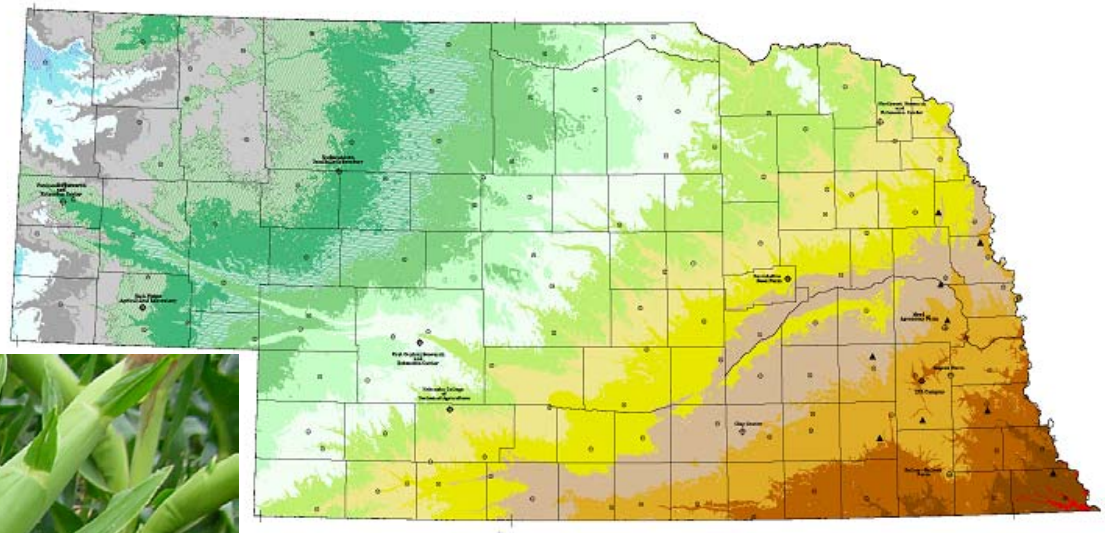
A simulation approach for evaluating maize yield potential in different environments



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What is yield potential?

Yield of a cultivar in the environment to which it is adapted when grown with minimal possible biotic or abiotic stresses.

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$$Y_p = \int_{emergence}^{maturity} (Genetics \times Solar \times Temp)\,dt$$

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To achieve yield potential of an environment:

- Maximize utilization of growing season (= optimal cultivar)
- Minimize possible biotic and abiotic stresses (nutrients, water, pests)
- Optimize plant population

Why yield potential important?

- Cultivar selection & crop management
- Risk assessment
- Carbon sequestration
- Global food security & preservation of natural ecosystems and biodiversity.

Objectives:

Quantify

- Yield potential of maize grain across NE
- Yield potential of maize stover across NE
- Their temporal variability?

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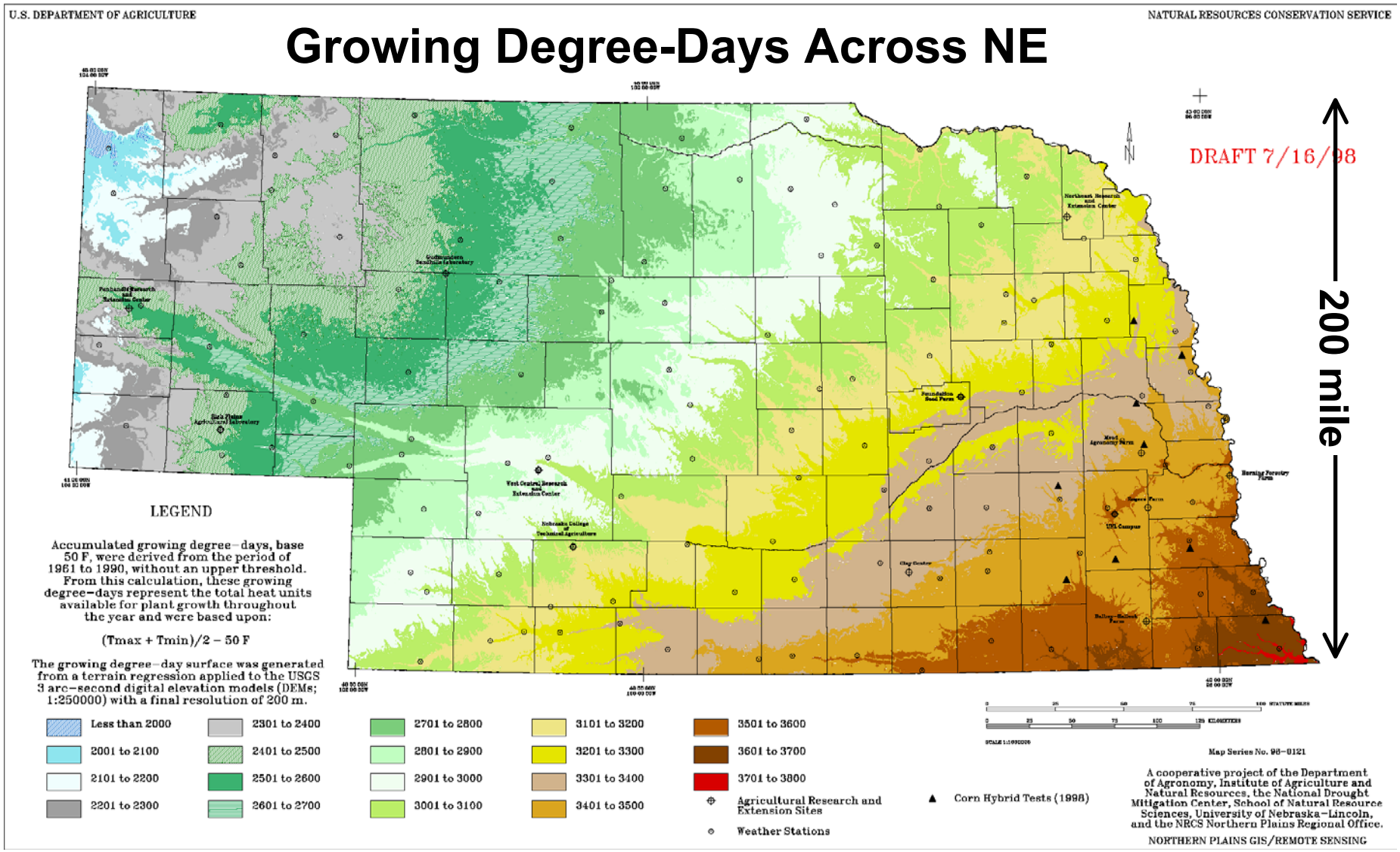
Nebraska (NE):

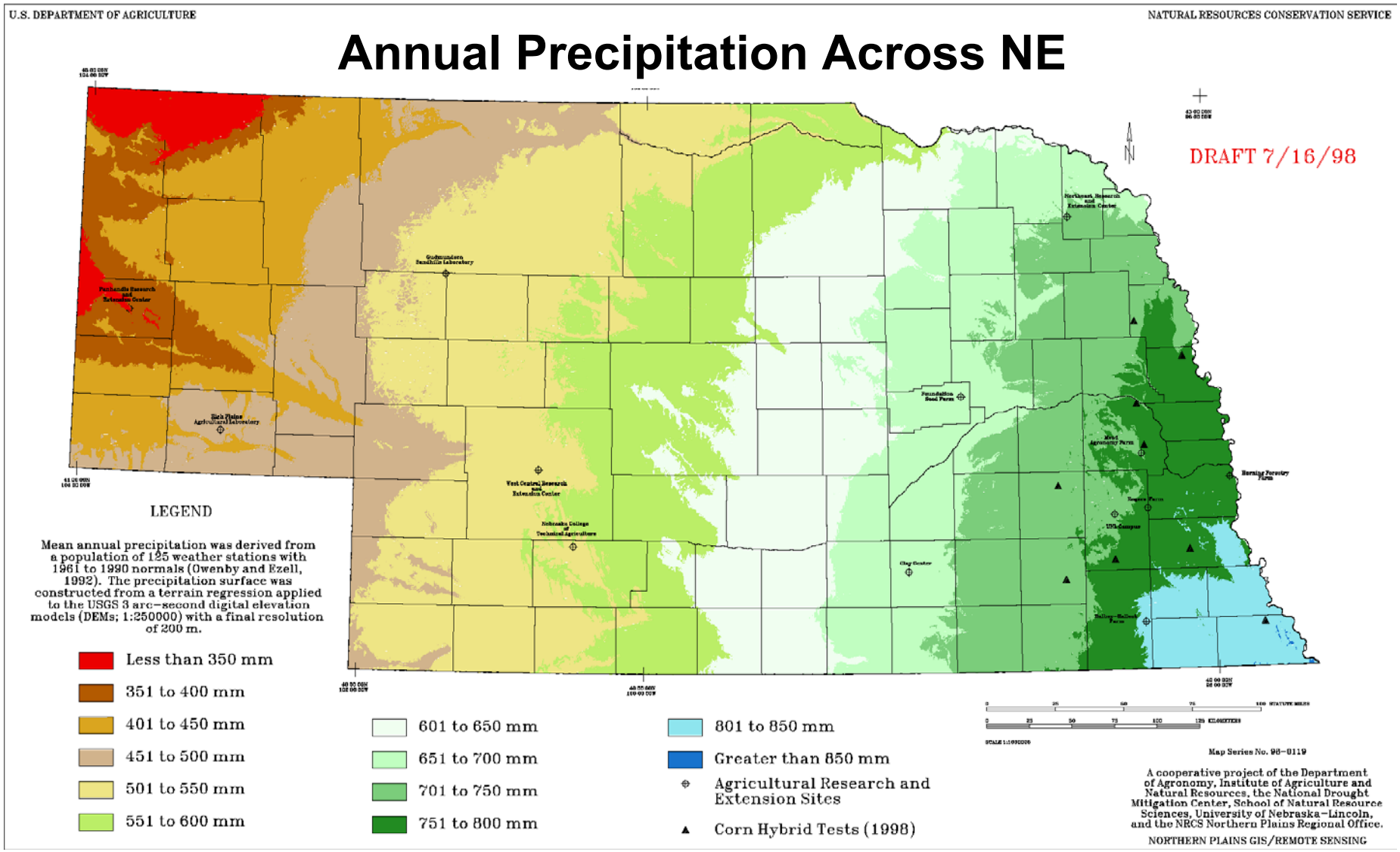
- A wide range of environmental conditions
- The climatic variation from the western to eastern borders of Nebraska is greater than from the eastern Nebraska border to the Atlantic ocean

Growing Degree-Days Across NE

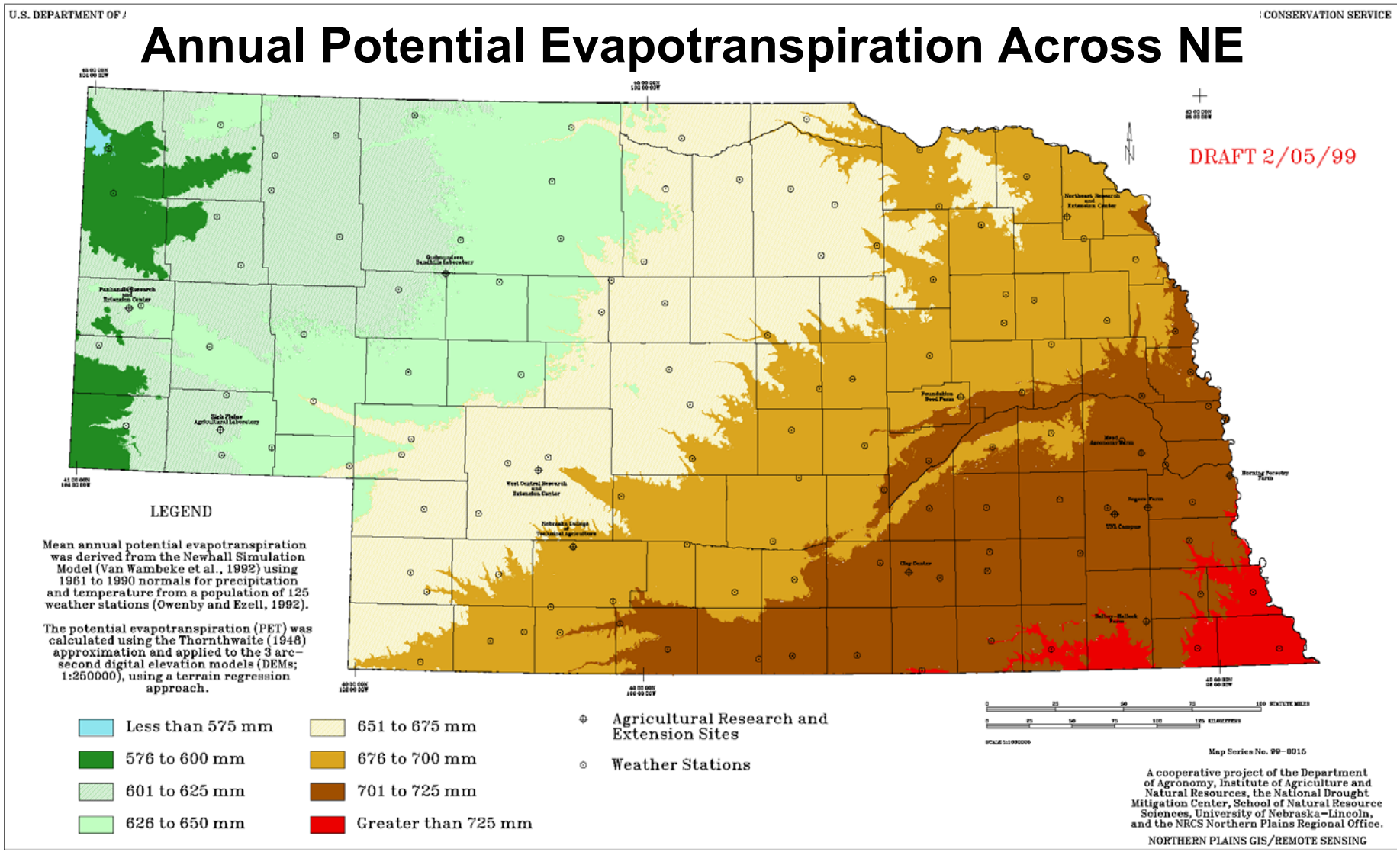


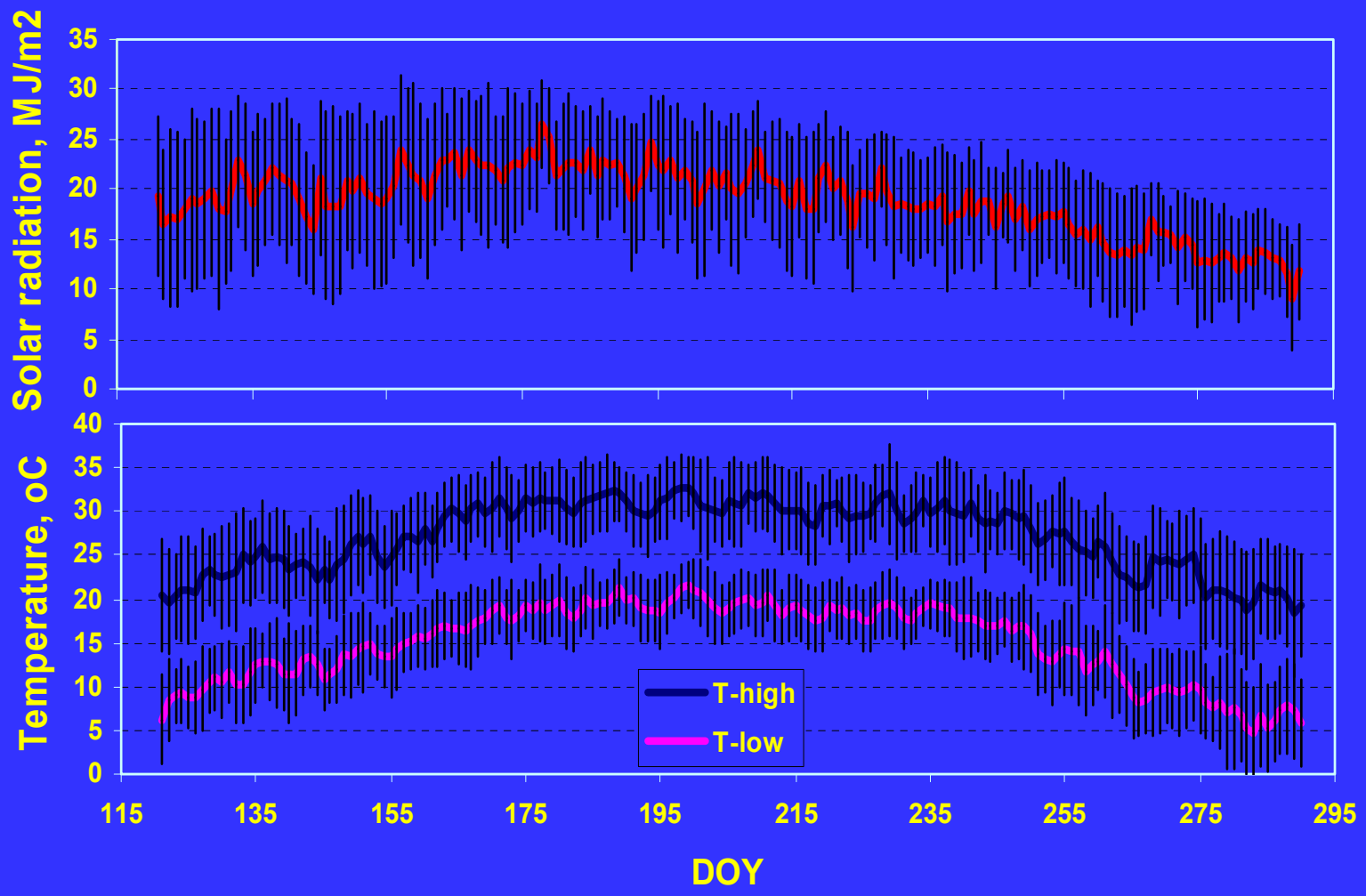
420 mile

Annual Precipitation Across NE



Annual Potential Evapotranspiration Across NE





18-yr mean and SD of daily solar radiation and temperature from May 1 to Oct 15 in Lincoln, NE.

To estimate yield potential across NE requires:

- Sufficient spatial coverage
- Sufficient temporal coverage

How to estimate yield potential across NE?

- ✓ Experimentation
  - + directly measured yields
  - -- limited in spatial and temporal coverage

How to estimate yield potential across NE?

- ✓ Experimentation
  - + directly measured yields
  - -- limited in spatial and temporal coverage

- ✓ Model simulation
  - + large spatial and temporal coverage
  - + can explore 'scenarios'
  - -- results need to be validated

Choice of model: *Hybrid-Maize* *(Yang et al, 2004, Field Crop Res., in press)*

- Hybrid of CERES-Maize + Generic Dutch crop model.
- Corn specific and growth driven by temperature.
- Mechanistic photosynthesis routine sensitive to temperature & light intensity.
- Growth and maintenance respiration included and sensitive to crop development and temperature.
- Robust in high yielding environments

❖ *Predict silking from total GDD*

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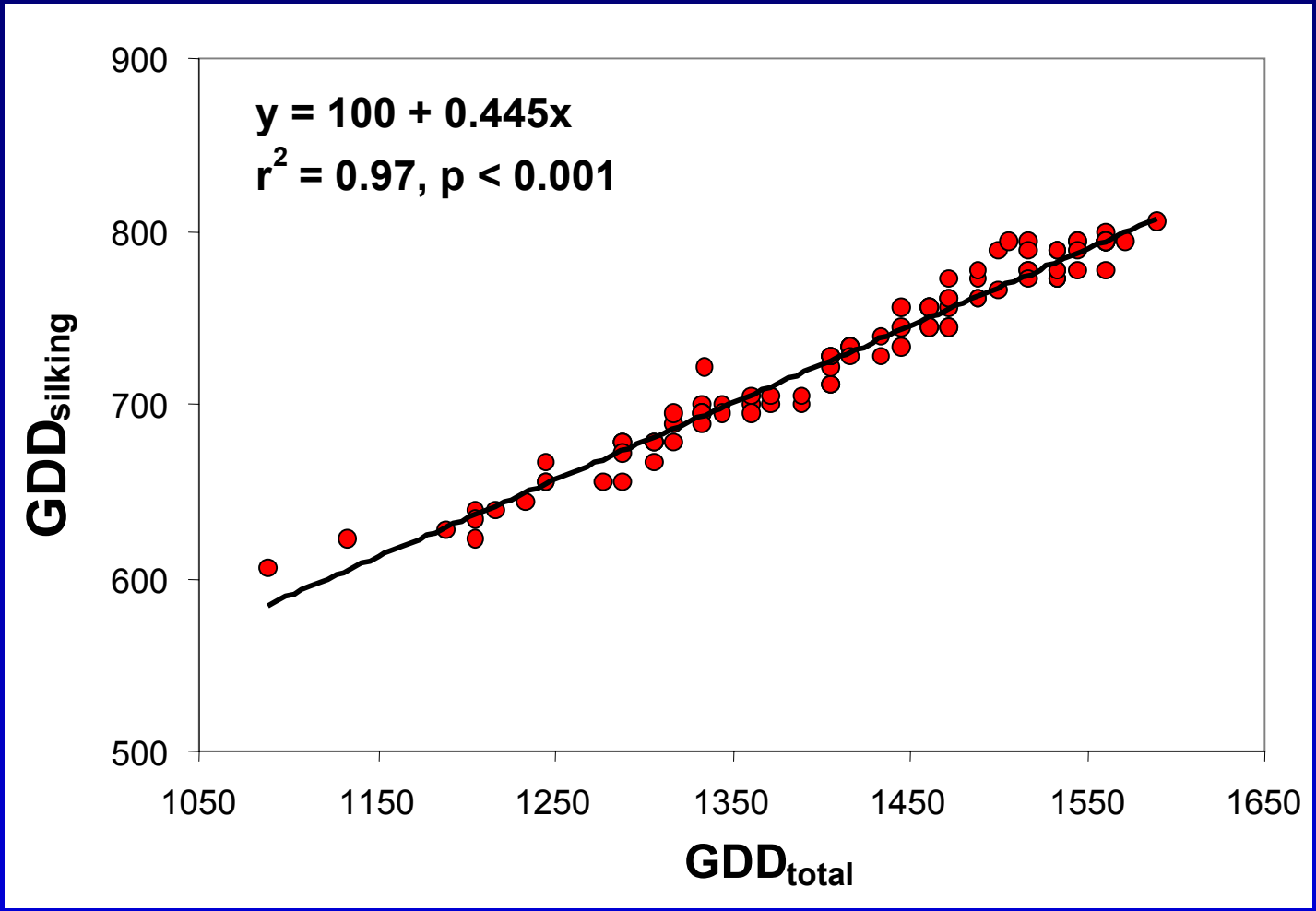
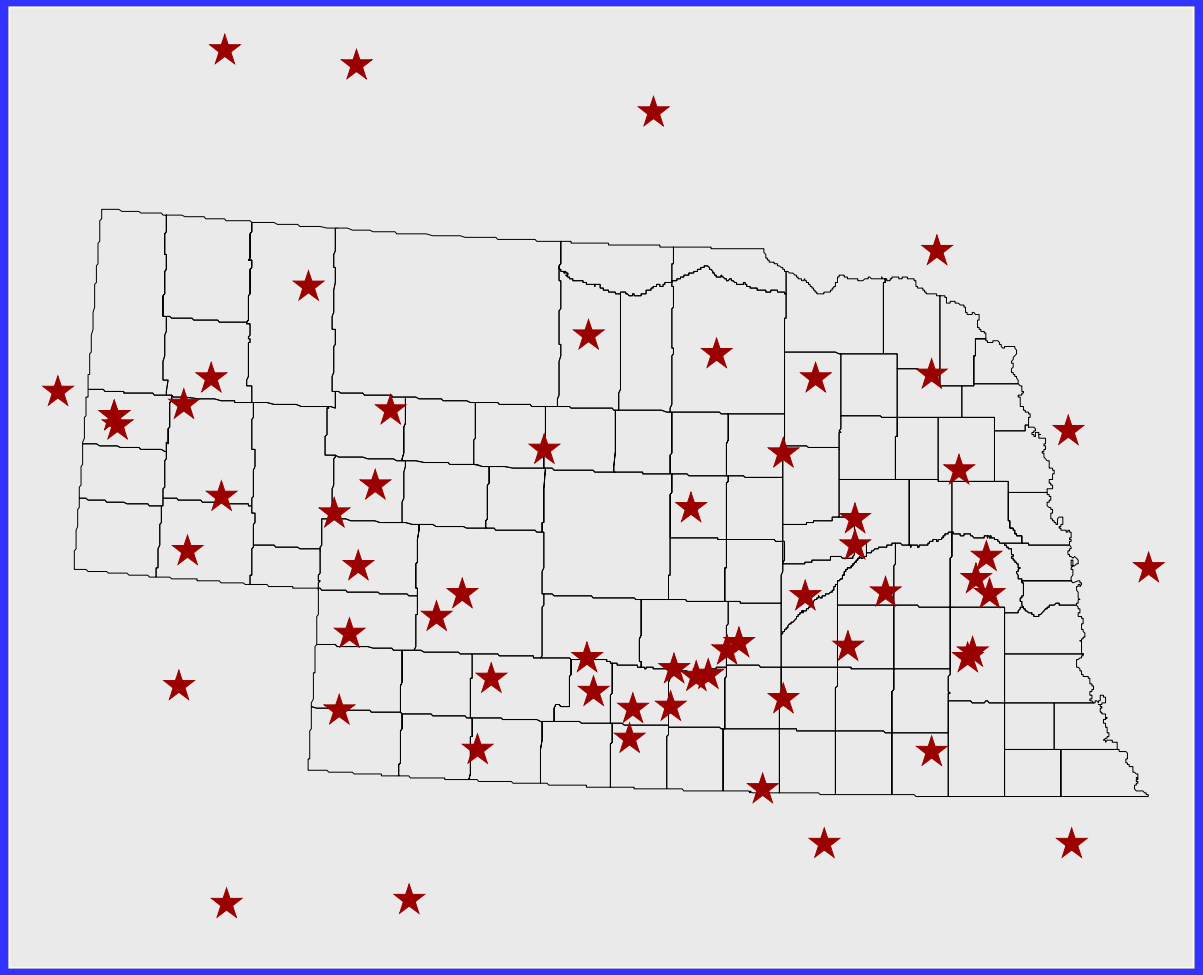


Regression of GDD to silking ($GDD_{silking}$) on total GDD (GDD_{total}) for 107 commercial maize hybrids from Pioneer Inc. Many points have the same values and thus overlap.

Collection of weather data



49 sites inside NE
12 sites out of NE

Yr /site (in NE)
- mean = 14
- min = 4 (2 sites)
- max = 21 (11 sites)

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Simulation of best yields under current practices

- Planting date: NASS* report
- Maturity: NASS report
- Plant pop: 74,000/ha (30,000/acre)

*Nebraska Agric. Statistics Service

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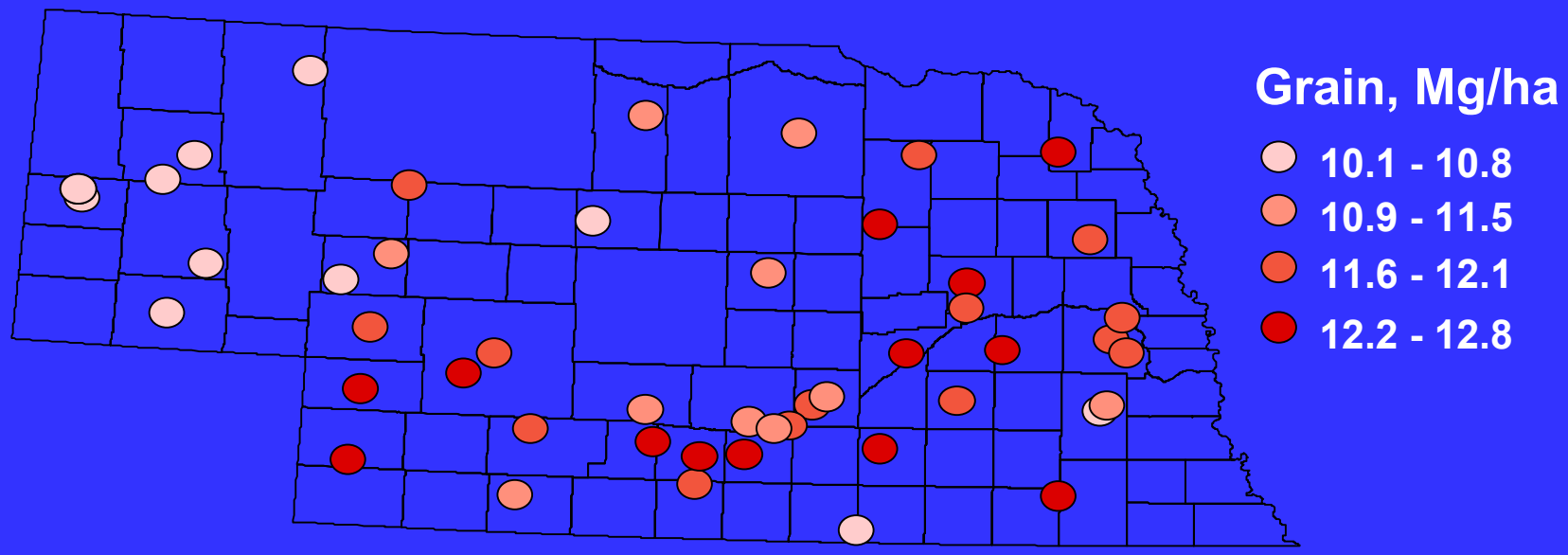
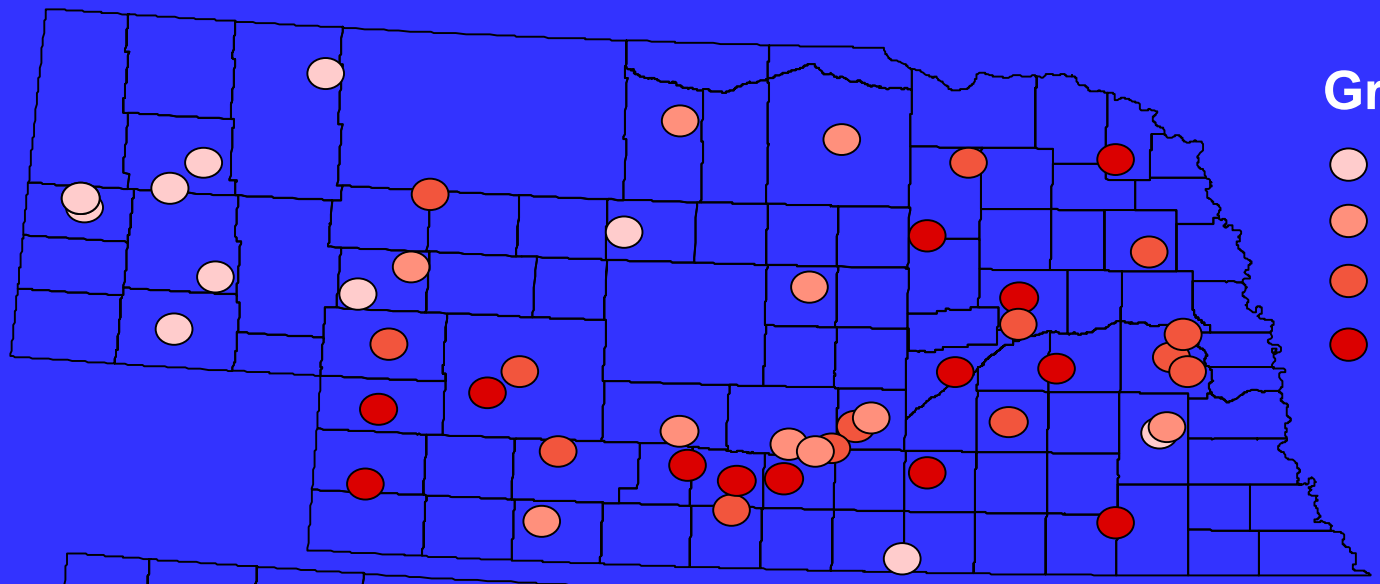
Current practices: *best yields*

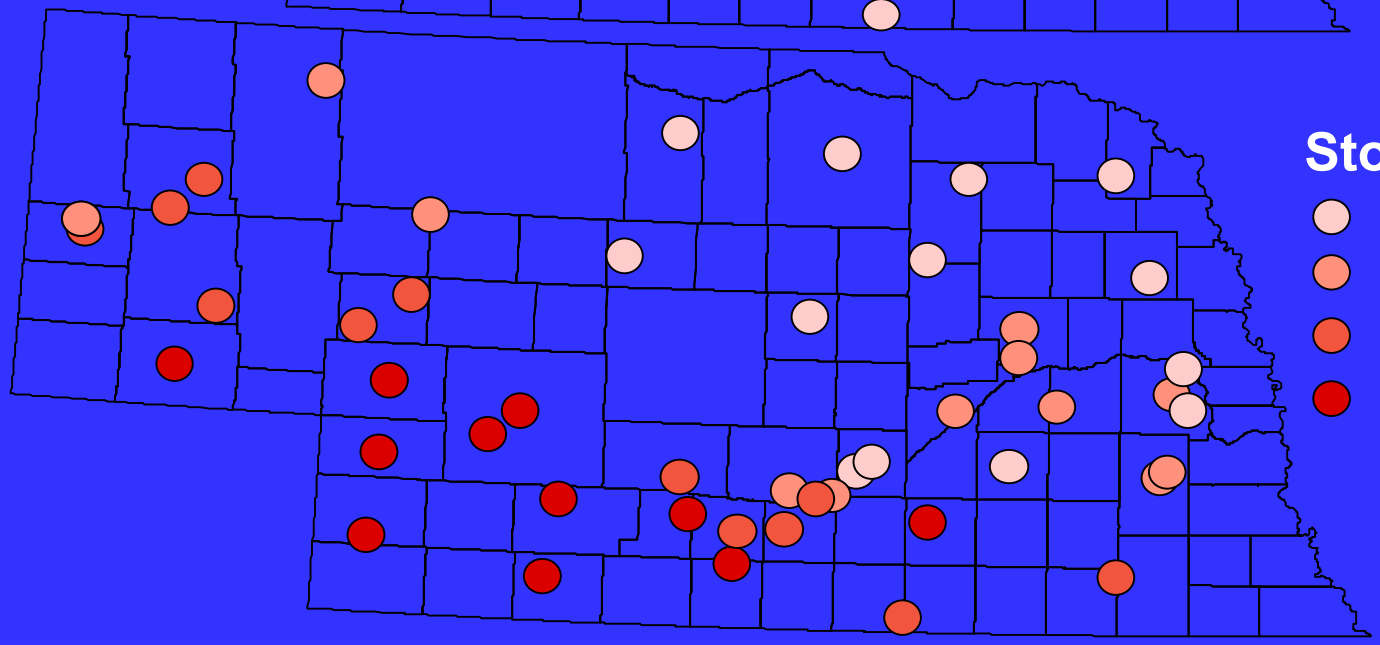


Current practices: *best yields*



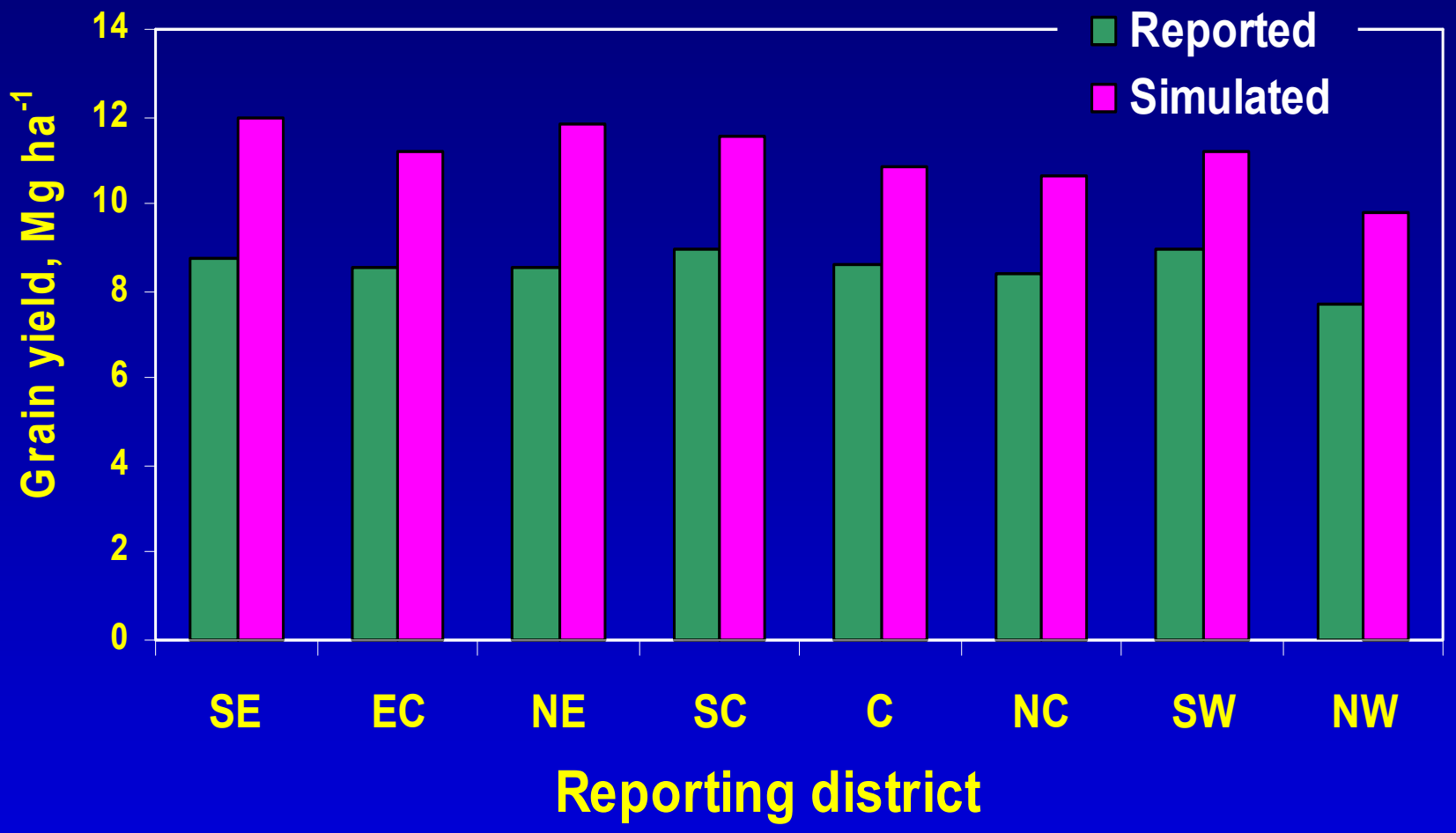
Grain, Mg/ha

- 10.1 - 10.8
- 10.9 - 11.5
- 11.6 - 12.1
- 12.2 - 12.8



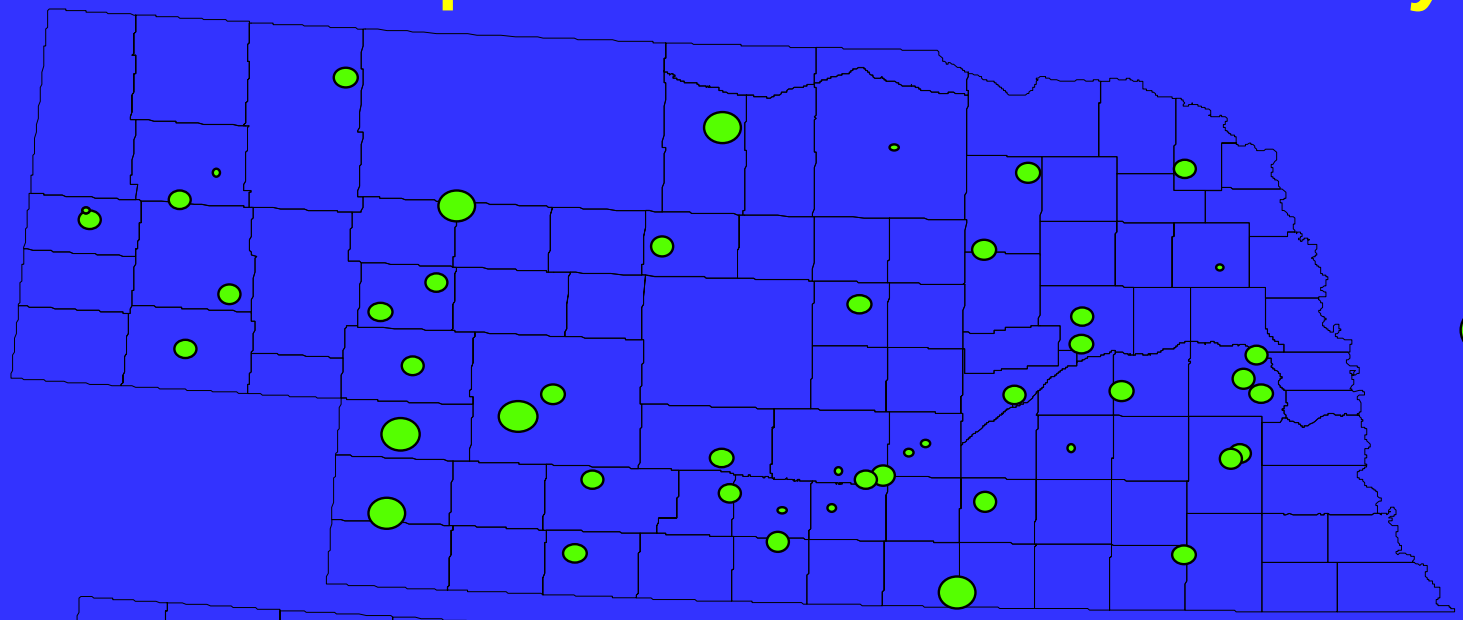
Stove, Mg/ha

- 9.6 - 10.9
- 11.0 - 11.4
- 11.5 - 12.0
- 12.1 - 12.8



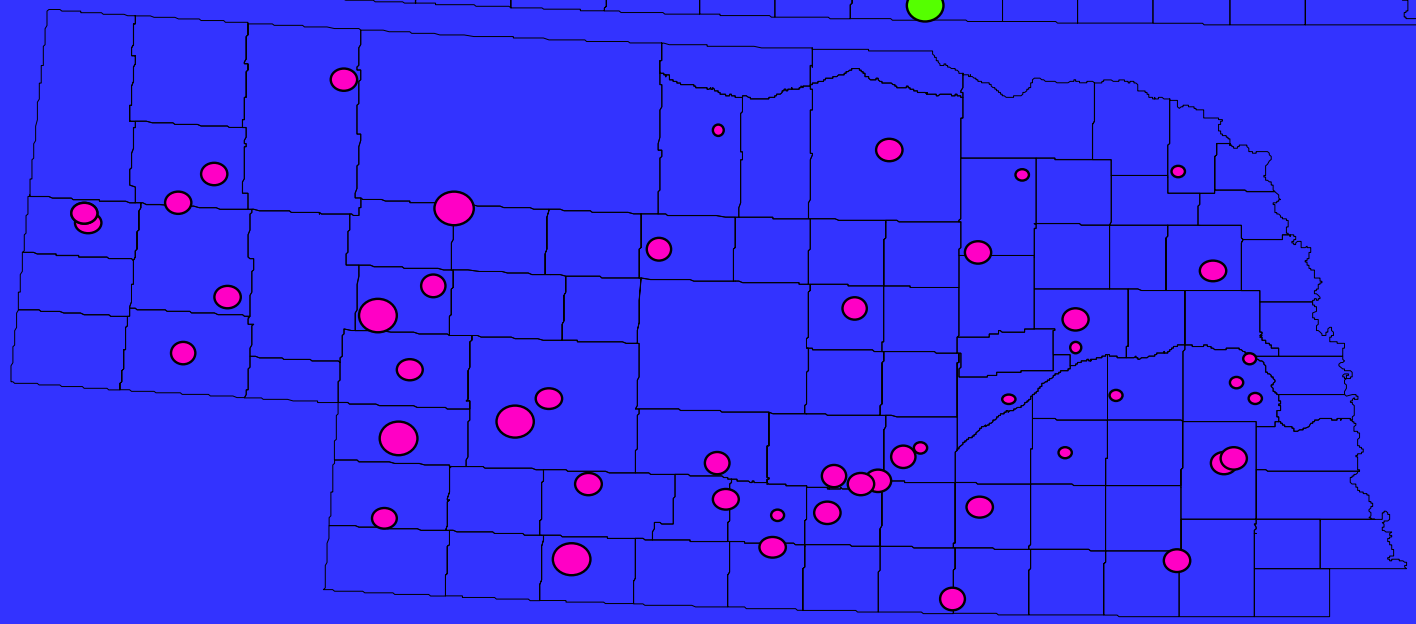
Average maize grain yield under irrigation in Nebraska by reporting district from NASS database 1998-2002 and corresponding simulation by Hybrid-Maize model.

Current practices: *variation of best yields*



SD of grain

- 0.6 - 1.0 Mg/ha
- 1.1 - 1.5
- 1.6 - 2.5



SD of Stover

- 0.4 - 1.1 Mg/ha
- 1.2 - 1.8
- 1.9 - 2.5

To achieving full yield potential:

optimal management

1. Determine maximum duration of growing season
2. Choose the right hybrid
3. Use optimal plant population
4. Grow under stress-free conditions.

To achieving full yield potential:

optimal management

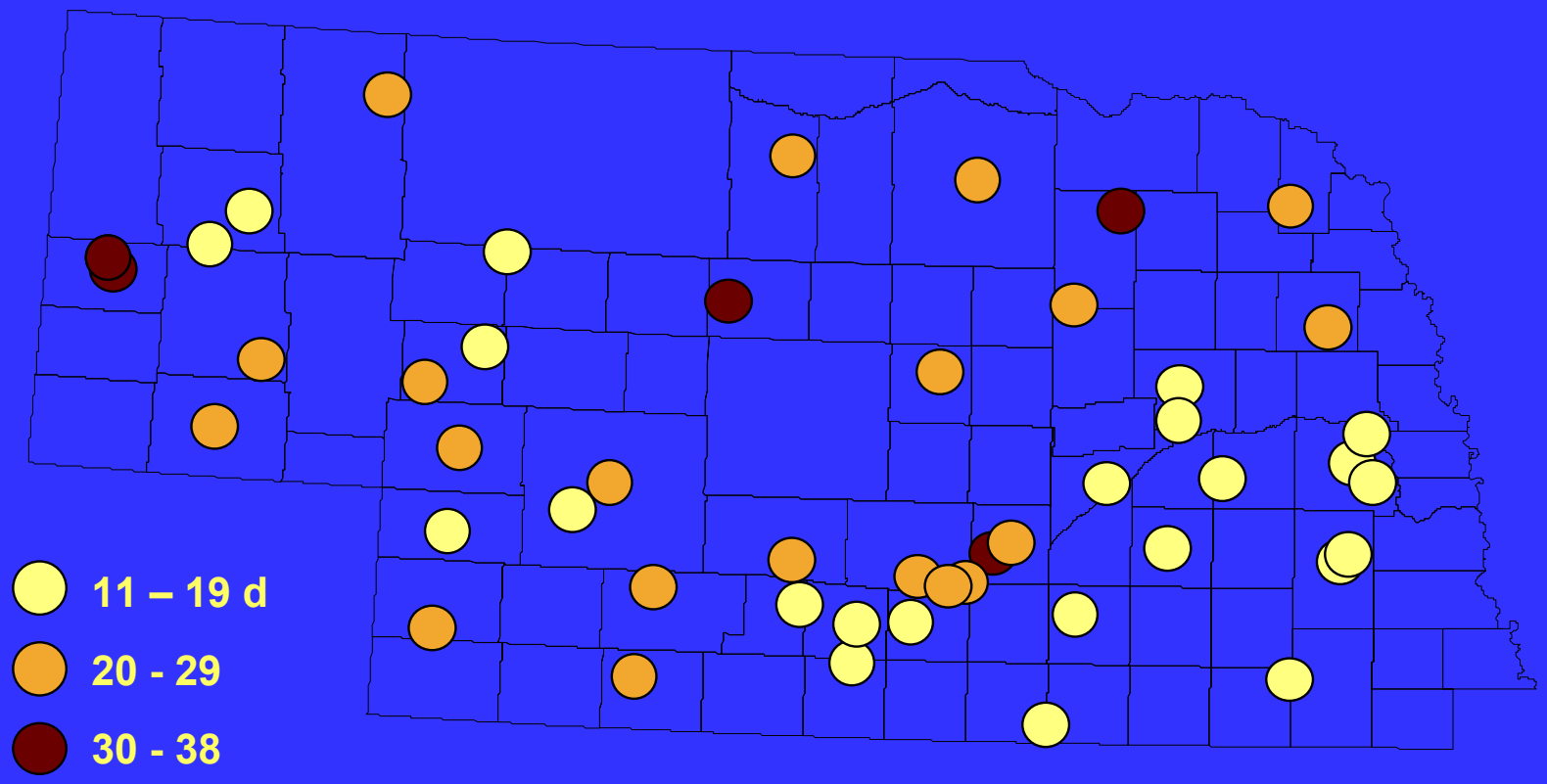
1. **Hybrid-Maize model search for (a) optimal sowing data and (b) the date when grain filling stops. It then derives total available GDD ($GDD_{available}$).**
2. **Set parameter GDD_{total}:**

