

# FUSE: Food-Water-Energy for Urban Sustainable Environments in Jordan

## FUSE Model Results

**F**ood-**w**ater-**e**nergy for  
**U**rban  
**S**ustainable  
**E**nvironments



**Steven Gorelick**  
**Stanford University**

**Water**

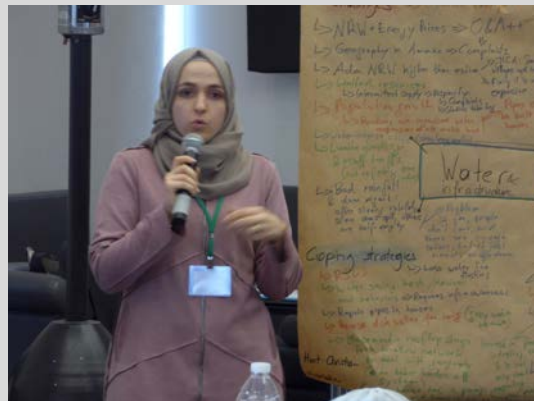


**Energy**

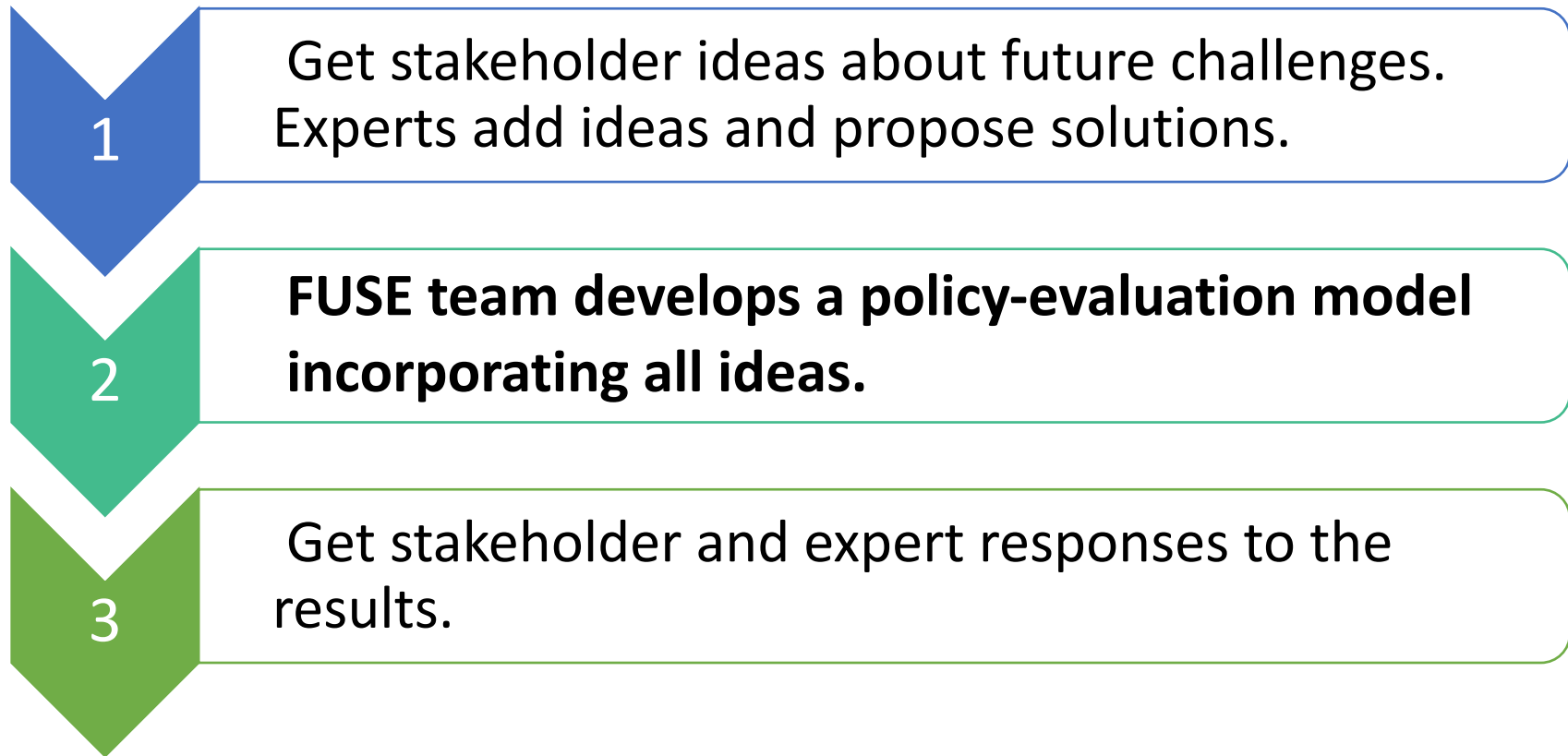
**Food**

This work was supported in part by the National Science Foundation under grant ICER/EAR-1829999 to Stanford University as part of the Belmont Forum – Sustainable Urbanisation Global Initiative (SUGI)/Food-Water-Energy Nexus theme. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.”

# 2019 Workshops: Stakeholders



## FUSE Process Steps:



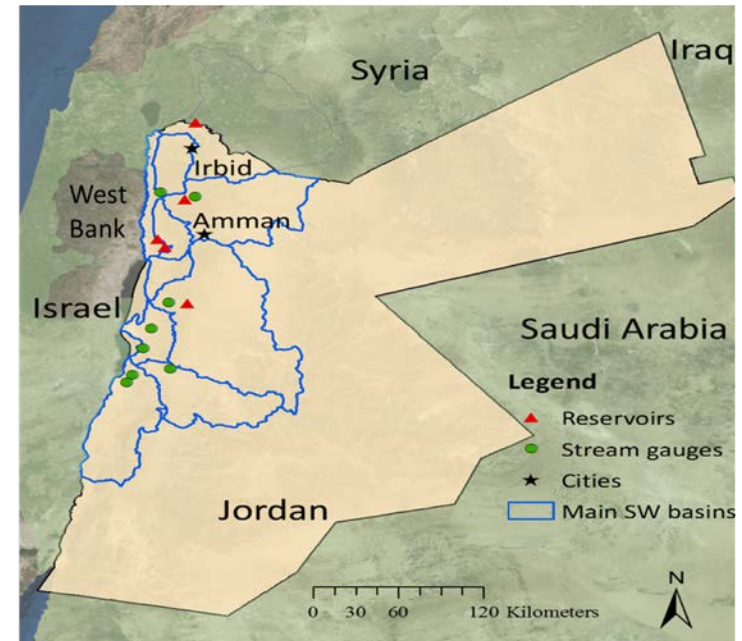
# Jordan Water Project and the FUSE Project

## Goals

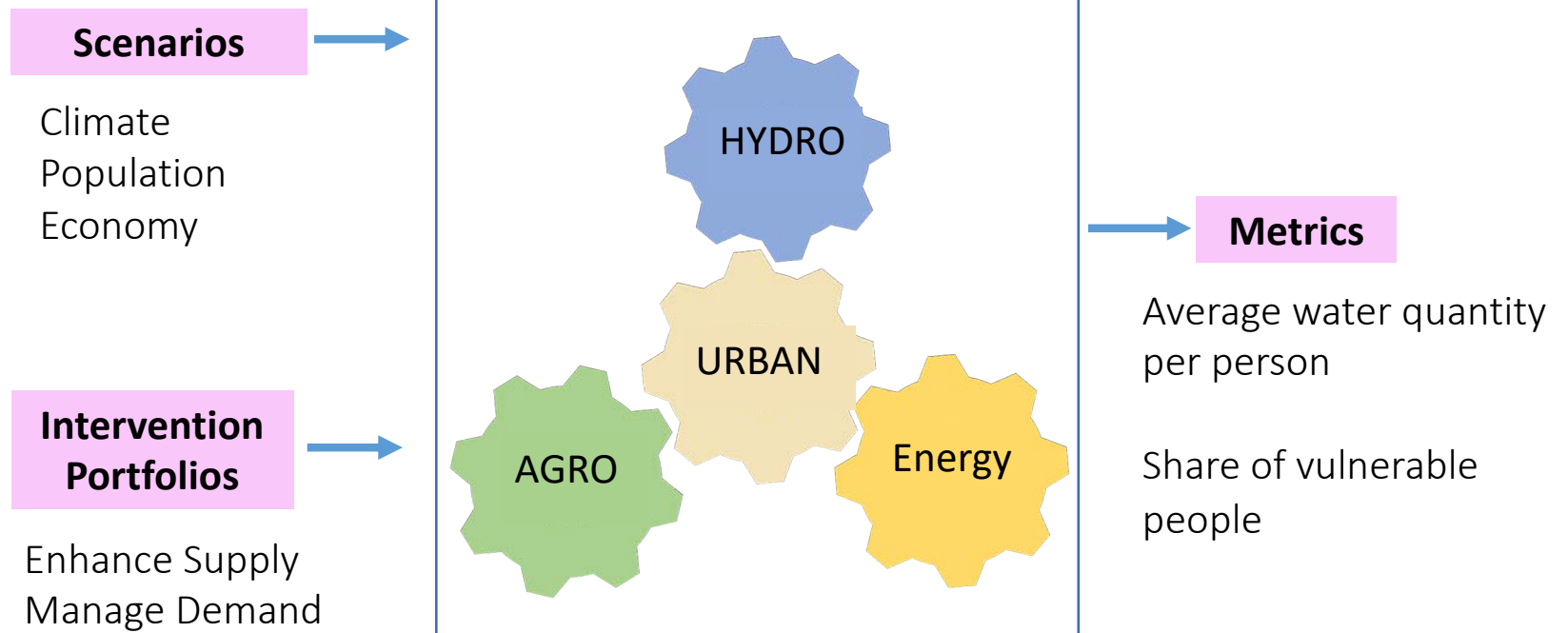
- 1) To develop a tool to **look into Jordan's water future** under different potential policy interventions aimed primarily at reducing freshwater vulnerability.
- 2) To **evaluate the impacts of these interventions** for Food-Water-Energy resources under various scenarios of climate, population, and economic condition.

