Collaboration with

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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January 28, 2022

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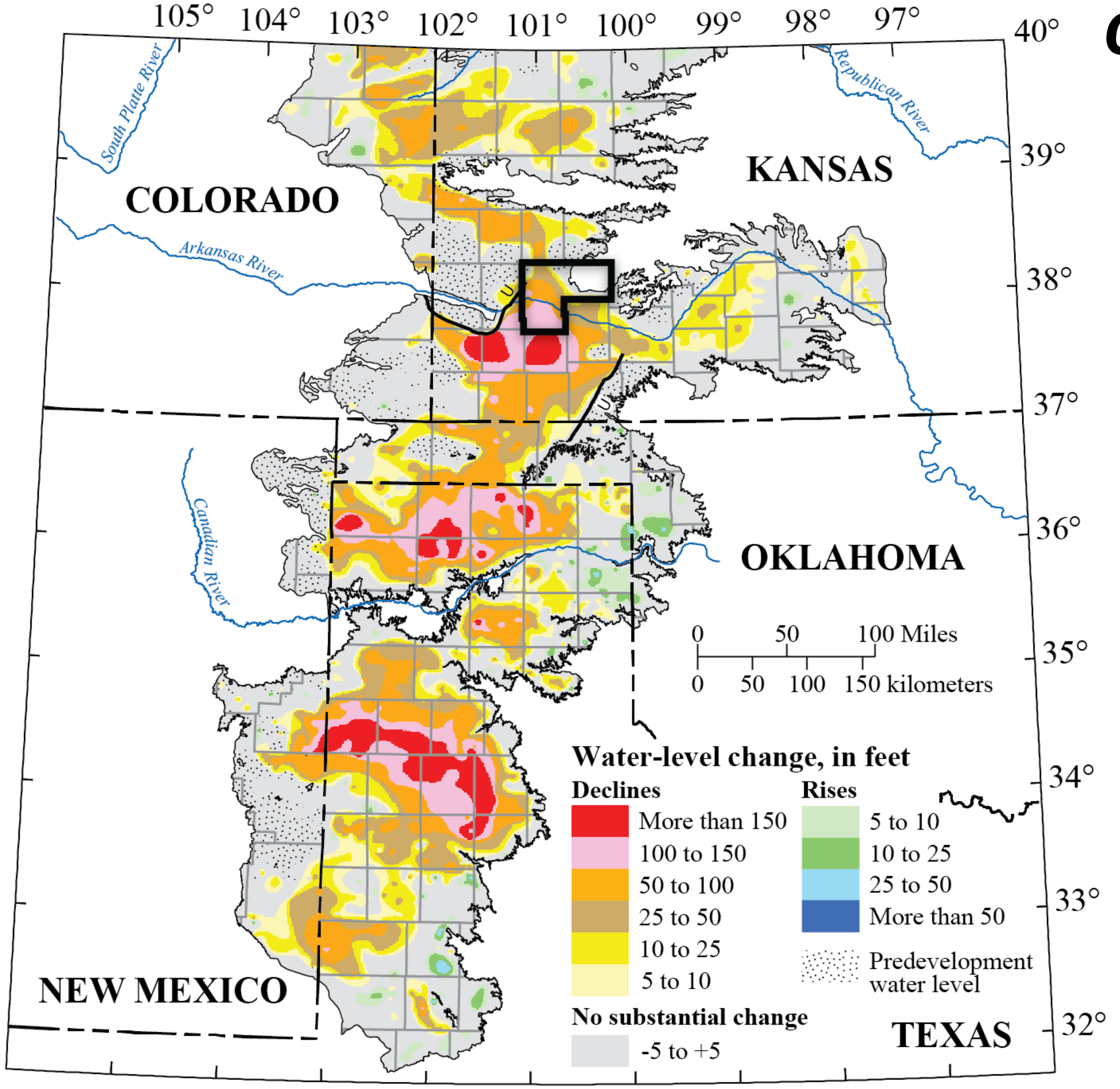
Introduction


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



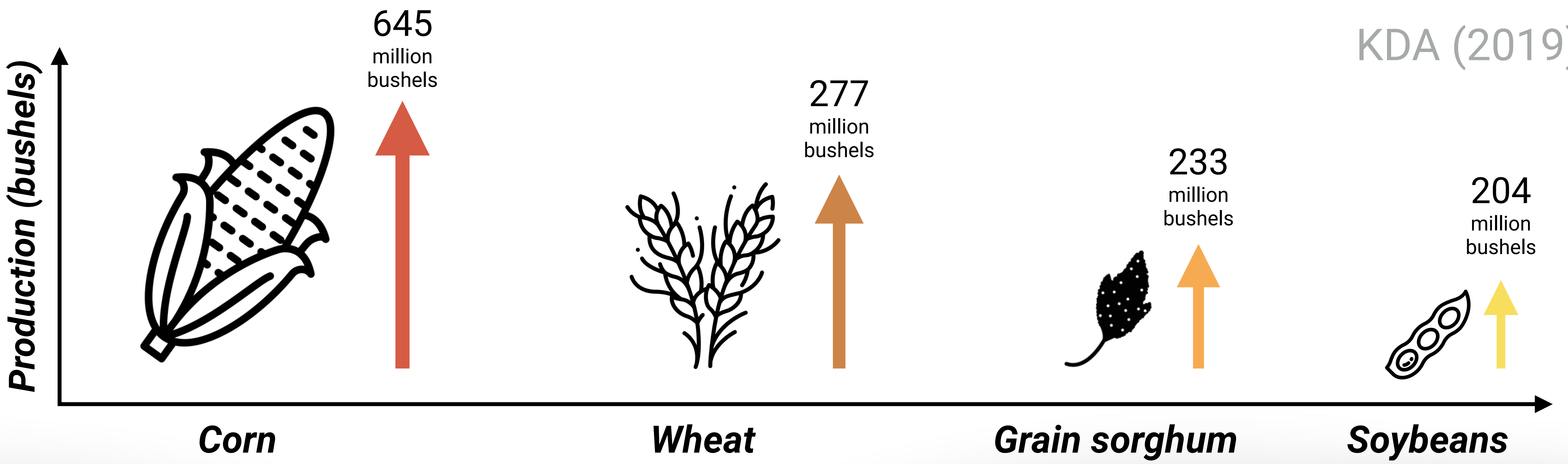
McGuire (2014)