   $= GDD_{available}$, if $GDD_{available} < GDD_{max}$

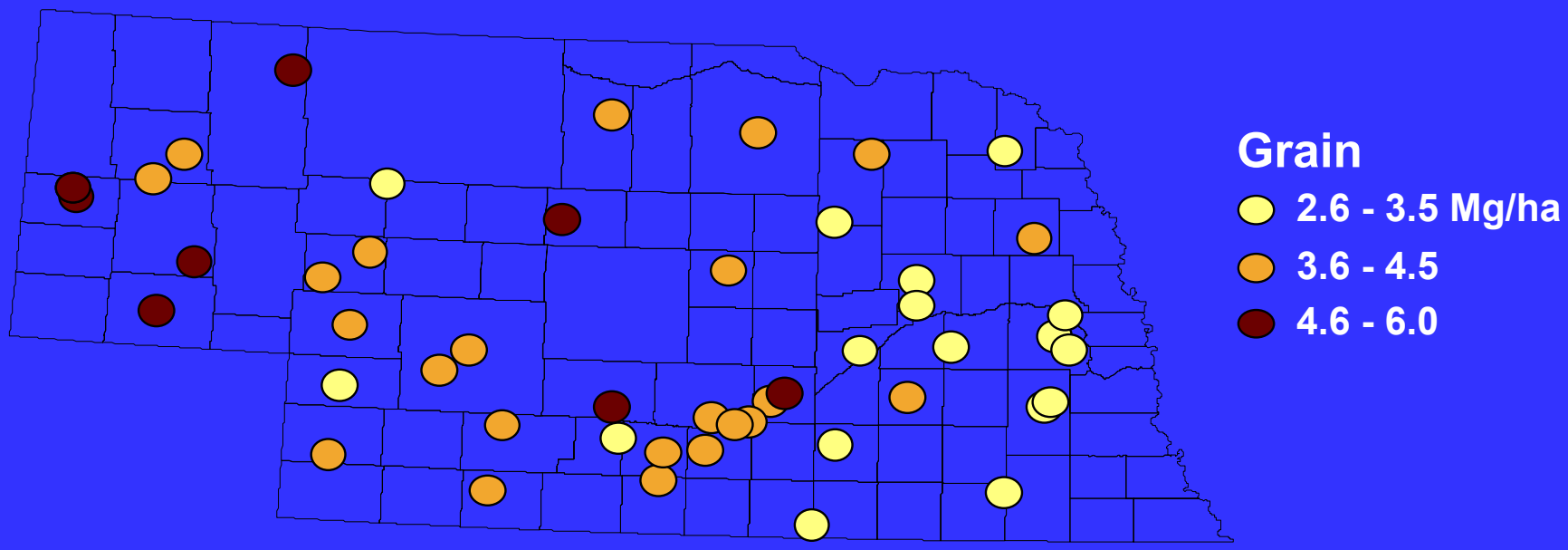
   $= GDD_{max}$, if $GDD_{available} > GDD_{max}$

3. **Plant pop = 99,000/ha (40,000/acre)**
4. **Run under stress-free conditions using other common settings.**

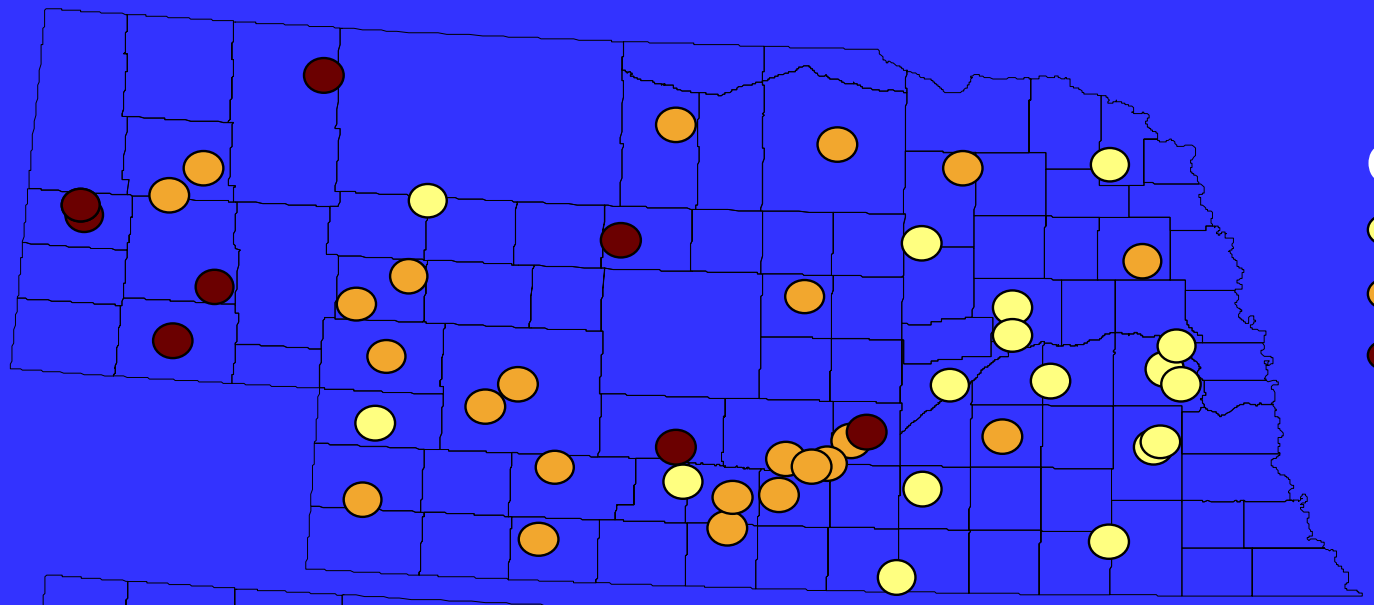
Optimal management: *gain in season length*