## Jordan Water Model

- **Policy-evaluation model** of Jordan's freshwater system
- **Not prescriptive:**
  - We don't tell anyone to do anything.
  - We analyze the impacts of interventions.
  - Only Jordan can determine which way to go.



## Integrated Nexus Model



## **Only Jordan has such a detailed evaluation tool**

**Detailed surface water and groundwater simulation models** using Jordan MWI data

**Water-demand estimation** using Jordan Department of Statistics survey data of water use from 18,000 households

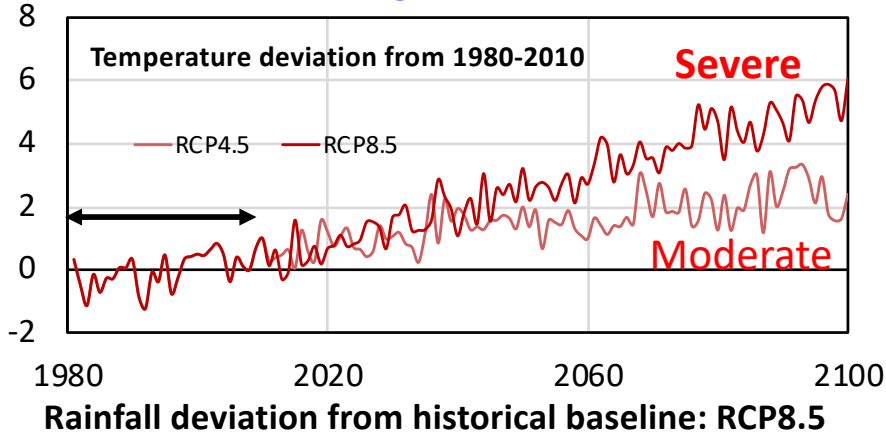
**Regional climate-change model for Jordan** based on global climate models

**Farmer planting and water-use decisions** on a subdistrict level

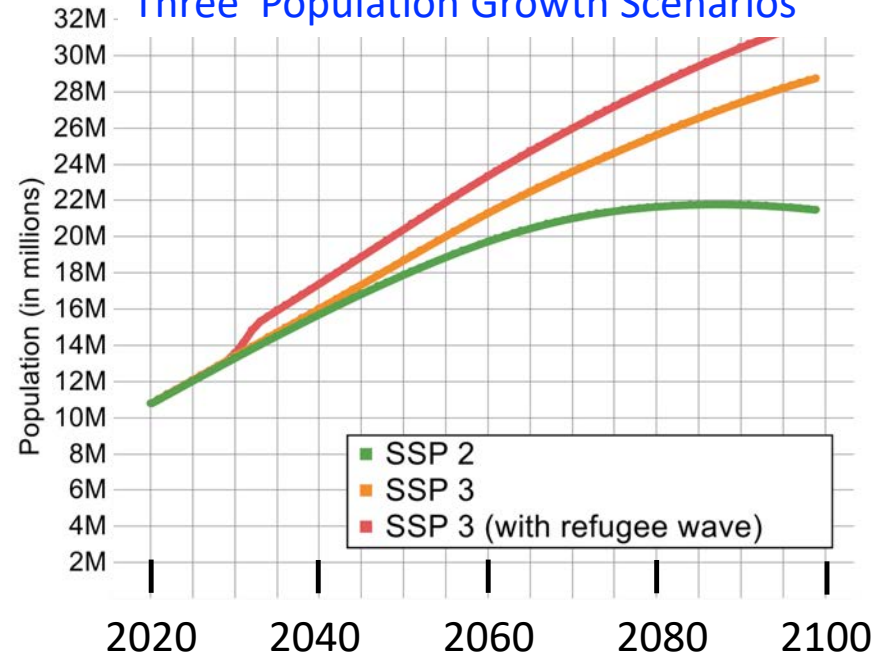
**This took us 25 person years!**

# Jordan Water Model Scenarios

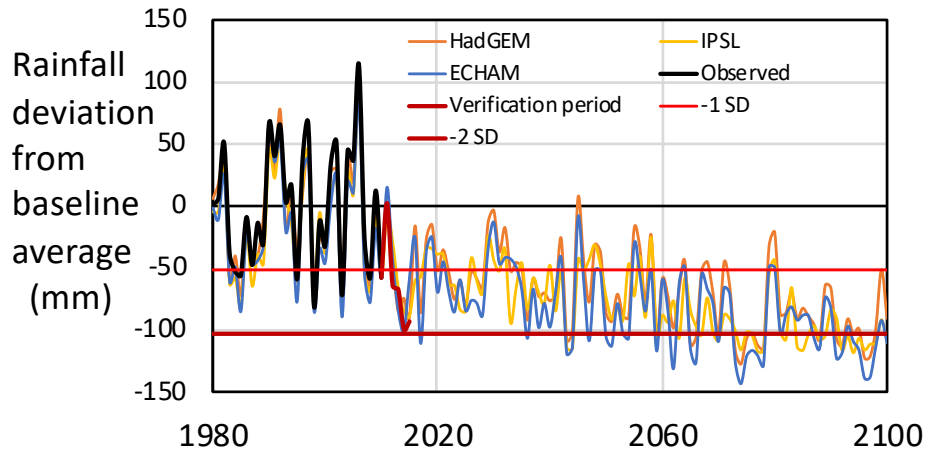
## Two Climate Change Scenarios



## Three Population Growth Scenarios



## Rainfall deviation from historical baseline: RCP8.5



## Socio-Economic Scenarios

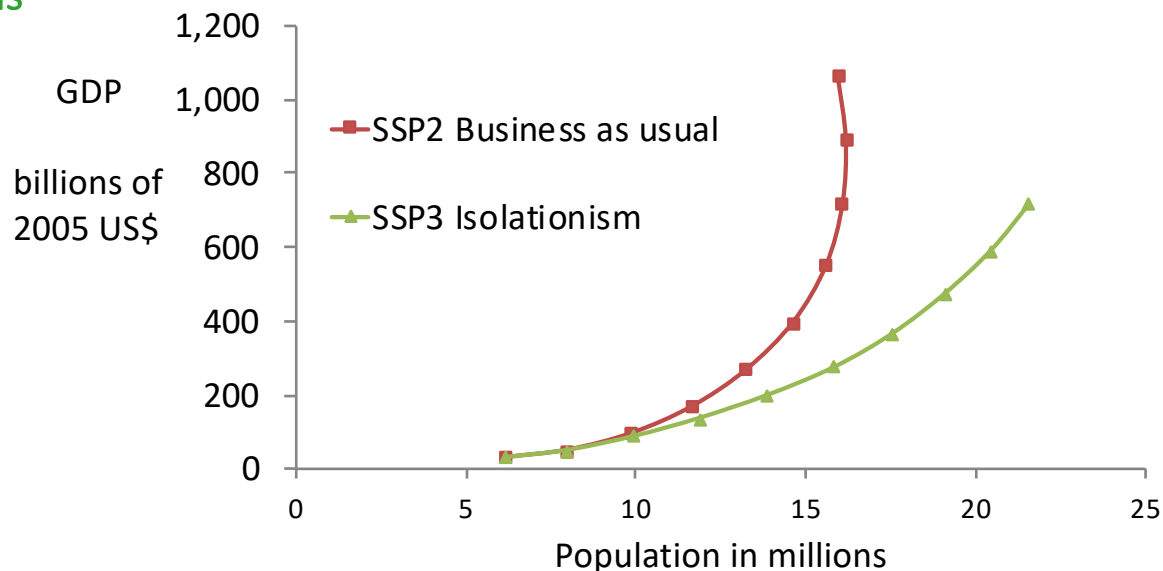
Shared Socio-Economic Pathways (SSPs)

