



Collaboration with



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# An Agent-based Approach for Managing Food-energy-water Systems Under Future Climate Scenarios Using FEWCalc and DSSAT:

Opportunities and Challenges for Local Decision-makers in Thailand

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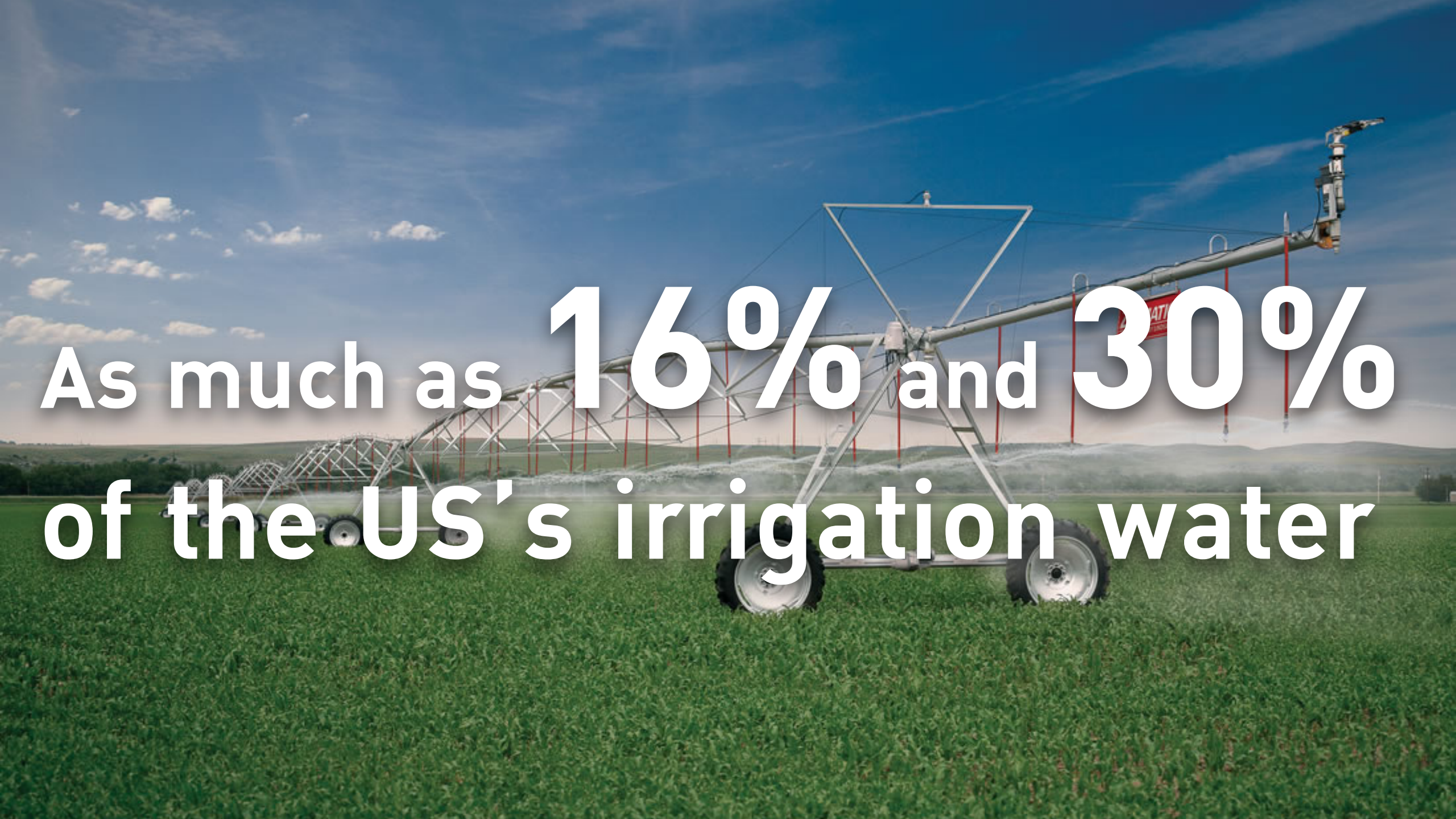


# Contents

- Introduction
  - Methods
  - Results
  - Conclusions
  - Opportunities and Challenges in Thailand
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- The bottom of the slide features a decorative graphic consisting of several overlapping, wavy horizontal bands in various shades of blue, creating a sense of movement and depth.

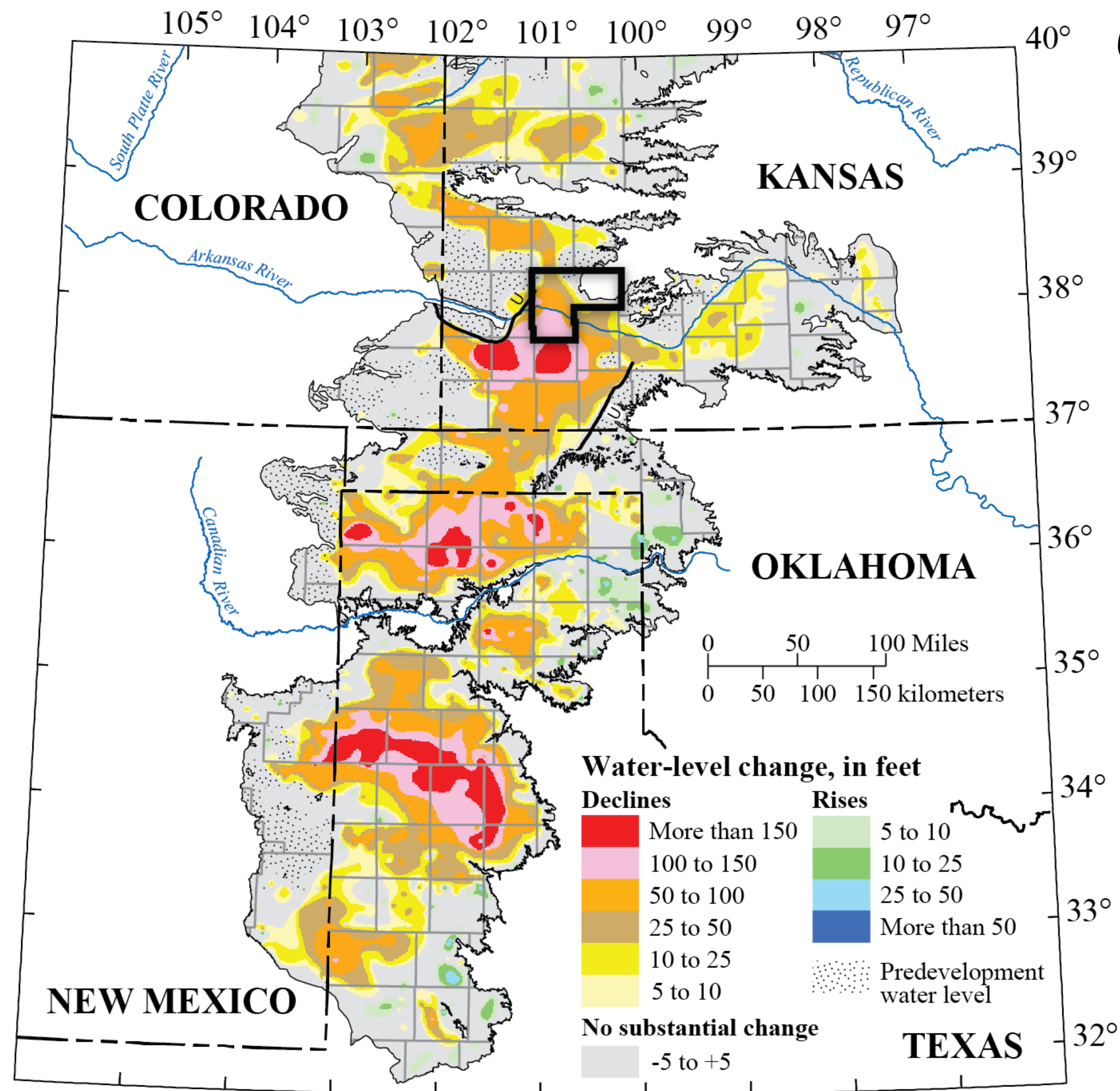
# Introduction





As much as **16%** and **30%**  
of the US's irrigation water





McGuire (2014)

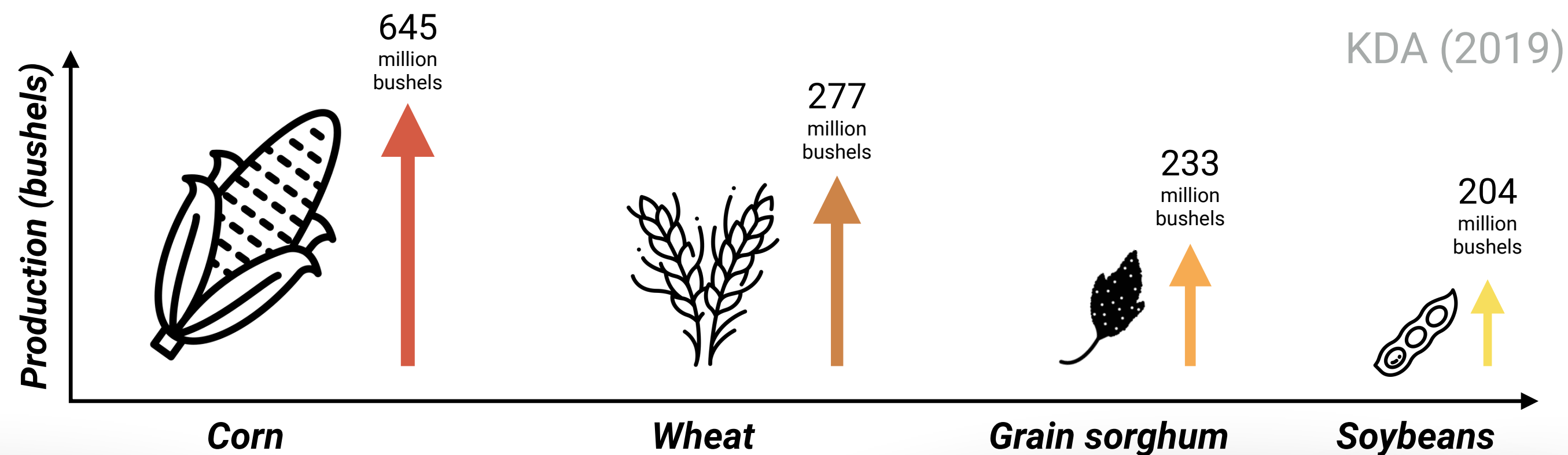
## Groundwater-Level Changes Since 1950

- The area-weighted average water level declined by 25.5 feet in Kansas
- Up to 150 feet in Finney County, KS, and more than 150 feet in nearby counties



## Crops Grown in Kansas

- Agriculture is a significant contributor
- It contributed ~65.7 billion dollars to the state economy