Optimal management: *gain in yield*

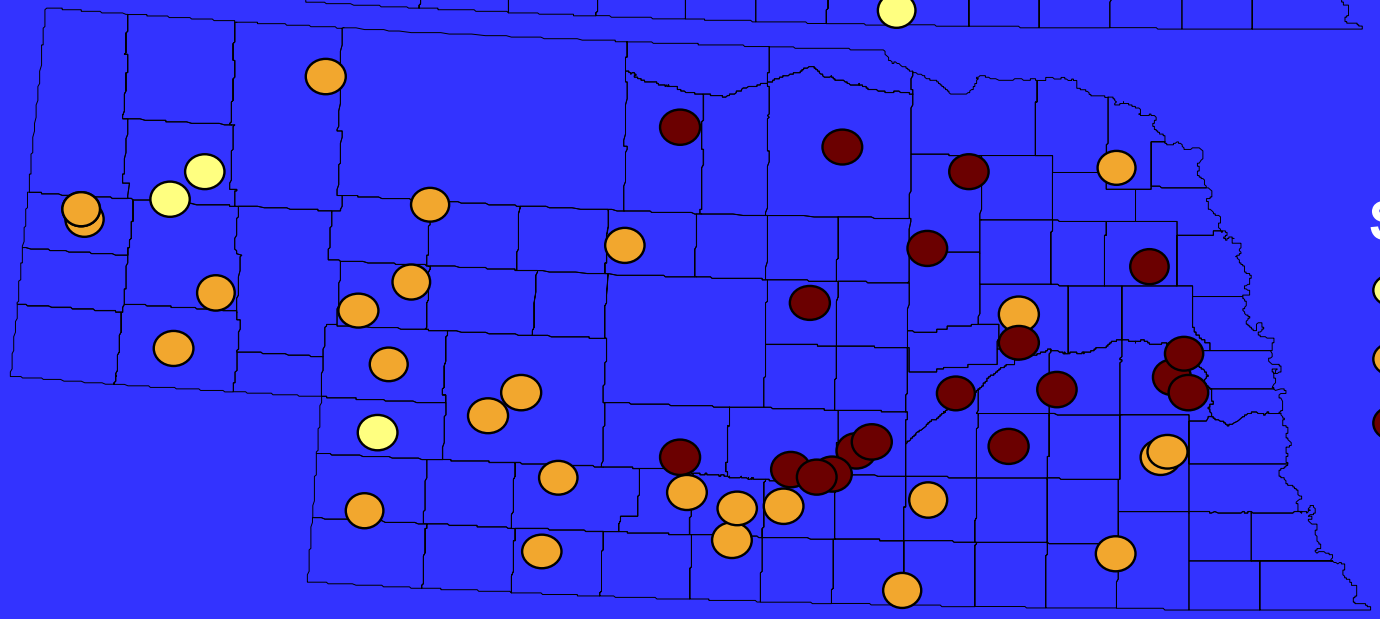


Optimal management: *gain in yield*



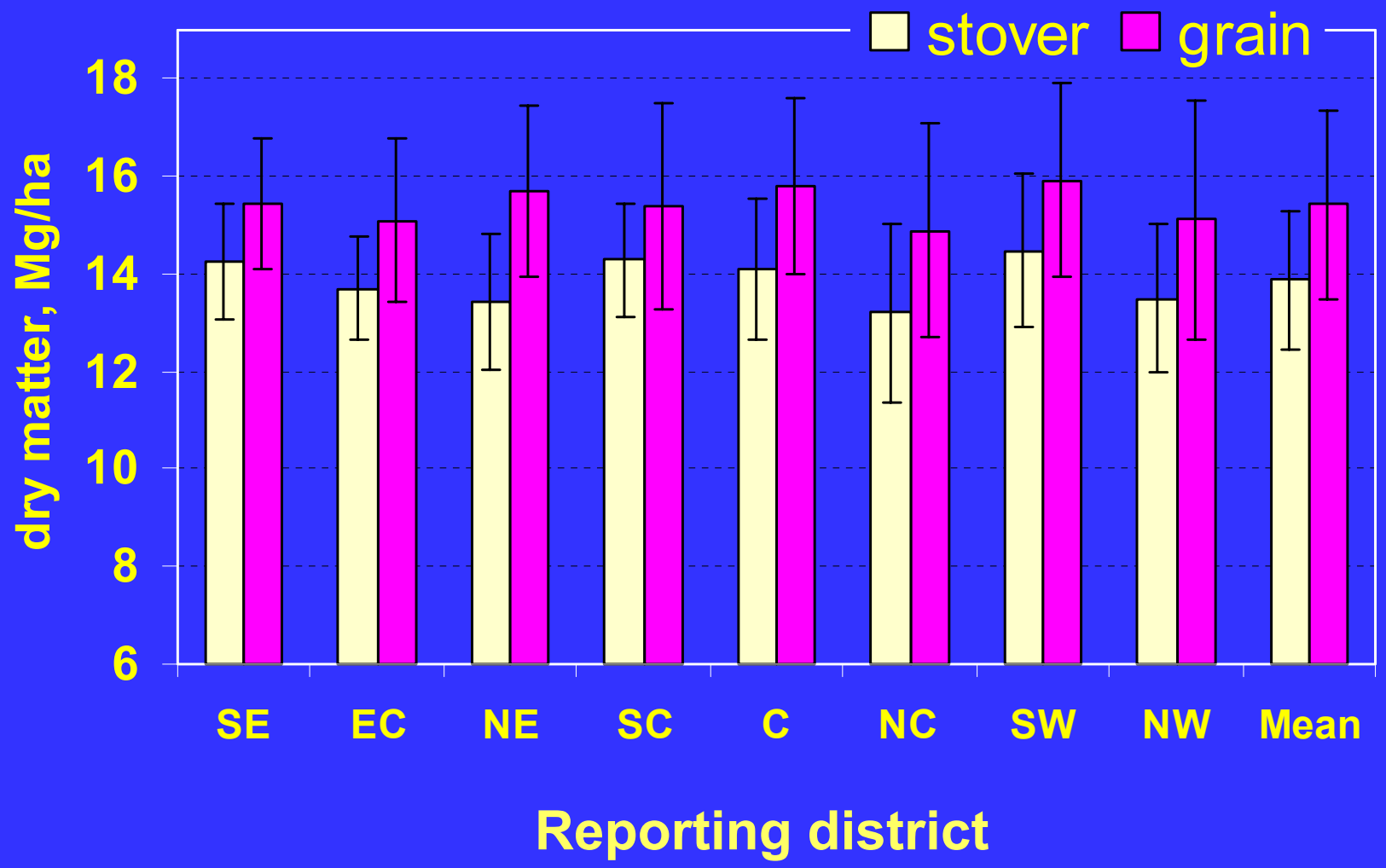
Grain

- 2.6 - 3.5 Mg/ha
- 3.6 - 4.5
- 4.6 - 6.0

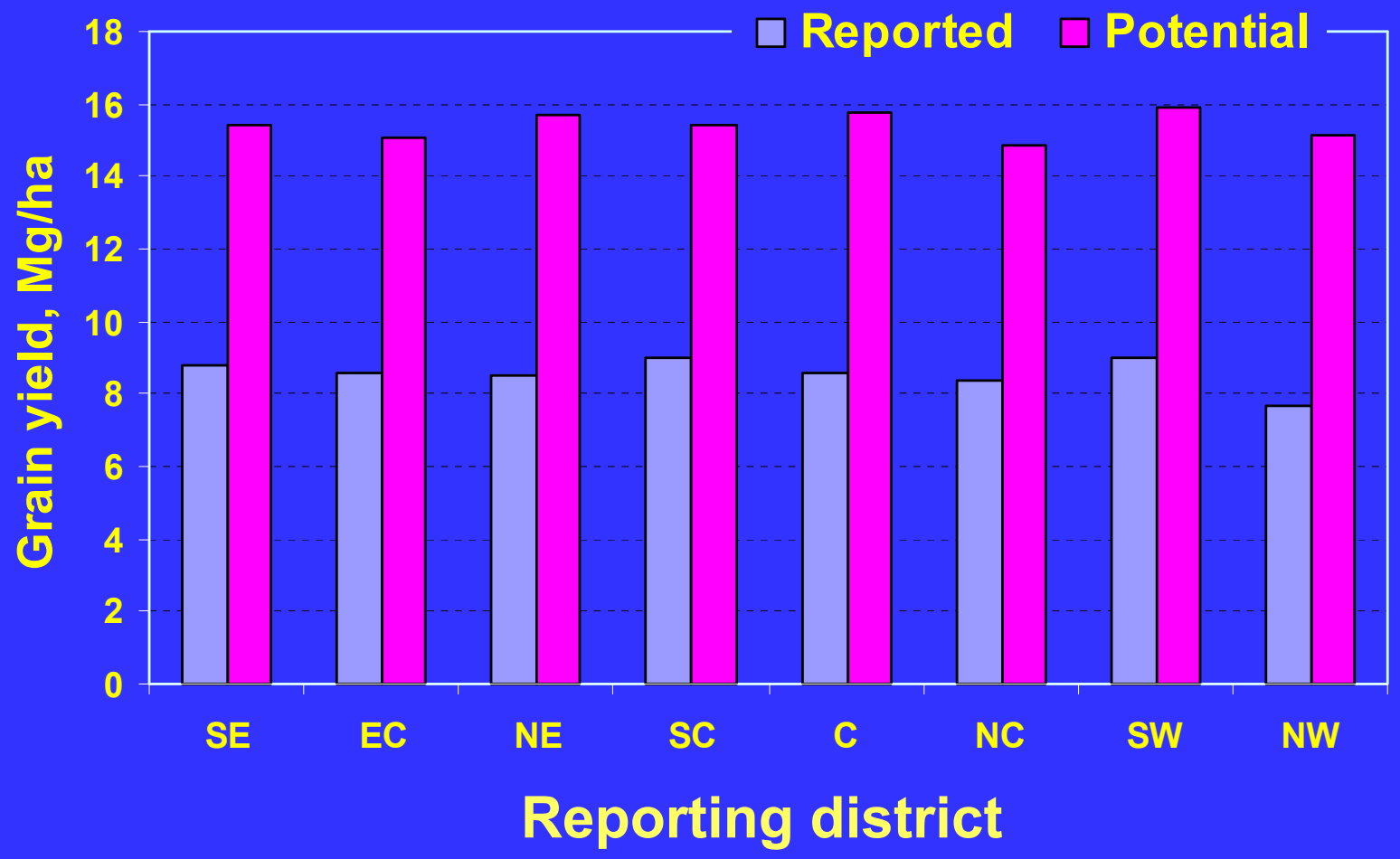


Stover

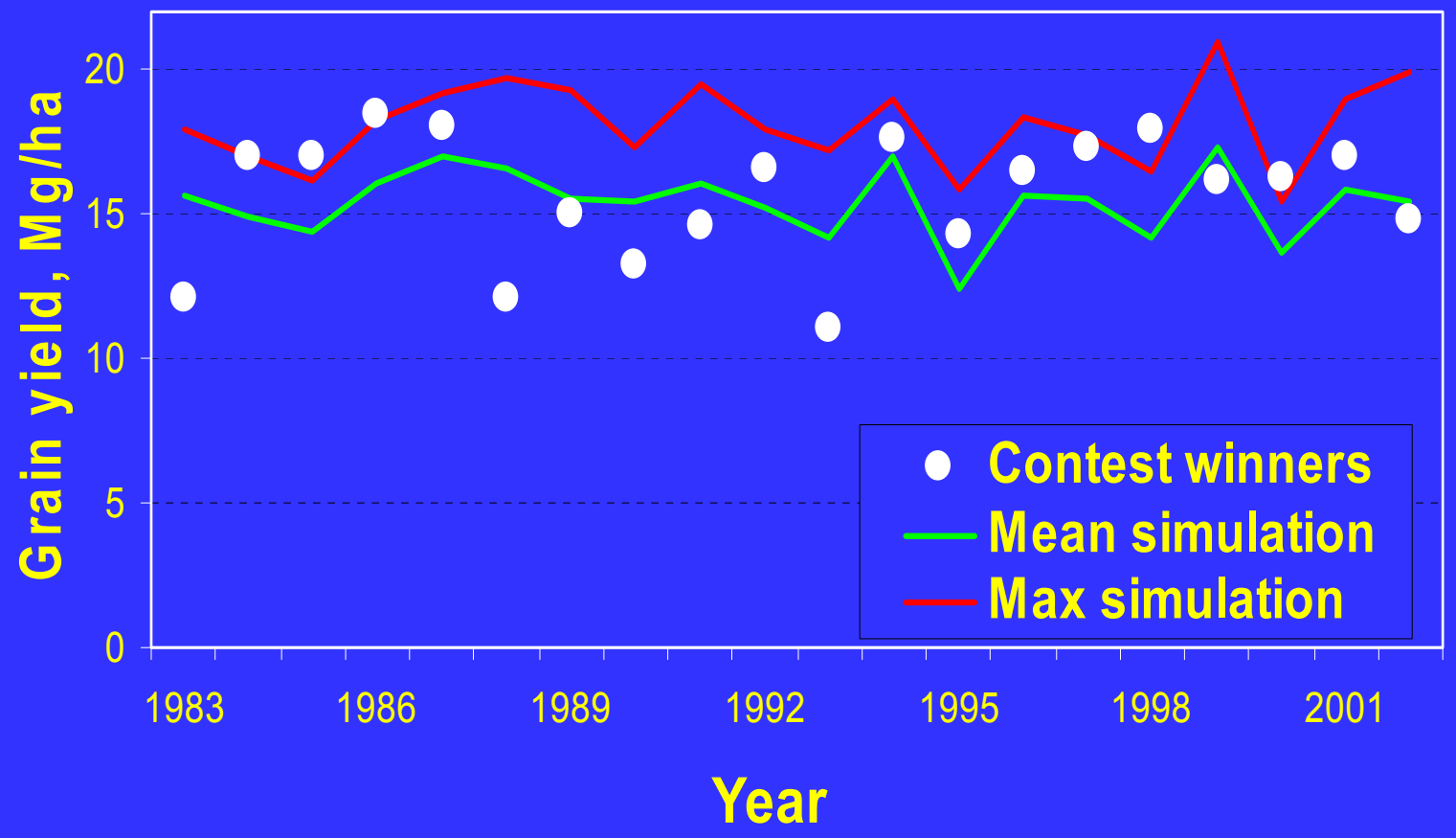
- 0.9 - 1.5 Mg/ha
- 1.6 - 2.5
- 2.6 - 3.2



Maize yield potential across NE estimated by Hybrid-Maize model (error bars are SD over time)



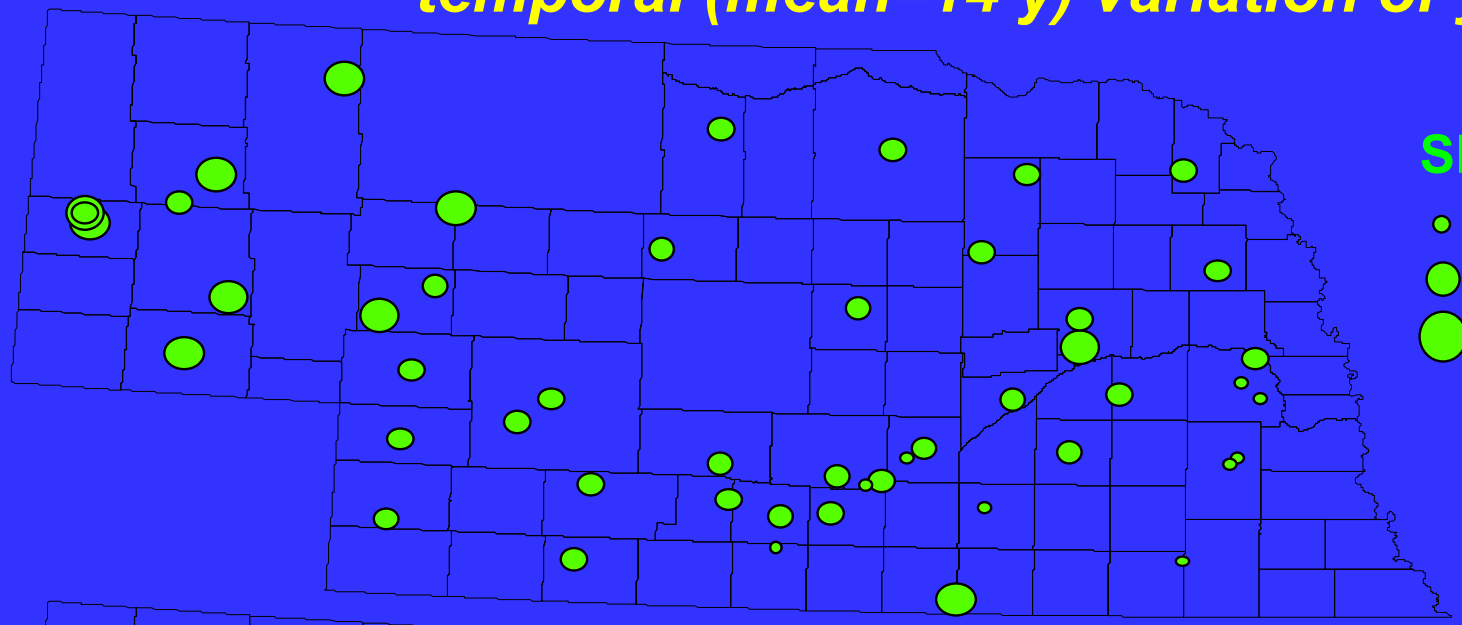
Maize yield potential across NE estimated by Hybrid-Maize model in comparison with actual yields (means of 1998-2002)



Maize yield potential simulated by Hybrid-Maize compared to the yield of NE contest winners.

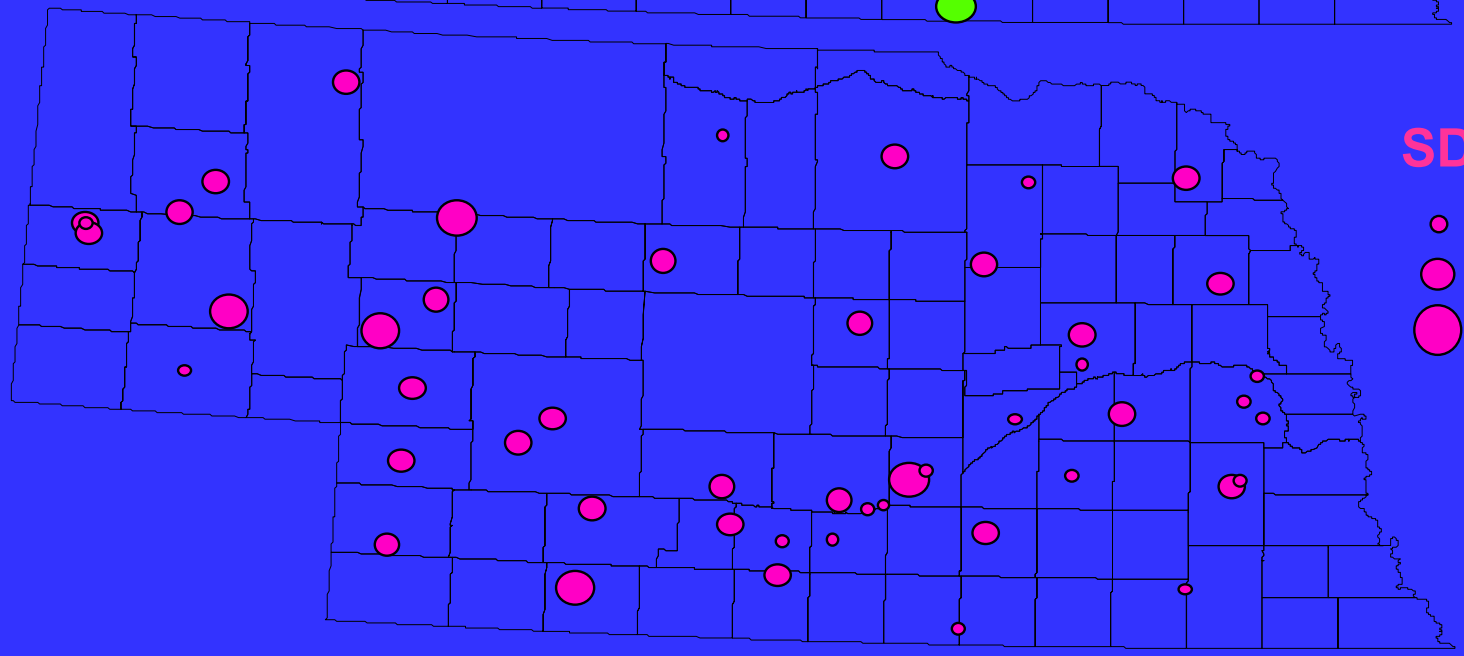
Optimal management:

temporal (mean=14 y) variation of yields



SD of grain

- 0.9 - 1.5 Mg/ha
- 1.6 - 2.2
- 2.3 - 3.0



SD of stover

- 0.3 - 1.1 Mg/ha
- 1.2 - 1.7
- 1.8 - 2.5

Conclusions

- **Model simulation is a powerful tool in understanding maize yield potential in diverse environments.**
- **Across NE, the current irrigated maize yield is only 56% of the yield potential.**
- **Achieving that potential requires longer-maturity cultivars (esp. N-W) and higher plant density.**
- **Temporal variation of maize yield potential increases from S-E to N-W across Nebraska due to greater variation in length of growing season in N-W than S-E.**

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Thank you