- International Panel on Climate Change developed Jordan-specific projections



The rate and level of economic development is also a scenario

### SSP Projections for Jordan (2010-2100)



## Scenarios

### Optimistic

Moderate Climate Change RCP 4.5  
More flow from Syria  
Modest population growth



### Drier Climate

Severe Climate Change RCP 8.5  
Less flow from Syria  
Modest population growth



### Population Growth

Moderate Climate Change RCP 4.5  
More flow from Syria  
Greater population growth



### Crisis

Severe Climate Change RCP 8.5  
Greater population growth  
Less flow from Syria  
New wave of refugees in 2030



# Interventions

**Baseline:** No interventions - business as usual

**Demand Management:** 2x Water Tariff on Larger Consumers + 50% Reduction in Theft

**Ag to Urban:** 25% **Transfer** of Highland Agricultural Well Water From Ag to City

**Enhanced Supply:** **Add** Red Sea Desalination + 50% Reduction in Physical Water Loss

**Comprehensive Action:** Do Everything and All Planned Water Projects

## Results – 2020 to 2100

Our analysis provides forecasts of domestic freshwater use under different scenarios and interventions

We also estimate values over time of freshwater vulnerability

**Vulnerability** = Share of population receiving less than 40 liters/person/day

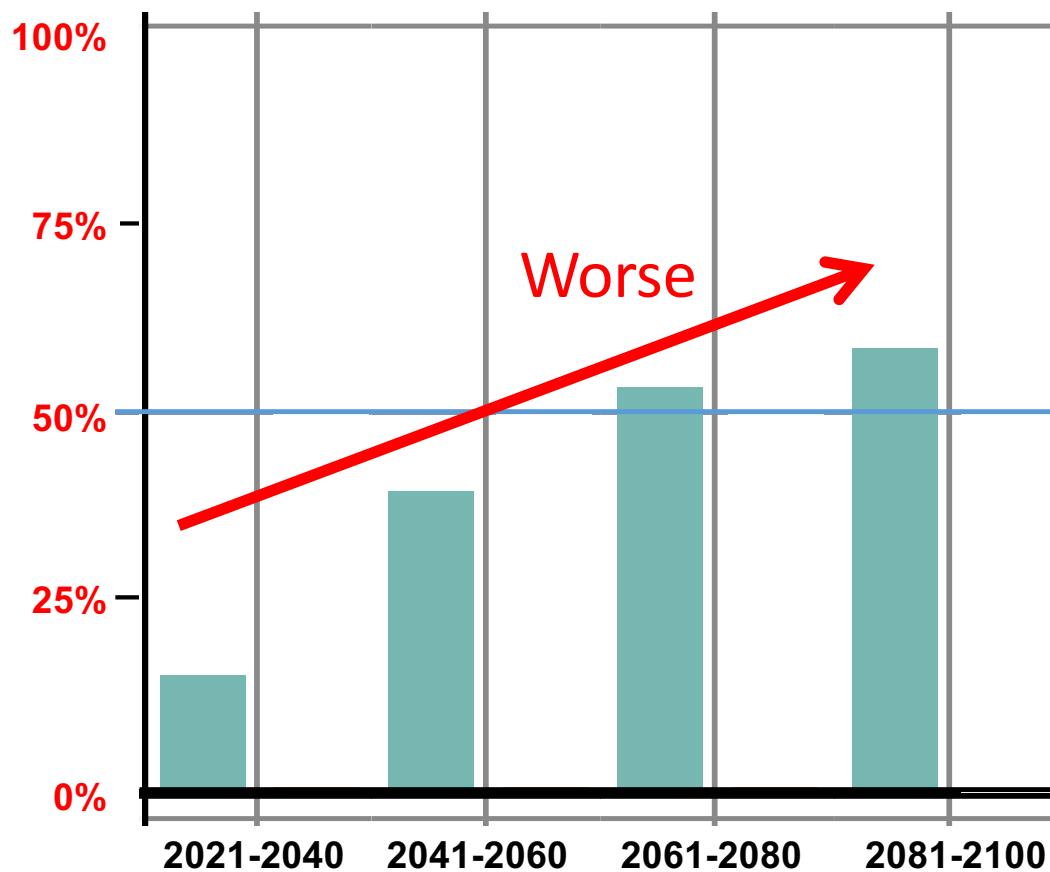
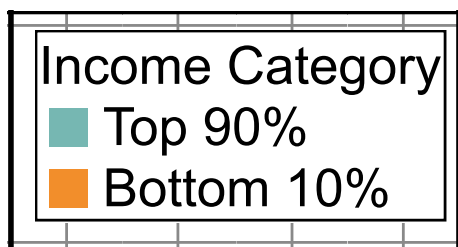
This is less than half of what you get today!



### Example Narrative:

- Baseline Intervention
- Optimistic Scenario

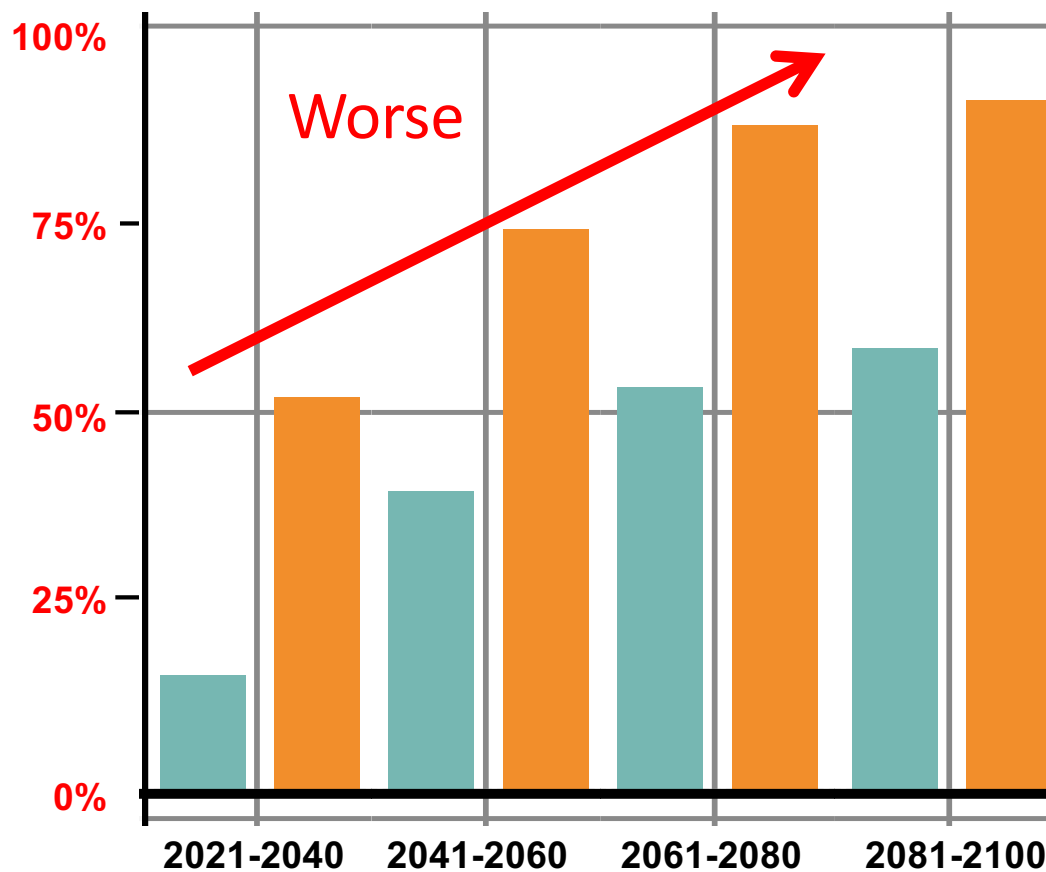
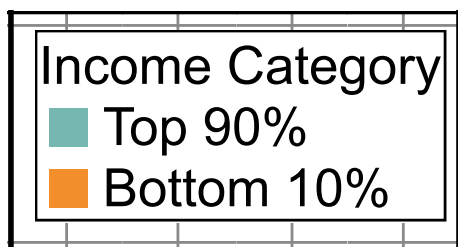
**Vulnerability:** Percent of Population Getting < 40 Liters per person per day



### Example Narrative:

- Baseline Intervention
- Optimistic Scenario

**Vulnerability:** Percent of Population Getting < 40 Liters per person per day



Set of Results – 2020 to 2100

**Water Supply Vulnerability < 40 liters/person/day**

Series of 20 possibilities

**5 Interventions**

**4 Scenarios**

Baseline >Demand Ag-Urban >Supply Comprehensive

**Optimistic**

	Baseline	>Demand	Ag-Urban	>Supply	Comprehensive
		← Optimistic			
Drier Climate	↑				
Population Growth	Baseline				
Crisis					

Drier Climate

Population Growth

Crisis

# Vulnerability Metric < 40 liter/capita/day

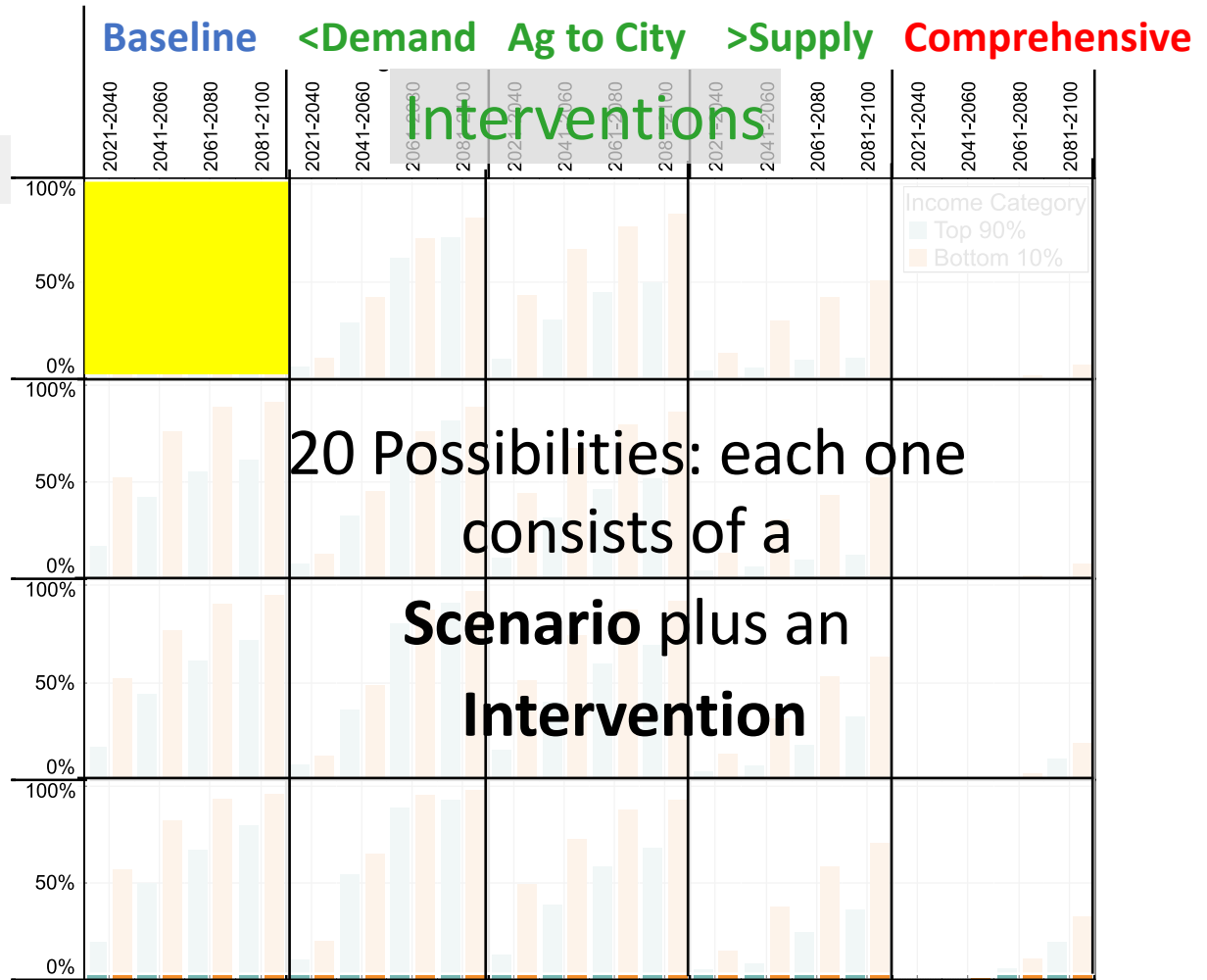
## Scenarios

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 Moderate Climate Change RCP 4.5  
 More flow from Syria  
 Modest population growth

**Drier Climate**  
 Severe Climate Change RCP 8.5  
 Less flow from Syria  
 Modest population growth

**Population Growth**  
 Moderate Climate Change RCP 4.5  
 More flow from Syria  
 Greater population growth

**Crisis**  
 Severe Climate Change RCP 8.5  
 Greater population growth  
 Less flow from Syria  
 New wave of refugees in 2030



