



# THE DEVELOPMENT OF AN AGRICULTURAL DROUGHT VULNERABILITY ASSESSMENT TOOL FOR PENNSYLVANIA



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# Project Goal

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- Improve the understanding of agricultural drought risk in Pennsylvania through the development of a drought assessment tool that can assess the vulnerability of Pennsylvania's diverse soils to agricultural drought



# Agricultural Drought

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- Drought is the primary contributor to crop failure
- Results from an inability to meet plant water demands due to soil moisture stress
- Short term moisture deficits during critical stages of crop development can severely reduce yields



# Drought Indices

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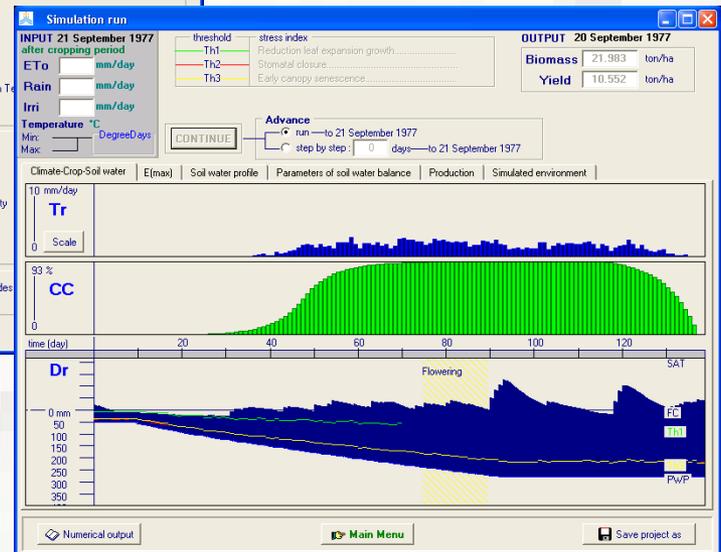
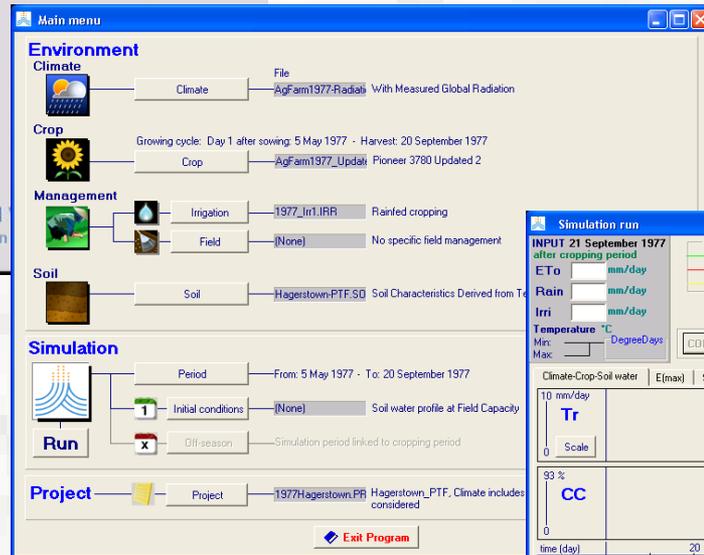
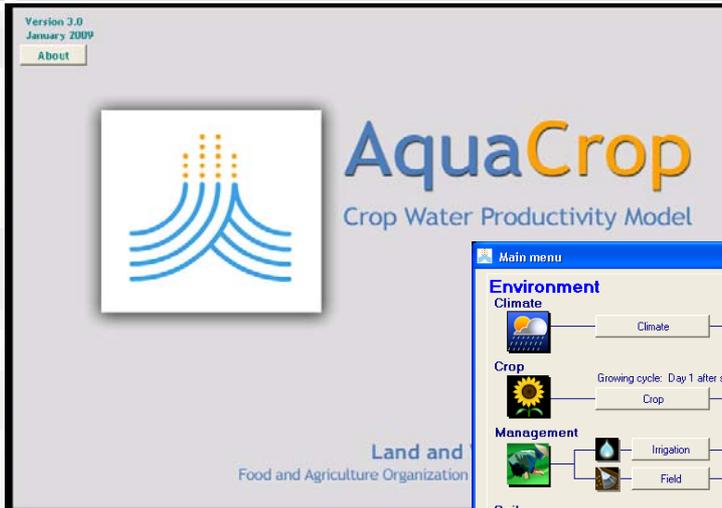
- Widely used drought indices:
  - Palmer Drought Severity Index (PDSI)
  - Crop Moisture Index (CMI)
  - Surface Water Supply Index (SWSI)
  - Standardized Precipitation Index (SPI)
  - Normalized Difference Vegetation Index (NDVI)
  - Vegetation Condition Index (VCI)