# Is it sustainable?





# Methods



# Crop-water simulation

Inputs



Crop model

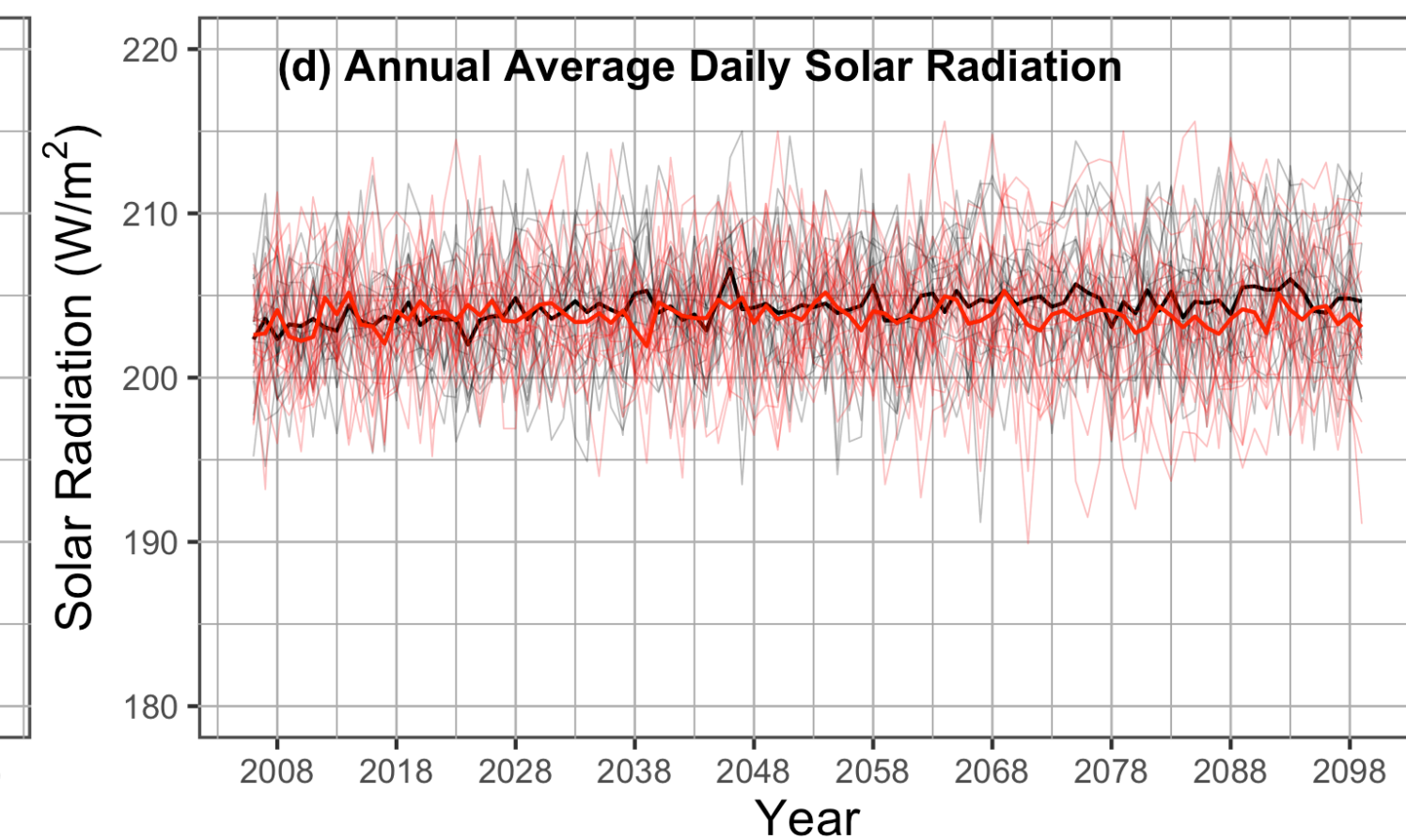
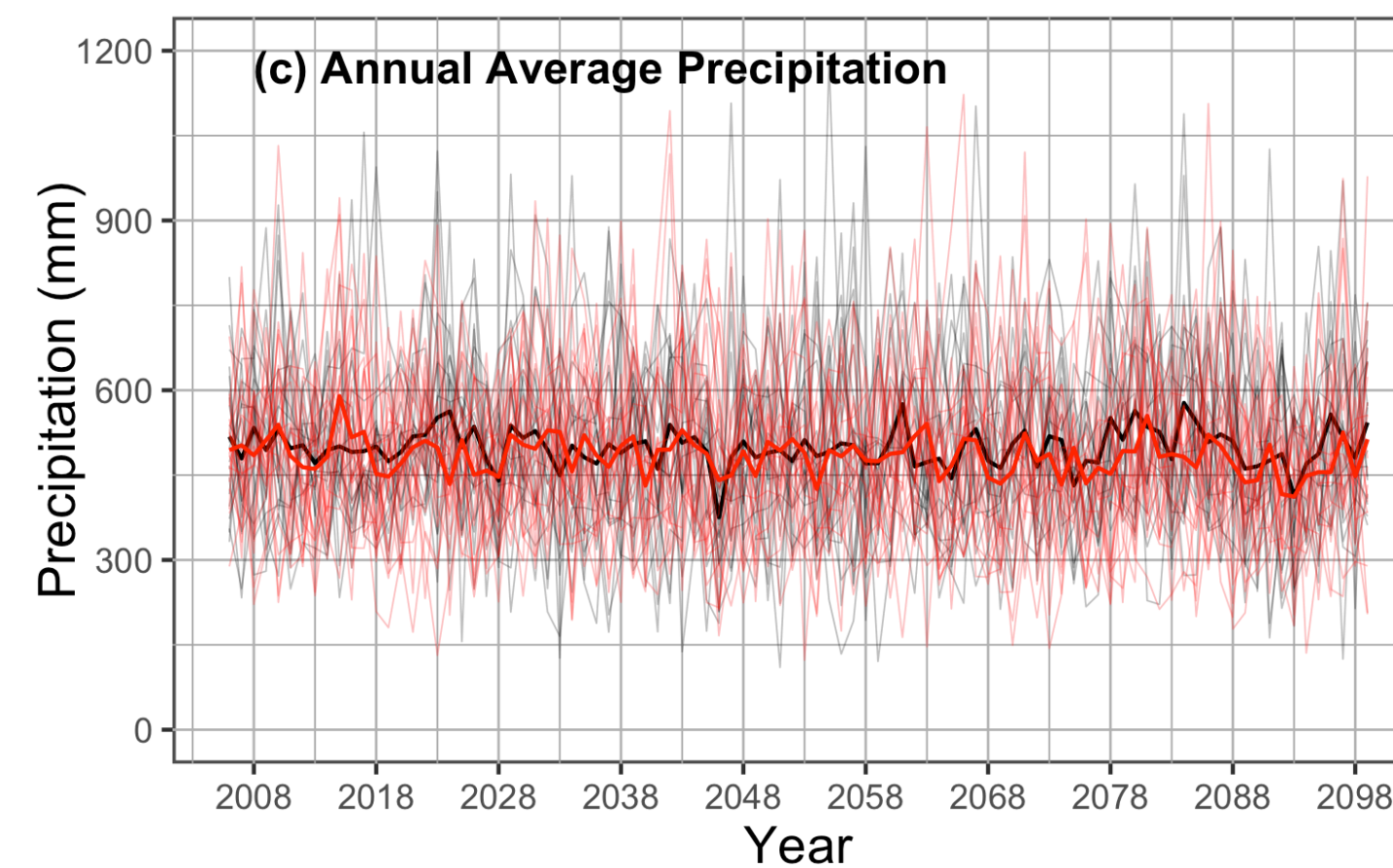
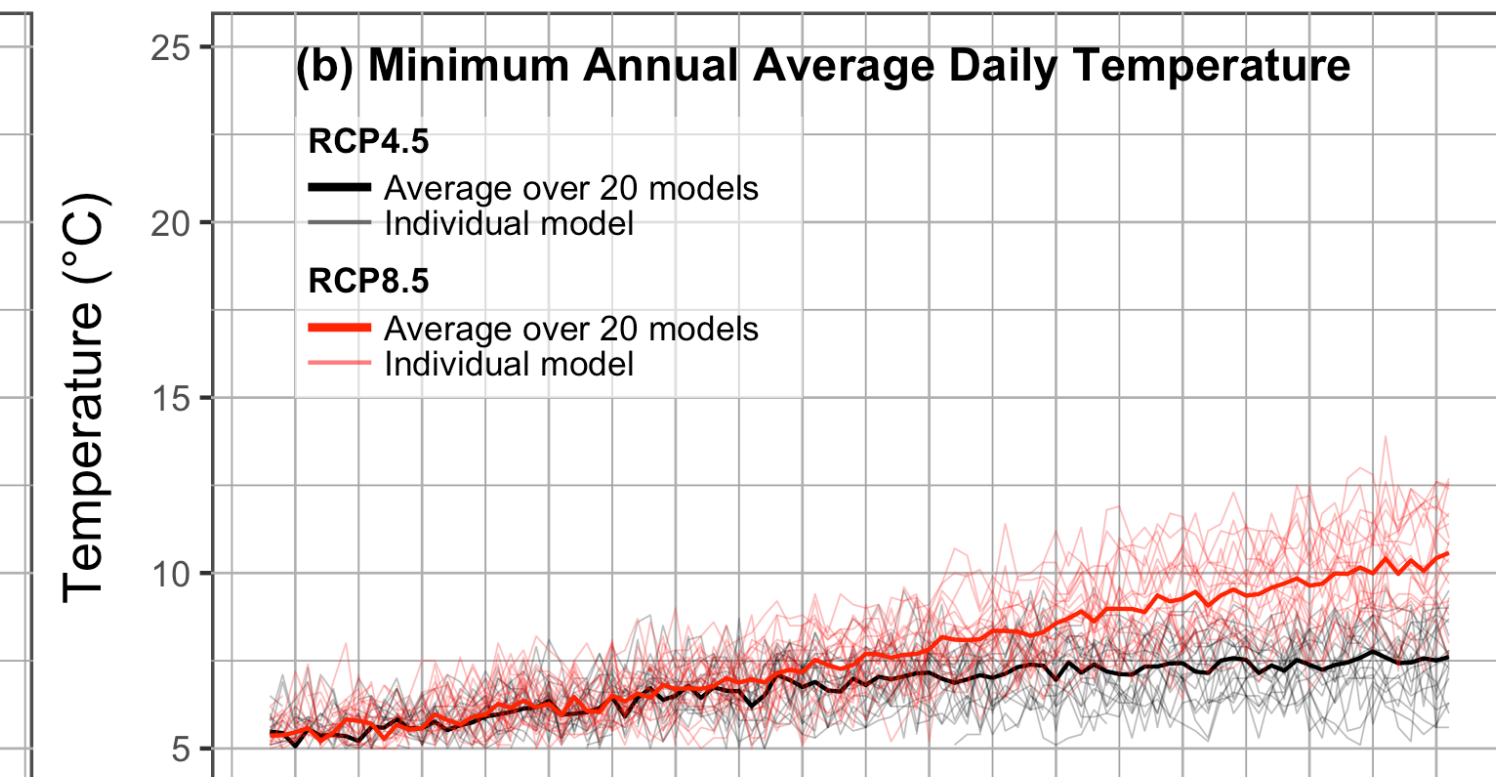
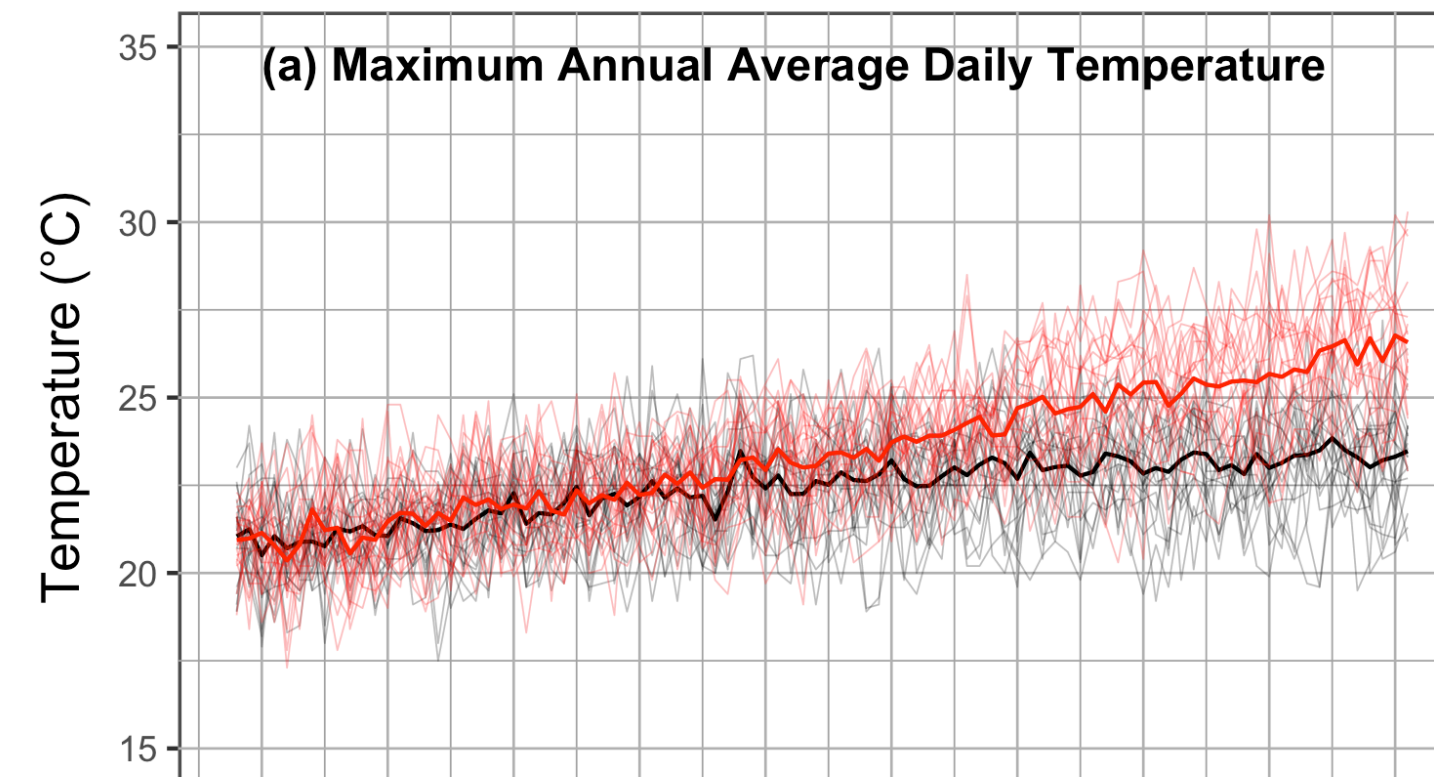