# Vulnerability Metric < 40 liter/capita/day

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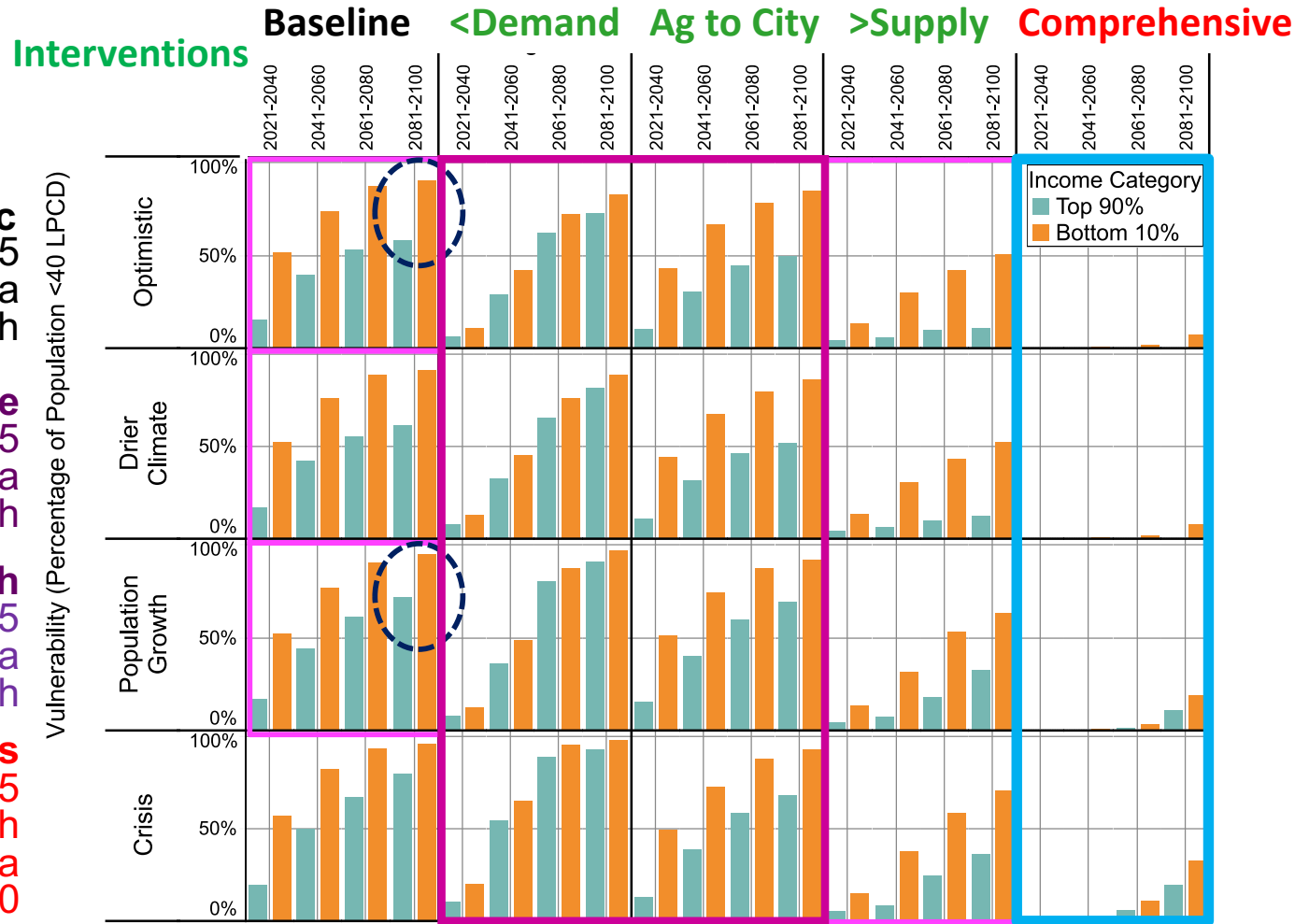
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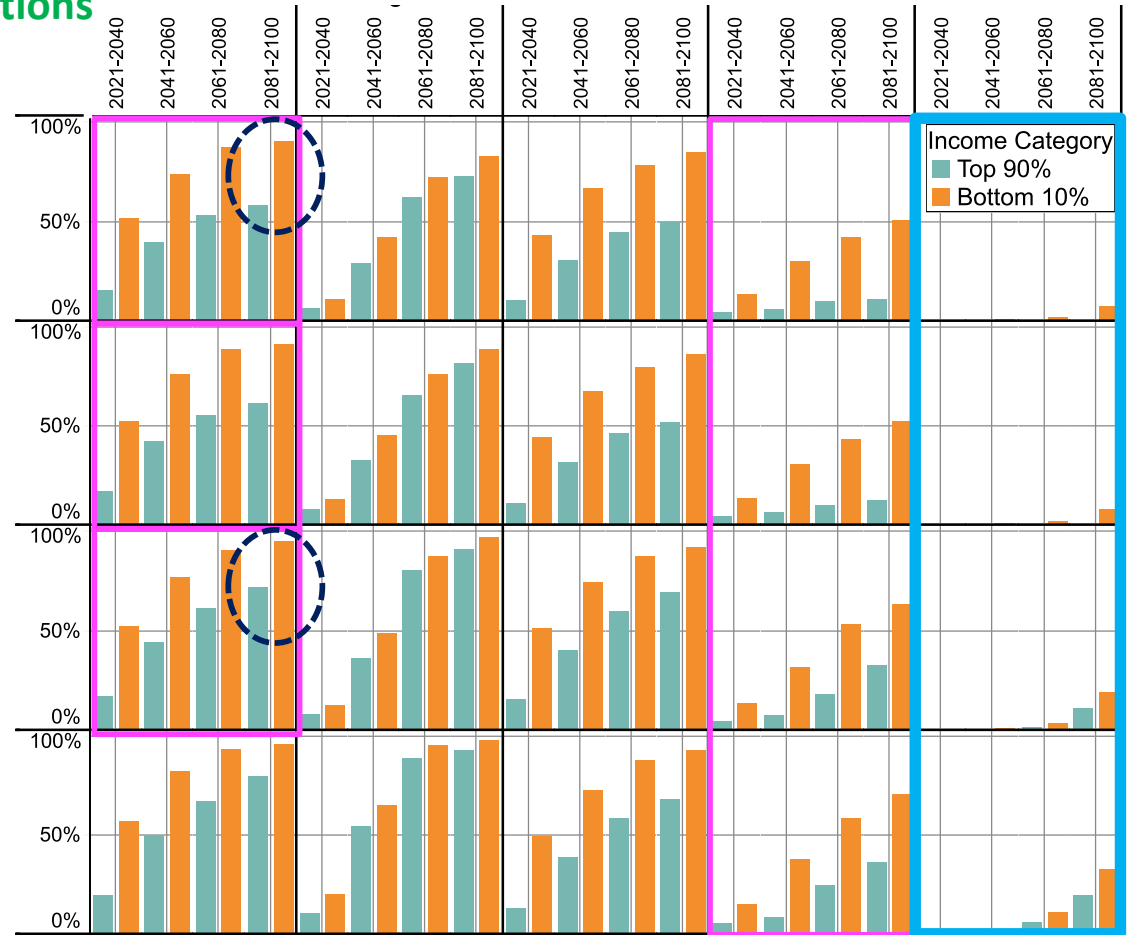
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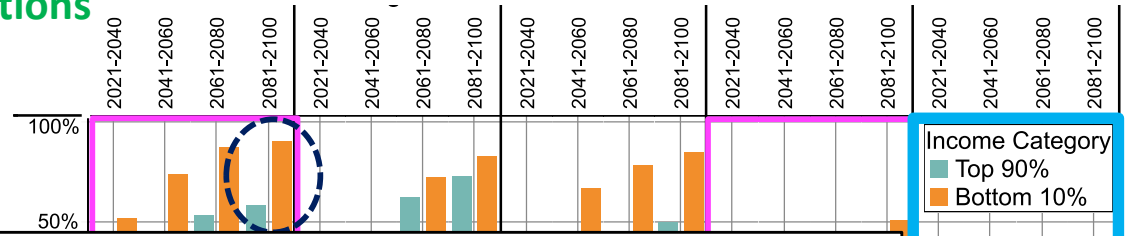
**Interventions**  
 Baseline <Demand Ag to City >Supply Comprehensive



**Vulnerability Metric**  
**< 40 liter/capita/day**

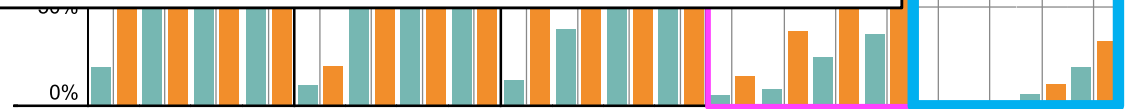
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 Optimistic

**Interventions**  
 Baseline <Demand Ag to City >Supply Comprehensive



**Comprehensive Action Means Do Everything**  
 All Planned Projects + Red Sea Desalination  
 50% Physical and Administrative NRW Reduction  
 Double Water Price (for higher tiers)  
 Reduce Supply Duration Disparity  
 Transfer 25% of Agricultural Well Water to Cities

Less flow from Syria  
 New wave of refugees in 2030



# FUSE: Food-Water-Energy for Urban Sustainable Environments in Jordan

## Detailed Results

Christian Klassert  
UFZ Germany

**F**ood-**w**ater-**e**nergy for  
**U**rban  
**S**ustainable  
**E**nvironments

Energy



Water



Food

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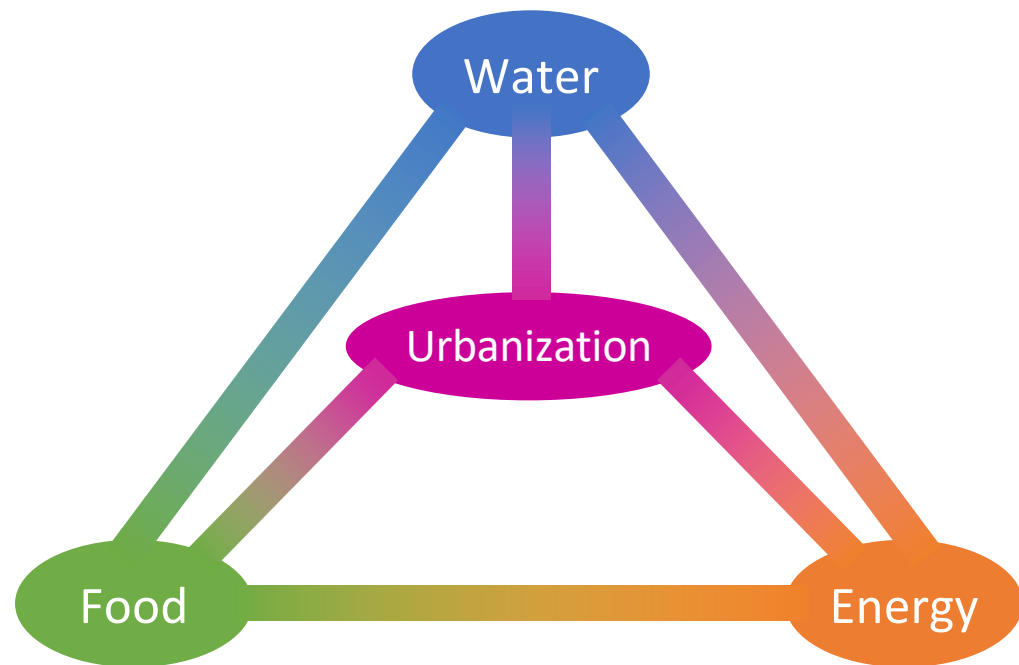
## All Nexus sectors can help achieve the visions developed & overcome challenges

We analyzed interventions – *improvements society can influence* – involving all Food-Water-Energy Nexus sectors and their linkages.

Their design was informed by:

- (a) Suggestions of 2019 Sustainability Living Lab (SLL), as well as your feedback to our recent survey
- (b) Our Food-Water-Energy Nexus analyses.

The results will be discussed today.



