Agricultural Outlook Forum
U.S. Department of Agriculture

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# Spatial Climate Datasets and Tools for Improved Agricultural Risk Management in a Changing Climate

Christopher Daly & David Hannaway

# Spatial Climate Datasets and Tools for Improved Agricultural Risk Management in a Changing Climate

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**Corvallis, OR**

# Topics

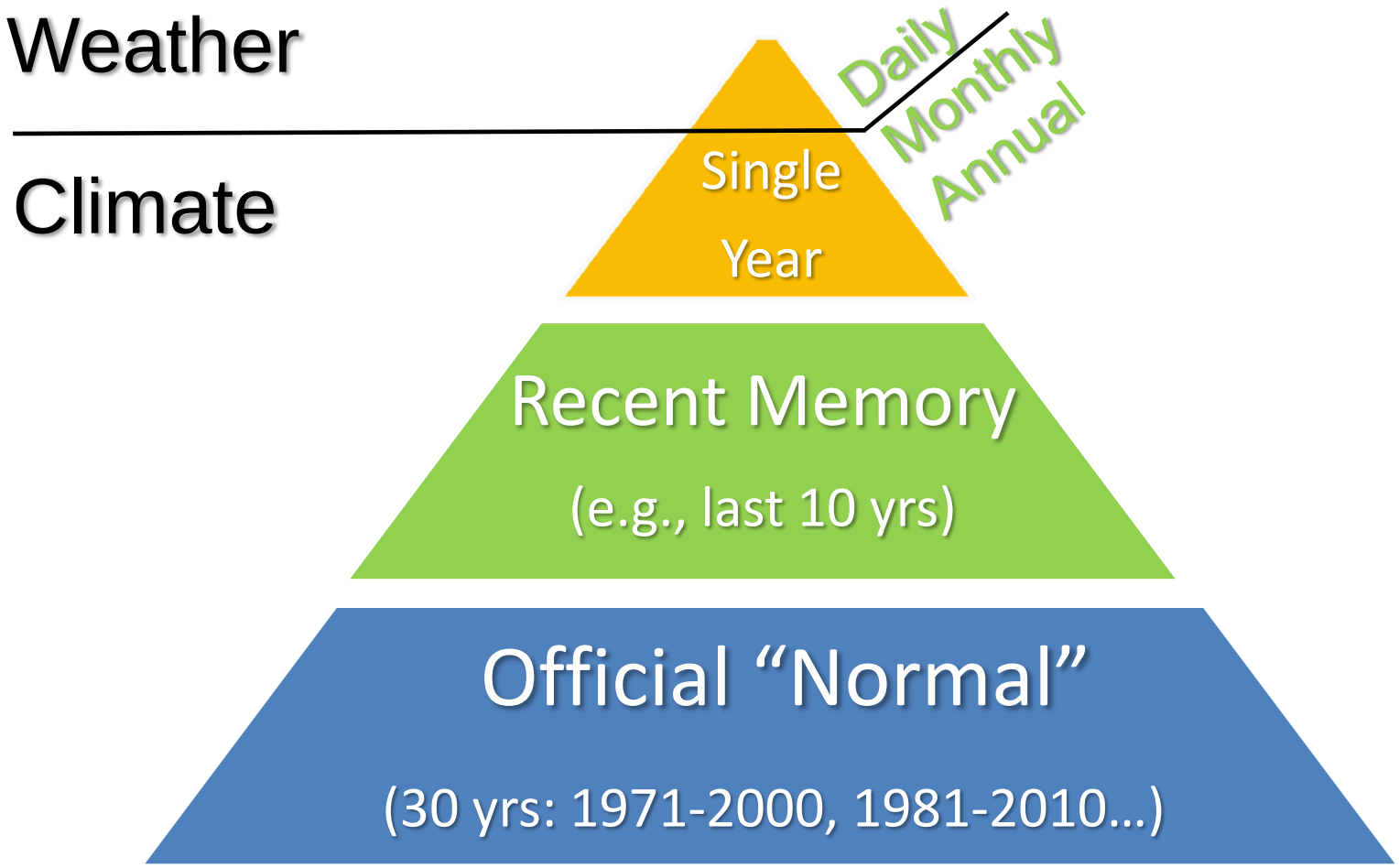
- The Importance of Climate in Crop Insurance
- Climate Mapping with PRISM - overview
- PRISM RMA Weather and Climate Portal
- How growers and others can contribute to our maps
- Crop Suitability Mapping
- The 2012 Plant Hardiness Zone Map

# Typical Cause-of-Loss Language

- "Crop could not be planted due to excessively wet conditions"
- "Crop failed due to insufficient moisture"
- "Harvest was delayed and crop quality was reduced due to cold and wet weather"
- "Crop was damaged due to unusually hot weather"

**Given a changing climate, how do claims managers evaluate whether an event was unusual?**

# Answer: Place Weather Events in their Climatological Context



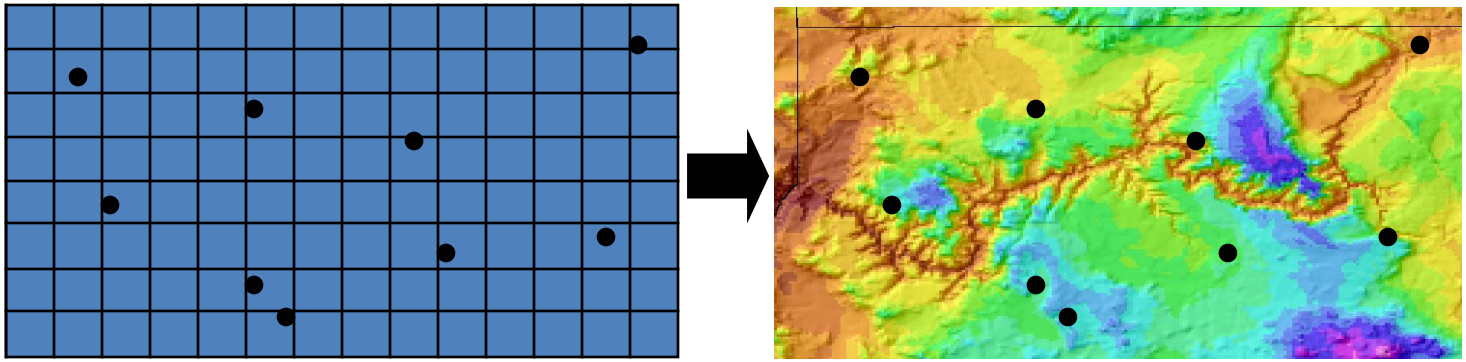
# Why are the Spatial Aspects of Weather and Climate Important?

- The location of interest is often not represented by a nearby weather station
- Variations in geographic factors can create large differences in climate or weather over small distances

**We need detailed weather and climate maps so that we can see what has been happening on any given field over various times scales**

# What is Climate Mapping?

The process of interpolating climate statistics at irregularly-spaced station locations to a regular grid



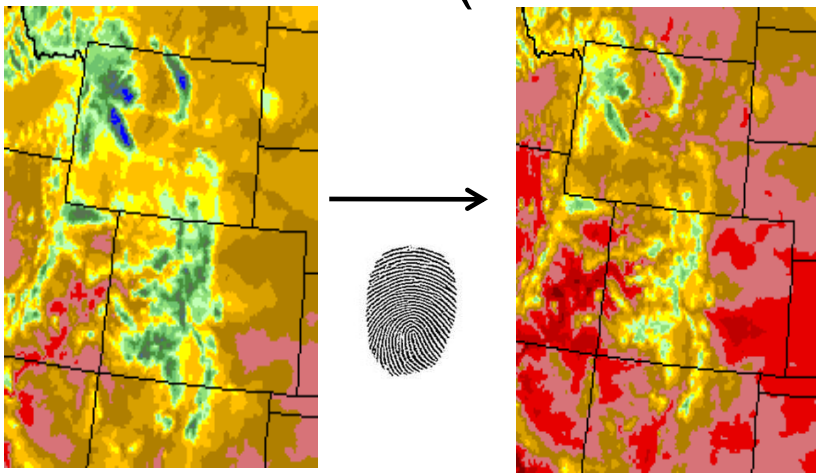
"Geospatial Climatology"

The study of the spatial and temporal patterns of climate on the earth's surface and their causes

# Good Climate Mapping Makes for Good Weather Mapping

- Climate provides a long-term context for weather events
- Weather is a variation on typical climate conditions
- The spatial patterns of long-term climate inform the spatial patterns of weather ("Climate Fingerprint")

1971-2000
July Tmax

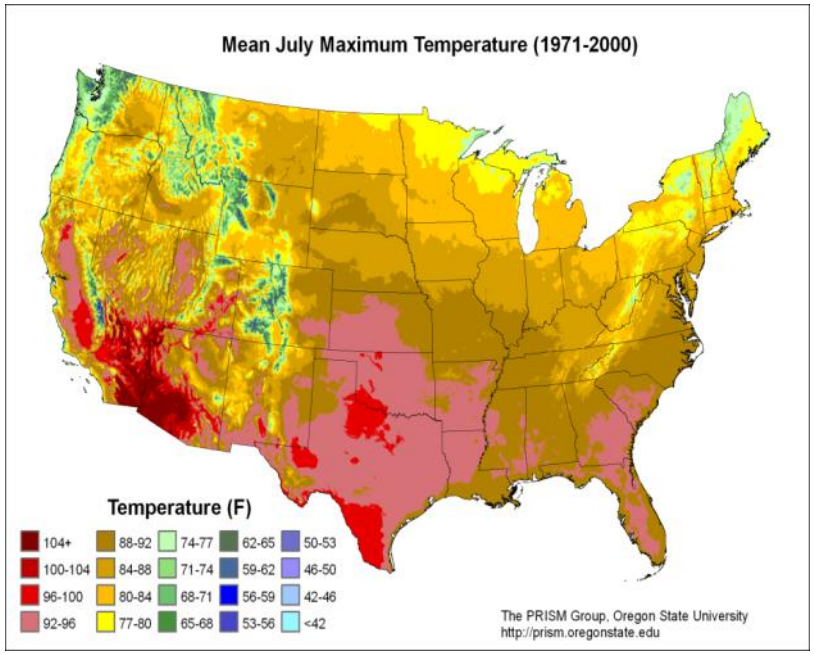


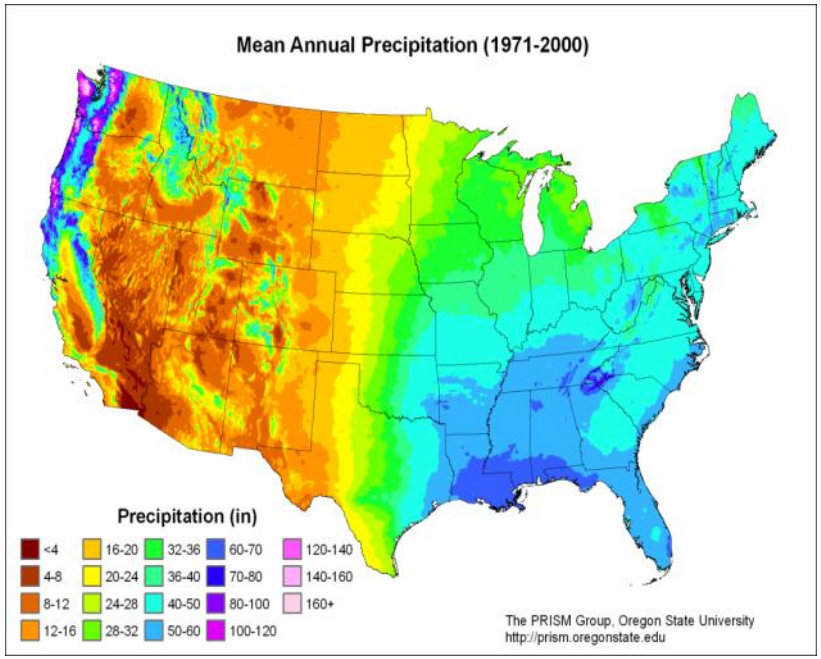
2003
July Tmax
(One of Hottest on Record)

Different values, but similar spatial pattern

# PRISM
## Digital Climate Maps

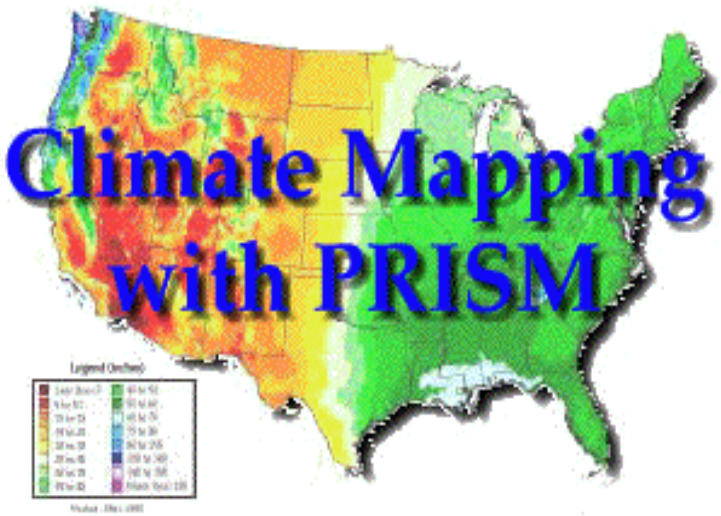
- The world's most advanced climate mapping science
- Developed and operated by the PRISM Climate Group, Oregon State University
- Official climate maps of the USDA
  - Funded by NRCS since 1993 and RMA since 2010



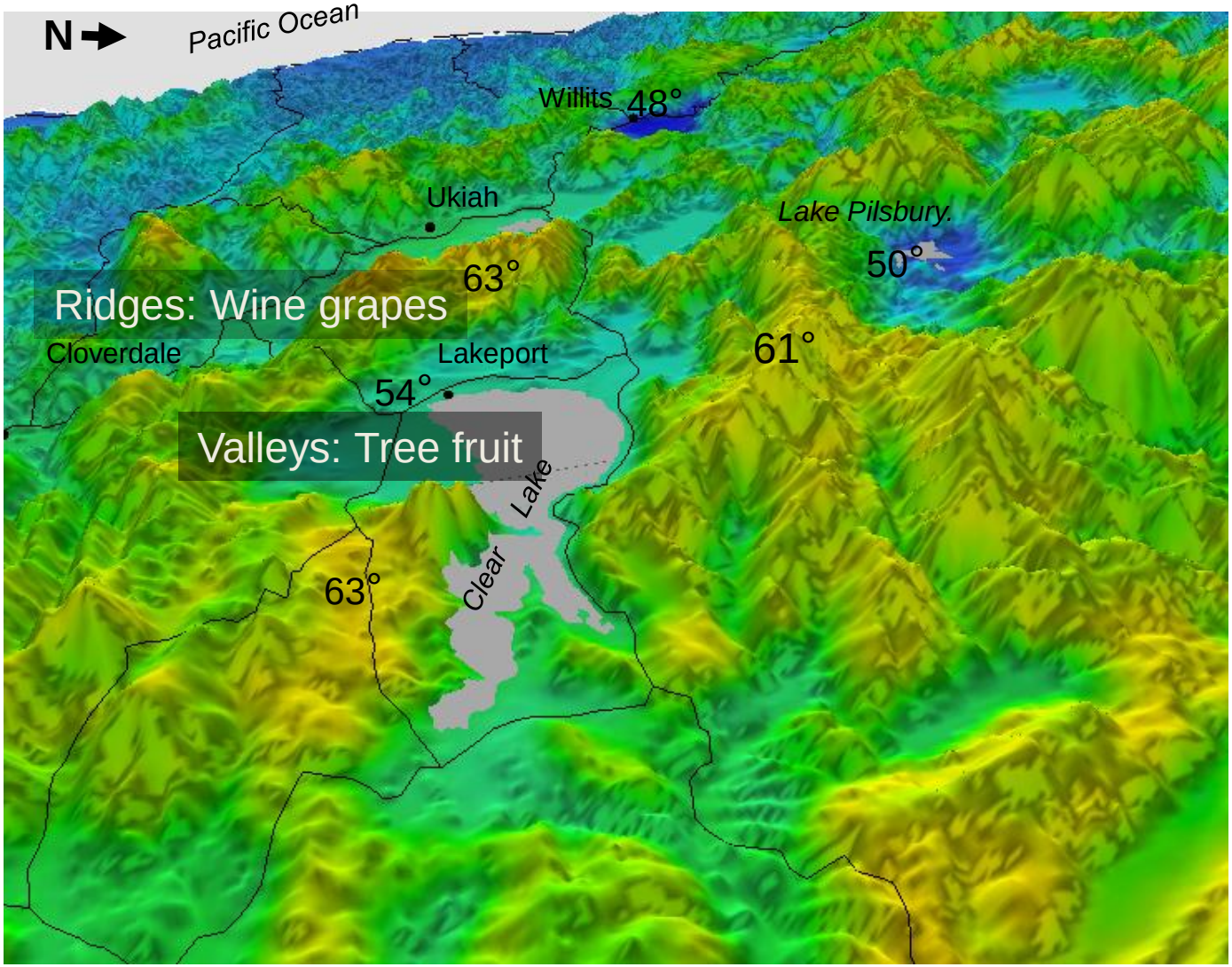



# PRISM

- PRISM spatial climate knowledge base accounts for spatial variations in climate due to:
  - Elevation – lapse rates
  - Terrain orientation – rain shadows
  - Terrain profile – terrain enhancement of precipitation
  - Moisture regime – exposure to moisture sources
  - Coastal proximity – marine air intrusion
  - Two-layer atmosphere – inversion layer, free atmosphere
  - Topographic position – susceptibility to cold air pooling



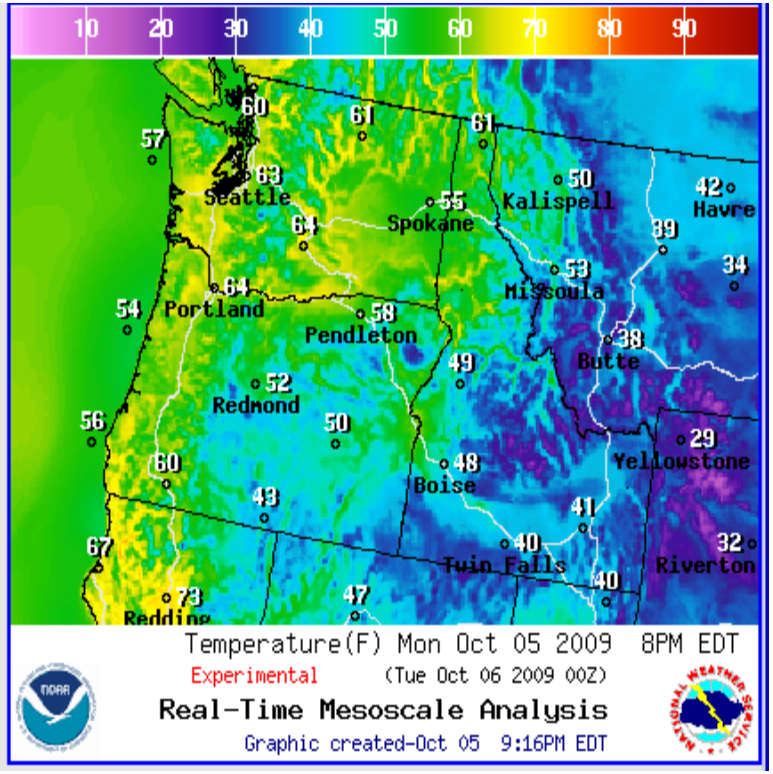
# Inversions and Agriculture – 1971-00 July Minimum Temperature Northwestern California

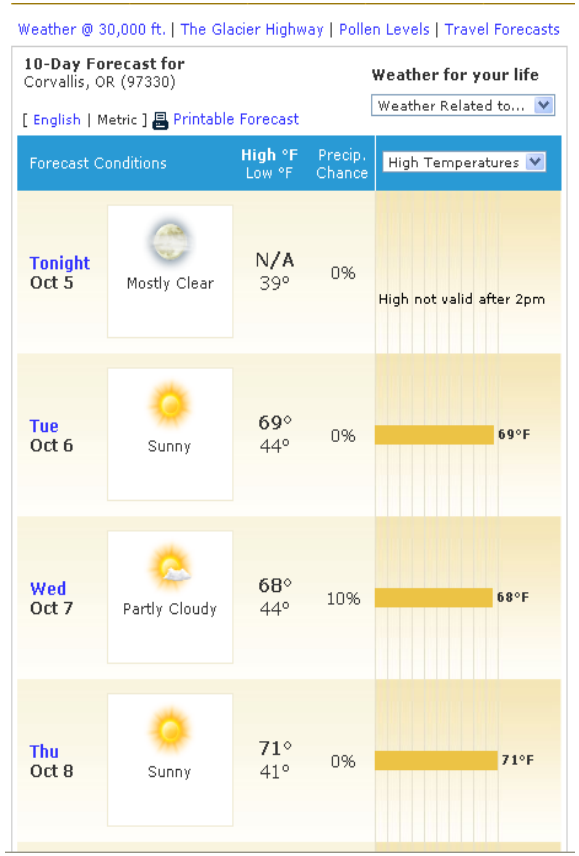


# Products Guided by PRISM Climatologies

## Spatial Forecasts

National Weather Service Gridded Forecasts

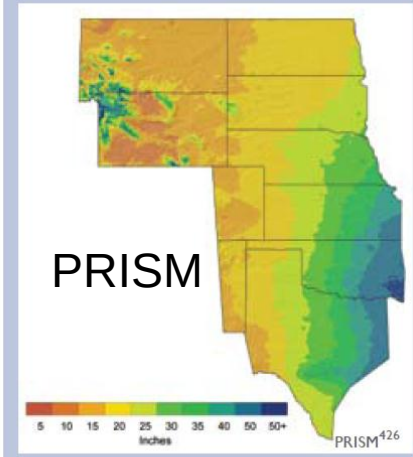


# PRISM Datasets are Heavily Used to Guide Spatial Projections of Climate Change

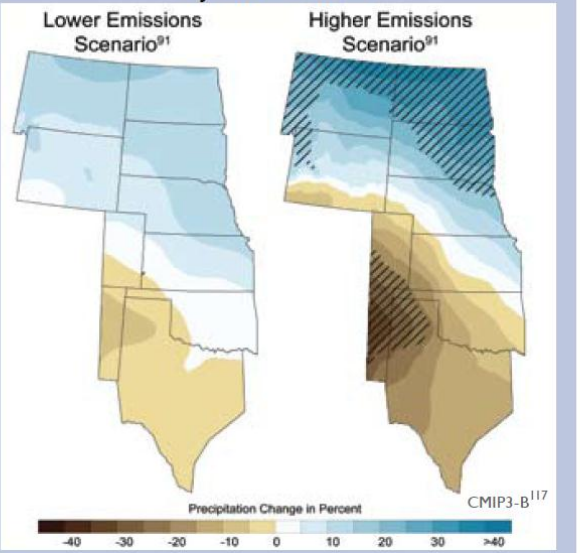
**Regional Climate Impacts:** Great Plains

Average Annual
Observed Precipitation
1971-2000




The Great Plains currently experiences a sharp precipitation gradient from east to west, from more than 50 inches of precipitation per year in eastern Oklahoma and Texas to less than 10 inches in some of the western parts of the region.

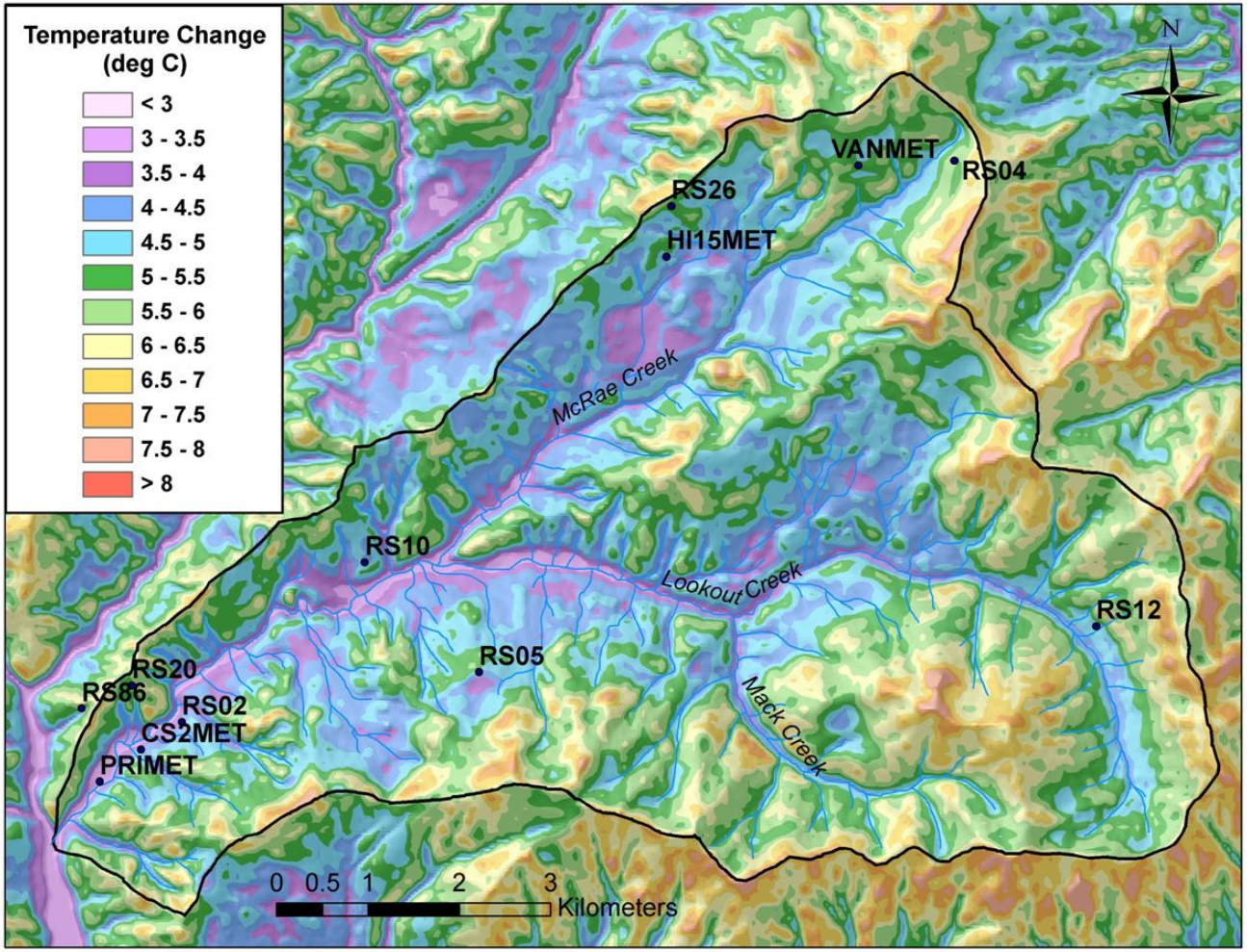
Projected Spring Precipitation Change
by 2080s-2090s




Northern areas of the Great Plains are projected to experience a wetter climate by the end of this century, while southern areas are projected to experience a drier climate. The change in precipitation is compared with a 1960-1979 baseline. Confidence in the projected changes is highest in the hatched areas.

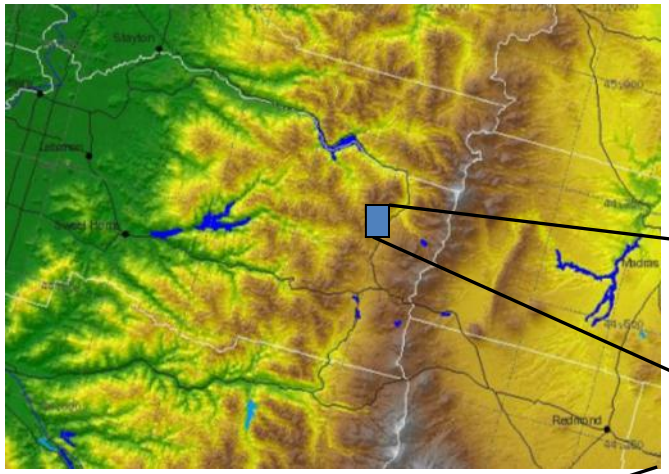
Source: US Global Change Research Program report, 2009

# Ground-Breaking Research: Spatial Patterns of Climate Change at the Landscape Scale

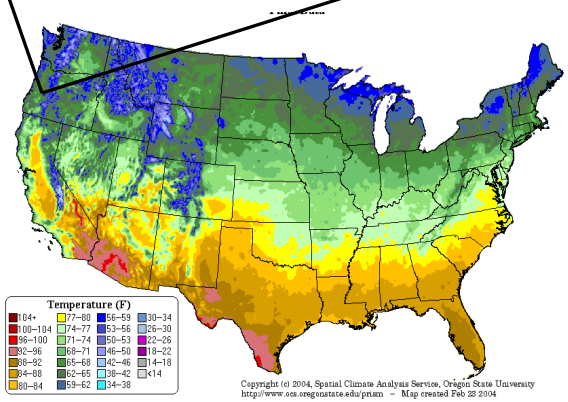


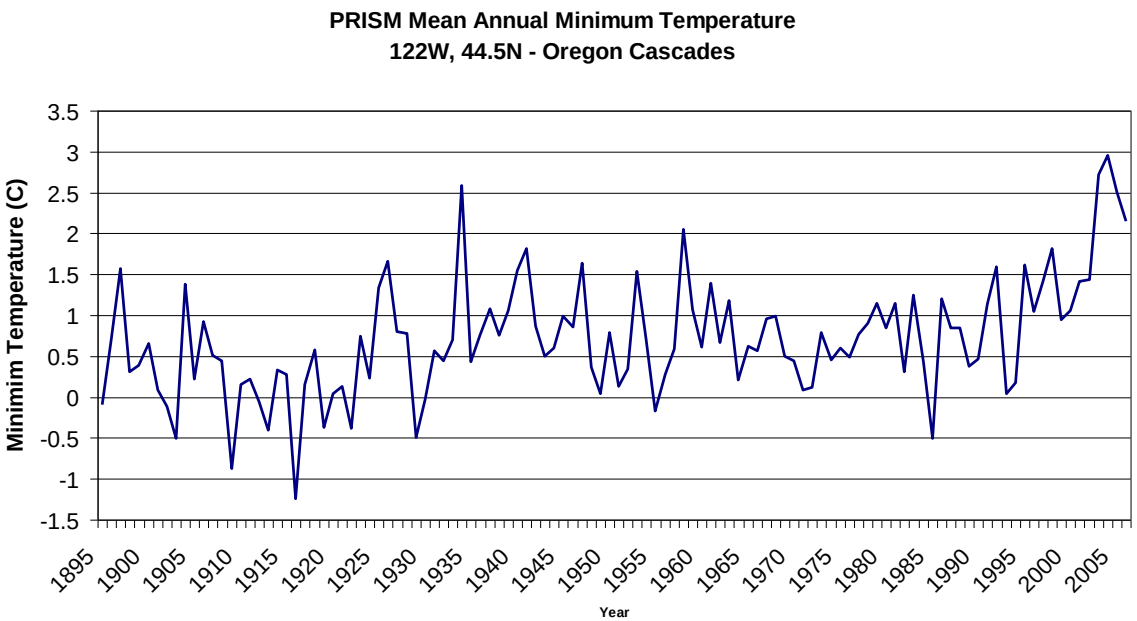

Projected December Maximum Temperature Change
HJ Andrews Experimental Forest, Oregon

# CONUS 1895-present Monthly Climate Time Series




116 years of monthly precipitation, min and max temperature, dew point, and vapor pressure

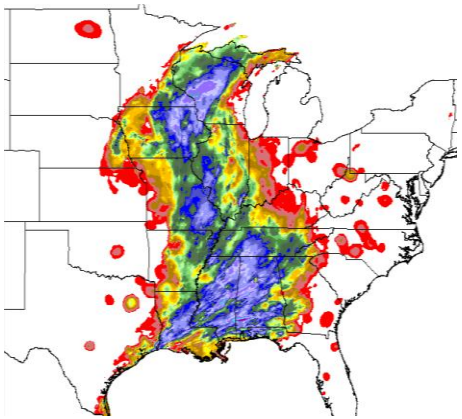


# PRISM Support for Crop Insurance Compliance

Provide high-quality weather and climate maps to expedite claims

- Did the claimed damaging event occur?
  - Short time scale: Daily and monthly PRISM maps over the lower 48 states in near real time
- Was the event unusual enough to support a loss claim?
  - Long time scale: Climatic context for the event
- Make the assessment process quick and easy
  - Web-based tools



# PRISM/RMA Weather & Climate Portal

- New portal being developed for RMA
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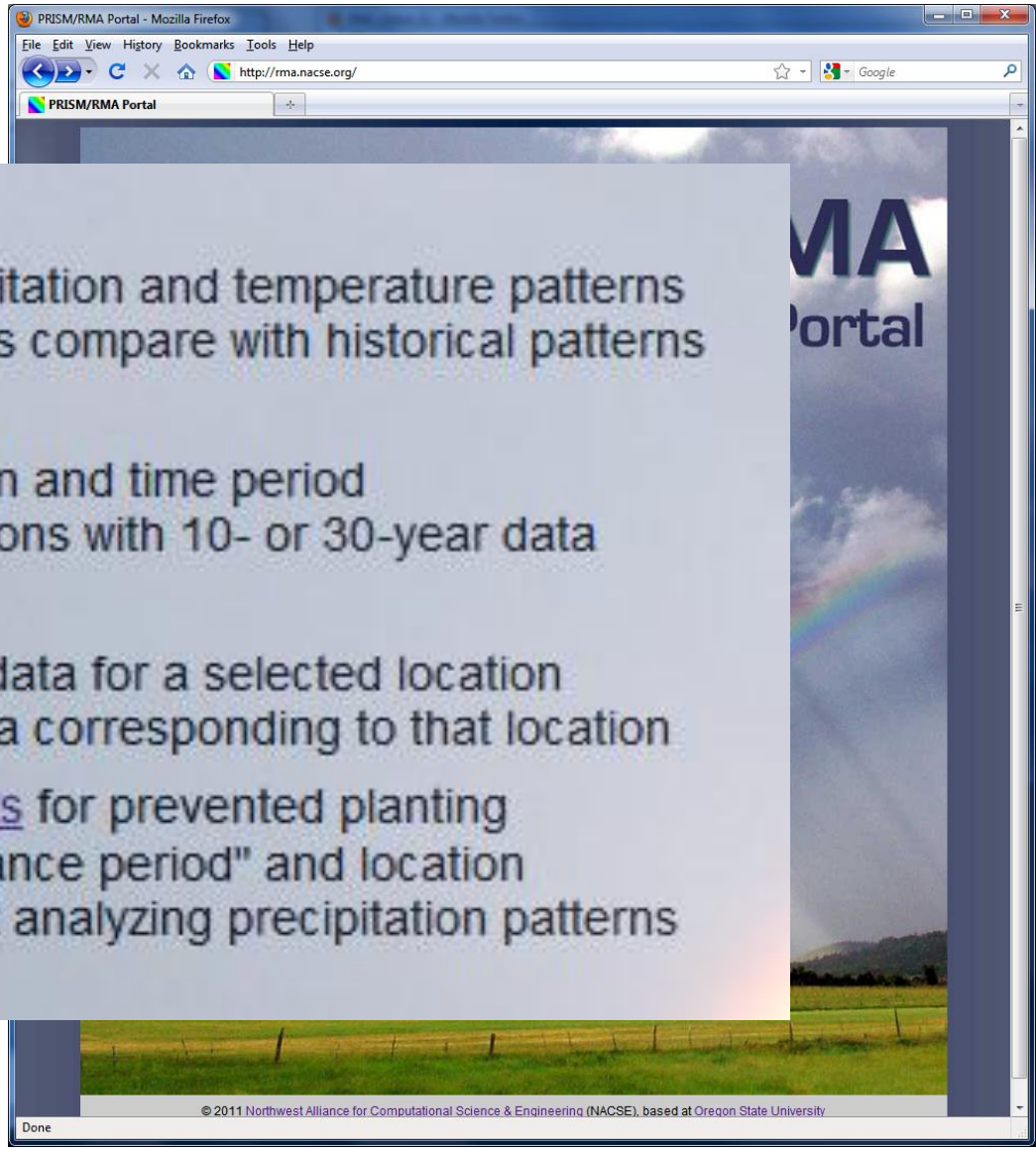


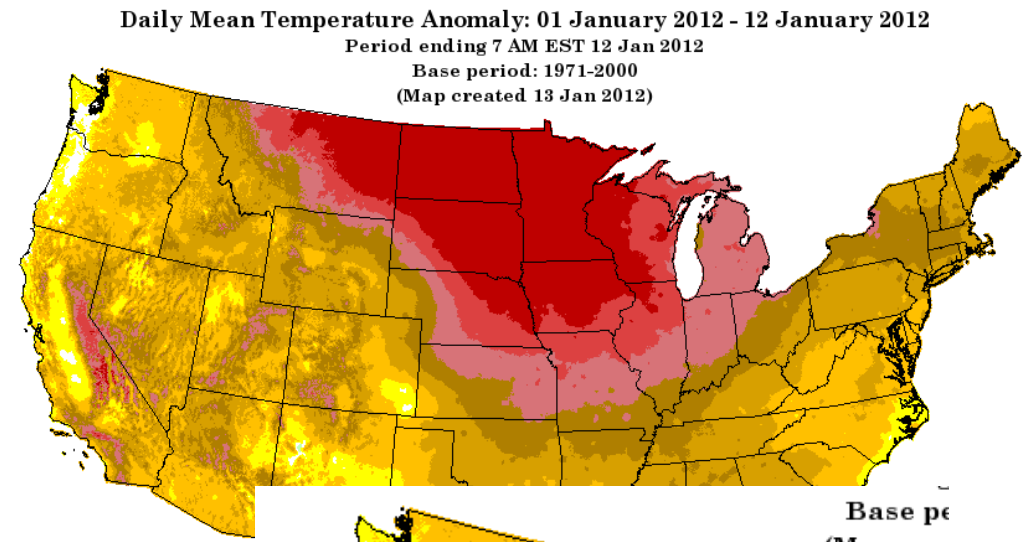

Check recent conditions
- View national-level precipitation and temperature patterns
- See how recent conditions compare with historical patterns

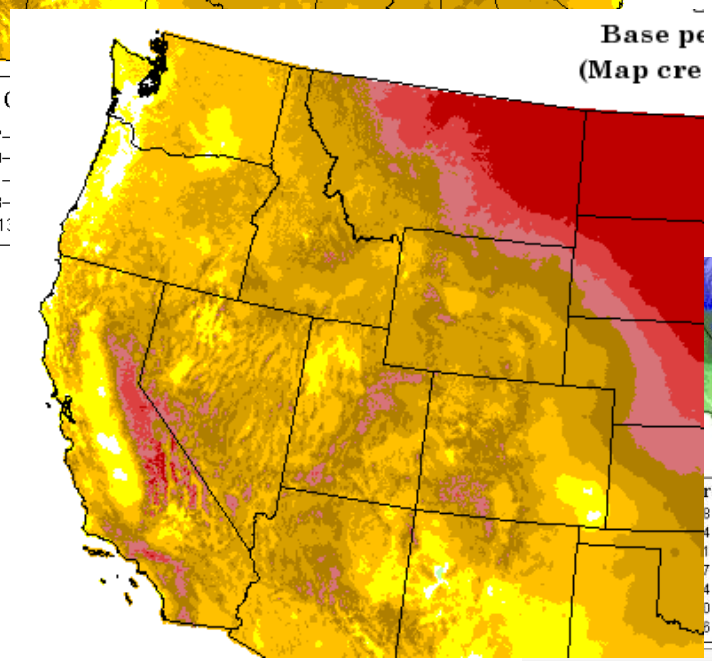
View summary assessment
- Select a particular location and time period
- Compare average conditions with 10- or 30-year data

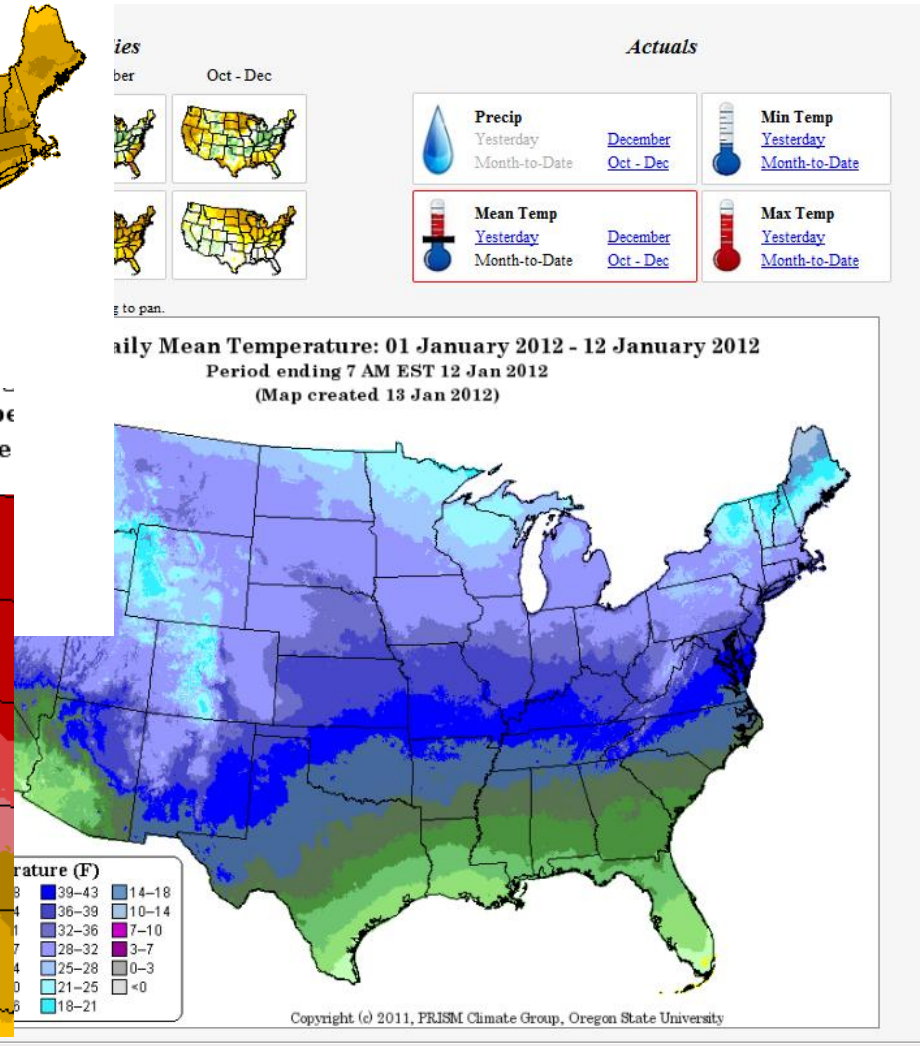
Explore detailed data
- View plots of time-series data for a selected location
- Download time-series data corresponding to that location

Generate customized reports for prevented planting
- Select a 16-month "insurance period" and location
- Get an on-demand report analyzing precipitation patterns

# Task 1: Check Recent Conditions



# Map Interface – Summary Assessment

Time period [How data stability is calculated]

- Daily time period (current limit is 16 months)
  - Starts: 2011 December 10 Data for this date is ...
  - Runs through: 2011 December 10 Data for this date is ...
- Monthly time period (current limit is 16 months)
  - Starts: 2010 April Data for this date is **unlikely to change**
  - Runs through: 2010 November Data for this date is **unlikely to change**

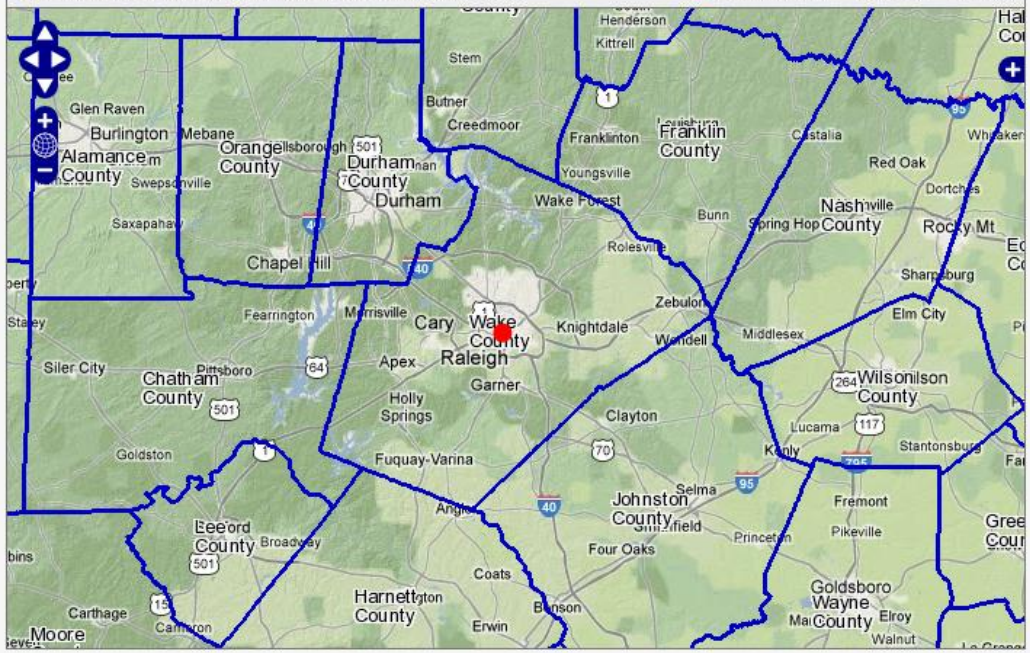
Compare to Prior 10 years 30-year normals (1971-2000) [How normals are calculated]

Location

- State & County North Carolina Wake
- PLSS North Carolina Wake --------- --------- ---------
- Coordinates Latitude: 35.79 Longitude: -78.6503
- Click-to-choose

View Assessment

Click to select. Click & drag to pan. Use mouse wheel to zoom. Latitude: 35.79 Longitude: -78.6503



# Summary Assessment: Raleigh, NC 2010 Tobacco Season

Start Date: **April 2010** Data for this date is **unlikely to change** [How data stability is calculated]

End Date: **November 2010** Data for this date is **likely to change**

Assessment Basis: **30-year normals (1971-2000)** [How normals are calculated]

| Precipitation (total inches) | Mean Temperature (overall average °F) | Maximum Temperature (daytime highs °F) | Minimum Temperature (nighttime lows °F) |
|---|---|---|---|
| **Dry** | **Unusually Warm** | **Unusually Warm** | **Unusually Warm** |


View Details

| | Selected Period | 1971-2000 Normal | Percent of 1971-2000 Normal | Rank in Normal Period & Assessment | [How rank is used] |
|---|---|---|---|---|---|
| **Precipitation** (total) | 26.42" | 30.81" | 85.8% | **23/30 = Dry** | |

| | Selected Period | 1971-2000 Normal | Deviation from 1971-2000 Normal | Rank in Normal Period & Assessment | [How rank is used] |
|---|---|---|---|---|---|
| **Mean Temperature** (overall average) | 70.5°F | 67.5°F | +3.0°F | **1/30 = Unusually Warm** | |
| **Maximum Temperature** (daytime highs) | 82.1°F | 78.9°F | +3.2°F | **1/30 = Unusually Warm** | |
| **Minimum Temperature** (nighttime lows) | 59.0°F | 56.2°F | +2.8°F | **1/30 = Unusually Warm** | |

# Classification Scheme – 30 Years

| Precipitation | Rank | Percentile Range | Rank | Temperature |
|---|---|---|---|---|
| Unusually Wet | 1, 2, 3 | 90-100th | 1, 2, 3 | Unusually Warm |
| Wet | 4, 5, 6, 7, 8, 9 | 70-90th | 4, 5, 6, 7, 8, 9 | Warm |
| Typical | 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 | 30-70th | 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 | Typical |
| Dry | 22, 23, 24, 25, 26, 27 | 10-30th | 22, 23, 24, 25, 26, 27 | Cool |
| Unusually Dry | 28, 29, 30 | 0-10th | 28, 29, 30 | Unusually Cool |

# Task 3: View Detailed Data

- Download data to a spreadsheet

Location: **Lat: 46.2507 Lon: -119.1143 (Washington - Franklin County); T9N R30E Sec 19**

Start Date: **15 October 2011** Data for this date is **likely to change** [How data stability is calculated]

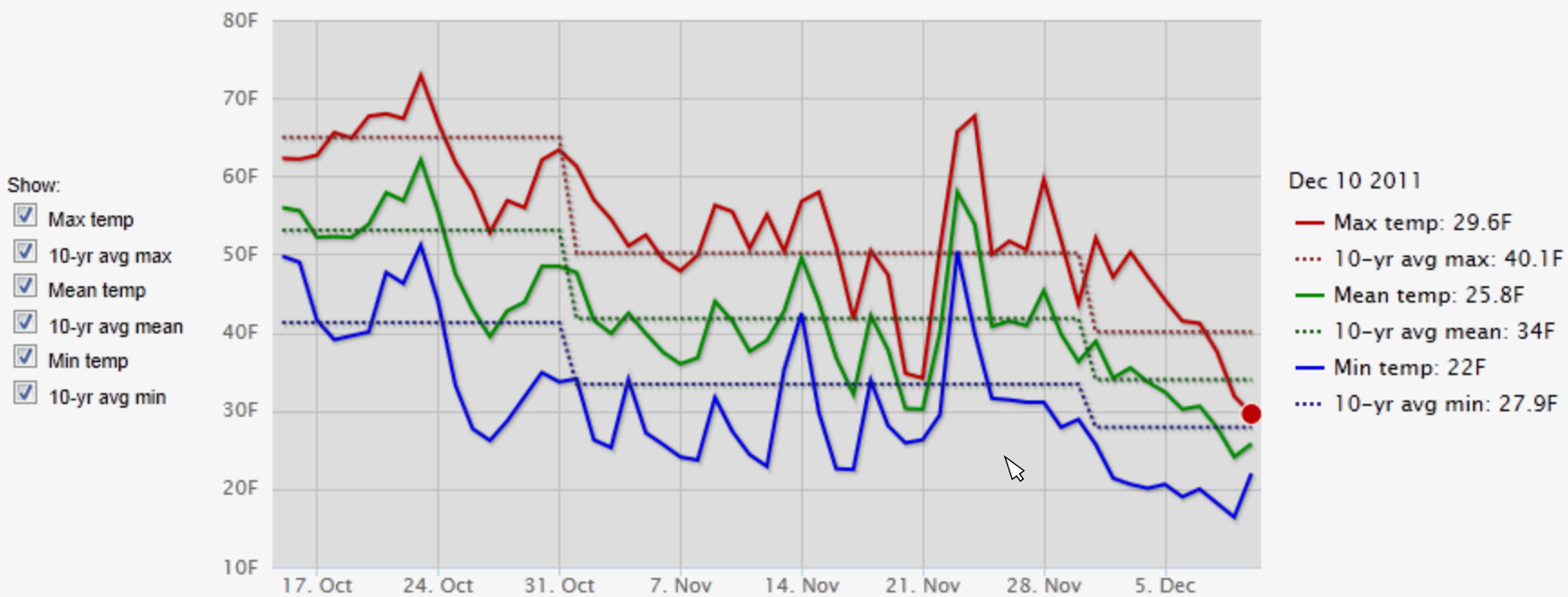
End Date: **10 December 2011** Data for this date is **preliminary**

Assessment Basis: **Prior 10 years (2001-2010)** [How normals are calculated]

Mouseover to view individual values
Click-and-drag to zoom
"Reset zoom" link restores full display

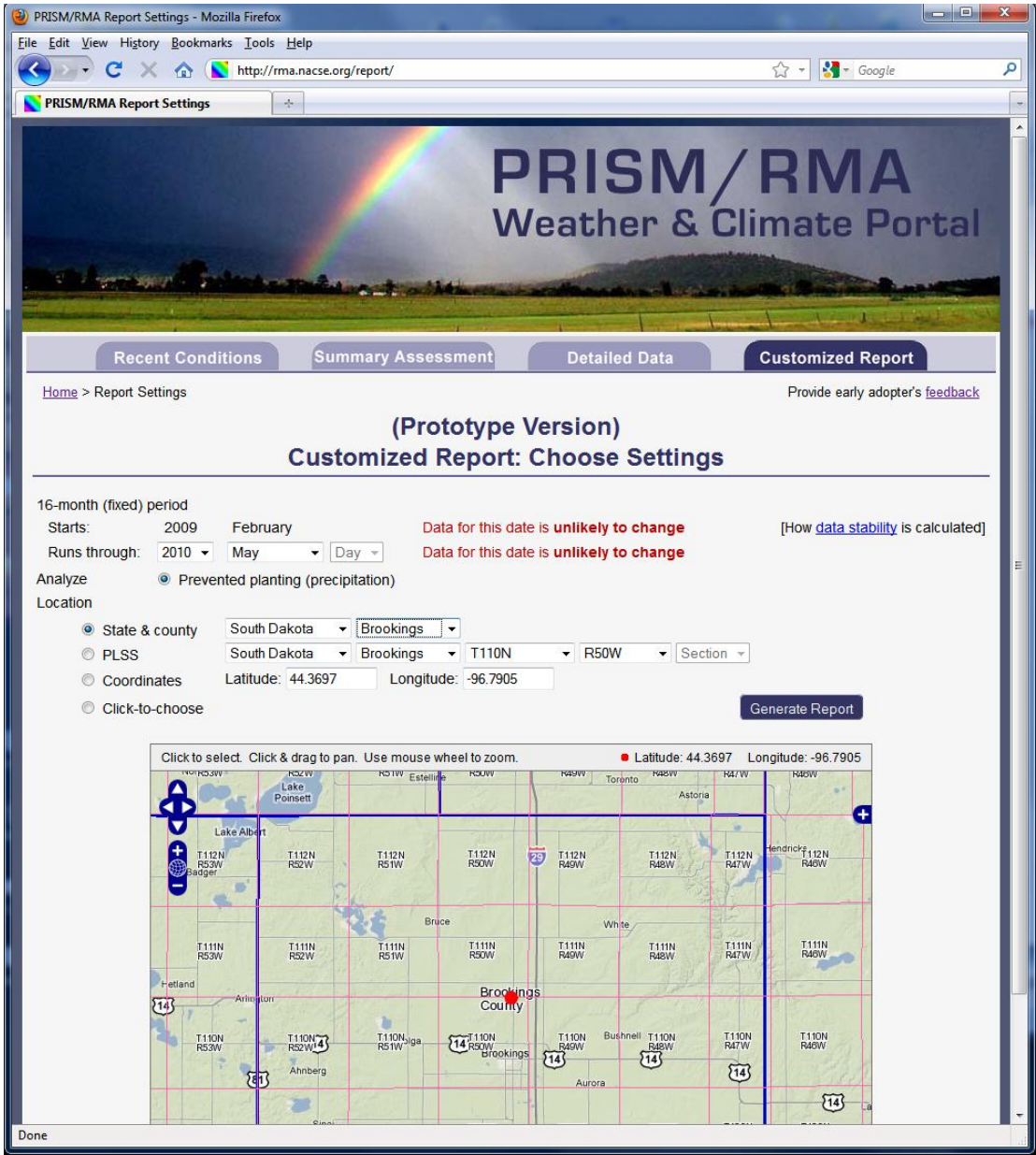
**Temperature °F (maximum, mean, minimum)**
View or download data values

10-year averages are available only as monthly values, so they appear as flat lines on the plot



# Task 4: Generate Customized Report

- Select a 16-month "insurance period" and location
- Get an on-demand prevented planting report
- Future plans
  - Other types of reports



# Customized Report: Interactive Tables and Graphs

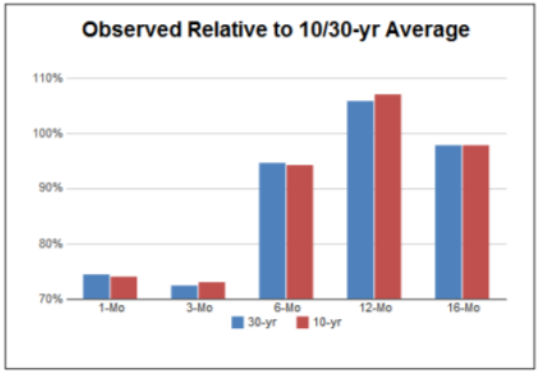



**Figure 4.** Cumulative precipitation conditions at the parcel over five time periods leading up to and including May 2010, expressed as a percentage of the 10- and 30-year averages. Mouse over a column to see the data value.

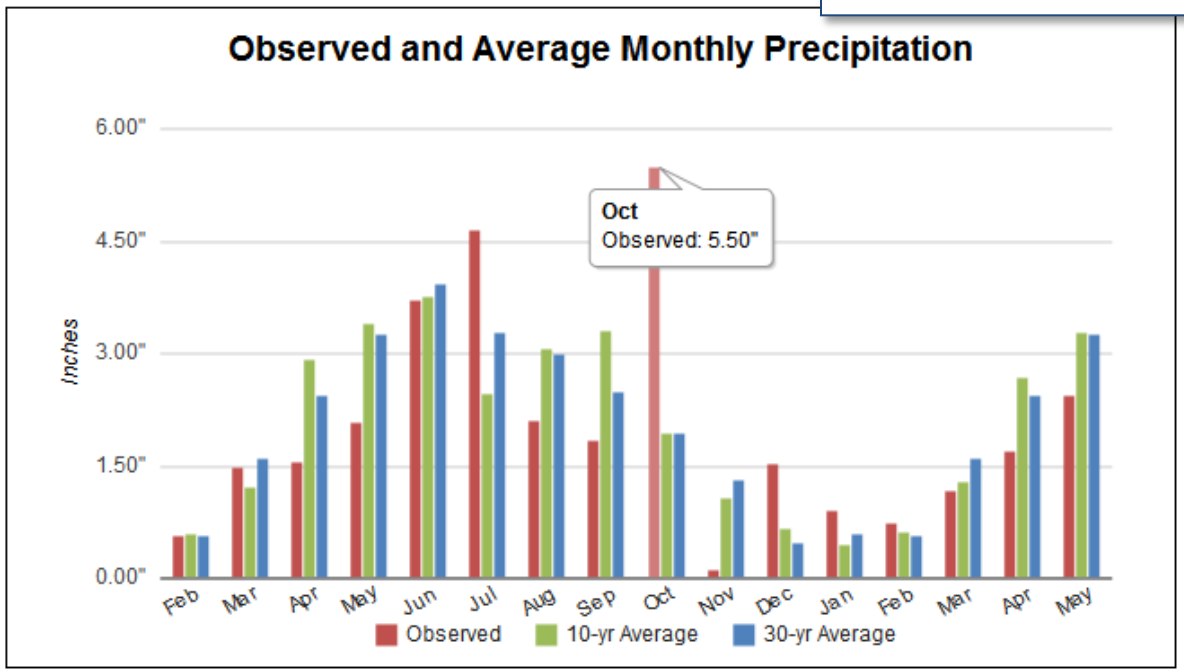
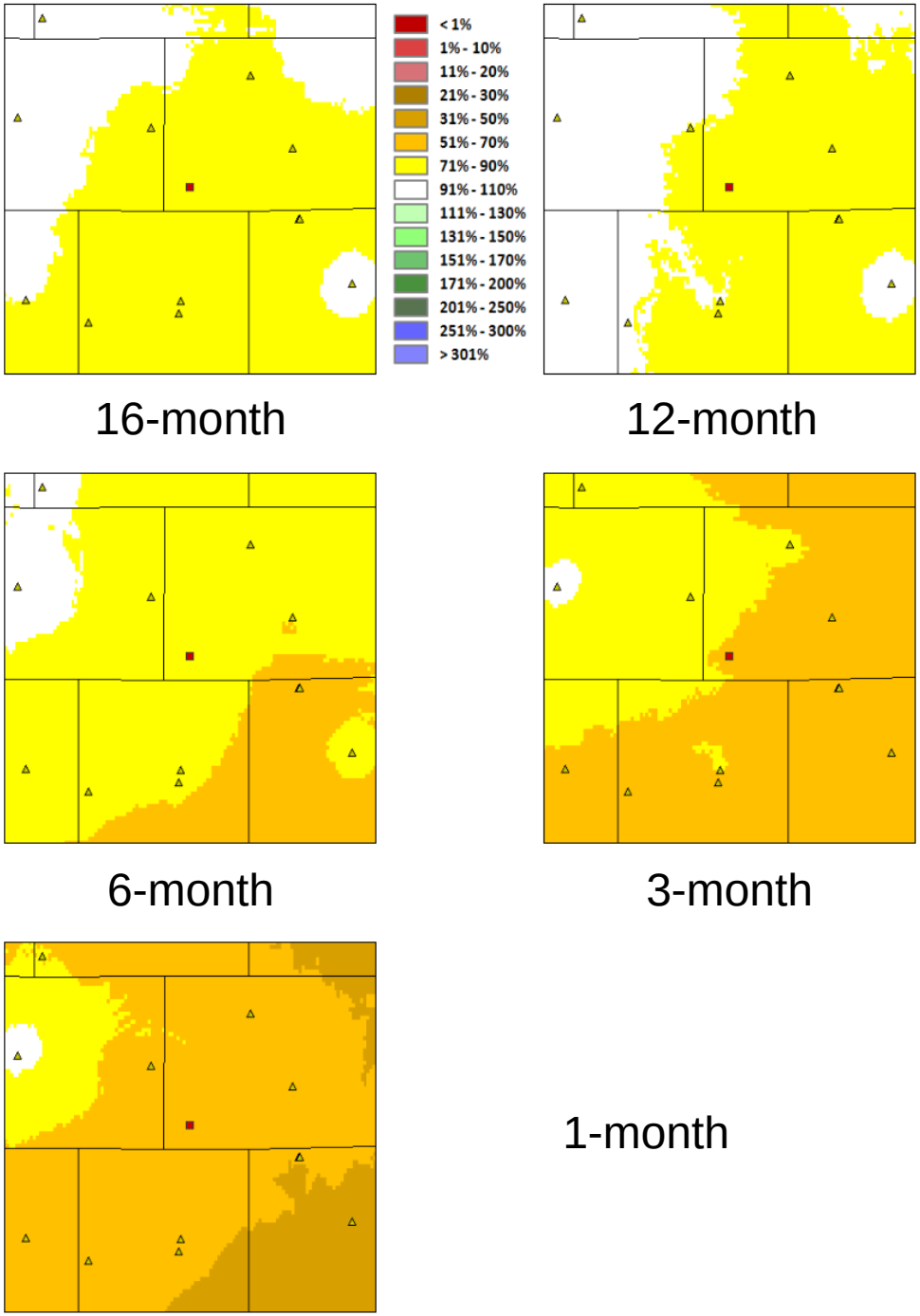



**Figure 3.** Precipitation conditions at the parcel for the 16-month period leading up to and including May 2010, compared to the averages over the 10- and 30-year periods. Mouse over a column to see the data value.

# Customized Report: Maps of Cumulative Precipitation Compared to Normal



# Customized Report: Summary Section

## SUMMARY

This document provides an analysis of the precipitation conditions for a parcel in Brookings County, SD and vicinity over the 16 months leading up to and including May 2009.

For the 16-month period of February 2008 through May 2009, compared to months in the 30-year normal period (1971-2000), 11 months were classified as typical, 2 months were wet or unusually wet, and 3 months were dry or unusually dry. Compared to months in the 10-year period, 9 months were typical, 3 months were wet or unusually wet, and 4 months were dry or unusually dry.

Cumulative precipitation at the parcel also was calculated, starting at May 2009 and working backward. Compared to the 30-year normal period (1971-2000), the 16-month accumulation was typical, the 12-, 6-, and 3- month periods were dry to typical, and the 1-month accumulation (May 2009 only) was typical. Compared to the 10-year period (1998-2008), the 16-month accumulation was dry, the 12-, 6-, and 3- month periods were unusually dry to dry, and the 1-month accumulation was dry.

# Next Steps for Portal

- Currently in prototype stage
- Open to RMA offices only
- Taking feedback from RMA “early adopters”
- Plan to open portal to AIP early adopters for review and comment in March 2012
- Long range plan – open up (at least partially) to growers

# How Can Growers Participate in the Weather and Climate Assessment Process?

- Growers live and breath the weather!
- Many take their own precipitation measurements
- We cannot accept these measurements because of unknown methods and equipment
- But there is now a way for them to participate…

# Community Collaborative Rain, Hail & Snow Network

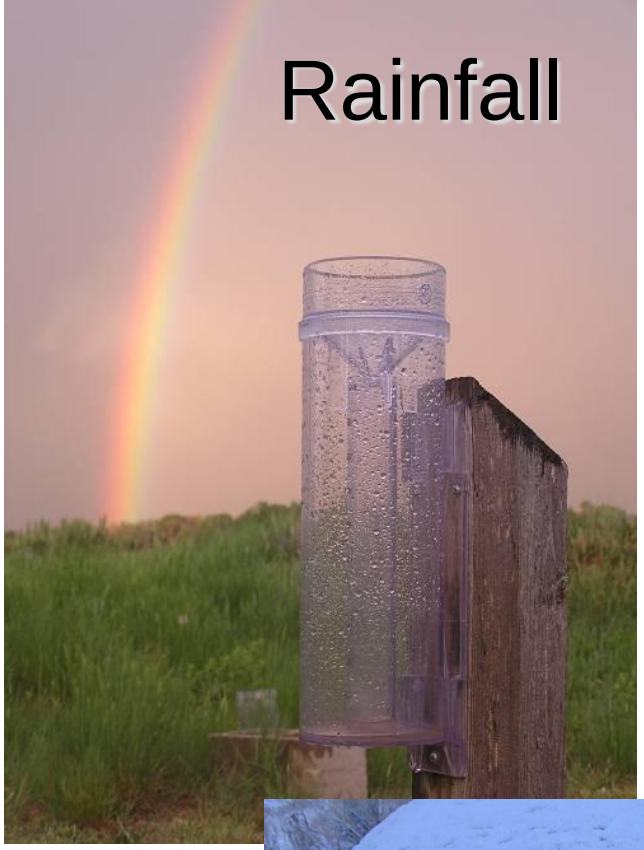

Photo: Christy Johnson

# CoCoRaHS

**Citizen observers use simple 4" plastic rain gauges to measure precipitation.**

**The network has suddenly become the nation's *largest* source of daily precipitation measurements (15,000+ observers)**

**Data are QC'ed every day and incorporated into PRISM weather and climate datasets**


Rainfall

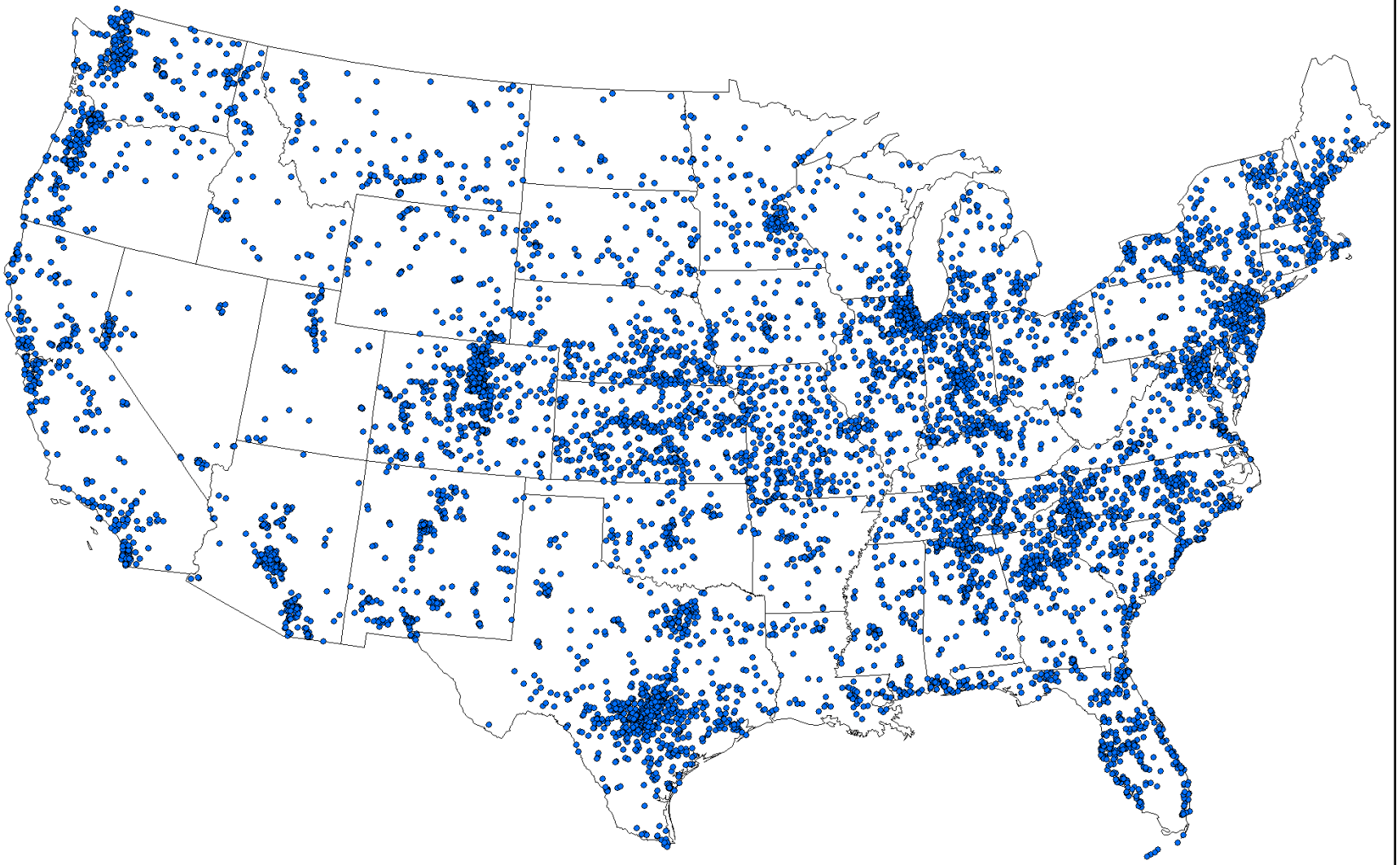
Hail


Large Hail ≥ 1"


4
5
6
7
WESTCOTT
RULER


CoCoRaHS
Snowfall

# Current CoCoRaHS Precipitation Stations



# Getting Started

- Anyone can join CoCoRaHS
  - Buy a <$30 rain gauge
- We encourage growers to participate, and contribute data from their farms!
- To get started, go to

**http://cocorahs.org**

# PRISM Support for Crop Insurance Underwriting: Crop Suitability Maps

- Develop suitability maps based on climate and soils
  - Relative yield potential (0-100%) based on climate and soil conditions
  - Provide a climatic “reality check” for yield guarantees (currently based on grower’s reported yield history)
  - Should a current crop be insured, or is too risky?
  - Where can a new biofuel feedstock be grown successfully?

# Origins of our Suitability Mapping Approach

## China: Market Opportunities for U.S.-Grown Cool Season Grasses and Legumes

- **Goal: Improve the marketing of US-grown grass seeds in China by developing better tools for selecting optimal species and varieties for forage, soil conservation, and amenity grasses.**

**Project performed between 1998 and 2005**

# Project Rationale

- **China is growing rapidly, and demands have greatly expanded for:**
  - **Improved forage-livestock systems**
  - **urban beautification**
  - **improved environmental protection**

- **Result is increased market demands for high quality grass seeds**

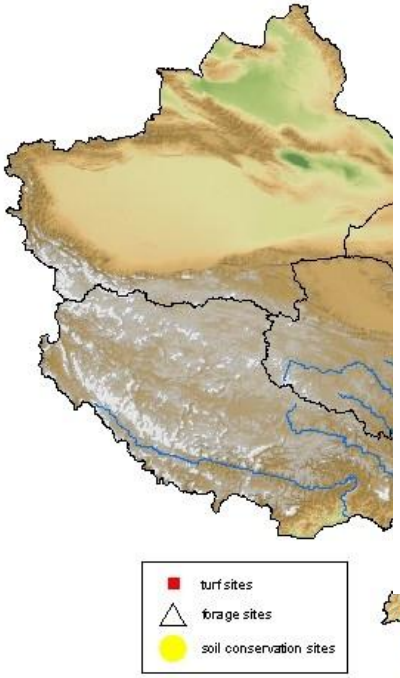
- **Effective marketing of our high quality US-grown seeds requires that we be able to identify all of the areas suitable for using these grasses**

  - **Until now that has been impossible on a wide scale. Field-based trials are not effectively extrapolated to other locations.**

  - **Current computer technology makes it possible to create detailed maps of climate and soils and combine them with species tolerances to accurately identify suitable growing areas for effective marketing**

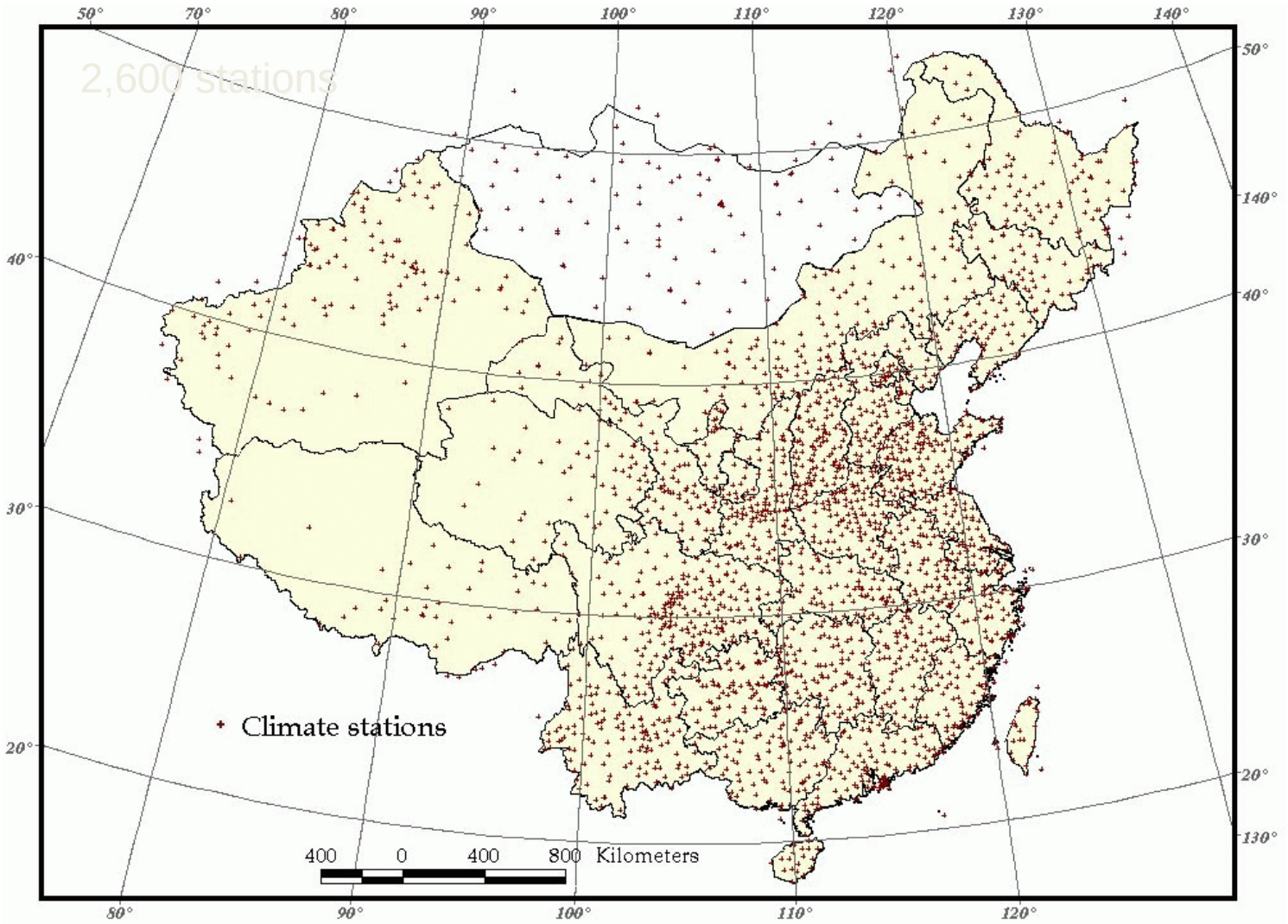
# Traditional Method:

## Field-based evaluation trials

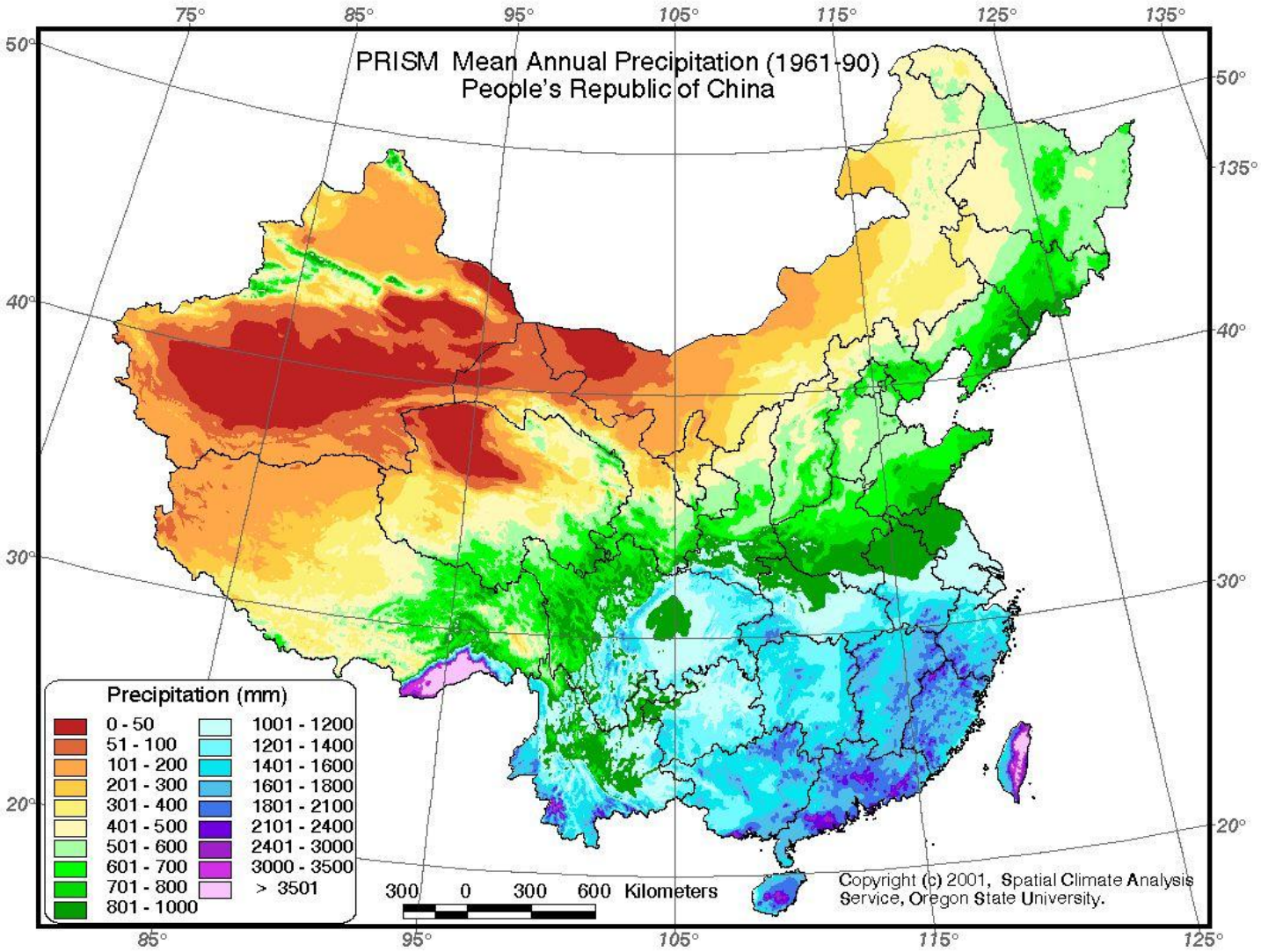



- Expensive
- Time Consuming
- Unpredictable
- Cooperators Hard to Find
- Management Issues

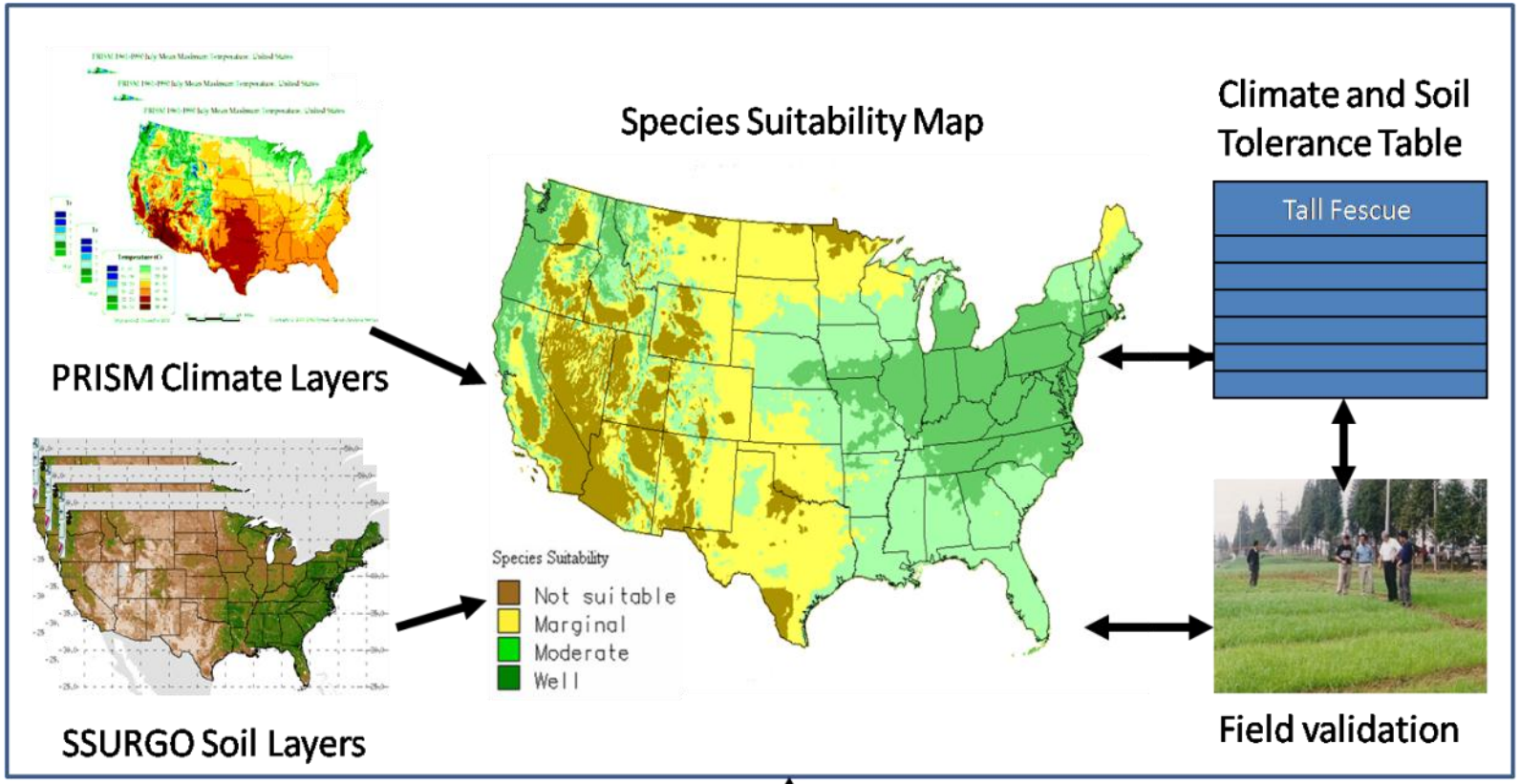
# Climate Station Data: 1961-90 mean monthly max/min temperature, precipitation



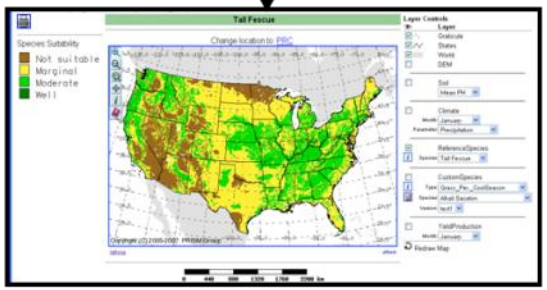
# PRISM Mean Annual Precipitation



# Species Suitability Mapping System



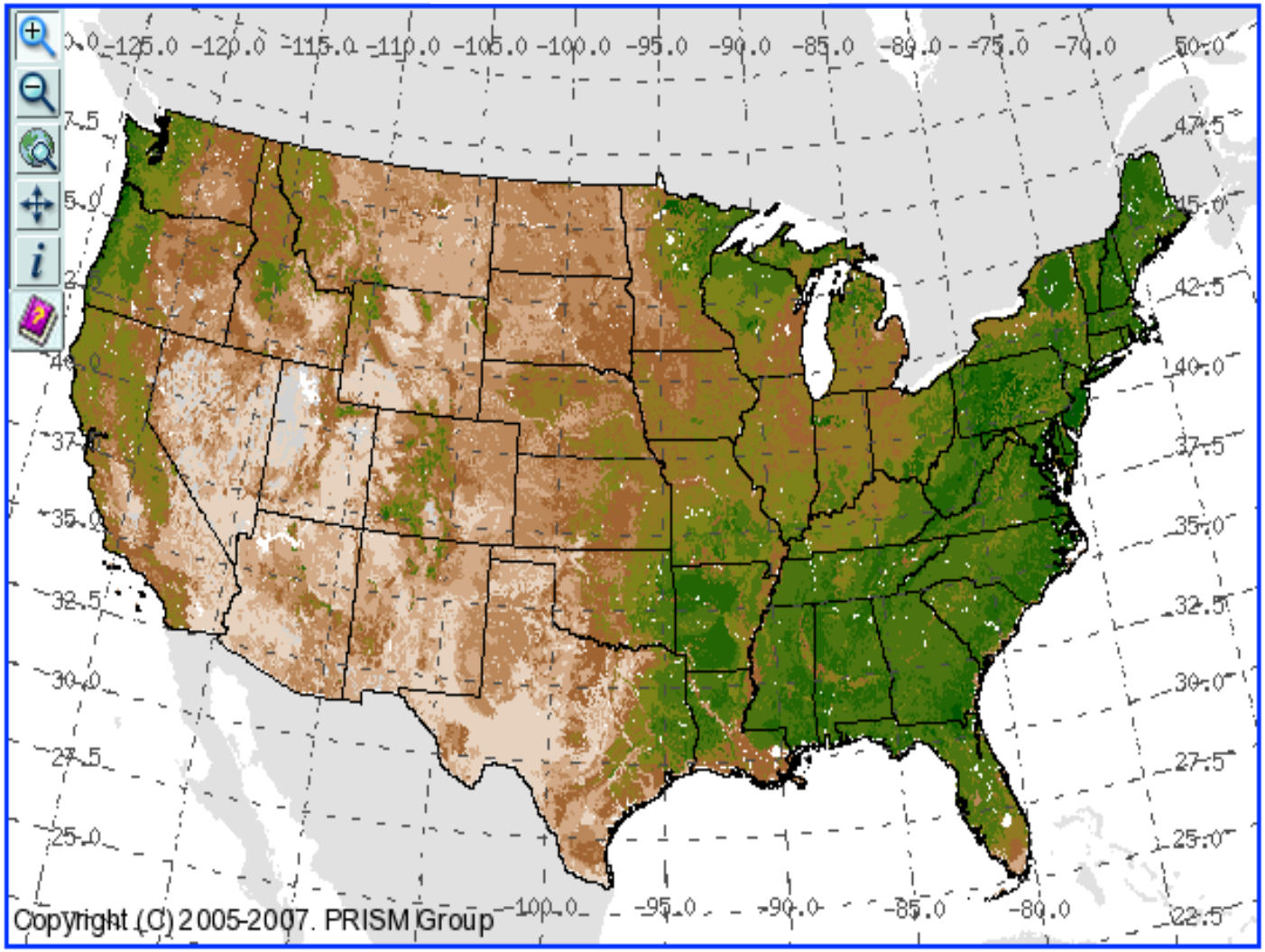

Internet Map Server



# USDA-NRCS SSURGO Soil pH

Soil pH

- NoData
- <4.5
- 4.5–5
- 5–5.5
- 5.5–6
- 6–6.5
- 6.5–7
- 7–7.5
- 7.5–8
- 8–8.5
- 8.5+



# Identify Quantitative Climate Tolerances in US Where Ranges are Better Known

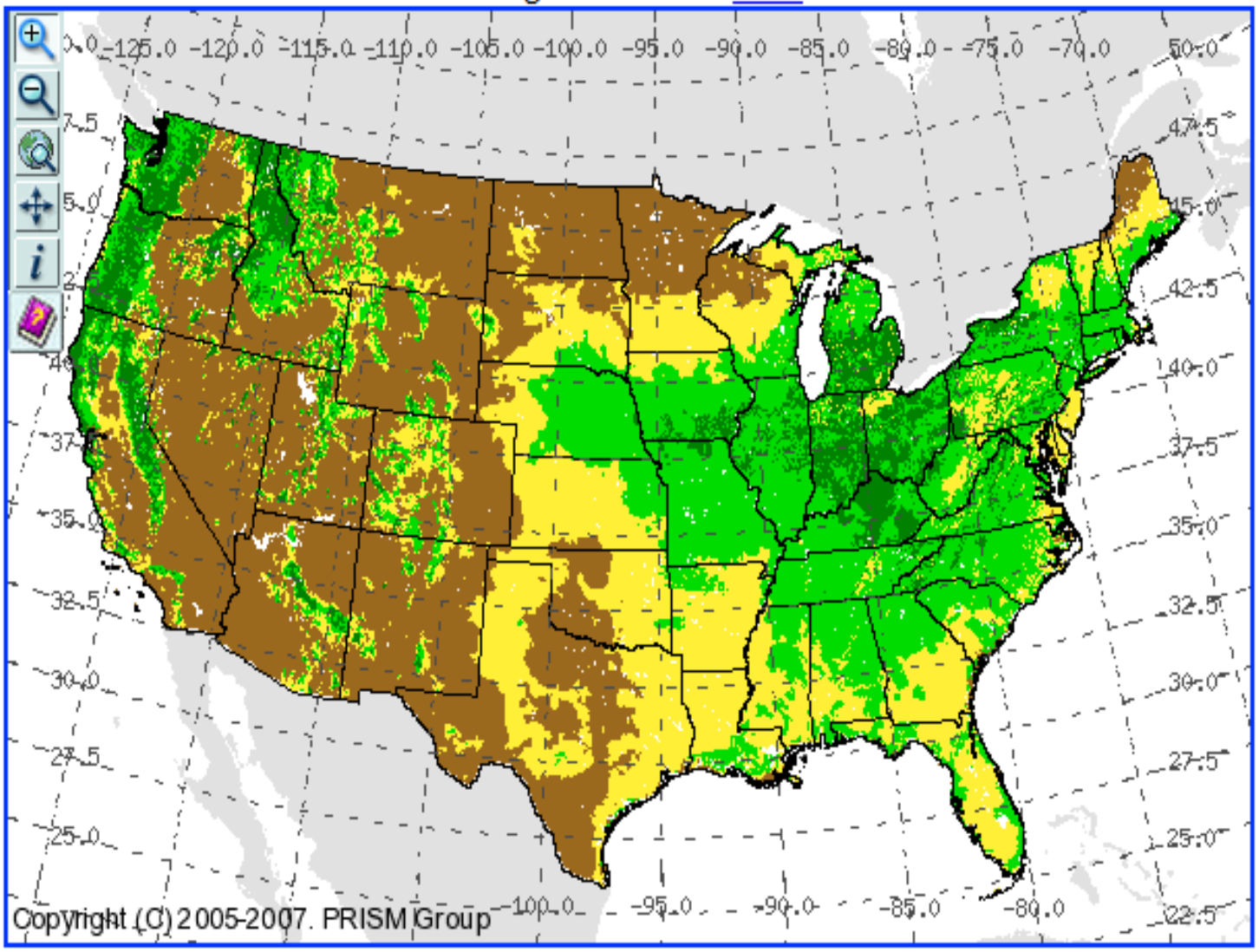
| Species | July Max. Temp (°C) | Jan Min. Temp (°C) | Annual Precipitation (mm) |
|---|---|---|---|
| **Well Suited** | | | |
| **Tall Fescue** | **22 - 32** | **≥ -10** | **≥ 625** |
| Orchardgrass | 22 - 31 | ≥ -7.5 | ≥ 625 |
| Perennial Ryegrass | 22 - 30 | ≥ -5 | ≥ 625 |
| **Moderately Suited** | | | |
| **Tall Fescue** | **20 - 34** | **≥ -15** | **≥ 450** |
| Orchardgrass | 20 - 33 | ≥ -12.5 | ≥ 490 |
| Perennial Ryegrass | 20 - 32 | ≥ -10 | ≥ 525 |
| **Marginally Suited** | | | |
| **Tall Fescue** | **18 - 36** | **≥ -20** | **≥ 300** |
| Orchardgrass | 18 – 35 | ≥ -17.5 | ≥ 375 |
| Perennial Ryegrass | 18 - 34 | ≥ -15 | ≥ 450 |

# Tall Fescue Suitability
## All Climate & Soil Constraints

Species Suitability

- Not suitable
- Marginal
- Moderate
- Well

Change location to: PRC

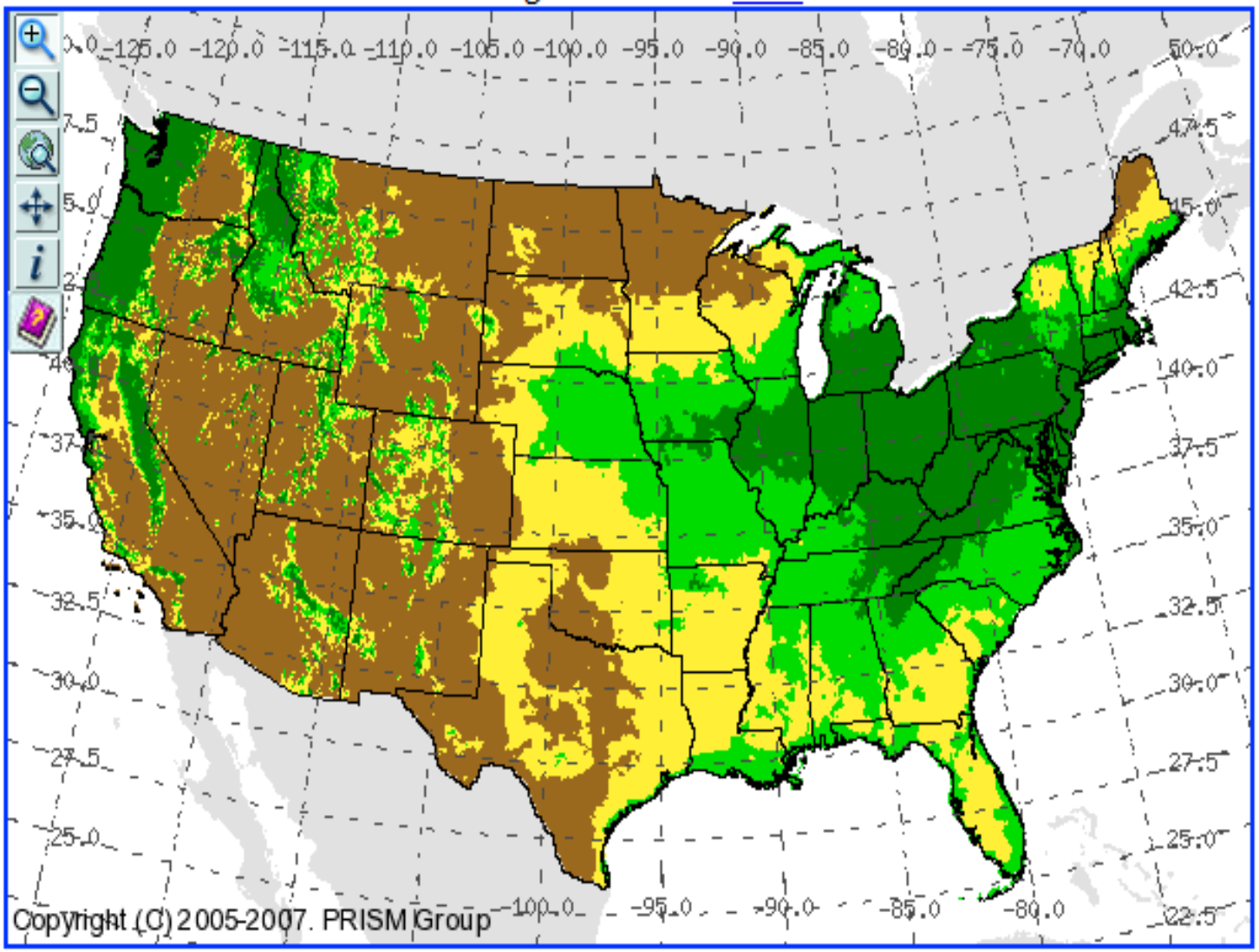


# Tall Fescue Suitability
## No Soil Constraints (Climate Only)

Species Suitability

- Not suitable
- Marginal
- Moderate
- Well

Change location to: PRC

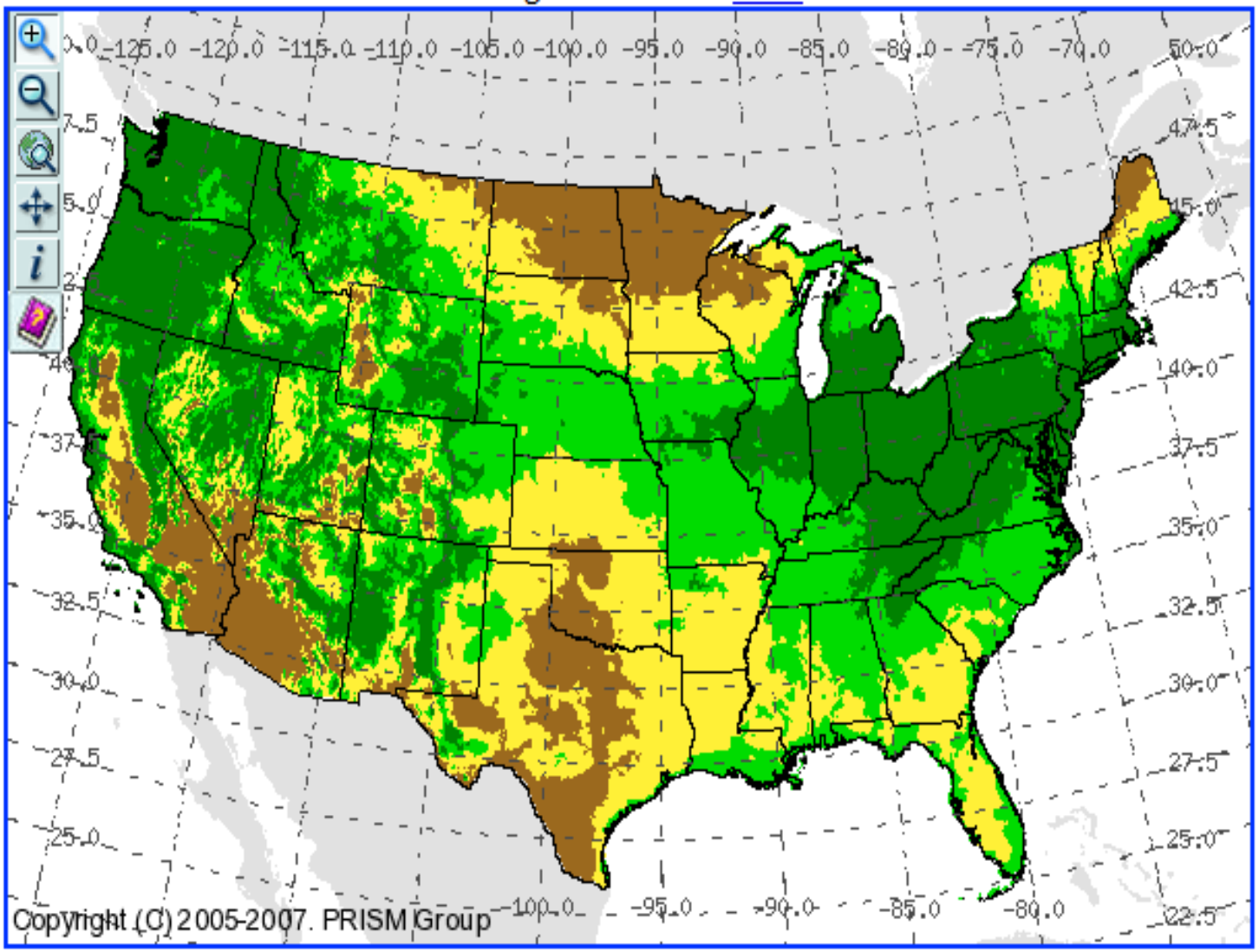


# Tall Fescue Suitability
## No Precip Constraint (Irrigated)

Species Suitability

- Not suitable
- Marginal
- Moderate
- Well

Change location to: PRC



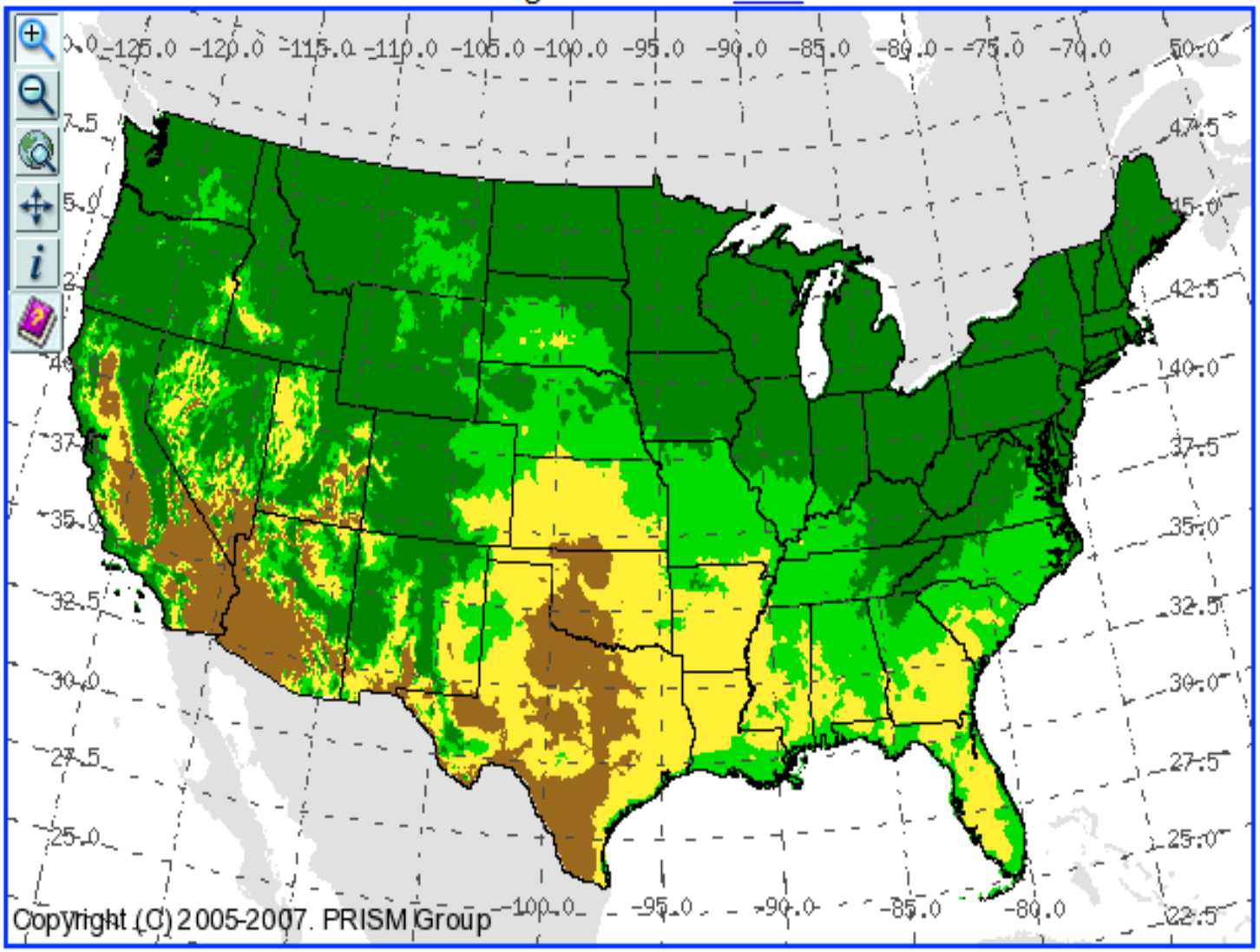
# Tall Fescue Suitability

## No Soils, Irrigated, No Overwintering (Annual)

Species Suitability

- Not suitable
- Marginal
- Moderate
- Well

Change location to: PRC

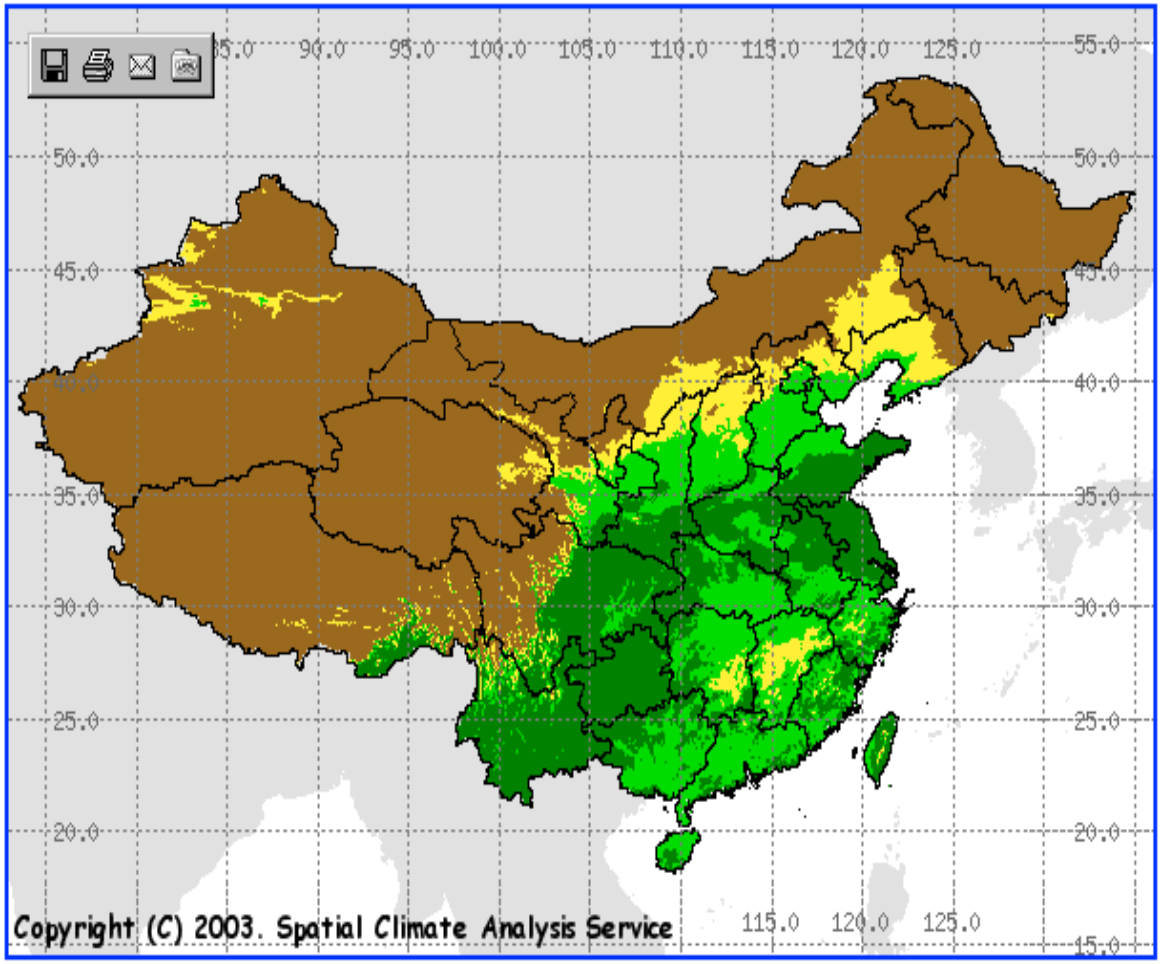


# Tall Fescue Suitability Map: China

Grass_Per._CoolSeason - Tall Fescue - climate only

Species Suitability

- Not suitable
- Marginal
- Moderate
- Well




**Transfer Tolerance Table from US to China**

0 600 1200 1800 2400 3000 km

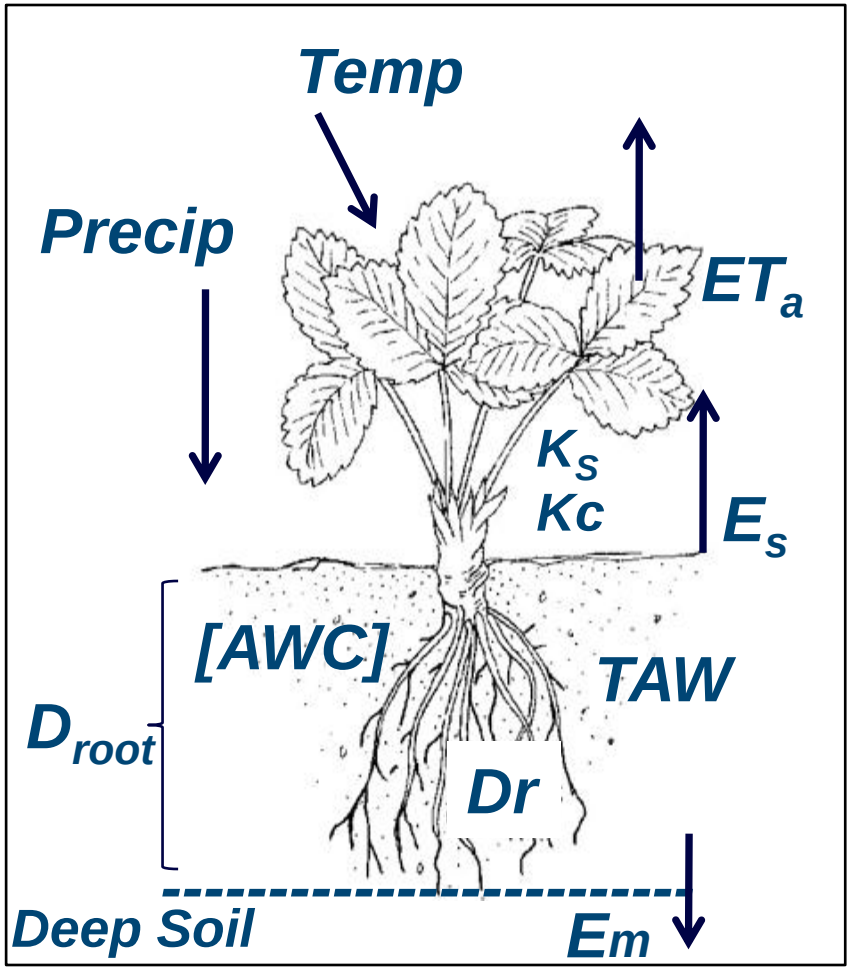
# Benefits

- Suitability maps provided an early estimate of grower success throughout the country
- