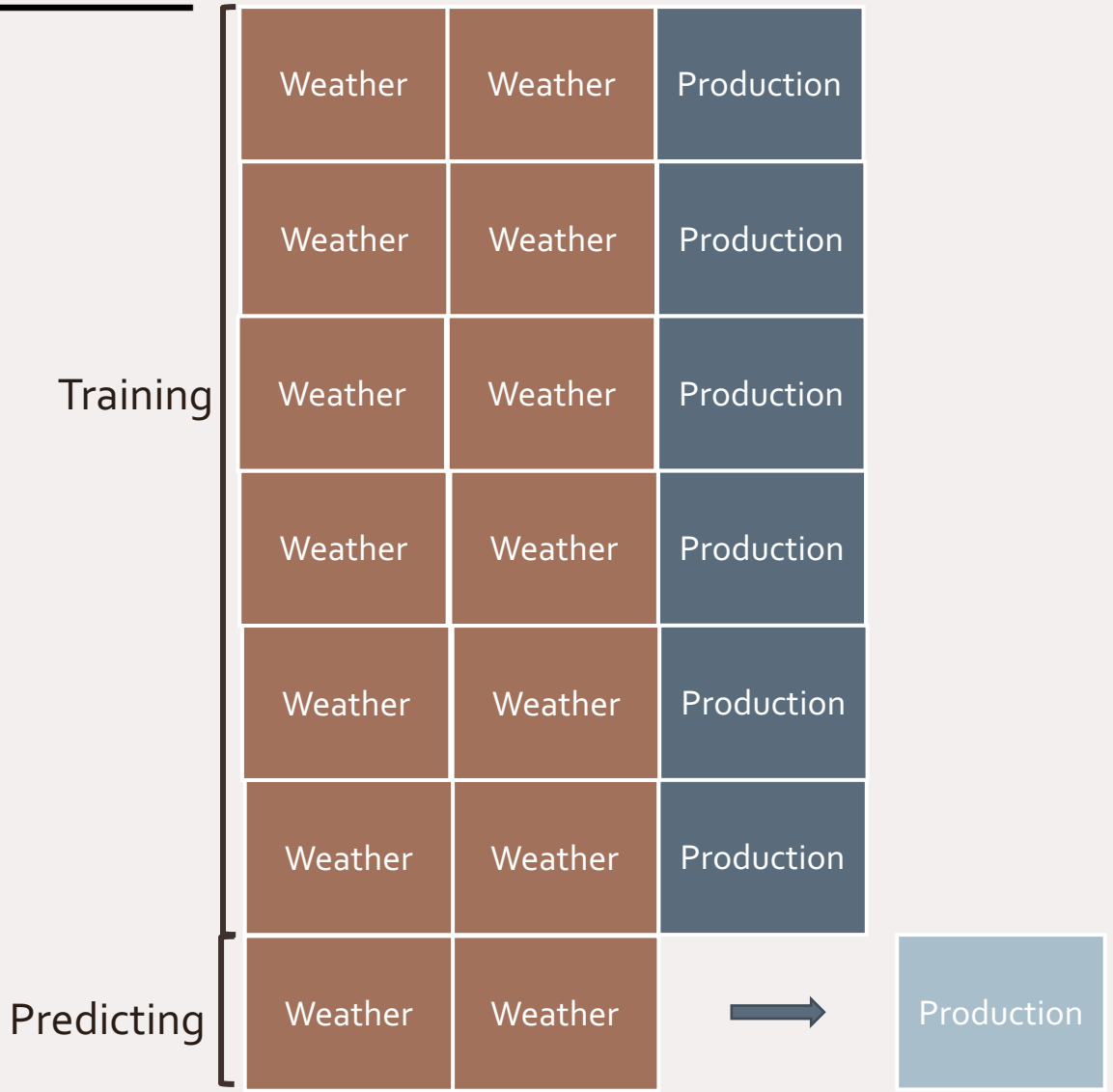


Best model:

Lasso (regularized regression), alpha = 1

Predicting water production



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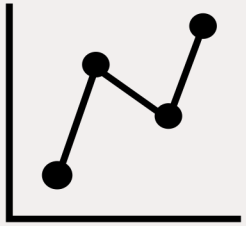
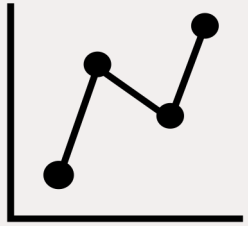


Predicting water production

Production = 45816.23
37276.80
52957.86
68582.92
83653.62
37606.94
58947.98
77416.53
33330.96
95174.87
59950.84
47003.18
87201.67
26546.84
43439.99
...
72873.59

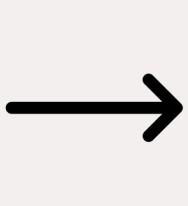
...gallons per person for 2023

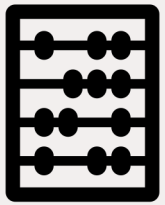
Pipeline



Predicting water production

Machine Learning





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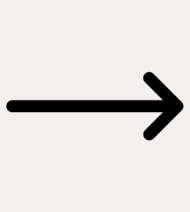
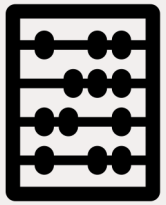