Outputs



Daily weather data

**20 Global Climate Models**

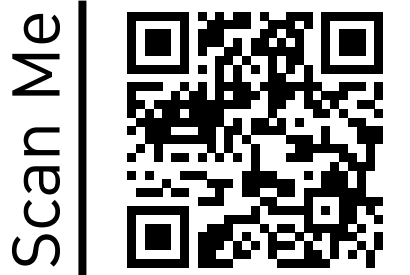


**Data from 20 individual models and their average**

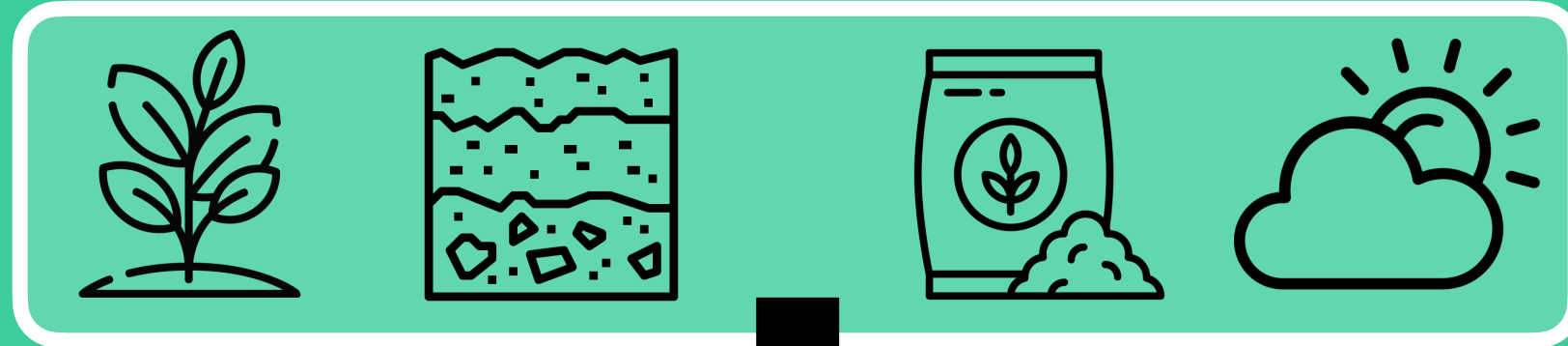
Phetheet et al. (2020) and Abatzoglou & Brown (2012)



# Crop-water simulation



Inputs  
Crop model  
Outputs



**Crop  
Yield**

**Water  
Demand**

*Import*

Daily weather data

**20 Global Climate Models**

## User-defined parameters

*Simulation  
Years*

*Crop  
Areas*

*Solar/Wind  
Energy*

*Installed  
Capacity*

*Aquifer  
Thickness*

*Climate  
Model*

## Calculations (NetLogo programming)

- Historical crop yield
- Projected crop yield
- Historical crop price
- Crop expenses
- Crop insurance

- Operation and maintenance cost
- Energy production
- Energy sale price

- Precipitation
- Applied irrigation
- Data-driven conversion
- Groundwater impact
- Surface-water contamination

## Outputs

Crop production

Farm energy income

Crop groundwater irrigation

Crop  
net income

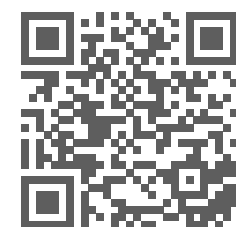
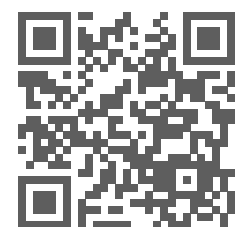
Income from  
crop insurance

Energy net income

Data-driven  
conversion

Total net income (Crop + Energy)

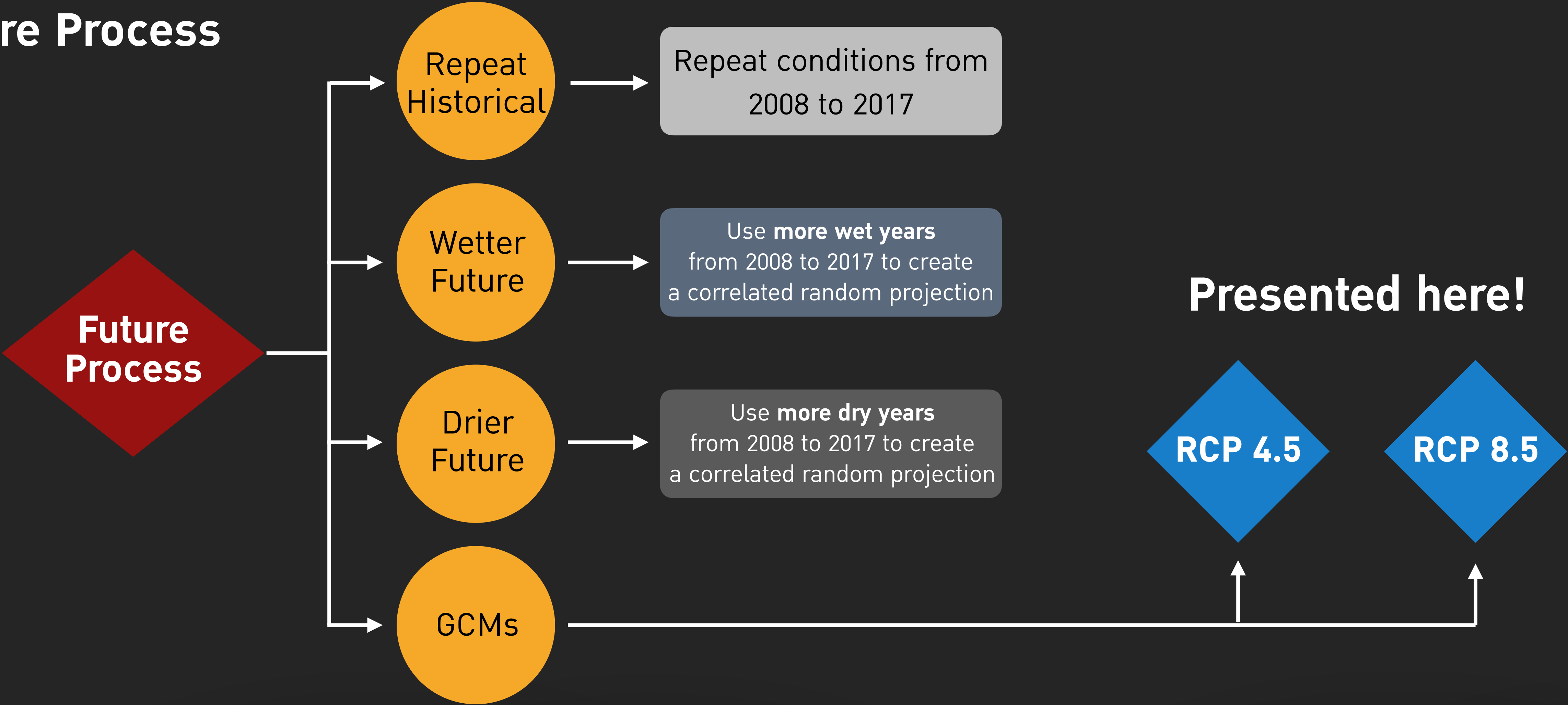
Groundwater level





# FEWCalc

## Future Process





# FEWCalc NetLogo Interface

InterfaceInfoCode

EditDeleteAdd

Button

normal speed

view updates

continuous

Settings...