## Analyses of additional metrics

### Location within the series of 20 result possibilities for 2020 to 2100

#### 5 Interventions

#### 4 Scenarios

Baseline >Demand Ag-Urban >Supply Comprehensive

#### Optimistic

Drier Climate  
Population Growth  
Crisis

	Baseline	>Demand	Ag-Urban	>Supply	Comprehensive
		← Optimistic			
	↑				
	Baseline				

Optimistic: Moderate climate change (RCP 4.5), higher transboundary flows (agriculture in the Syrian Yarmouk is low), moderate socio-economic growth (SSP 2), crop prices steady

## Intervention 1: Agriculture to Urban Transfer (Food-Water)

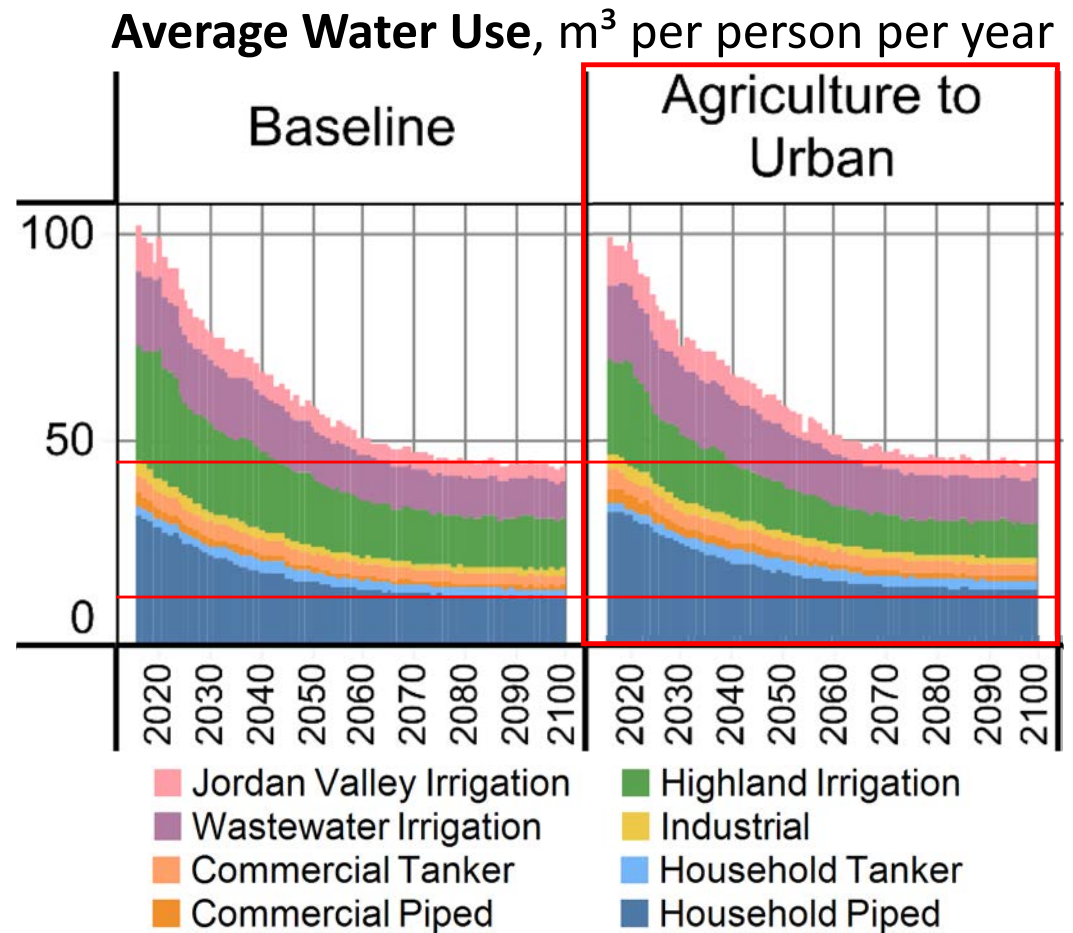
2019 SLL suggestion: Climate-adapted crops to free water for people

Intervention: Transferring 25% of agricultural well water to cities

Result: No increase in total water availability

Less agriculture

Household water supply grows by 15%



## Intervention 1: Agriculture to Urban Transfer (Food-Water)

2019 SLL suggestion: Climate-adapted crops to free water for people

Intervention: Transferring 25% of agricultural well water to cities

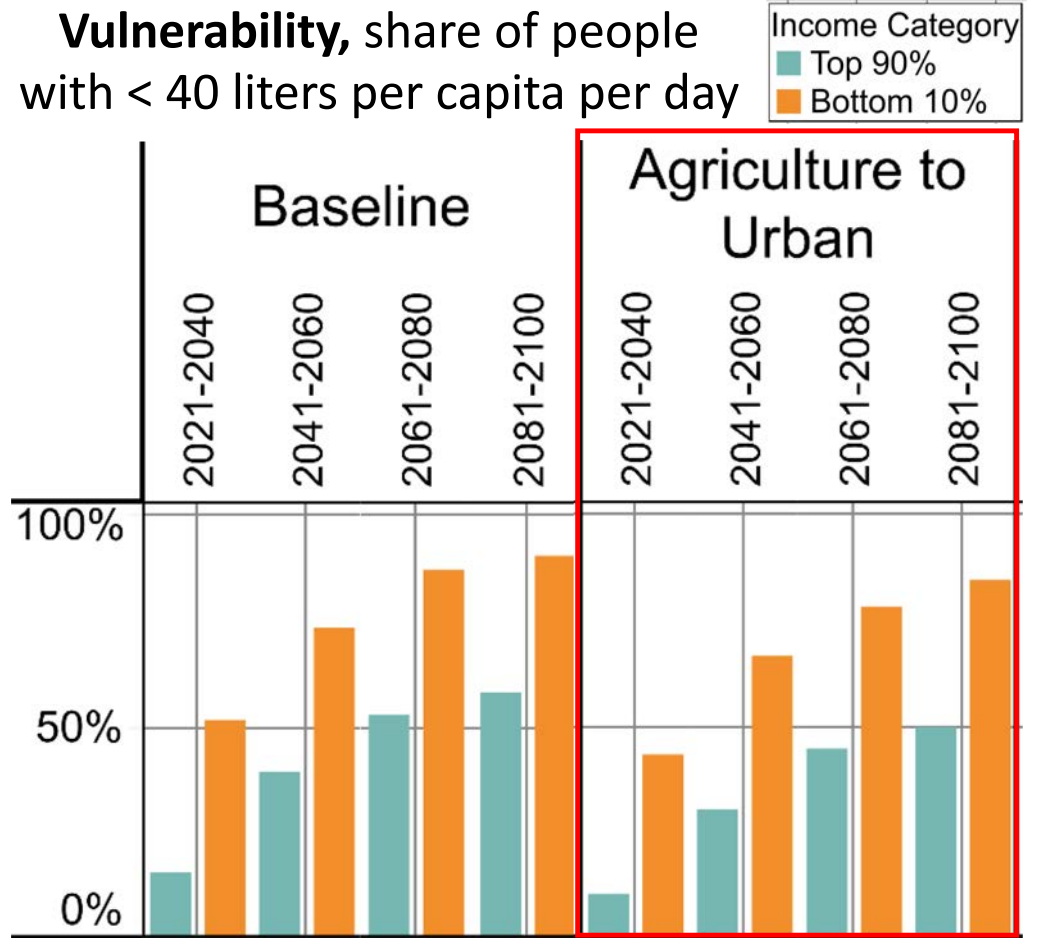
Result: No increase in total water availability