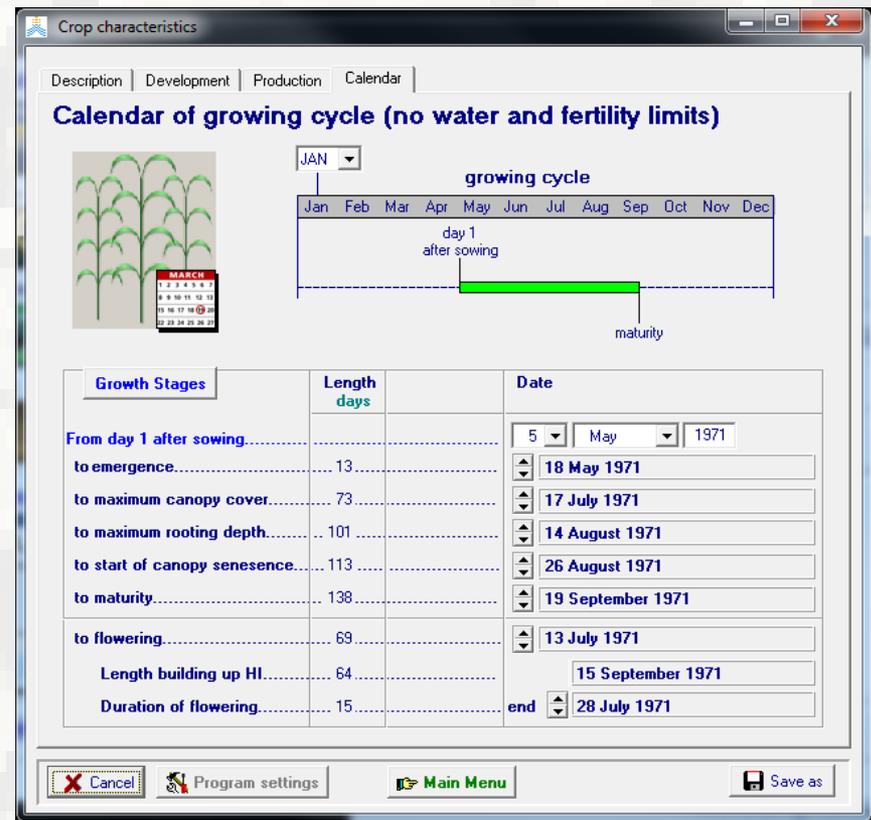
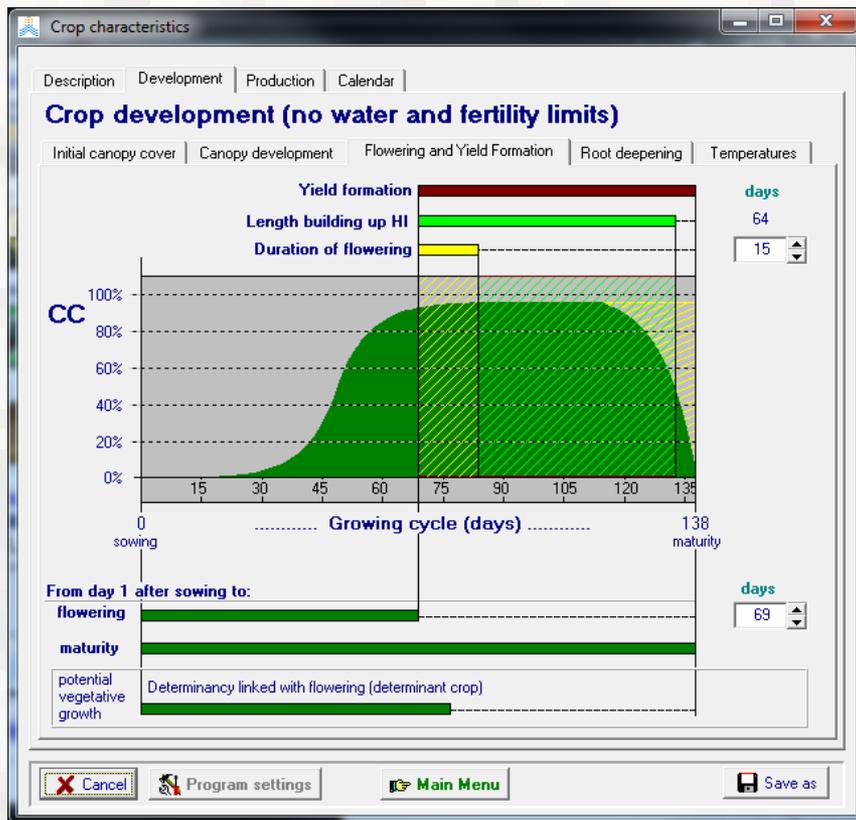
# Crop Models



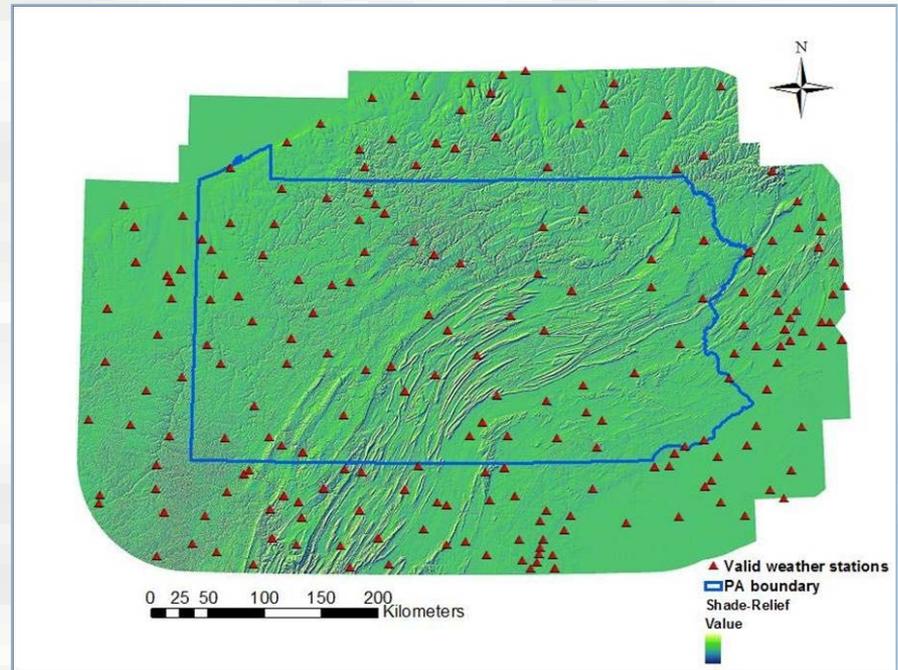
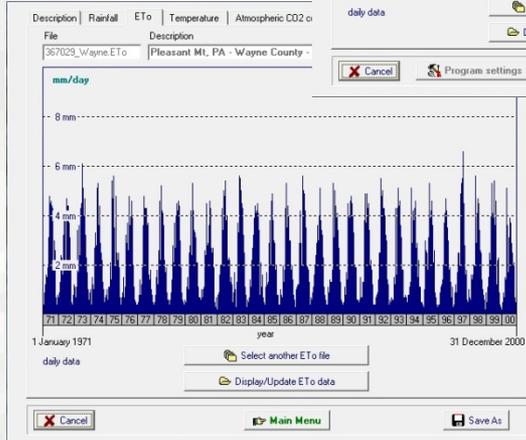
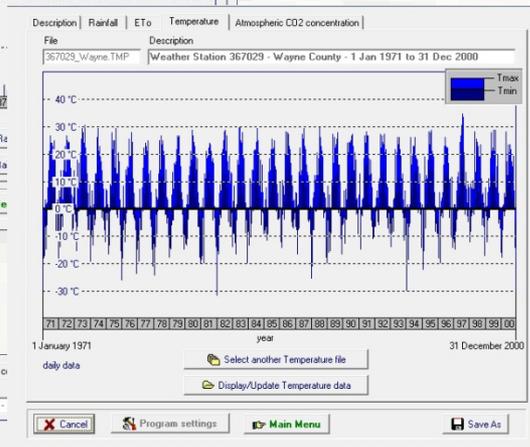
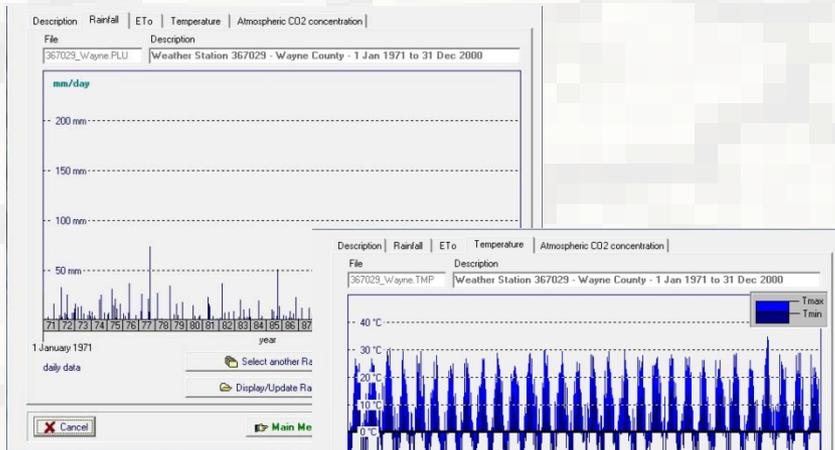
# AquaCrop: The FAO Crop Model