Years: 60

Simulation\_period 60 Yrs

Setup

Go once

Go

Restore Default

Agriculture

Corn\_area

200

Wheat\_area

125

Soybeans\_area

0

SG\_area

125

Circles show proportional crop areas (acres), SG =Grain sorghum.

Energy

Energy\_value 38.0 \$/MWh

Loan\_term 0.8

Interest 2.0 %

Wind: Wind degradation applies after 10 yrs

#Wind\_turbines 2

Nyear\_W 30 Yrs

Cost\_W 1470 \$/kW

Capacity\_W 2 MW

Degrade\_W 1.0 %/yr

Wind\_factor 42.1 %

Solar: 1 set = 1,000 panels

#Panel\_sets 3.0

Nyear\_S 25 Yrs

Cost\_S 1750 \$/kW

Capacity\_S 250 W

Degrade\_S 0.5 %/yr

Sun\_Hrs 5.6 hrs/day

Tax Credits: Wind

PTC\_W 0.000 \$/kWh

Solar. Choose 1, ITC OR PTC

ITC\_S 30 %

PTC\_S 0.000 \$/kWh

Water

Effects on surface water (SW) quality are accumulated.

Irrigation comes from groundwater (GW) pumping

Aquifer\_thickness 200 Ft

Min\_Aq\_Thickness 30 Ft

Climate Scenario

Alternative future annual values for temperature (T), precipitation (P), and solar radiation (S).

Future\_Process

Repeat Historical

For "GCM"

Climate\_Model

RCP8.5

FEWCalc 1.0.1

- First 10 years use historical data (2008–2017), subsequent years apply Future Process. Year represents a sequential year. Year 1 is 2008 and year 60 is 2067.
- FEWCalc requires NetLogo version 6.1.0 or higher.
- Global climate models (GCMs) are used to project future climate. Climate projections are largely based on greenhouse gas (GHG) emissions. RCP4.5 represents an intermediate scenario, whereas RCP8.5 is a scenario with very high GHG emissions.

Agriculture

Crop Production

276 Bu/ac

0 60 Years

Corn Wheat Soybeans SG

SG = Grain sorghum

Ag Net Income

90000 \$

-54000 60 Years

Corn Wheat Soybeans SG US\$0

SG = Grain sorghum

Energy

Farm Energy Production

16200 MWh

0 60 Years

Wind Solar 0 MWh

Energy Net Income

522000 \$

-66000 60 Years

Wind Solar US\$0

Water

Crop Groundwater Irrigation

25.3 Inches

0 60 Years

Corn Wheat Soybeans SG

SG = Grain sorghum

Groundwater Level

220 Feet

0 60 Years

GW level Min Aq Min+30

Farm Economy

Total Net Income

537000 \$

-113000 60 Years

Crop Energy All US\$0

Crop Insurance

Income From Crop Insurance

34000 \$

0 60 Years

Corn Wheat Soybeans SG

SG = Grain sorghum



# FEWCalc NetLogo Code

```
set corn-tot-yield (item (item n yrs-seq) corn-yield_4)
set wheat-tot-yield (item (item n yrs-seq) wheat-yield_4)
set soybean-tot-yield (item (item n yrs-seq) soybean-yield_4)
set milo-tot-yield (item (item n yrs-seq) milo-yield_4)

let k ticks
set corn-use-in item (k mod 10) corn-irrig_4
set wheat-use-in item (k mod 10) wheat-irrig_4
set soybean-use-in item (k mod 10) soybean-irrig_4
set milo-use-in item (k mod 10) milo-irrig_4
end

to energy-calculation
  set #Solar_panels (#solar_panel_sets * 1000)
  set solar-production (#Solar_Panels * Panel_power * 5 * 365 / 1000000)
  set wind-production (#wind_turbines * Turbine_size * 0.425 * 24 * 365)
  set solar-cost (#Solar_Panels * Panel_power / 1000 * 3050)
  set solar-sell (solar-production * 38)

  set wind-cost (((3000000 / 30) + 100000)) * #wind_turbines
  set wind-sell (wind-production * 38)
  set solar-net-income (solar-sell - (solar-cost / 30))
  set wind-net-income (wind-sell - (wind-cost))
  set energy-net-income (solar-net-income + wind-net-income)
end

to gw-depletion_1
  let k ticks

  set corn-use-in item (k mod 10) corn-irrig_1
  set wheat-use-in item (k mod 10) wheat-irrig_1
  set soybean-use-in item (k mod 10) soybean-irrig_1
  set milo-use-in item (k mod 10) milo-irrig_1

  set water-use-feet (((corn-use-in * corn-area) + (wheat-use-in * wheat-area) + (soybean-use-in * soybean-area) + (milo-use-in * milo-area)) / (12 * total-area))
  set gw-change ((-8.6628 * water-use-feet) + 8.4722)

  set consuming-patches (gw-change * 170 / (aquifer-thickness))

  ask aquifer-patches with [pycor > (current-elev - (consuming-patches))] [
    set pcolor 7
  ]
end

; Bob Johnson (bobjohnson@centurylink.net), Earnie Lehman (earnielehman@gmail.com)

; MWh = power(Watt) * 5hrs/day * 365days/year / 1000000
; MWh = power(MW) * Kansas_wind_capacity * 24hrs/day * 365days/year ;45% (Bob)
; Solar cost = #Solar_Panels * Panel_power * $3050/kW
; Sell = MWh * $38/MWh --> (Wholesale was $22-24/MWh, Retail price is $105/MWh)
; Wholesale < Coop $65 < Retail
; For 2MW wind turbine, Wind cost = 3000000/30 + (300000 maintenance/yr) * #wind_turbines ??????check
; Sell = MWh * $38/MWh
; assuming the cost spreads over 30 years with no interest or maintenance
; assuming the cost spreads over 30 years with no interest or maintenance
```

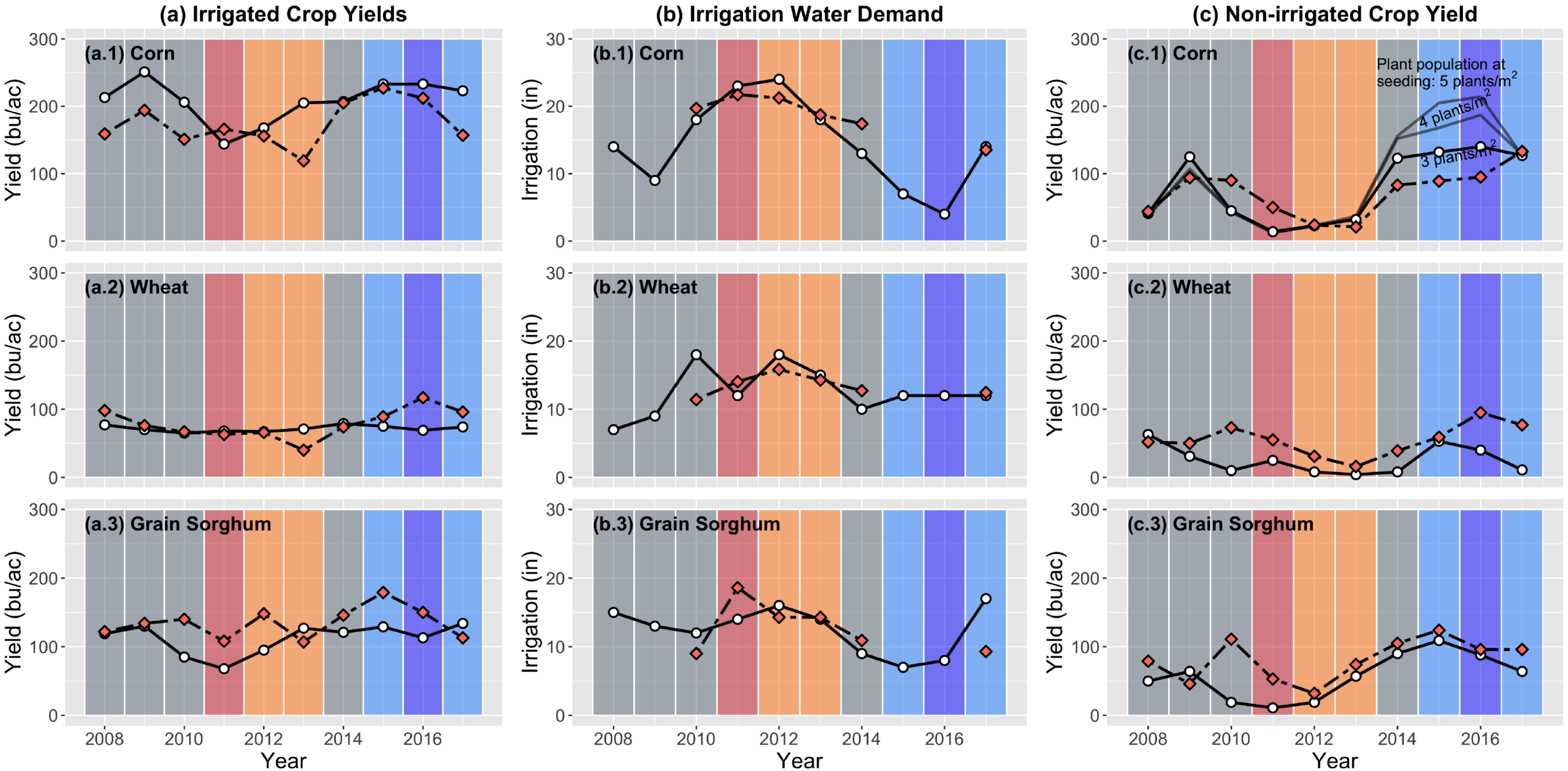


# Results

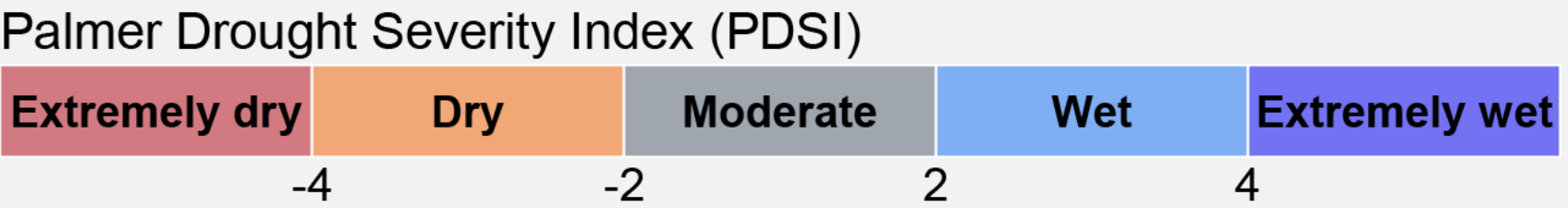


# Comparison: Historical vs. simulated

During 10-year base period

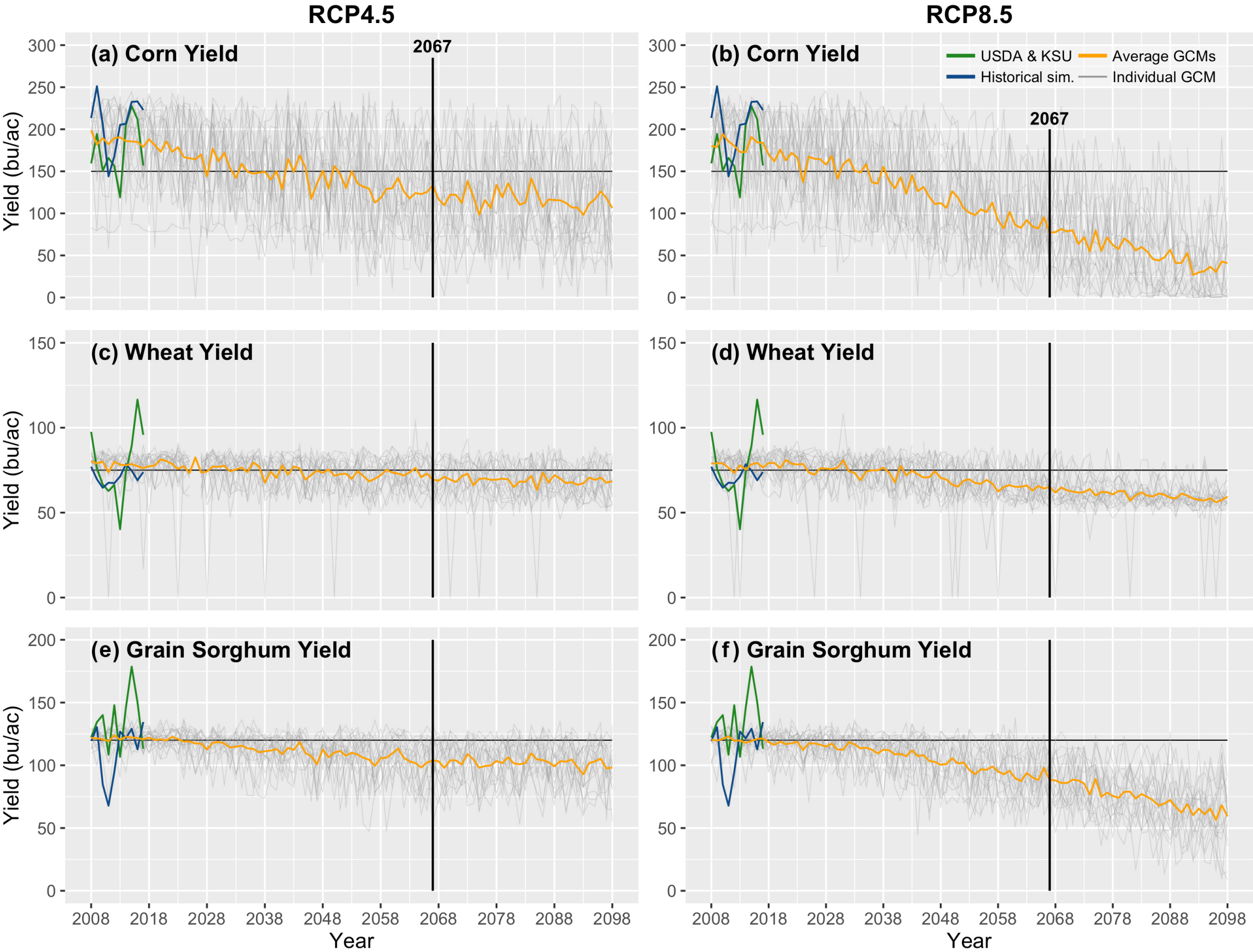


—○— DSSAT simulated results  
--◇-- Historical data: Yield (KSU), irrigation water demand (KDA)