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

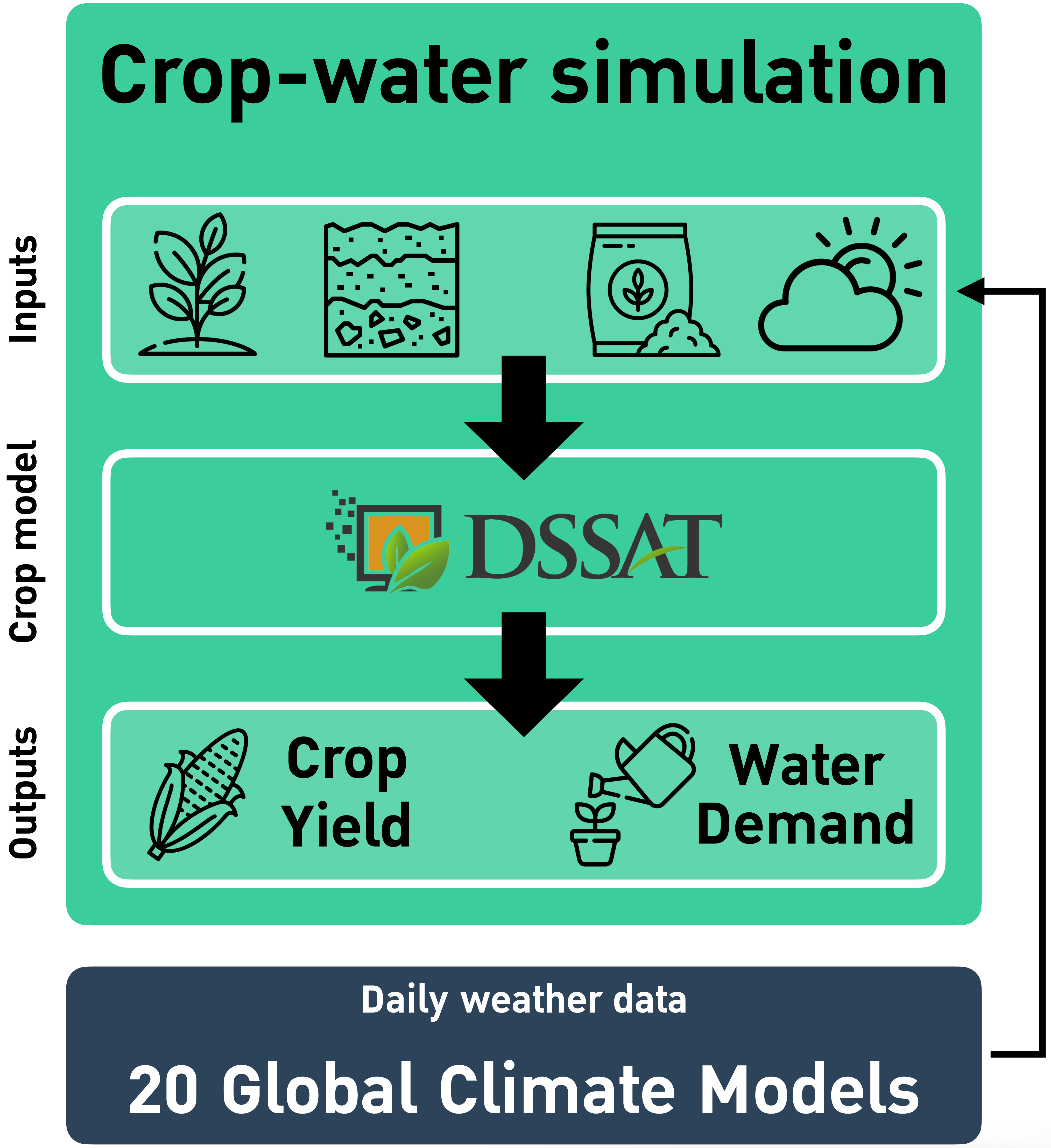


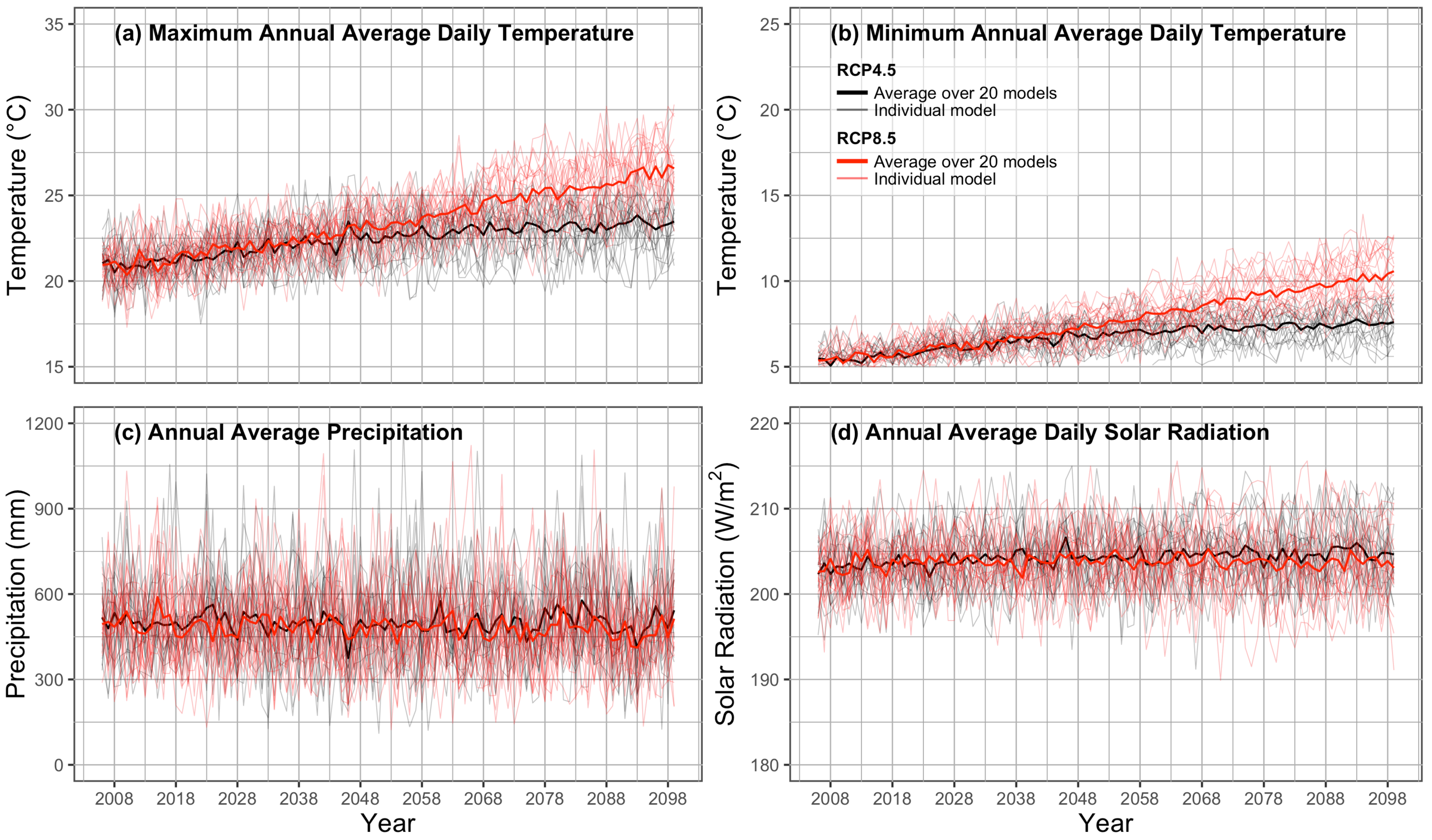
KDA (2019)

Is it sustainable?