Simulating policy interventions

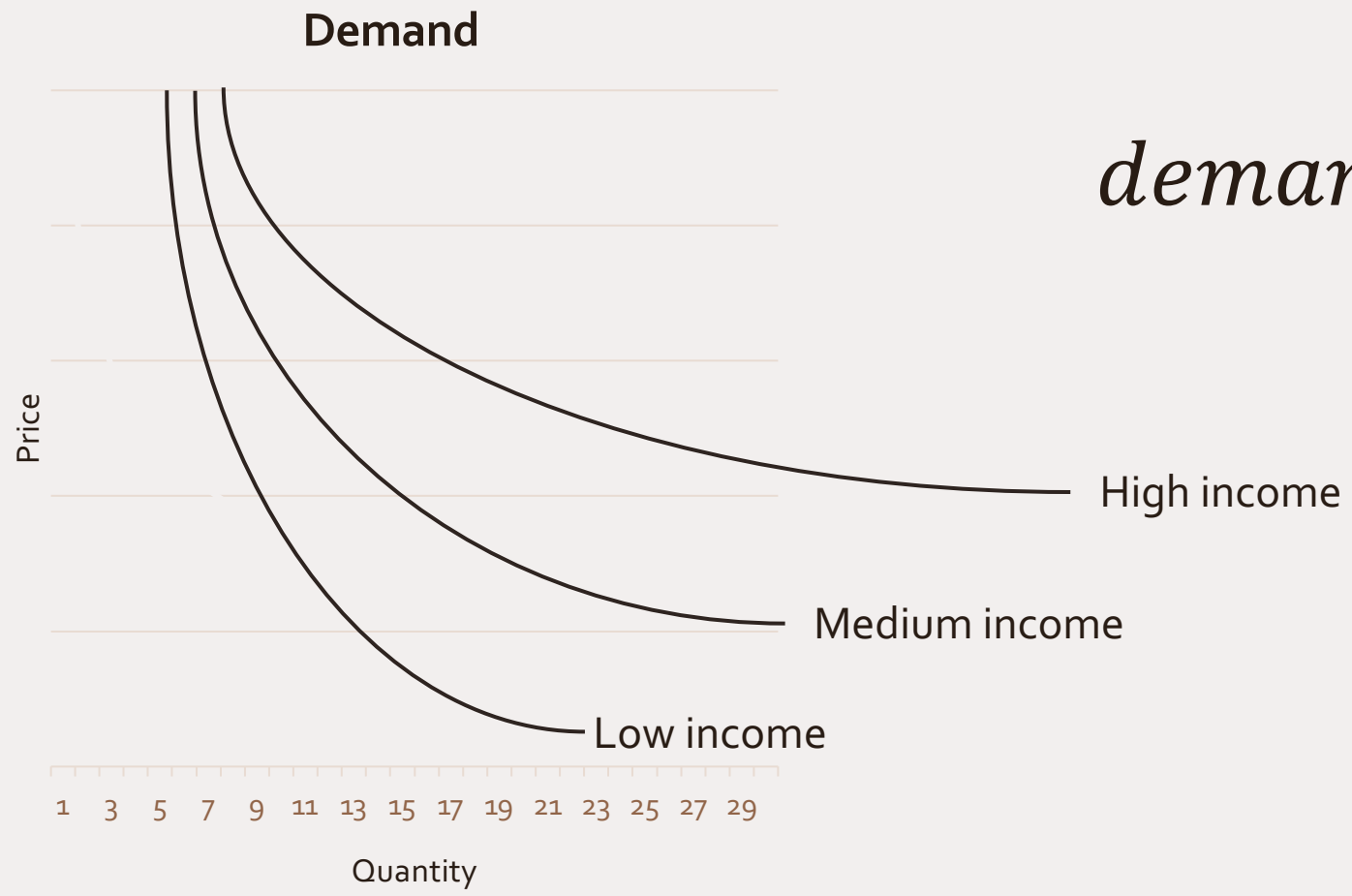
Simulation



Modeling demand

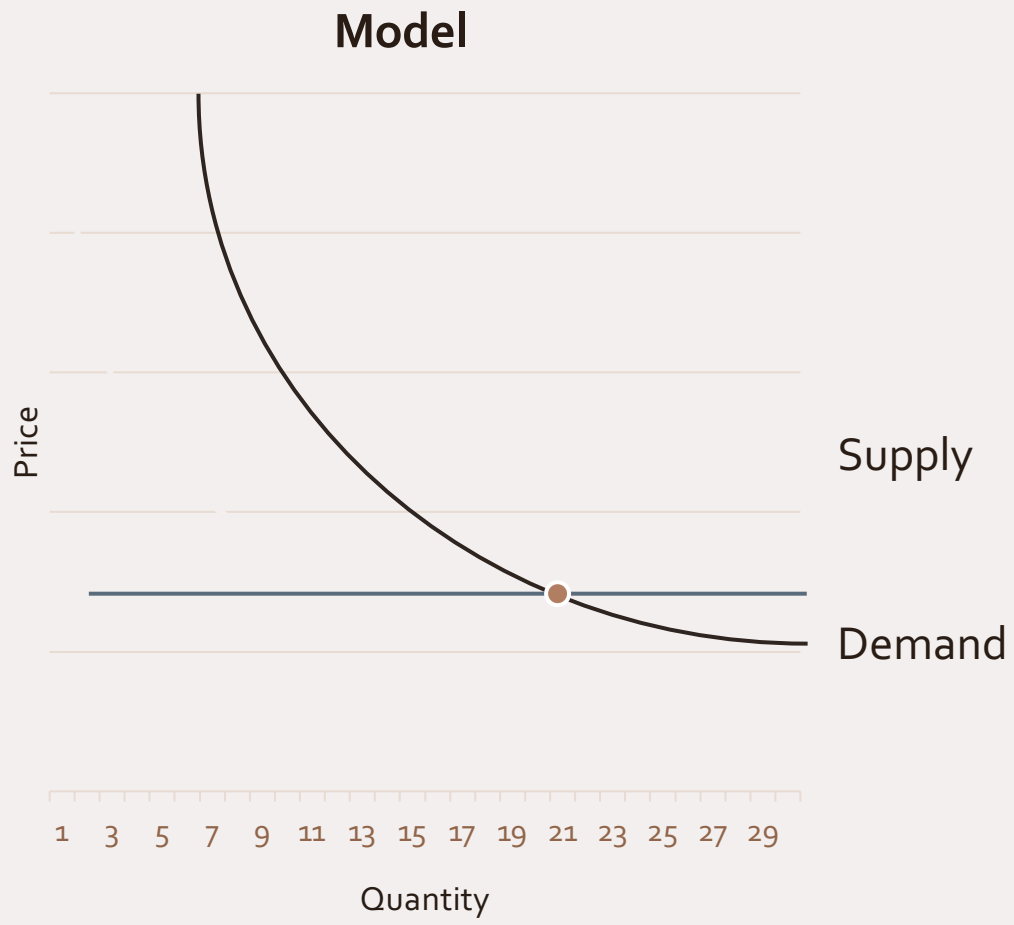
- Average demand elasticity = -0.435[1]
- Average use = 100 gallons per person per day[2]
- Average current expenses = $77 per month per household[3]
- Median income = $77,800[4] (on log-normal distribution)

Modeling demand



$$demand = q_1 * \left(\frac{price}{p_1}\right)^{\varepsilon}$$

Modeling demand



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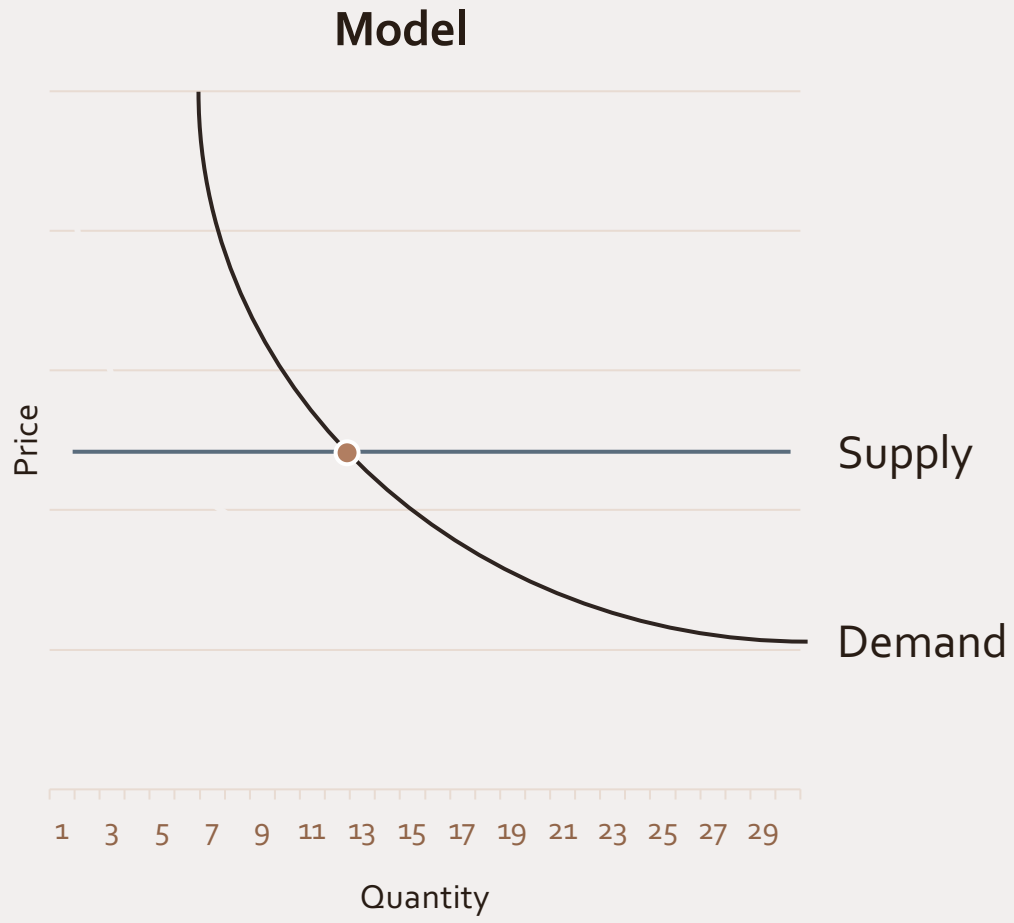