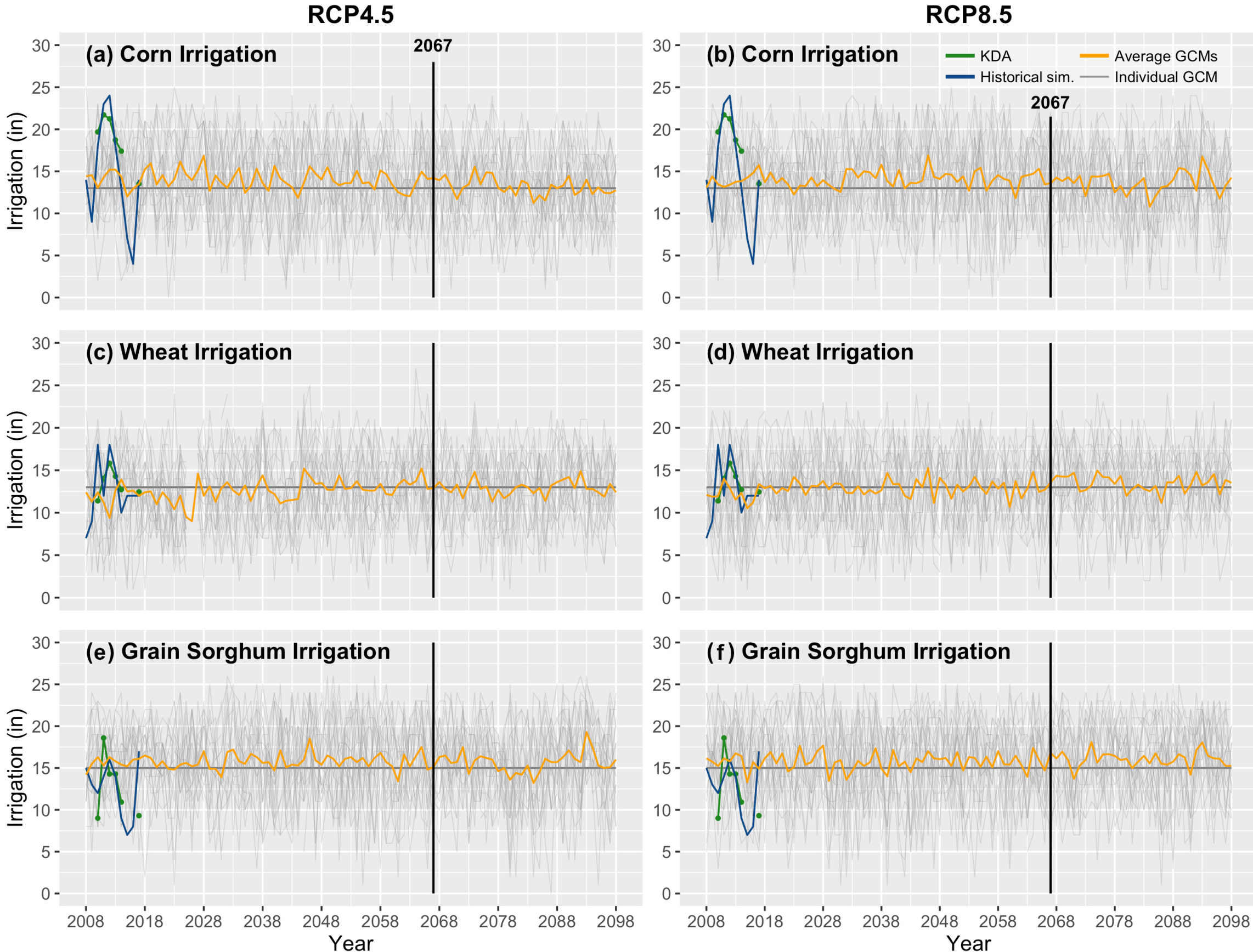




# Crop yield and Irrigation Demand under climate models



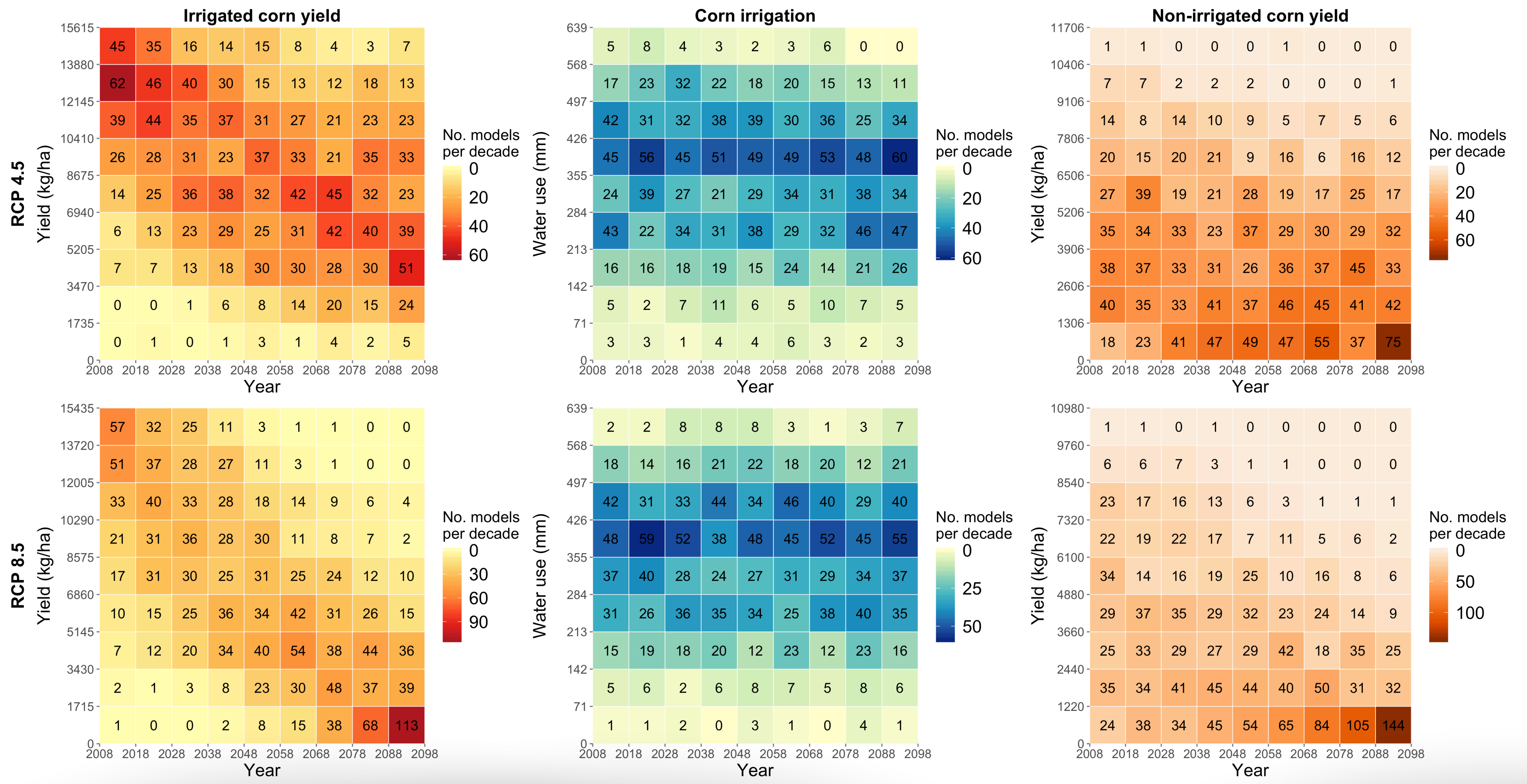
Irrigated corn



Irrigation demand



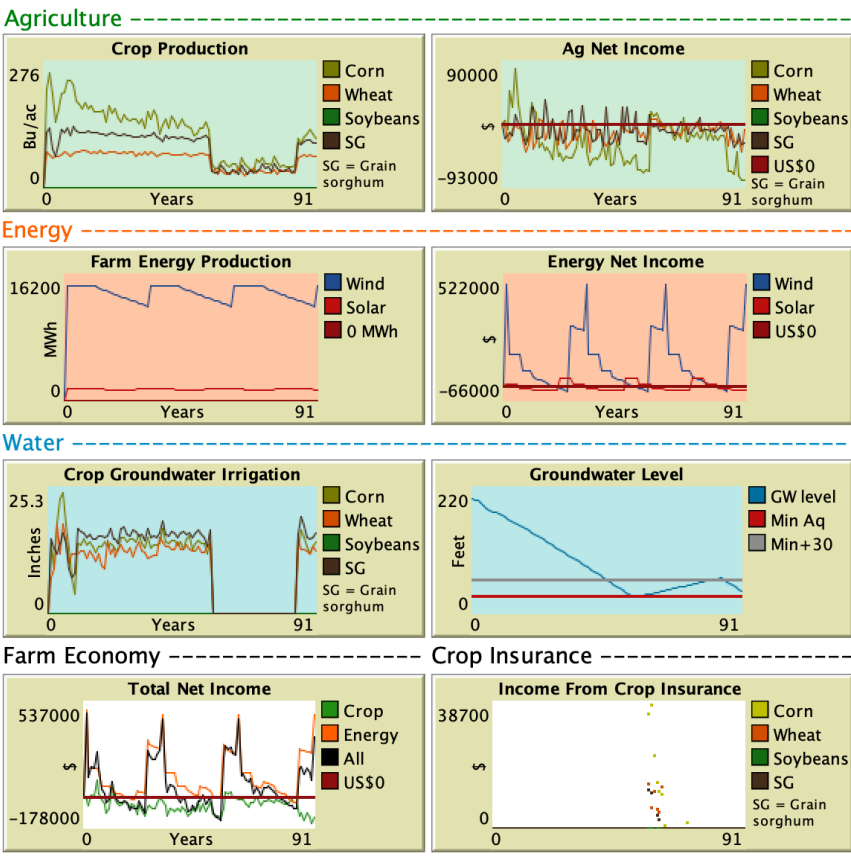
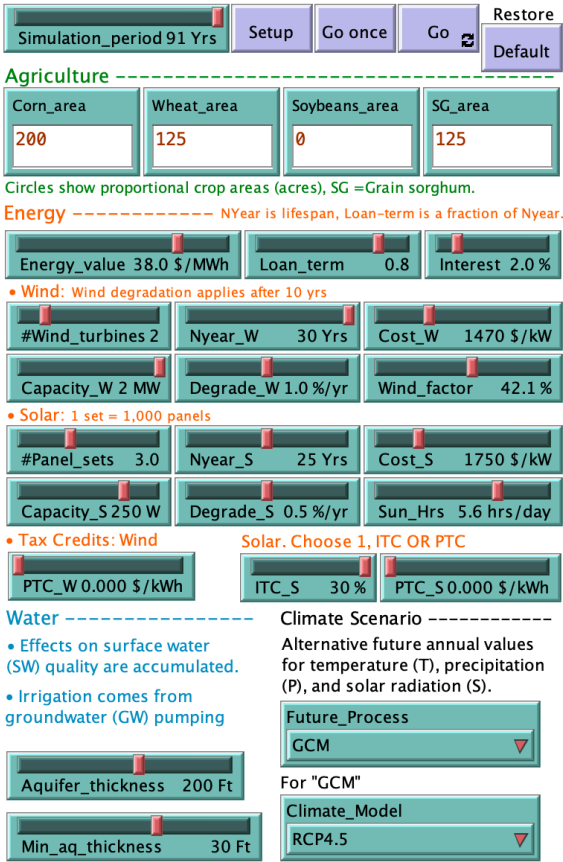
# Projected Trends and Variability



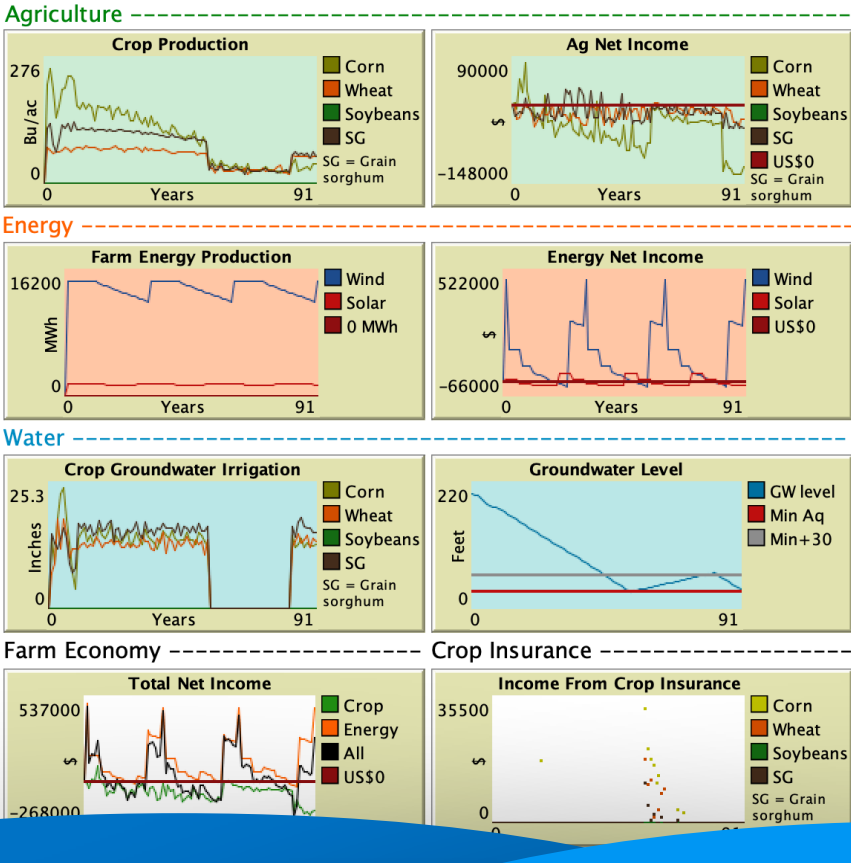
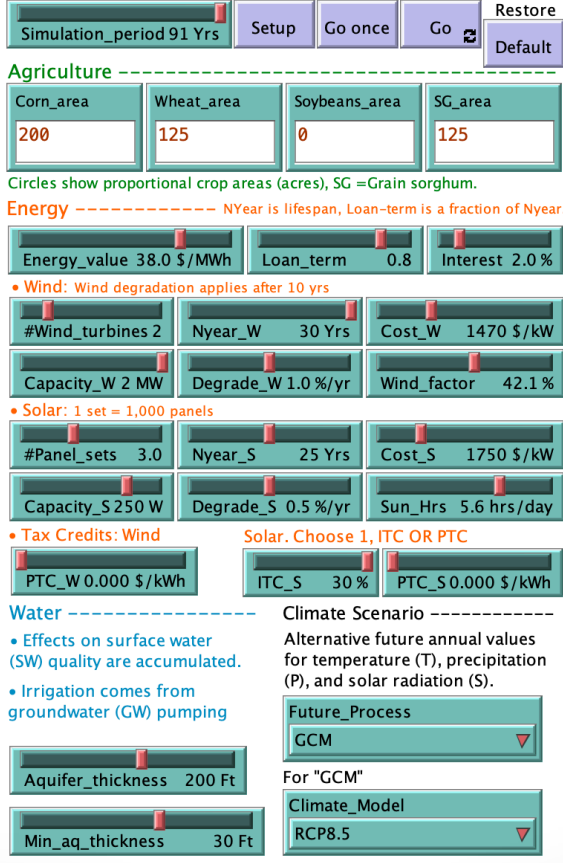


# FEWCalc Prediction

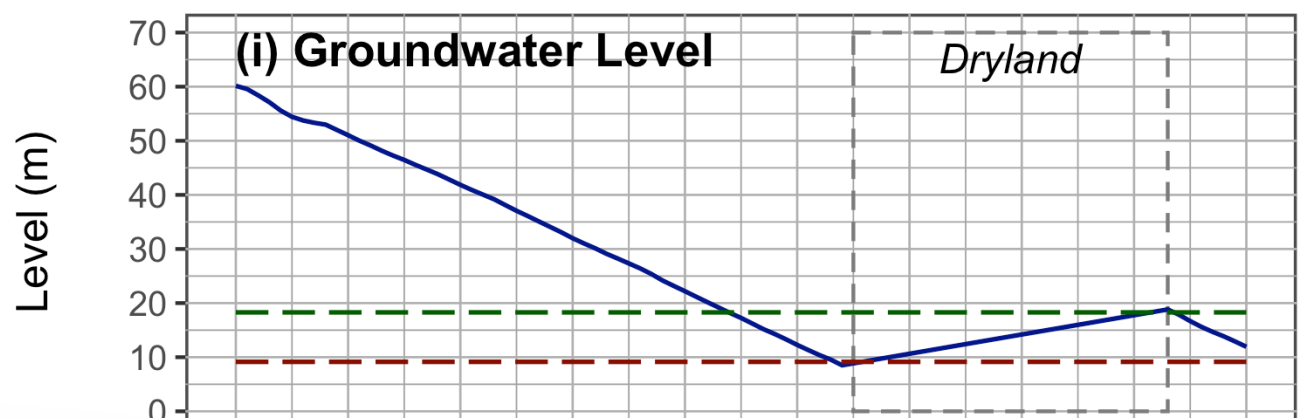
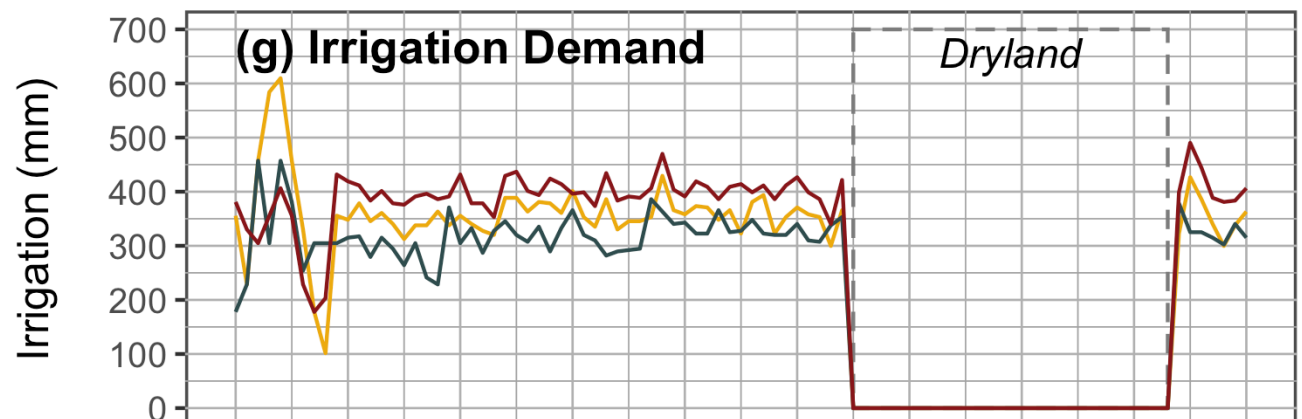
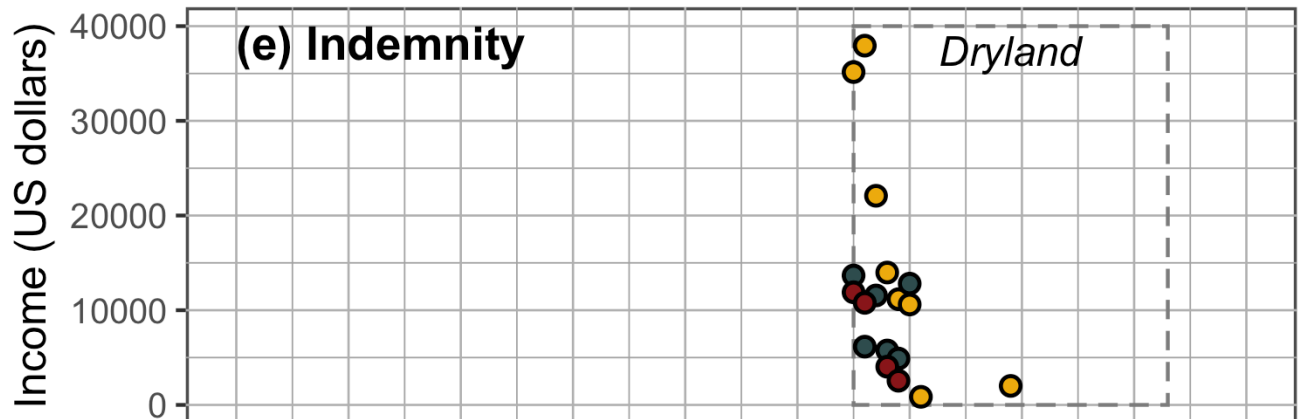
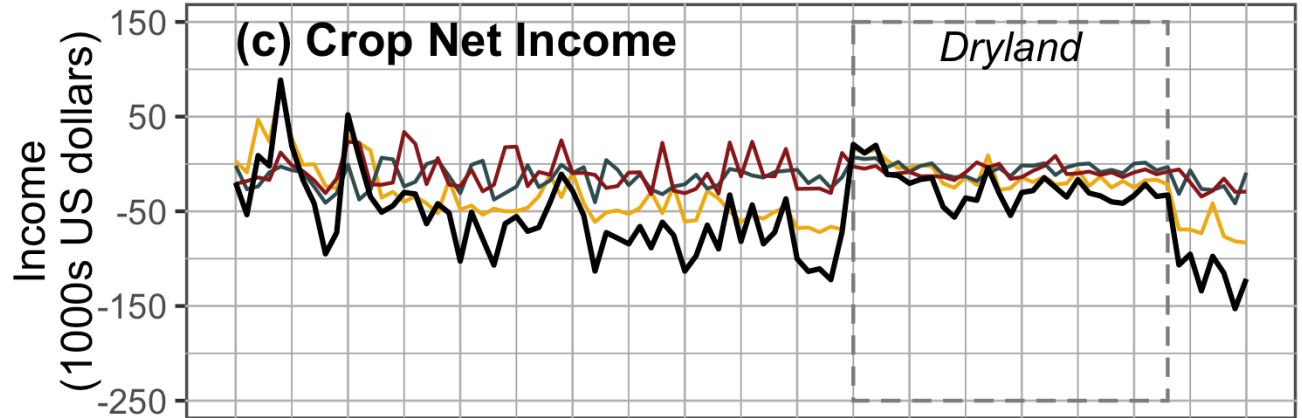
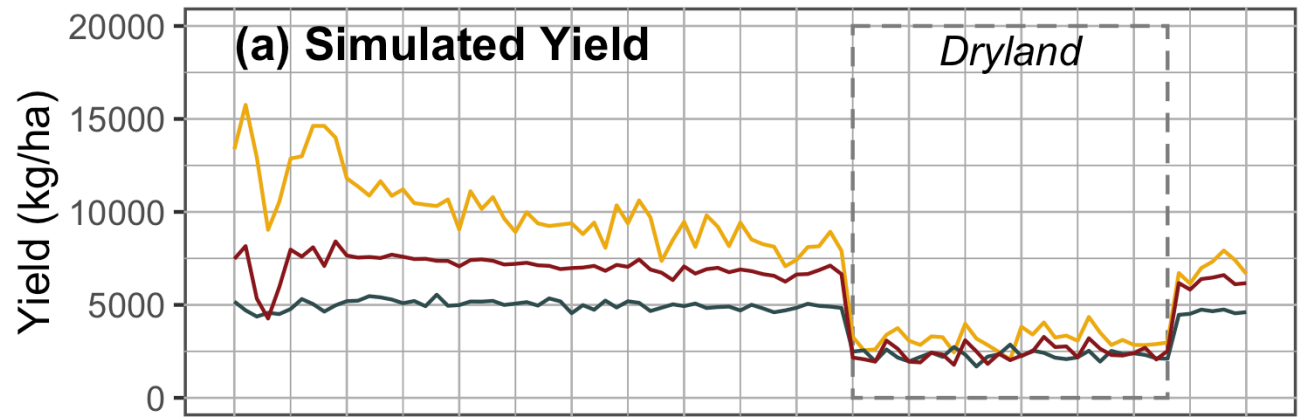
## RCP 4.5



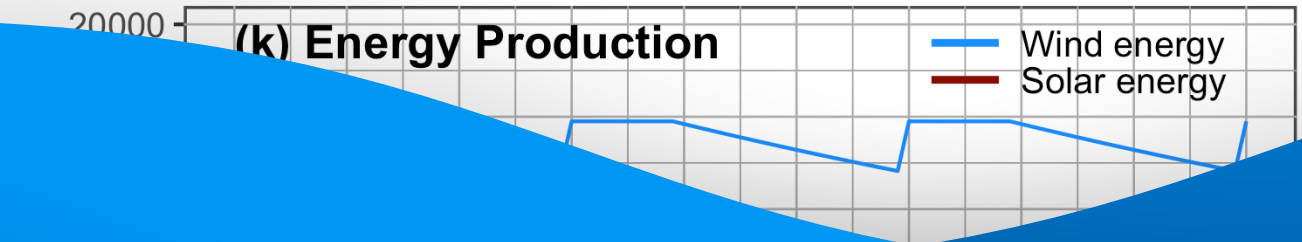
## RCP 8.5



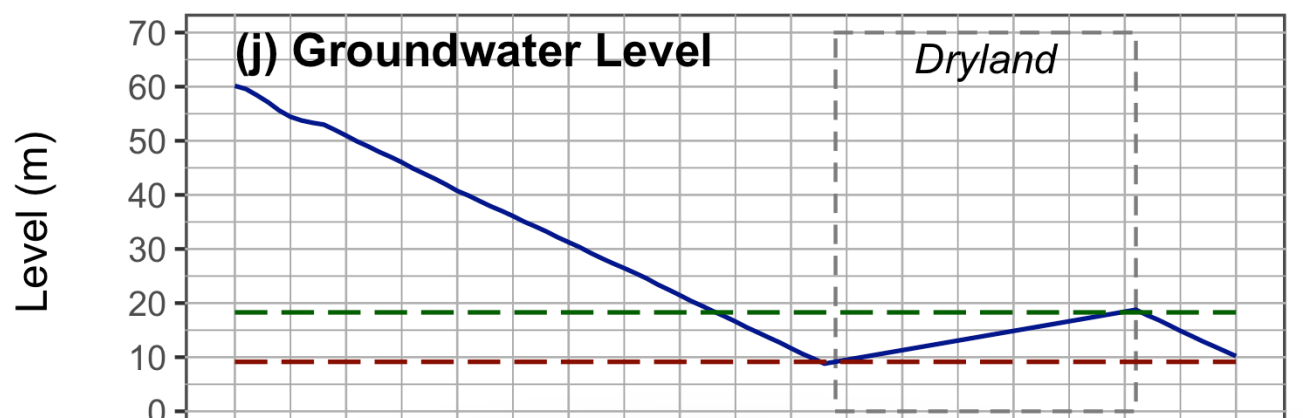
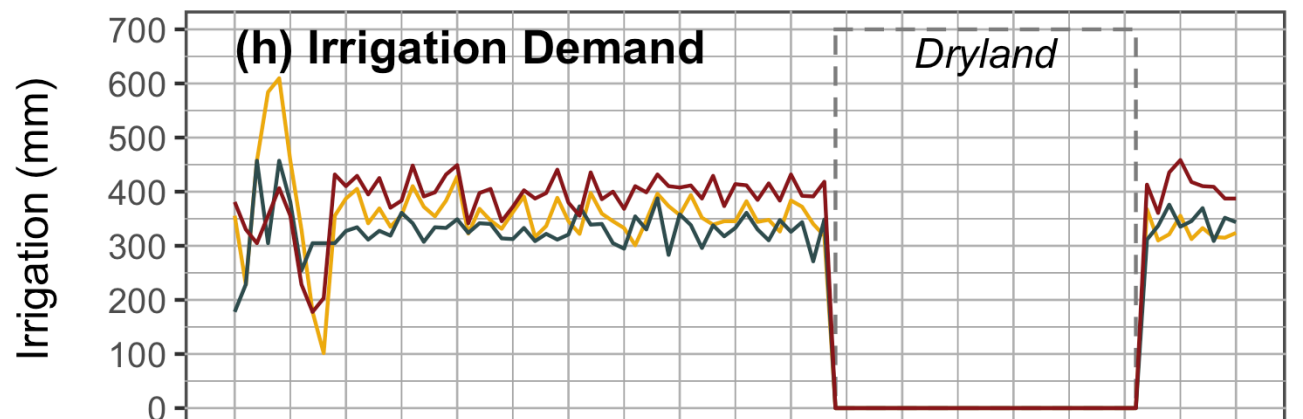
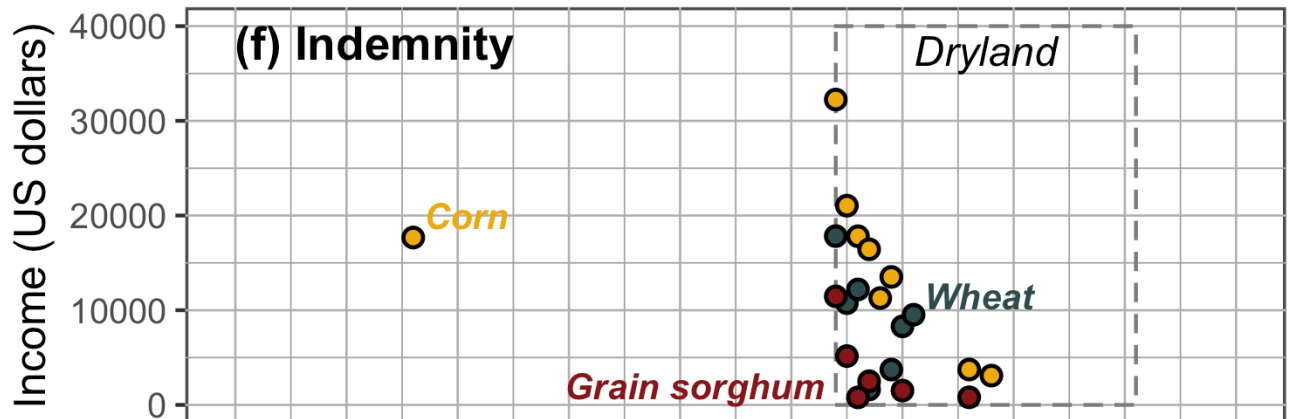
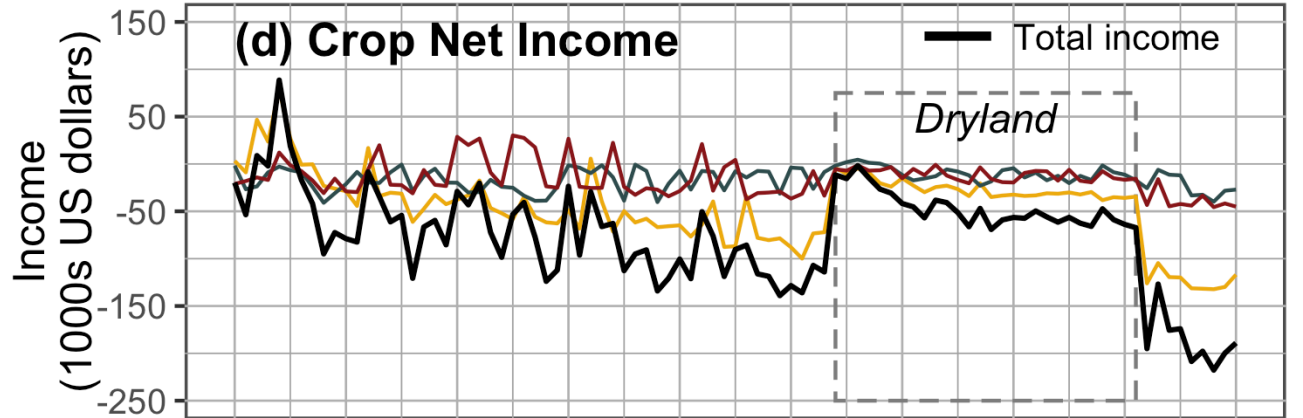
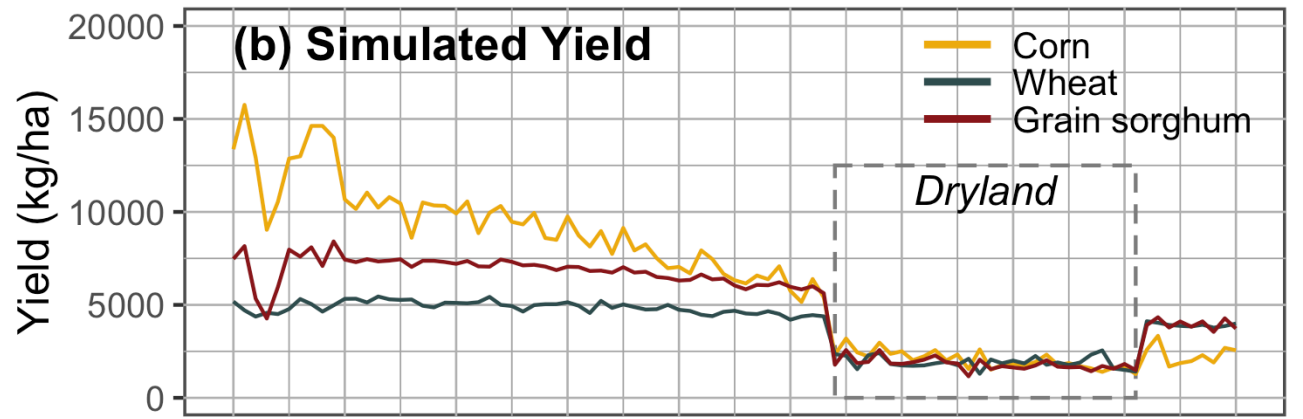
## RCP 4.5