Methods





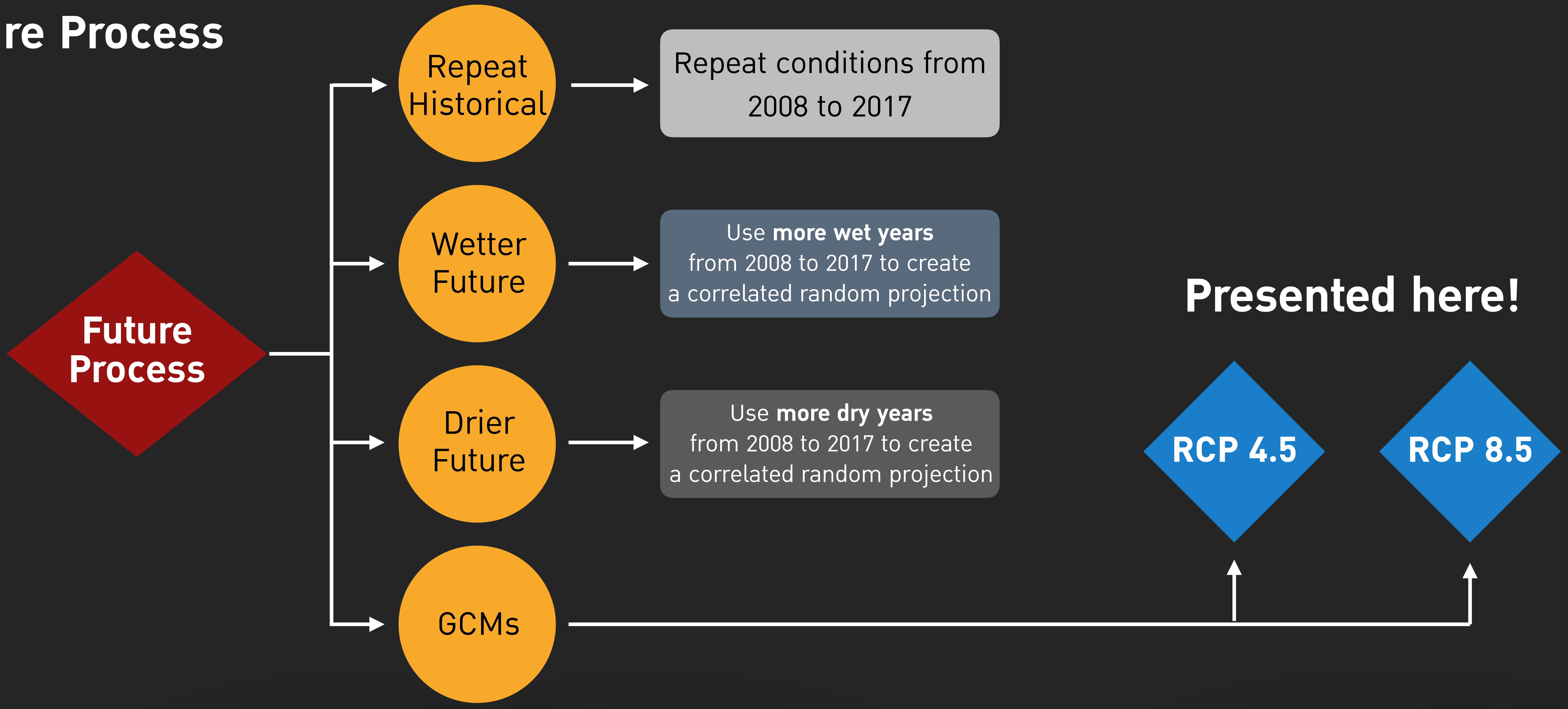
Data from 20 individual models and their average

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

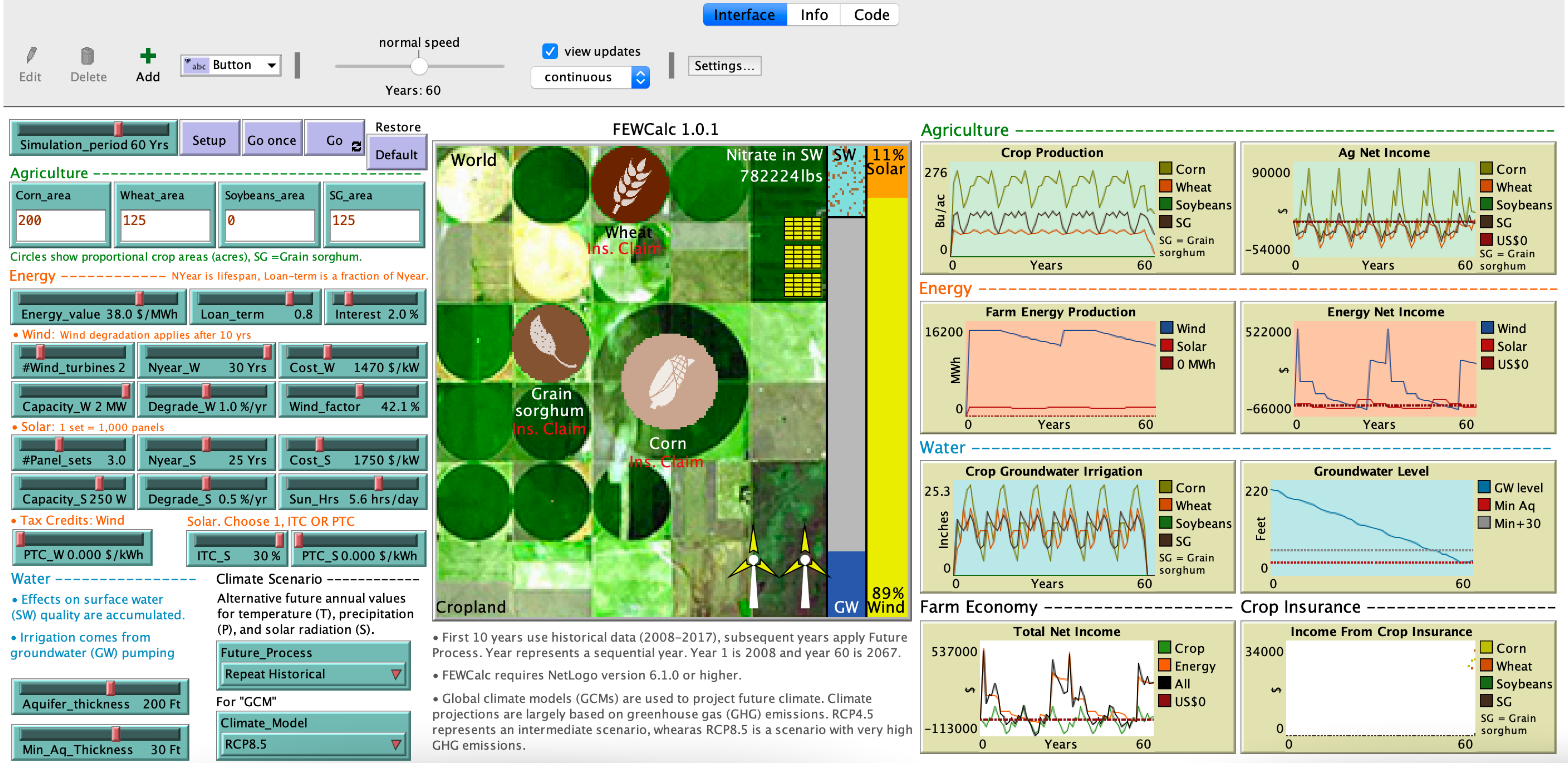
More details: Phetheet et al. (2020) and Phetheet et al. (2021)

FEWCalc

Future Process



FEWCalc NetLogo Interface



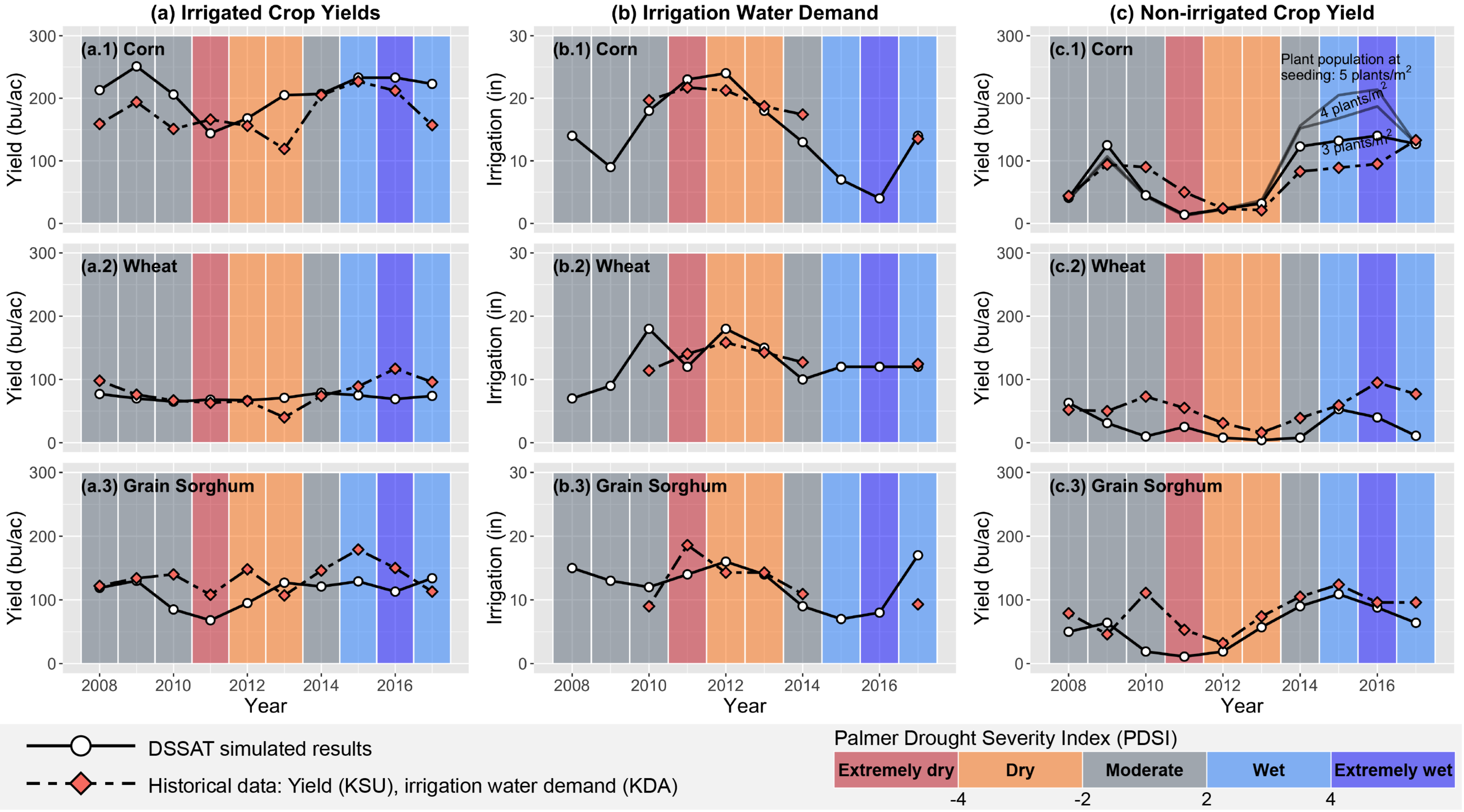
FEWCalc NetLogo Code

```
  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                                                                    ; Bob Johnson (bobjohnson@centurylink.net), Earnie Lehman (earnielehman@gmail.com)
  set #Solar_panels (#solar_panel_sets * 1000)
  set solar-production (#Solar_Panels * Panel_power * 5 * 365 / 1000000)                 ; MWh = power(Watt) * 5hrs/day * 365days/year / 1000000
  set wind-production (#wind_turbines * Turbine_size * 0.425 * 24 * 365)                 ; MWh = power(MW) * Kansas_wind_capacity * 24hrs/day * 365days/year                          ;45% (Bob)
  set solar-cost (#Solar_Panels * Panel_power / 1000 * 3050)                             ; Solar cost = #Solar_Panels * Panel_power * $3050/kW
  set solar-sell (solar-production * 38)                                                 ; Sell = MWh * $38/MWh                        --> (Wholesale was $22-24/MWh, Retail price is $105/MWh
                                                                                         ; Wholesale < Coop $65 < Retail
  set wind-cost (((3000000 / 30) + 100000)) * #wind_turbines                             ; For 2MW wind turbine, Wind cost = 3000000/30 + (300000 maintenance/yr) * #wind_turbines  ??????check
  set wind-sell (wind-production * 38)                                                   ; Sell = MWh * $38/MWh
  set solar-net-income (solar-sell - (solar-cost / 30))                                  ; assuming the cost spreads over 30 years with no interest or maintenance
  set wind-net-income  (wind-sell - (wind-cost))                                         ; assuming the cost spreads over 30 years with no interest or maintenance
  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
  ]
```

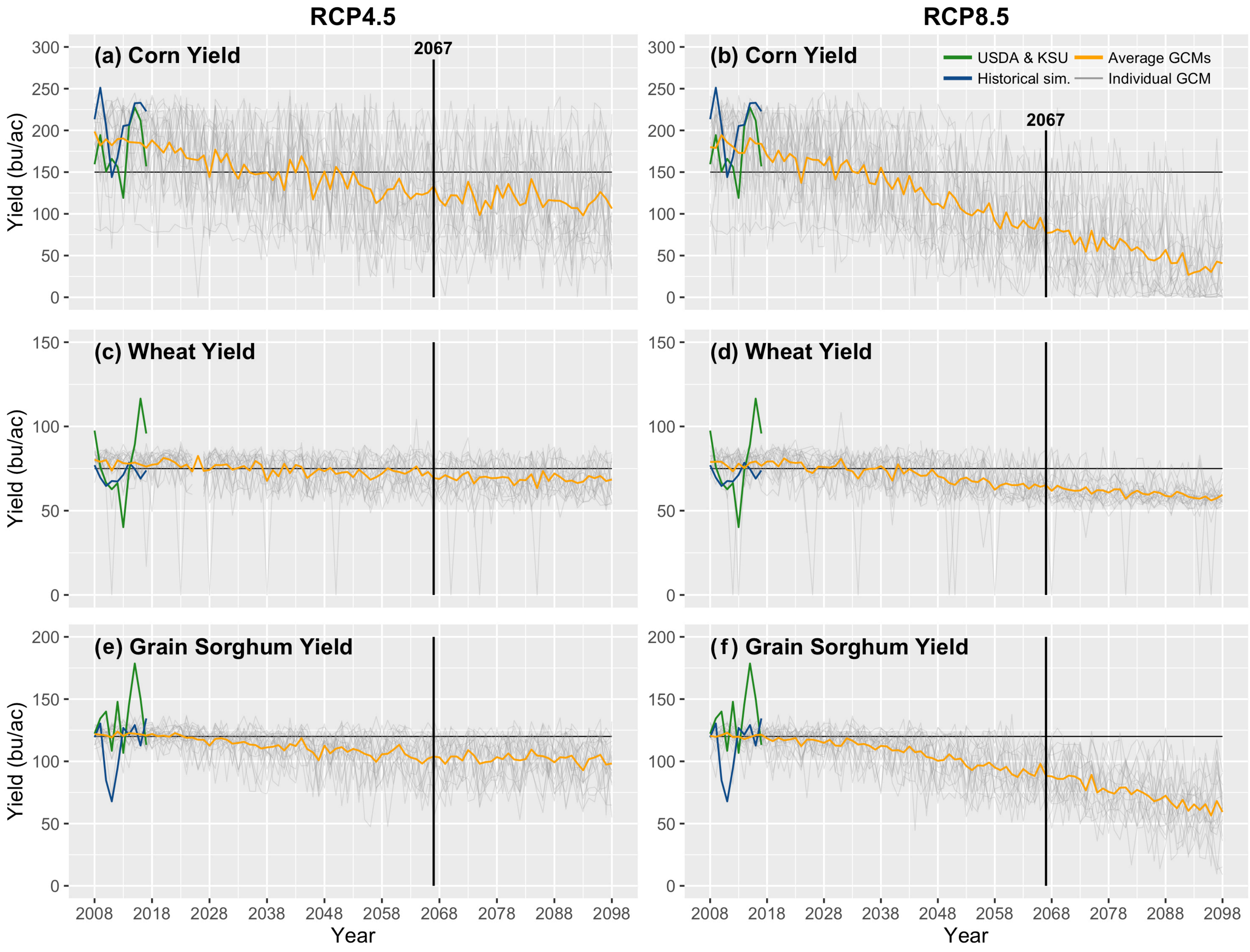
Results

Comparison: Historical vs. simulated

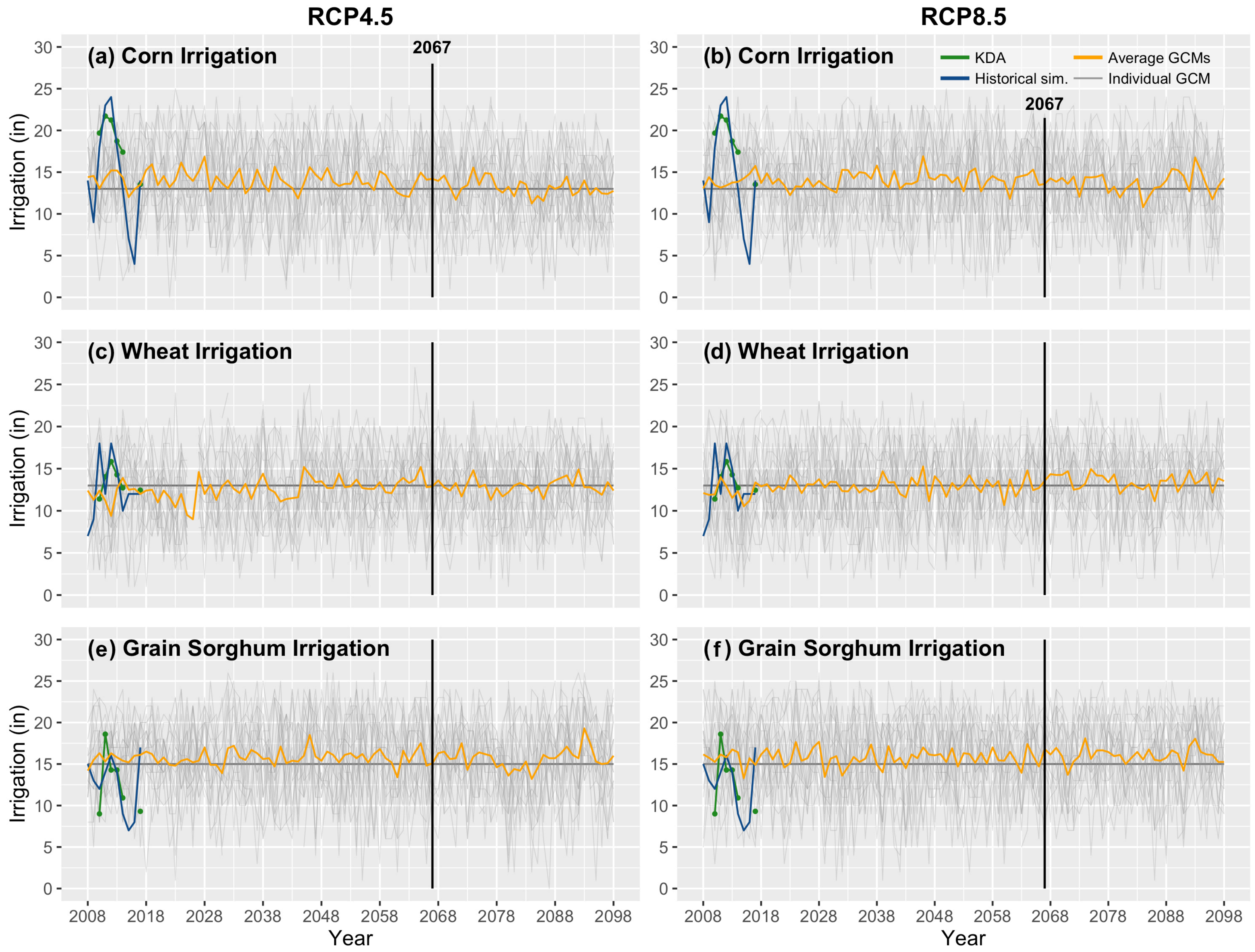
During 10-year base period



Crop yield and **Irrigation Demand** under climate models

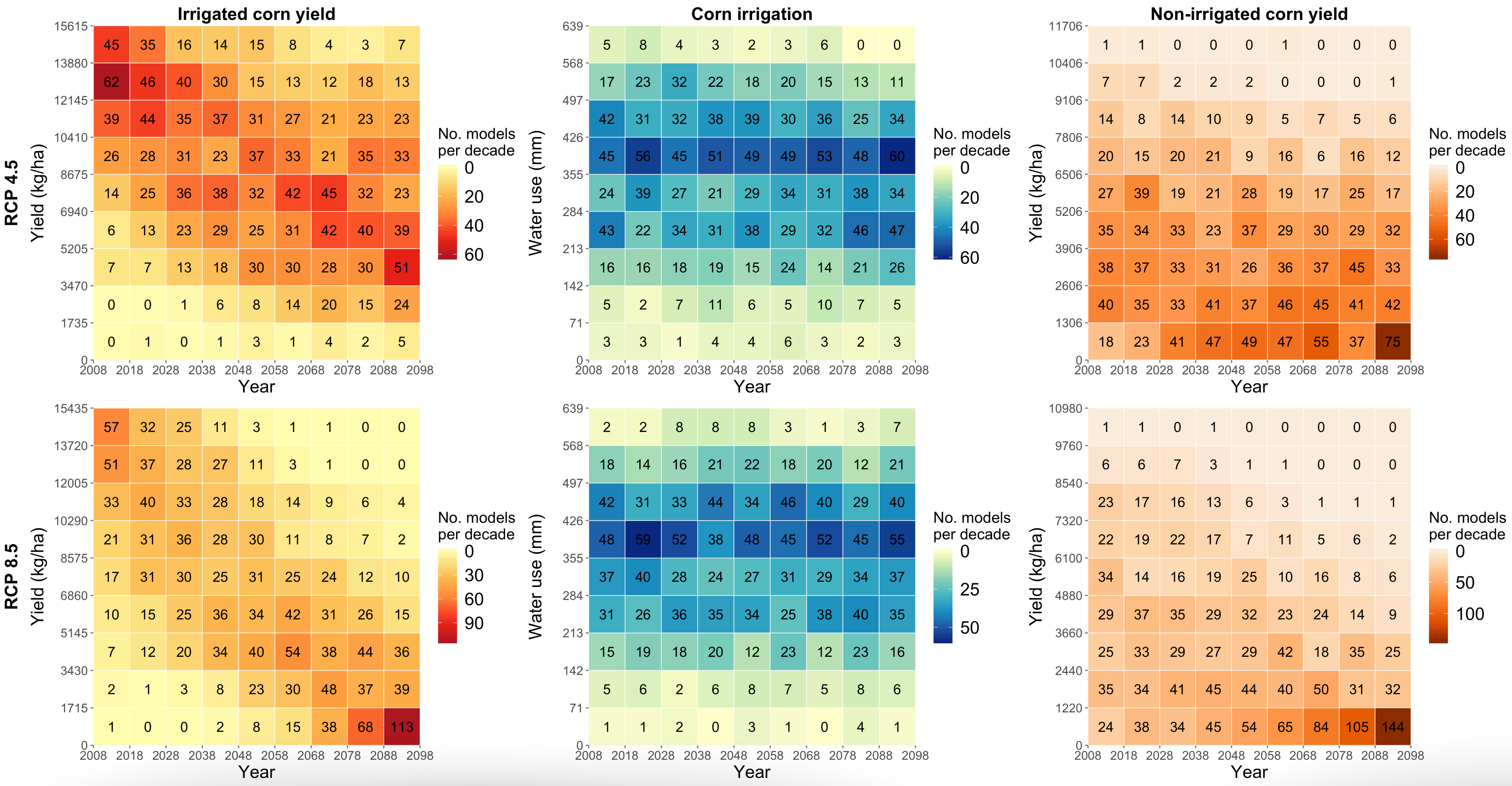


Irrigated corn



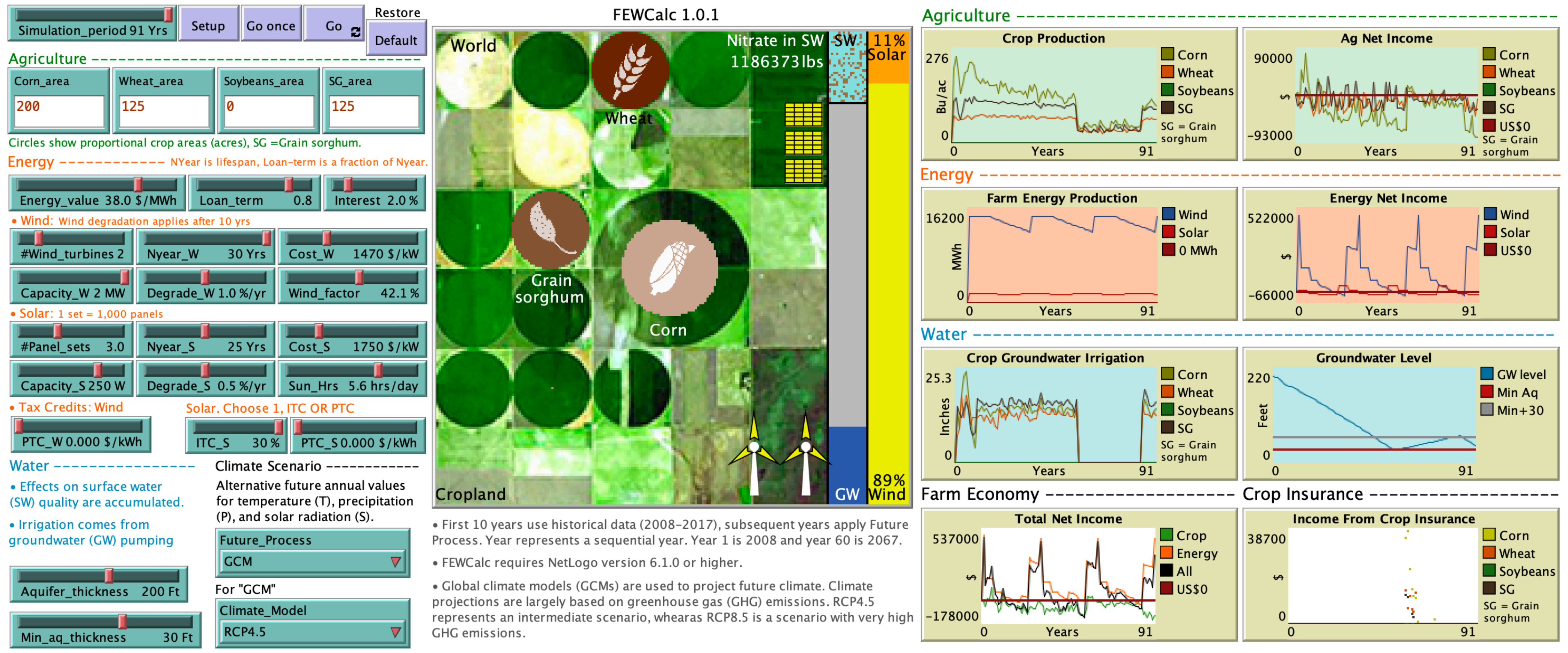
Irrigation demand

Projected Trends and Variability

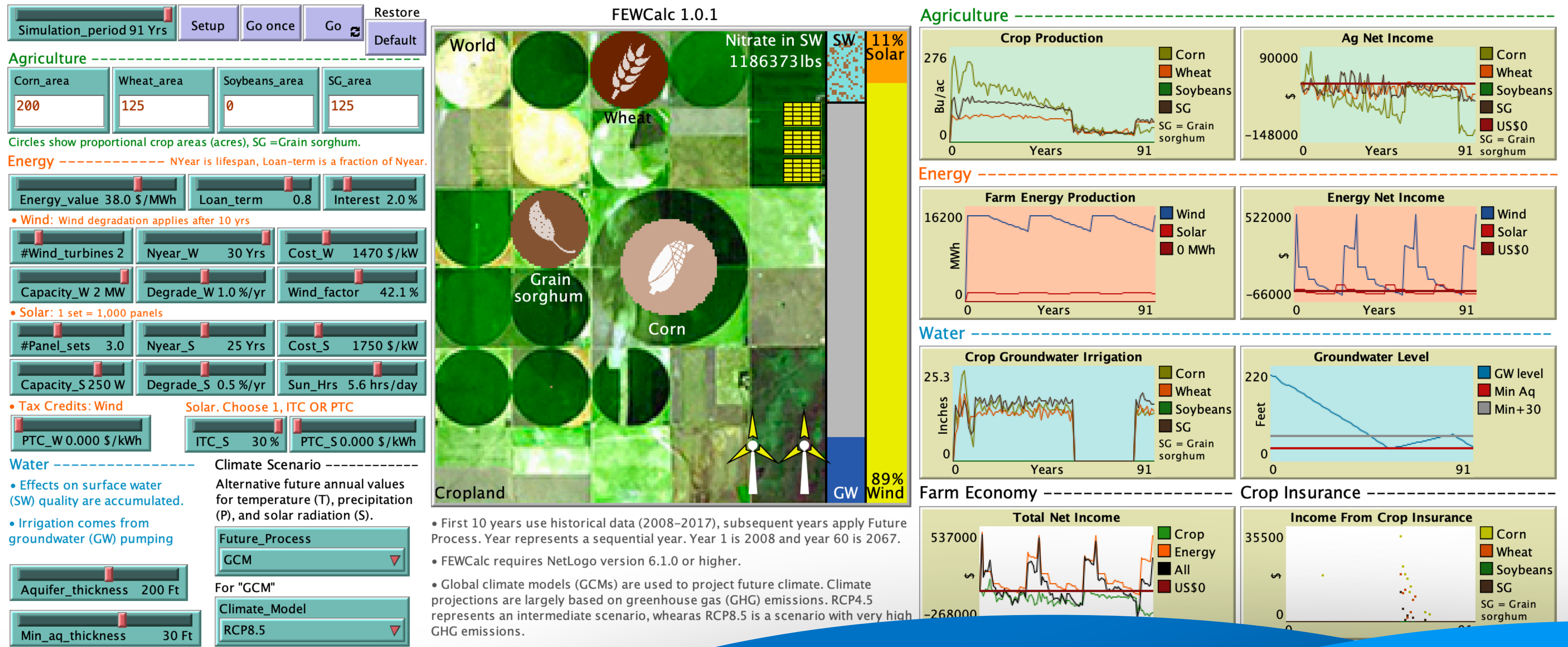


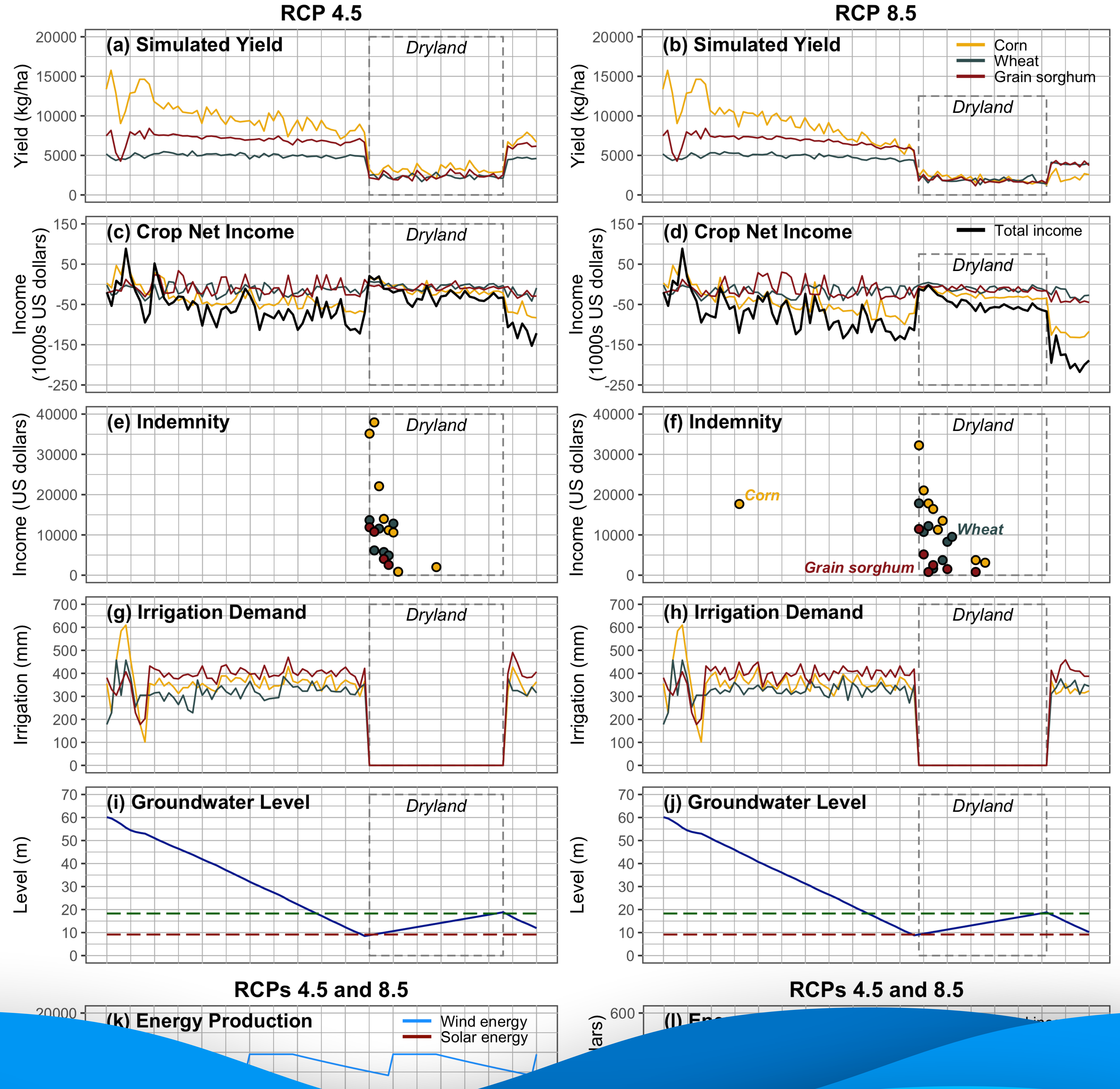
FEWCalc Prediction

RCP 4.5



RCP 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?