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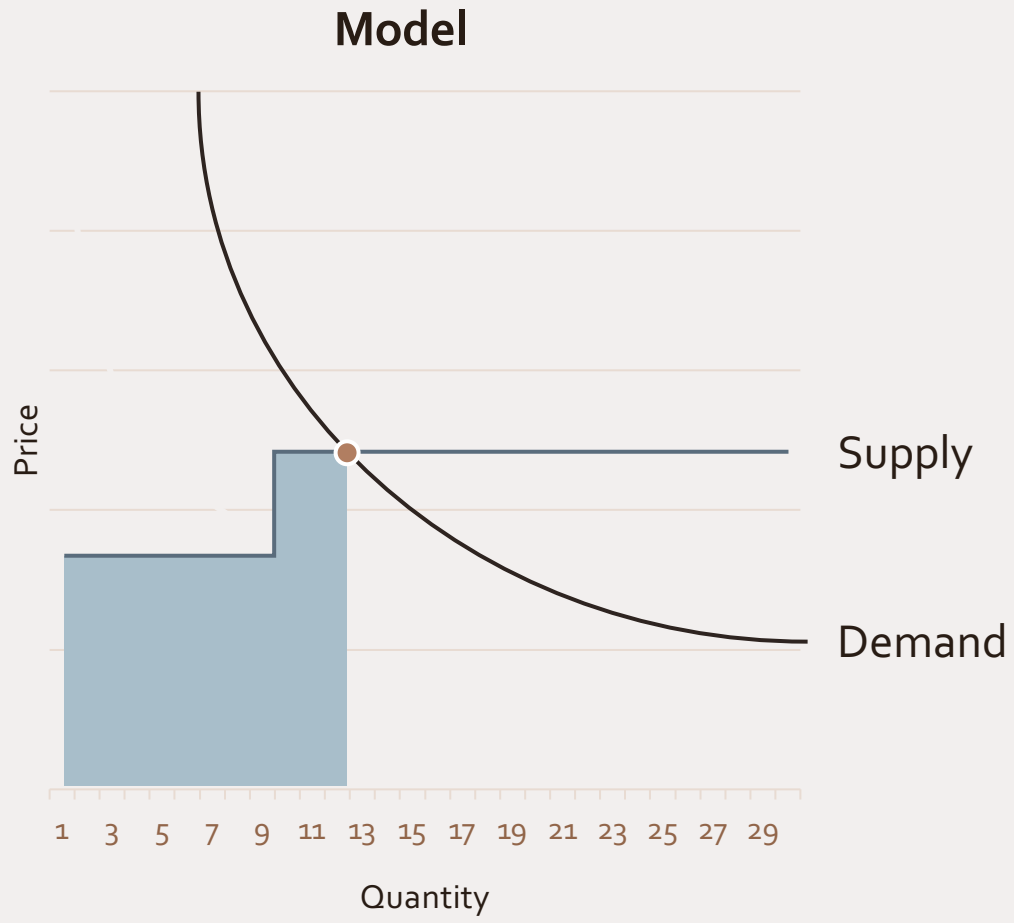

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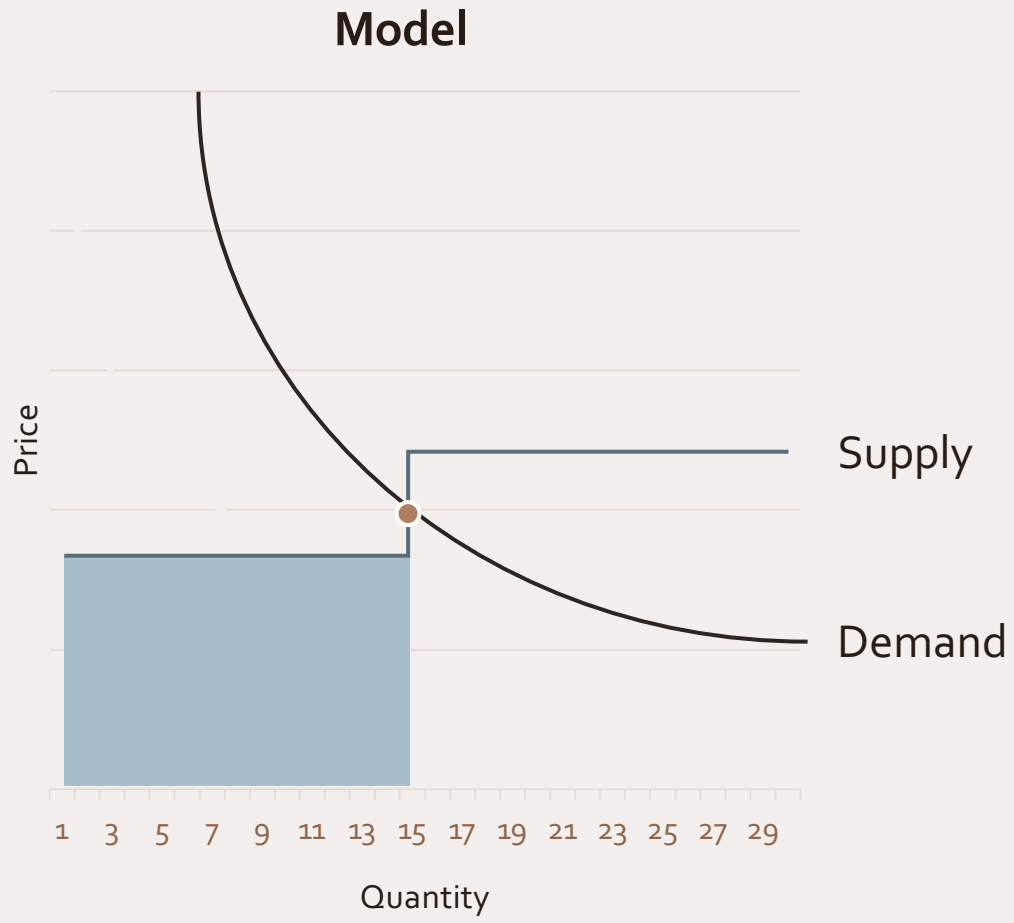