# AquaCrop Inputs: Crop Characteristics



# AquaCrop Inputs: Climatic Data



# AquaCrop Inputs: Soil Profile Characteristics

Description | Characteristics of soil horizons | Soil surface | Restrictive soil layer

Number soil horizons: 3

Plot hydraulic characteristics

Click button to select indicative values from list

--- soil water content at ---

| horizon | description | thickness<br>m | PWP | FC<br>vol % | SAT  | TAW<br>mm/m | Ksat<br>mm/day | tau  |
|---------|-------------|----------------|-----|-------------|------|-------------|----------------|------|
| 1       | H1          | 0.20           | 6.7 | 18.5        | 33.0 | 118         | 2439.1         | 1.00 |
| 2       | H2          | 0.36           | 6.0 | 10.7        | 22.0 | 47          | 7926.3         | 1.00 |
| 3       | H3          | 0.20           | 1.8 | 5.3         | 24.0 | 35          | 7926.3         | 1.00 |

Description | Characteristics of soil horizons | Soil surface | Restrictive soil layer

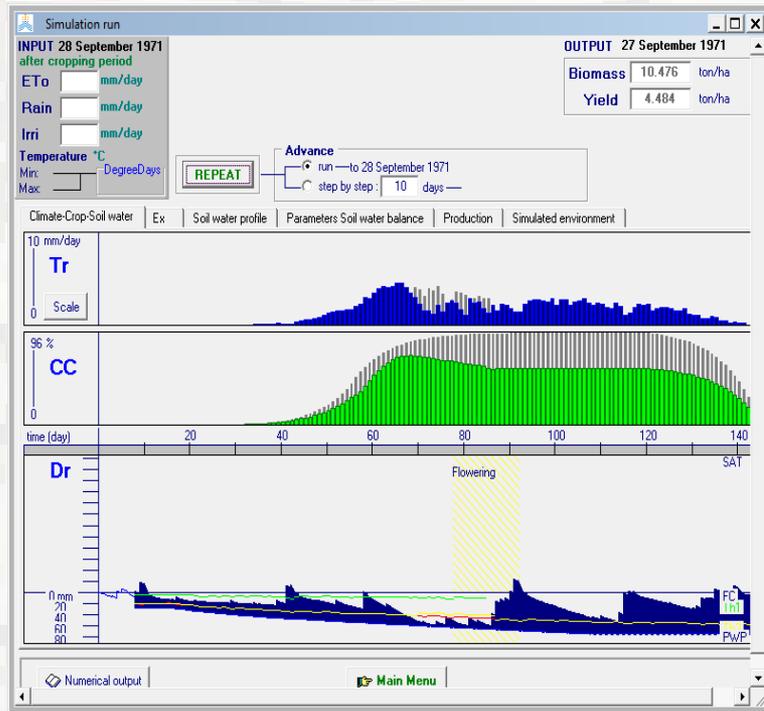
### Restrictive soil layer blocking root zone expansion

No restrictive soil layer

Restrictive layer at 1.00 meter

0.0 m  
1.0 m  
2.0 m  
3.0 m  
4.0 m  
5.0 m

# AquaCrop Outputs



Numerical output

Daily

Soil water content (profile and root zone)

Select Output File  
 Crop development and production  
 Soil water balance  
 Soil water content (profile and root zone)  
 Soil water content (compartments)  
 Net irrigation requirements

Time Aggregate  
 Day  
 10-day  
 Month  
 Year

Legend

| Day | Month | Year | DAP | Stage | Wt   | W(Sa) | W(F) | W(spc) | W(s) | W(rn) | W(PVP) |
|-----|-------|------|-----|-------|------|-------|------|--------|------|-------|--------|
| 24  | 5     | 1971 | 12  | 1     | 41.4 | 102.6 | 54.8 | 50.4   | 32.3 | 33.1  | 23.4   |
| 25  | 5     | 1971 | 13  | 1     | 42.8 | 107.0 | 56.9 | 52.4   | 34.5 | 34.6  | 24.6   |
| 26  | 5     | 1971 | 14  | 2     | 44.5 | 111.2 | 59.0 | 53.3   | 35.4 | 35.4  | 25.7   |
| 27  | 5     | 1971 | 15  | 2     | 46.1 | 115.2 | 60.9 | 53.1   | 35.5 | 35.5  | 26.0   |
| 28  | 5     | 1971 | 16  | 2     | 47.9 | 119.2 | 62.9 | 54.8   | 36.8 | 36.8  | 27.9   |
| 29  | 5     | 1971 | 17  | 2     | 49.3 | 123.1 | 64.8 | 58.1   | 39.1 | 39.1  | 29.0   |
| 30  | 5     | 1971 | 18  | 2     | 50.7 | 126.9 | 66.6 | 60.5   | 40.0 | 40.0  | 30.0   |
| 31  | 5     | 1971 | 19  | 2     | 52.2 | 130.6 | 68.4 | 61.2   | 41.4 | 41.4  | 31.0   |
| 1   | 6     | 1971 | 20  | 2     | 53.4 | 134.3 | 70.2 | 64.4   | 43.6 | 43.6  | 32.0   |
| 2   | 6     | 1971 | 21  | 2     | 54.7 | 137.9 | 72.0 | 65.8   | 44.6 | 44.6  | 33.0   |

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OK

Numerical output

Daily

Crop development and production

Select Output File  
 Crop development and production  
 Soil water balance  
 Soil water content (profile and root zone)  
 Soil water content (compartments)  
 Net irrigation requirements

Time Aggregate  
 Day  
 10-day  
 Month  
 Year

Legend

| Day | Month | Year | DAP | Stage | Tu/Tn | WP               | SBio | Biomass | HI  | Yield Part | BrefW |
|-----|-------|------|-----|-------|-------|------------------|------|---------|-----|------------|-------|
|     |       |      |     |       | %     | g/m <sup>2</sup> | %    | ton/ha  | %   | ton/ha     | %     |
| 31  | 7     | 1971 | 00  | 3     | 100   | 29.9             | 24   | 4.737   | 3.2 | 0.153      | 63    |
| 1   | 8     | 1971 | 81  | 3     | 100   | 29.9             | 15   | 4.953   | 3.6 | 0.177      | 63    |
| 2   | 8     | 1971 | 82  | 3     | 100   | 29.9             | 14   | 5.111   | 4.0 | 0.204      | 63    |
| 3   | 8     | 1971 | 83  | 3     | 100   | 29.9             | 5    | 5.295   | 4.5 | 0.236      | 63    |
| 4   | 8     | 1971 | 84  | 3     | 100   | 29.9             | 17   | 5.436   | 5.0 | 0.271      | 63    |
| 5   | 8     | 1971 | 85  | 4     | 100   | 29.9             | 77   | 5.478   | 5.6 | 0.305      | 63    |
| 6   | 8     | 1971 | 86  | 4     | 100   | 29.9             | 54   | 5.563   | 6.2 | 0.345      | 63    |
| 7   | 8     | 1971 | 87  | 4     | 100   | 29.9             | 39   | 5.673   | 6.9 | 0.391      | 63    |
| 8   | 8     | 1971 | 88  | 4     | 100   | 29.9             | 21   | 5.816   | 7.6 | 0.444      | 62    |
| 9   | 8     | 1971 | 89  | 4     | 100   | 29.9             | 5    | 5.987   | 8.5 | 0.506      | 62    |

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# Objectives

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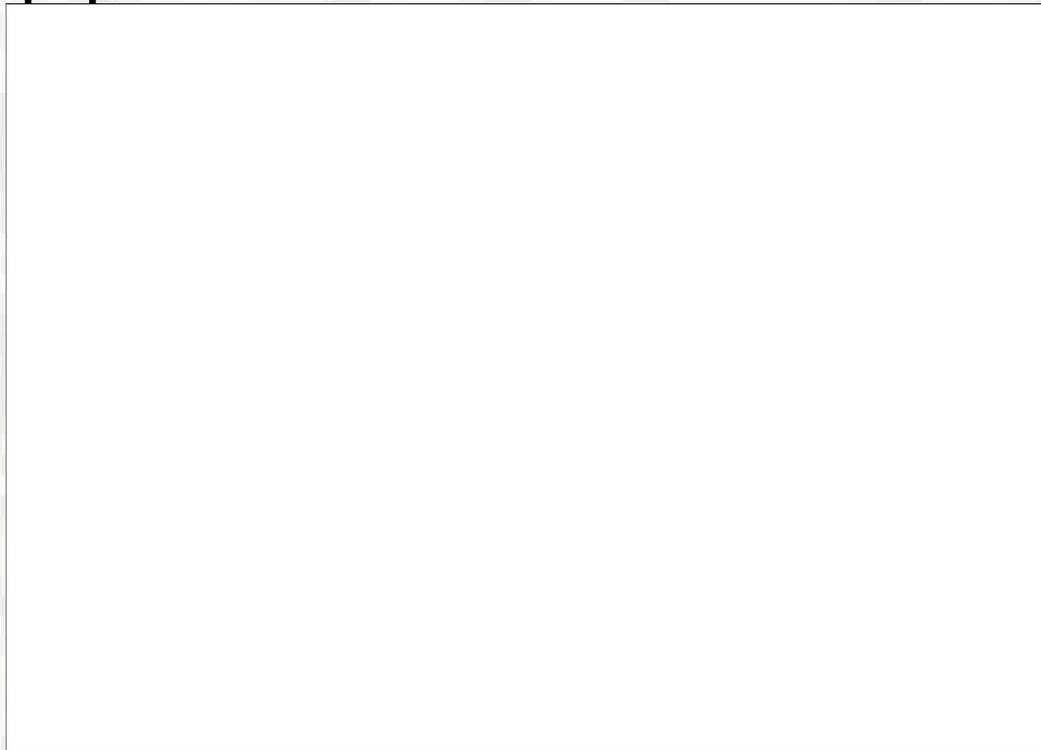
- Validate the ability of AquaCrop to simulate maize crop yields in Pennsylvania
- Develop a drought index to quantify the effects of soil type on agricultural drought vulnerability
- Generate an agricultural drought risk prediction map for Pennsylvania soils



# Study Area

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- Initial study will focus on a transect of nine counties that span across Pennsylvania's temperature and precipitation gradient.





# Methods: Objective 1

## AquaCrop Validation

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- Assess the ability of AquaCrop to simulate:
  - Biomass Growth
  - Final Biomass
  - Harvestable Yield
  
- Compare simulated and observed data
  - RMSE (root mean square error)
  - IoA (Index of Agreement)



# Methods: Objective 2

## Drought Index Development

- Conduct a daily soil water balance for agricultural soils
- Calculate daily root zone depletion ( $D_r$ )
- Calculate daily Total Available Water (TAW)
- Calculate daily Readily Available Water (RAW)
- Calculate daily water stress coefficient:

$$= \frac{TAW - D_r}{TAW - RAW}$$

(Allen et al. 1998)



# Methods: Objective 2

## Drought Index Development

- Calculate Daily Stress Index ( $S_D$ )
- Calculate a Weighted Daily Stress Index
  - ▣ Weights ( $W$ ):
    - Establishment and vegetative stages: 0.4
    - Flowering stage: 1.5
    - Yield Formation stage: 0.5

(Doorenbos and Kassam, 1979)

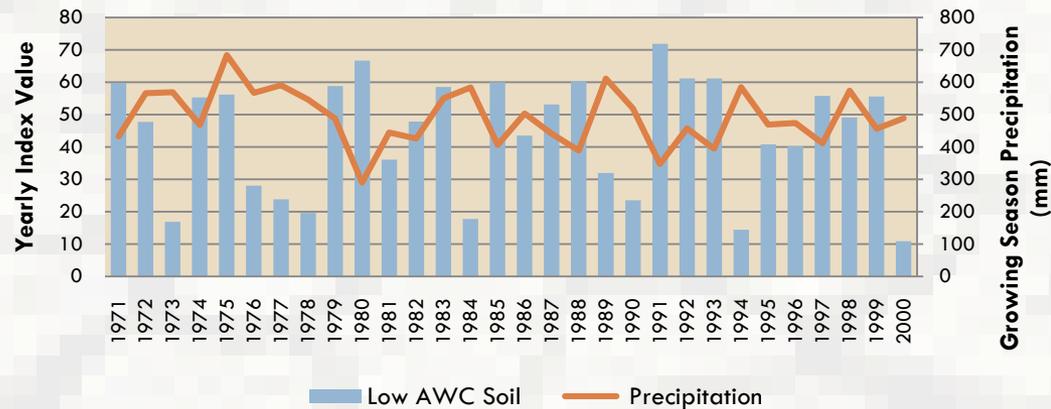
- Calculate Seasonal Water Stress Index:

$$= \sum_{i=1}^n (W_i)(S_{Di})$$

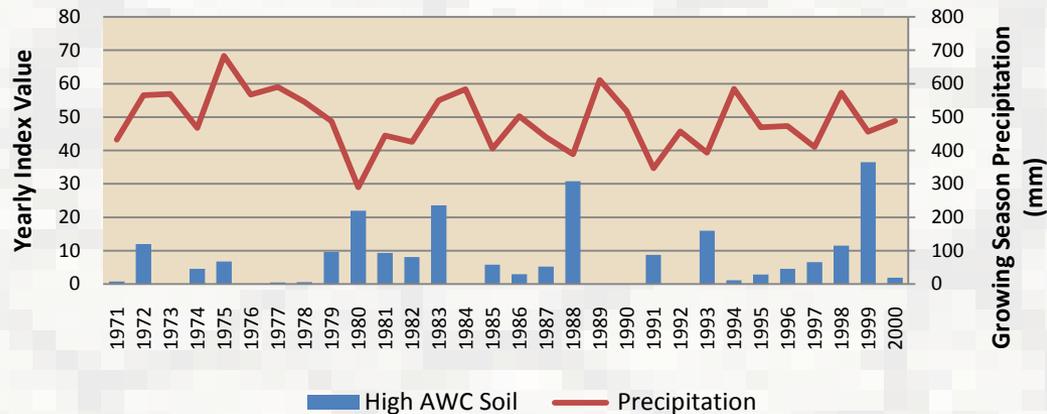
(Timlin et al., 1986)

# Preliminary Results

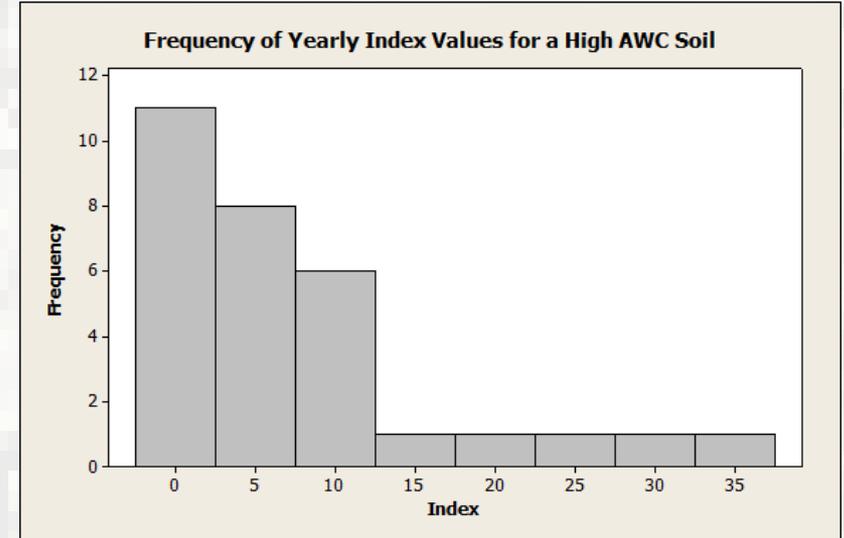
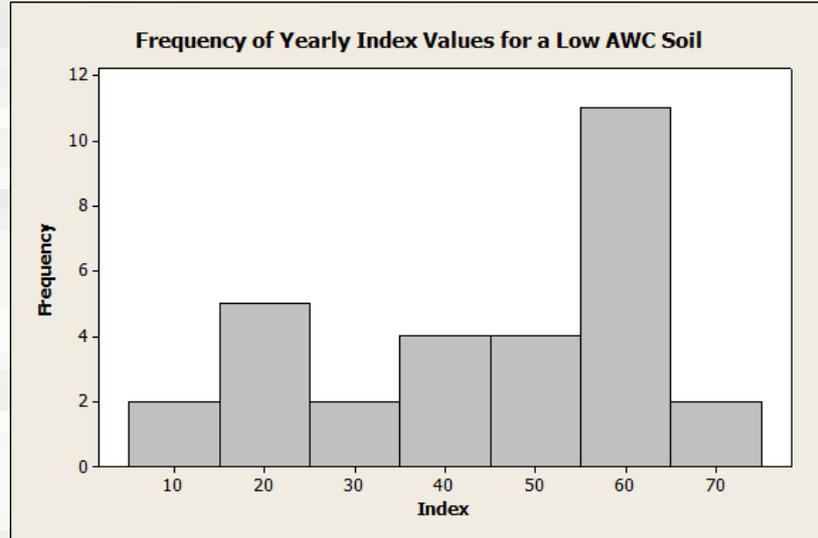
## Yearly Index Values for a Low AWC Soil



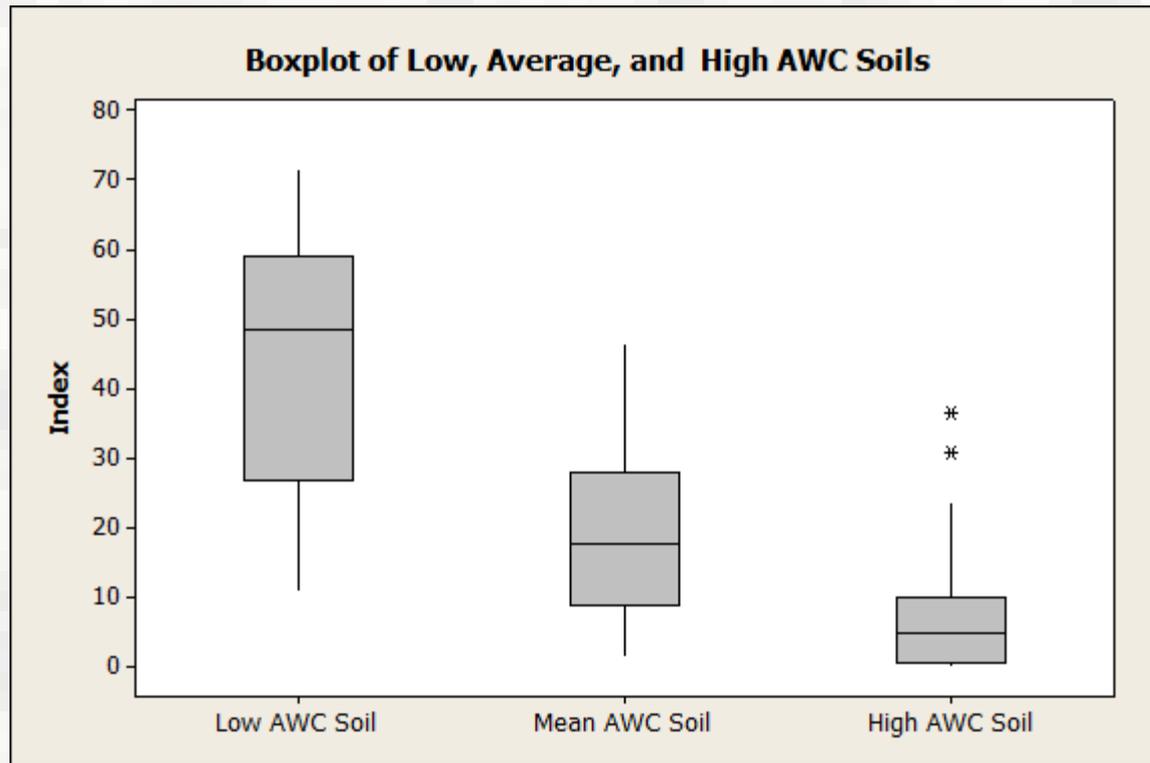
## Yearly Index Values for a High AWC Soil



# Preliminary Results



# Preliminary Results





# Methods: Objective 3

## Prediction Map

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- Develop the agricultural drought risk prediction map
  - ▣ Delineate polygons that represent the land area applicable to each weather station
  - ▣ Soils data from a SSURGO soil polygon will be combined with the climatic data from the representative station
  - ▣ Each soil polygon with similar characteristics within the boundary of the same climatic station will be assigned the same drought vulnerability index



# What's Next

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- Continue AquaCrop validation
- Continue processing the index values
- Finalize the relationship that relates the seasonal stress index to relative yield decreases
- Develop prediction map

# Funding Acknowledgement

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## **USDA NIFA**

*United States Department of Agriculture National  
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## **RGIS – Chesapeake**

*National Consortium for Rural and Geospatial  
Innovations in America - Chesapeake*