## RCPs 4.5 and 8.5



## RCP 8.5



## RCPs 4.5 and 8.5





# Conclusions



***Could local renewable energy resources provide opportunities to the farm system?***

Energy resources have potential to support local farm system, especially in the areas where the energy production factor is high.

***What effect does climate change have on the farm economy in terms of water use and food production?***

Water use and food production are sensitive to climate change. The increased temperature and change in precipitation patterns reduce crop productivity.

***How do agricultural production and farm income respond to groundwater shortage?***

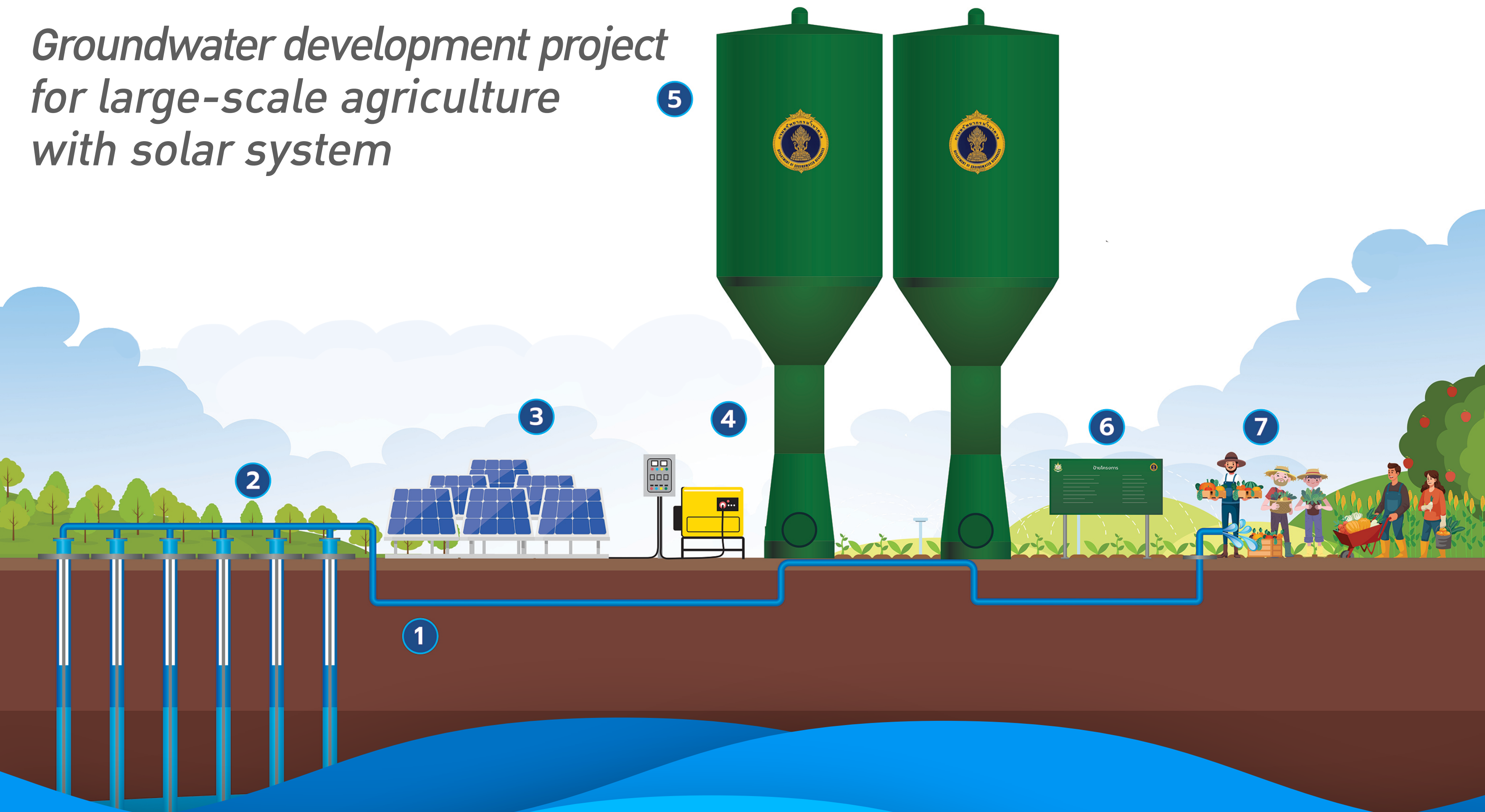
Water is a crucial resource for food production. Groundwater shortage affects crop irrigation system, and ultimately reduces crop yields.





# Opportunities and Challenges in Thailand

*Groundwater development project  
for large-scale agriculture  
with solar system*



- *Groundwater wells*
- *Solar-powered pumping system*
- *Electric generator*
- *Storage tanks*
- *Water distribution pipes*



**Improve  
crop productivity**

**Increase net income**





# Is it sustainable?





# Yes, it is.

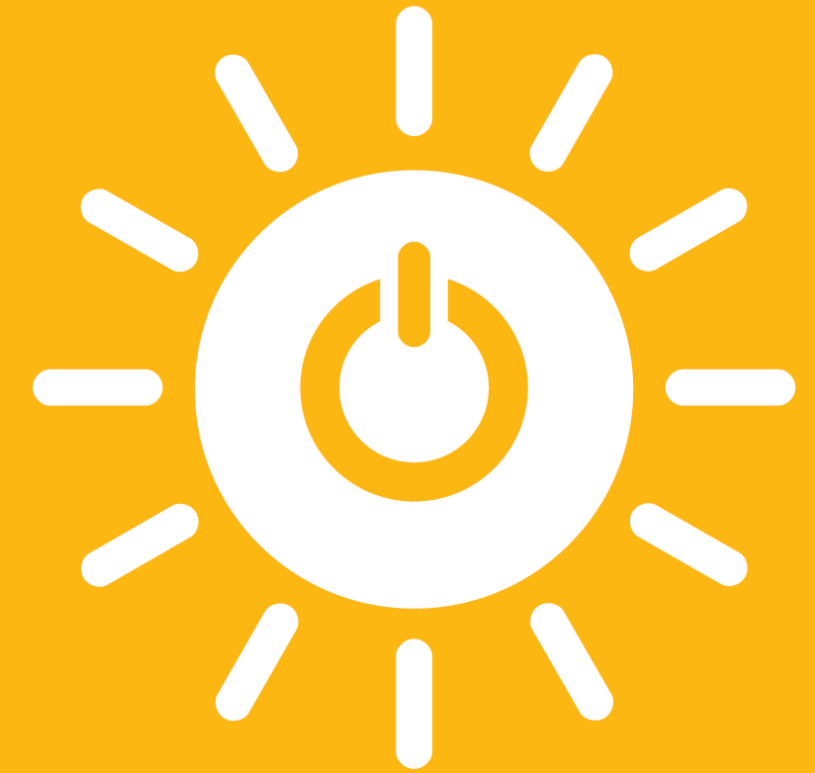
**2** ZERO  
HUNGER



**6** CLEAN WATER  
AND SANITATION



**7** AFFORDABLE AND  
CLEAN ENERGY





# References



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