Less agriculture

Household water supply grows by 15%

This reduces vulnerability

But: This intervention is not enough



## Intervention 2: Water Supply Enhancement (Energy-Water)

2019 SLL suggestion: New supply projects

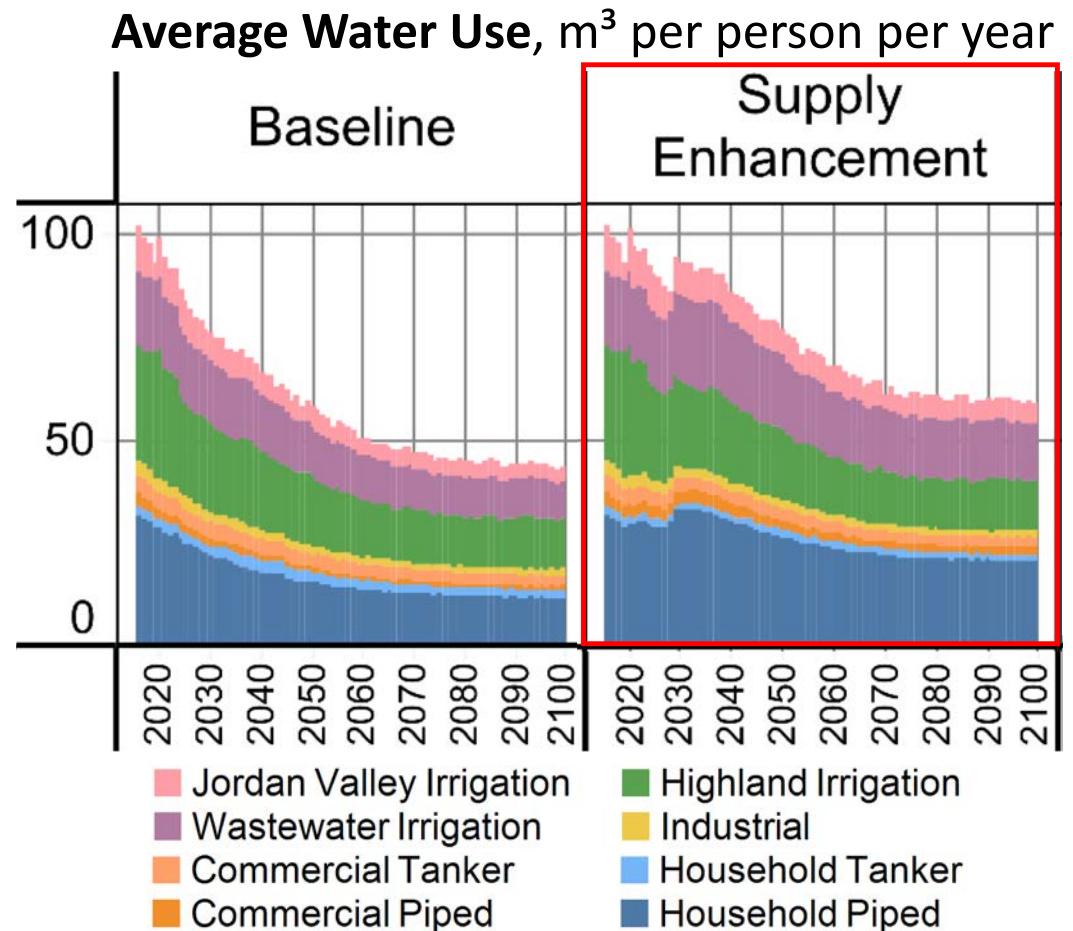
(1) Water supply increases:

- **Red Sea desalination:** +230 million m<sup>3</sup>/year
- **Other supply projects:** +132 million m<sup>3</sup>/year

(2) Fix pipe leaks: Reduce losses by 50%

Result: Total water use per person increases from 43 to 54 million m<sup>3</sup>/year

Requires investment and energy supply



## Intervention 2: Water Supply Enhancement (Energy-Water)

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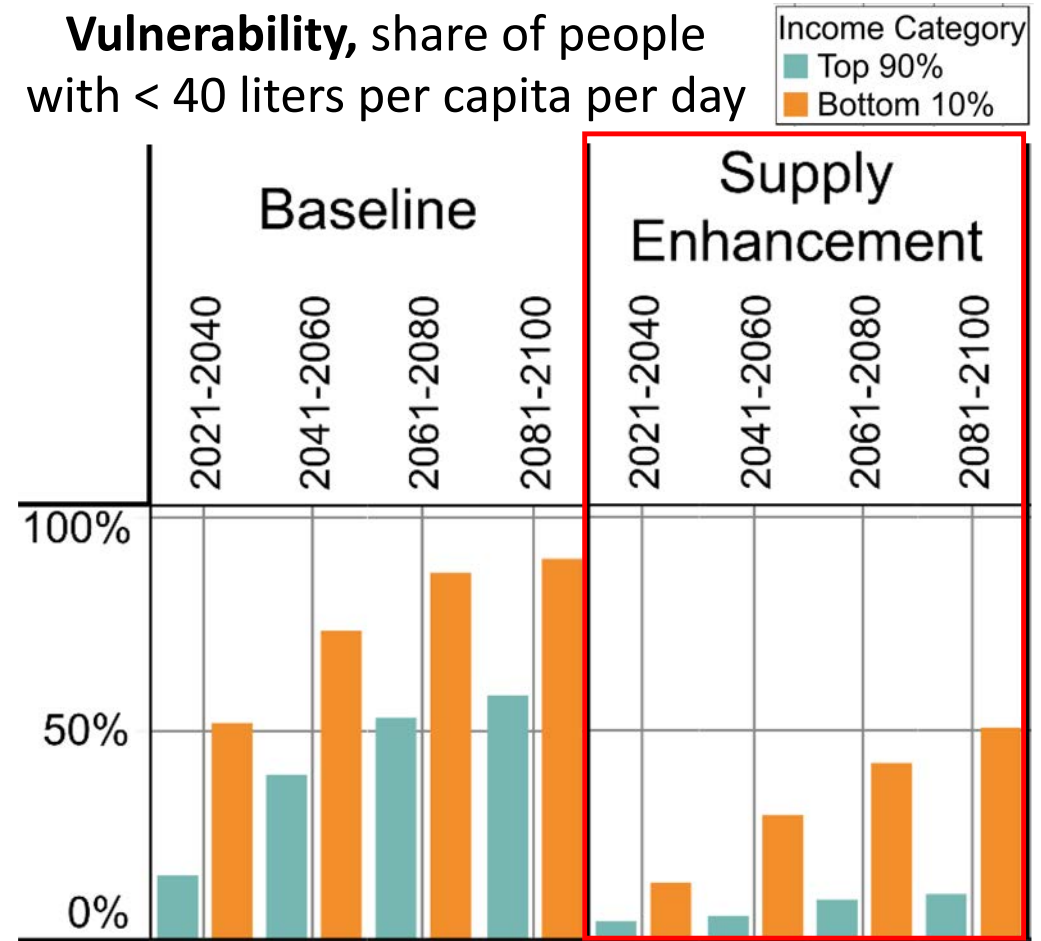
Result: Total water use per person increases from 43 to 54 million m<sup>3</sup>/year

Requires investment and energy supply

Reduces vulnerability

But: Not for low-income households

**Vulnerability**, share of people with < 40 liters per capita per day



## Intervention 3: Demand Management **Intervention (Urban-Water)**

2019 SLL suggestion: Promote water saving, reduce admin. non-revenue water (NRW)

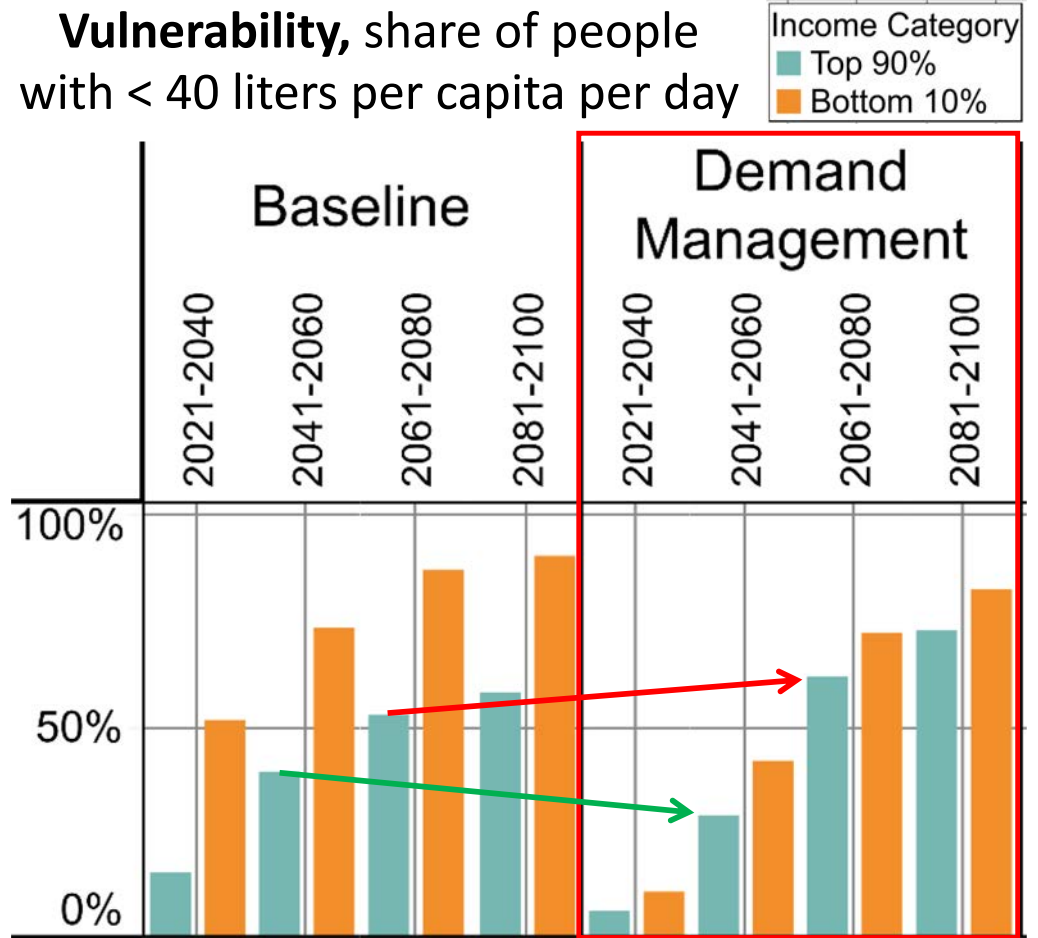
(1) **Equity:** reduce supply interruptions