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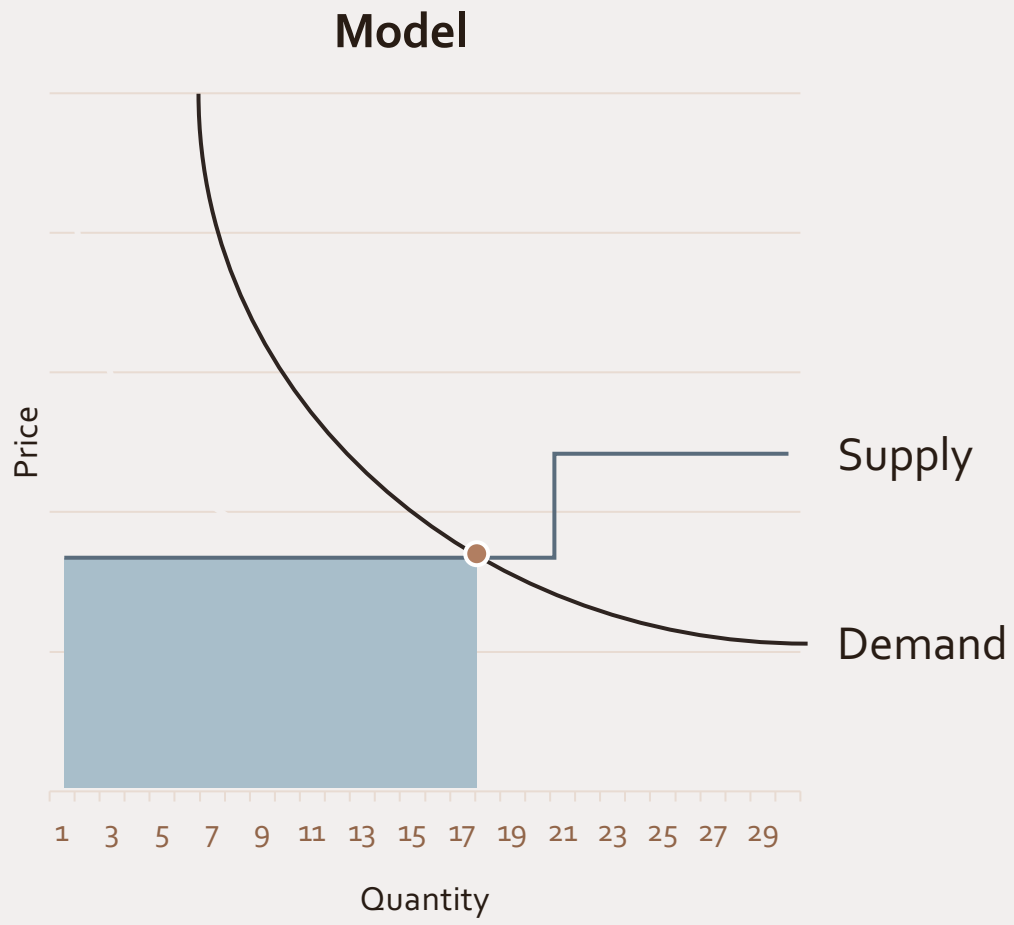
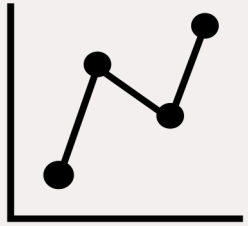
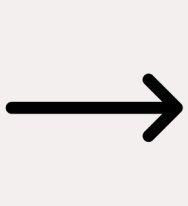


Pipeline



Predicting water production

Machine Learning



Modelling consumptions and price levels

Historical data and behavior modelling

Simulating policy interventions

Simulation

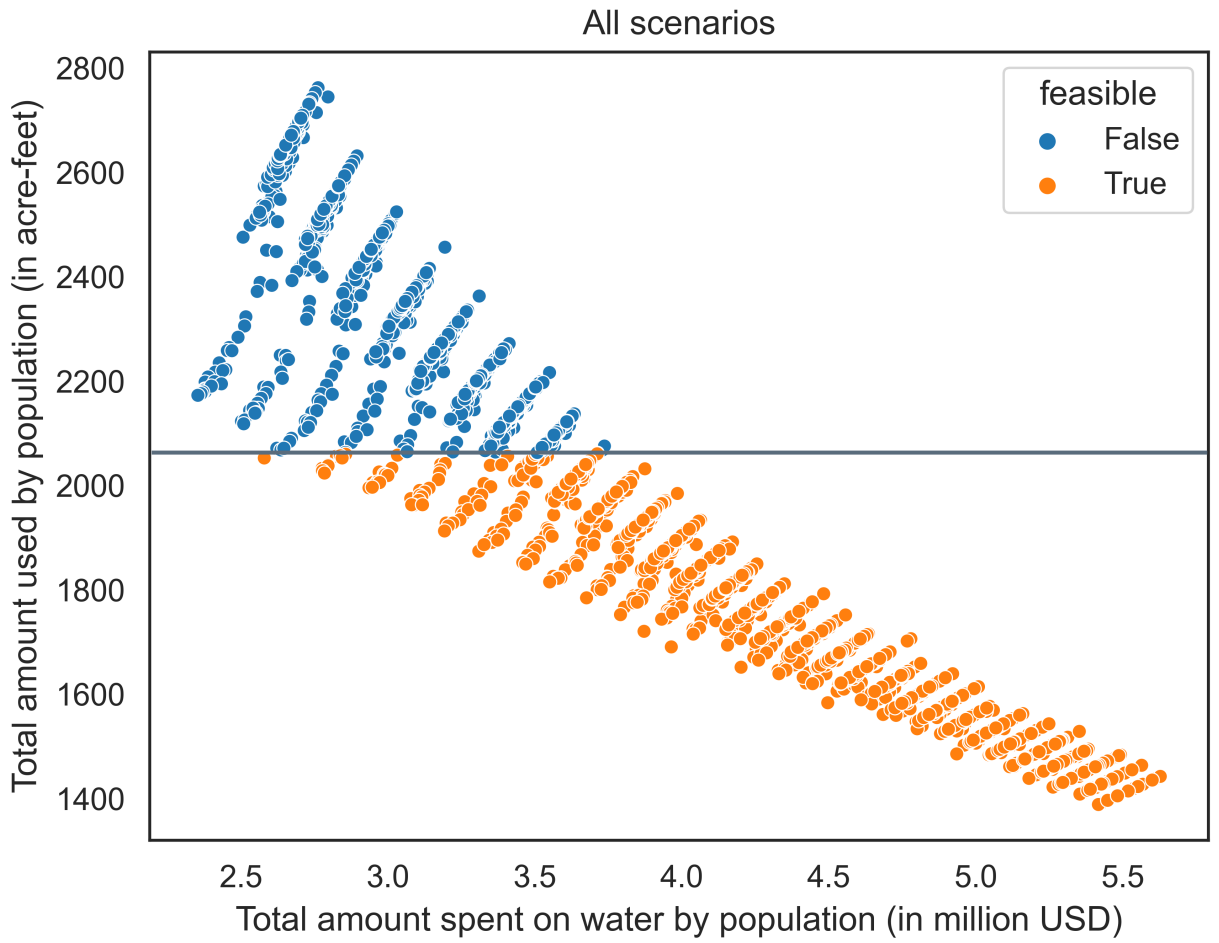
Simulation

- Simulating a fictitious town of 20,000 people
- All households have 4 persons
- Income distribution is equal to California's income distribution

Our demand curve revisited

Our model generates ~18,000 different scenarios by varying…

- Lower price
- Higher price
- Threshold between prices



How to find the right price?

Economy

A policymaker must consider the overall cost to the economy

higher water prices
→ reduce growth

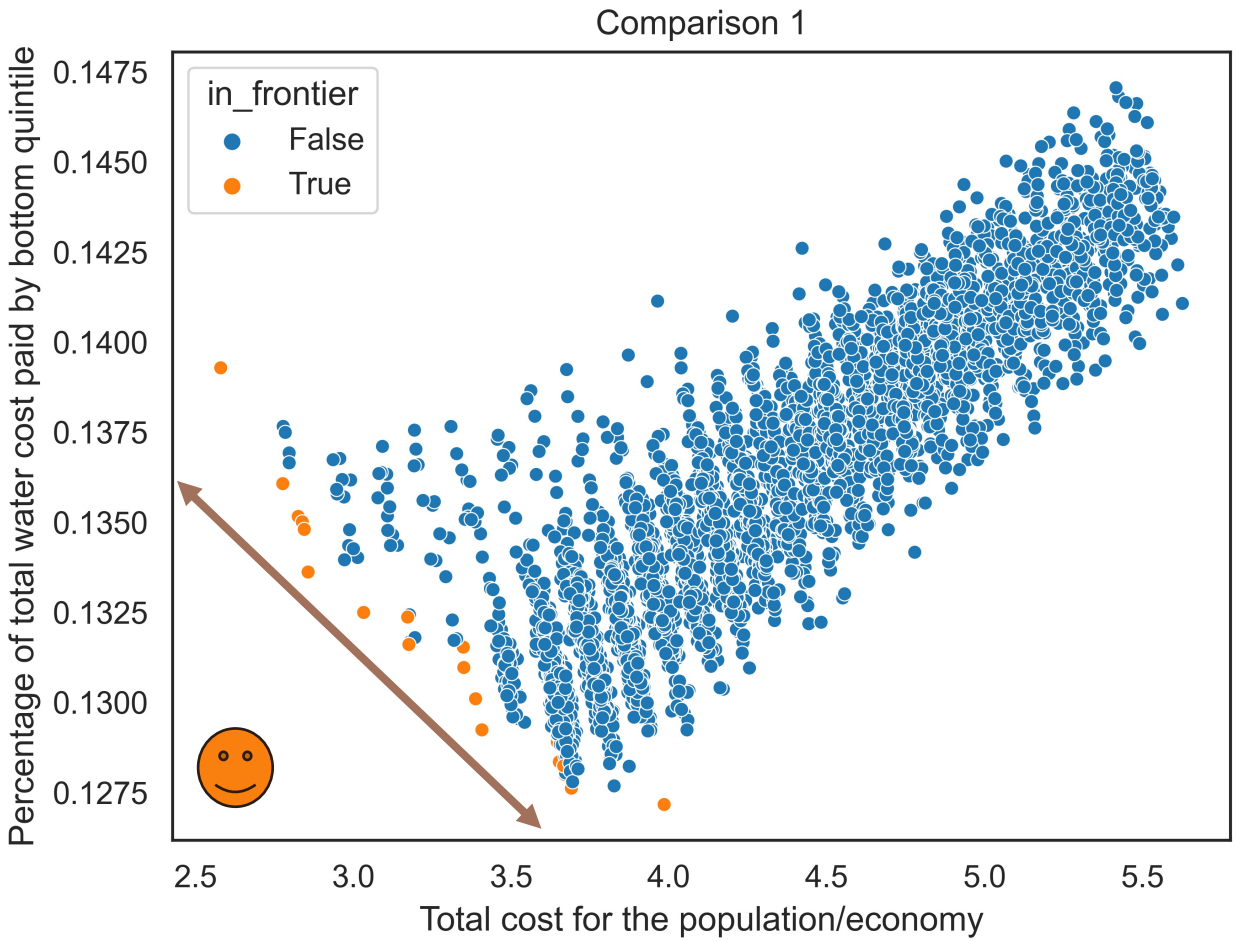
Equity

A policymaker also must make sure that the poorest in society still have access to affordable water

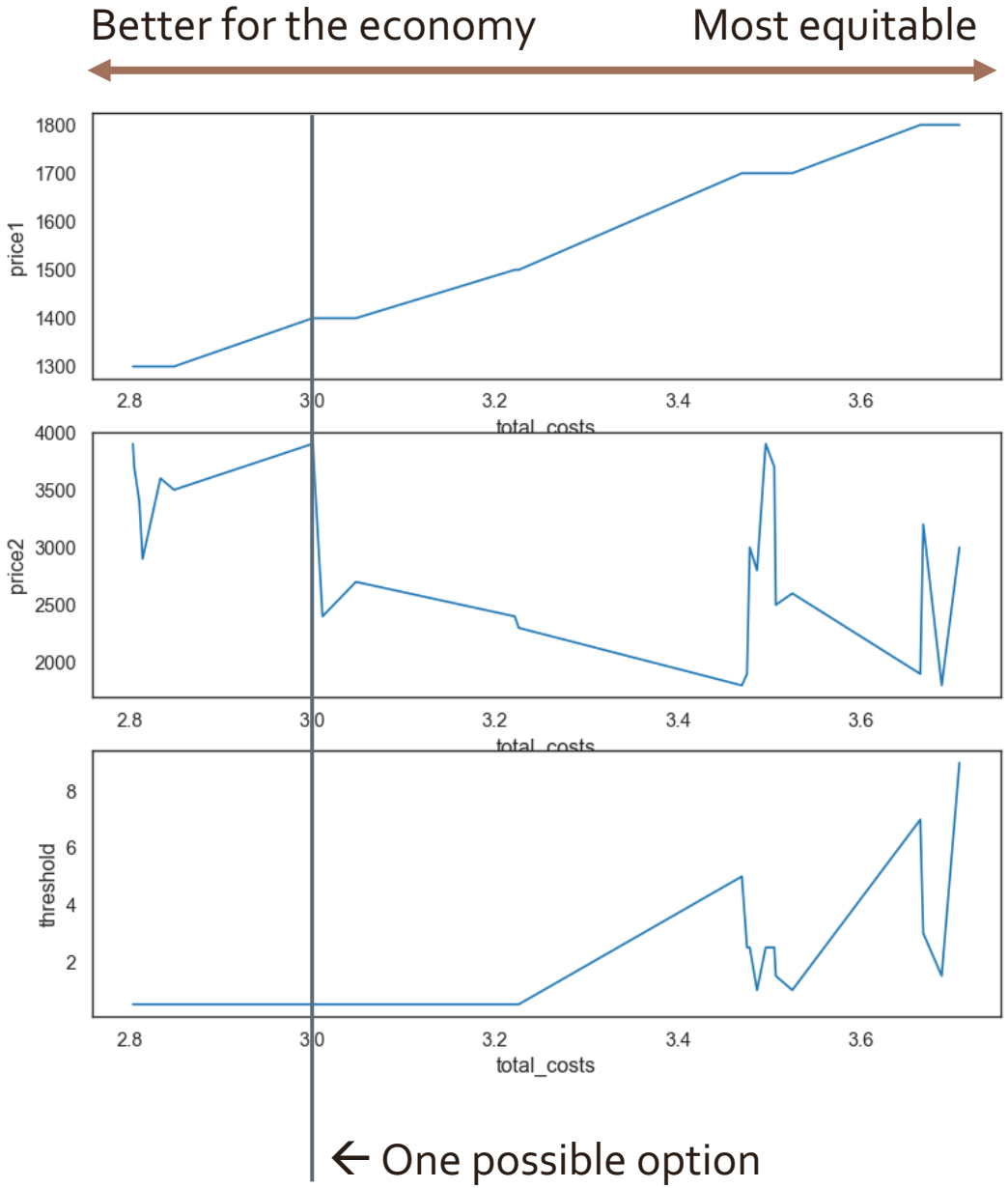
Equity can be defined in many ways

- Percentage of overall water expenses paid by poorest quintile
- Proportion of water used by poorest quintile (ideally 20%)
- Percentage of avg. water price of poorest compared to richest quintile

Economy vs. Equity



The options on the efficient frontier



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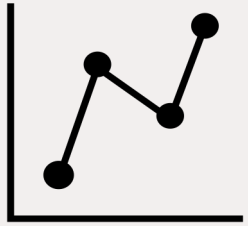

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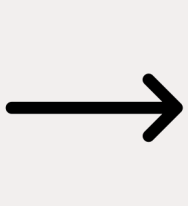

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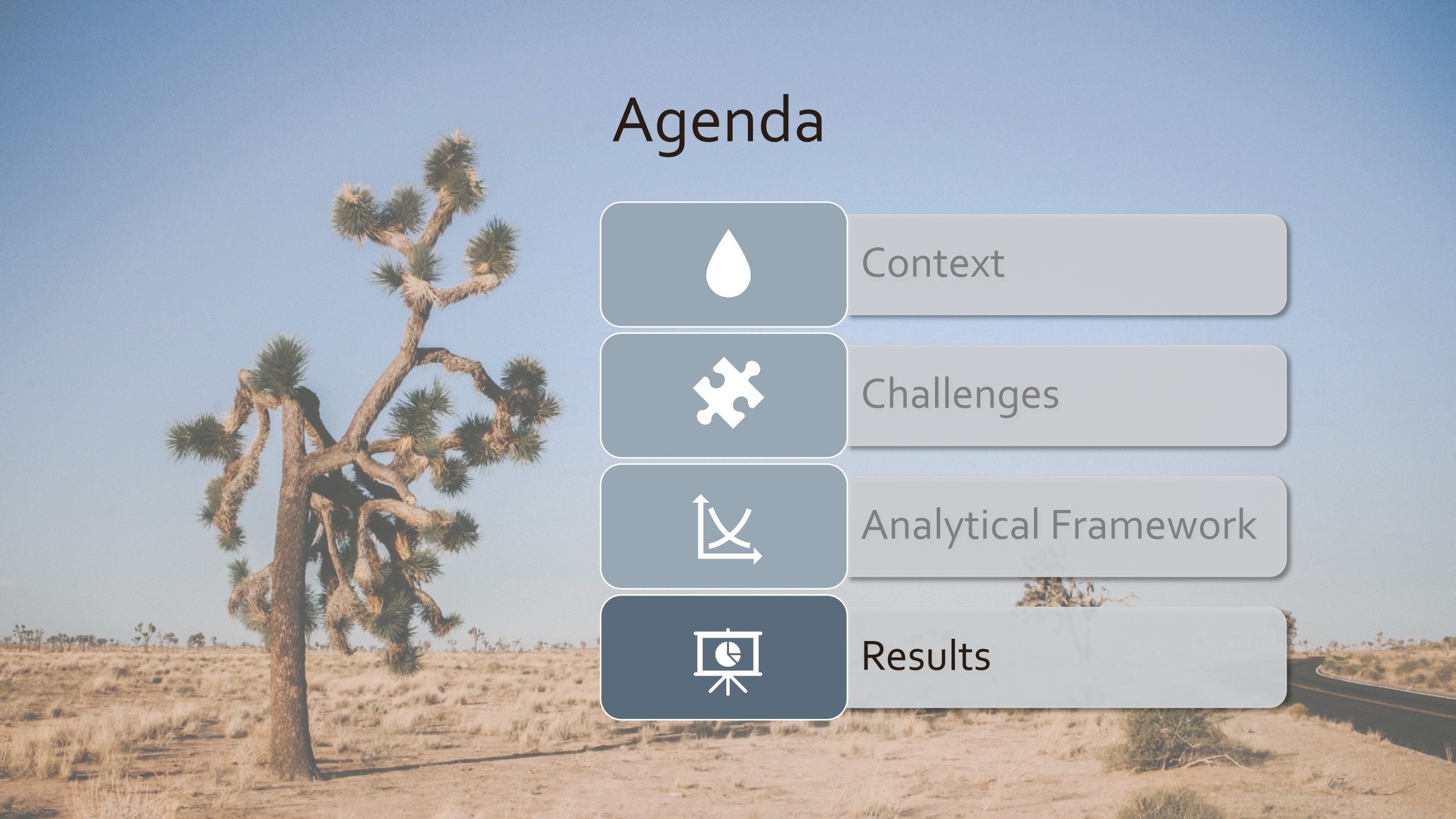

- Context
- Challenges
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- **Results**

Menu of options for policymakers

Best for the economy:

$0.4 ¢ until 0.4m gallons

$1.2 ¢ thereafter

-- middle ground --

Most equitable:

$0.5 ¢ until 2.6m gallons

$0.9 ¢ thereafter

Summary

Drought conditions likely to persist in California

Need for a comprehensive policy that matches demand to supply

Further consideration by policymakers when formulating potential water allocation policy

Q&A

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Shantanu Samant

Decision Analytics
for Business and Policy

7 Dec 2022