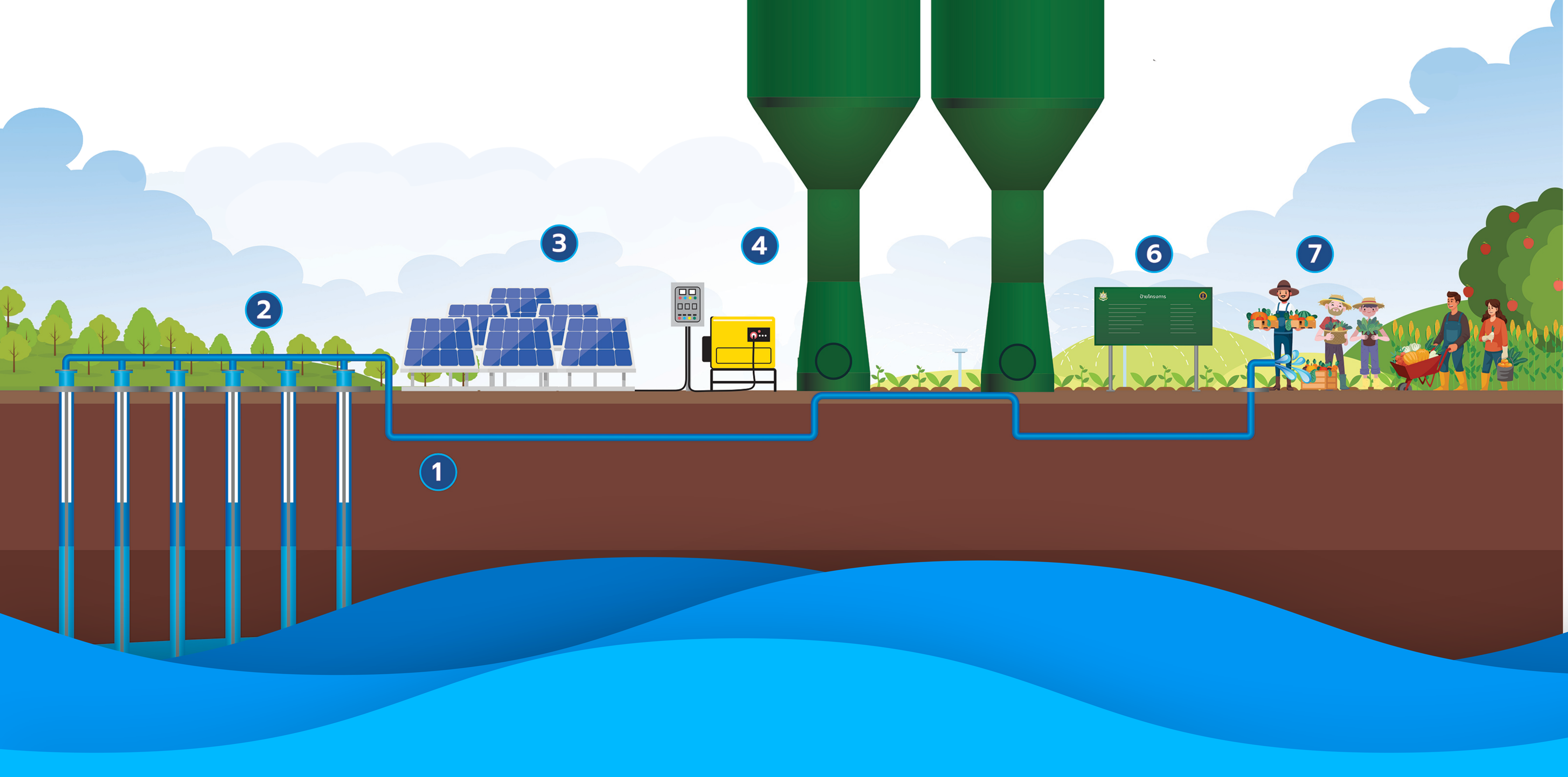
Water use and food production are sensitive to climate change. The increased temperature and change in precipitation patterns reduce crop productivity.

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

Abatzoglou, J. T., & Brown, T. J. (2012). A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology, 32(5), 772–780. https://doi.org/10.1002/joc.2312

KDA (Kansas Department of Agriculture). (2019). Kansas Farm Facts. https://agriculture.ks.gov/docs/default-source/ag-marketing/kansas-farm-facts-2019.pdf

McGuire, V. L. (2014). Water-level changes and change in water in storage in the High Plains aquifer, predevelopment to 2013 and 2011–13. In U.S. Geological Survey Scientific Investigations Report (No. 5218; p. 14). U.S. Geological Survey. https://doi.org/10.3133/sir20145218

Phetheet, J., Hill, M. C., Barron, R. W., Gray, B. J., Wu, H., Amanor-Boadu, V., Heger, W., Kisekka, I., Golden, B., & Rossi, M. W. (2021). Relating agriculture, energy, and water decisions to farm incomes and climate projections using two freeware programs, FEWCalc and DSSAT. *Agricultural Systems*, *193*, 103222. https://doi.org/10.1016/j.agsy.2021.103222

Phetheet, J., Hill, M. C., Barron, R. W., Rossi, M. W., Amanor-Boadu, V., Wu, H., & Kisekka, I. (2020). Consequences of climate change on food-energy-water systems in arid regions without agricultural adaptation, analyzed using FEWCalc and DSSAT. *Resources, Conservation and Recycling*, 105309. https://doi.org/10.1016/j.resconrec.2020.105309