(2) **Cost recovery:** Raise tariffs for high-income users and businesses

(3) **Theft reduction**

Results: Reduces vulnerability until 2060

*And it is necessary for helping low-income households!*

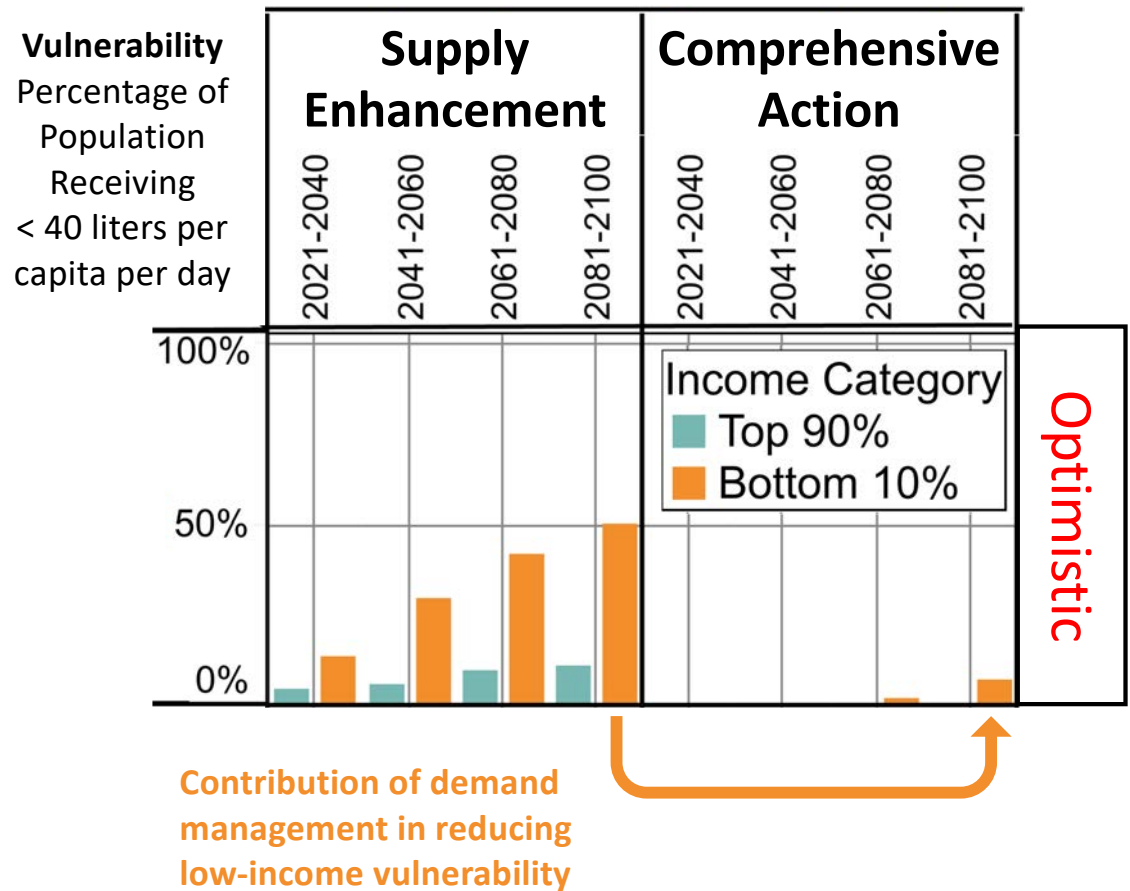


**Intervention 4: Agriculture-to-Urban (Food-Water) & Water Supply Enhancement (Energy-Water)**

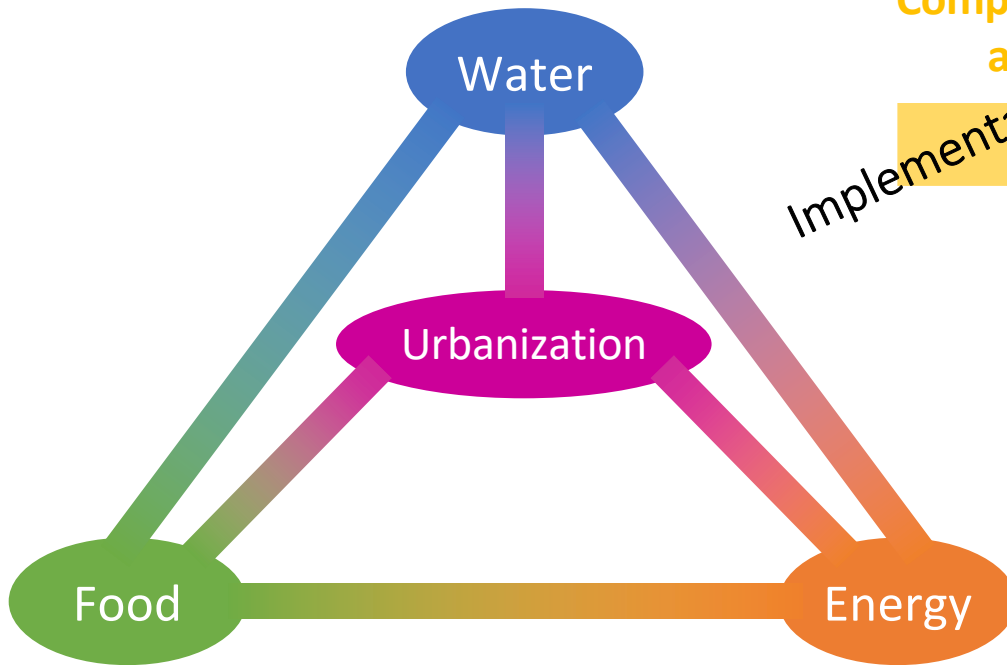
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**Water Demand Management (Urban-Water)**

Demand management can help households with the lowest water access, which are not reached by pure supply interventions

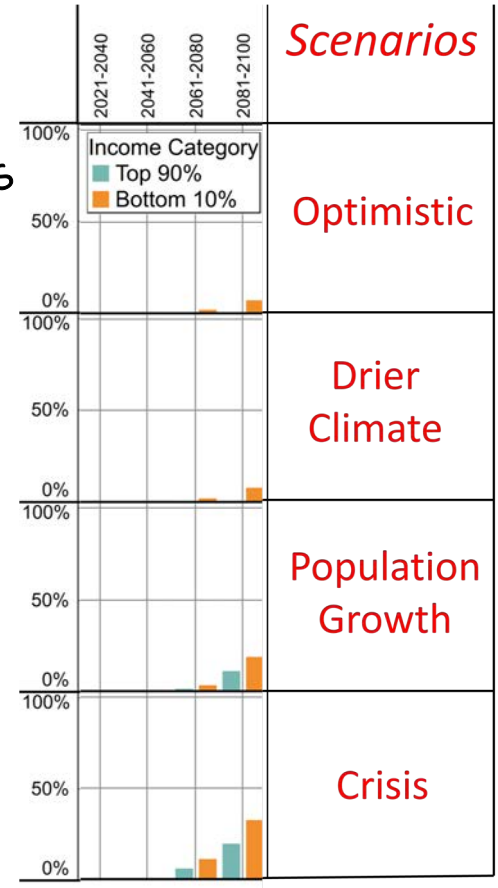


*Collaboration of all nexus sectors needed!*



**Comprehensive  
action  
Implementation Barriers**

**Vulnerability  
Metric**  
Percentage of  
Population  
Receiving  
< 40 liters  
per capita  
per day



## We have 4 key metrics

### Metric Name

### Metric Measure

<b>Vulnerability</b>	Percent of population with < 40 liters/person/day
<b>Stress Duration</b>	Number of continuous months getting less than 40 liters/person/day
<b>Inequity</b>	Gini coefficient of water use (1=supply disparity, 0= equity)
<b>Economic Well-Being</b>	Consumer surplus (benefit to consumers)

It's going to be an uphill climb.



*Thank you for your  
kind attention!*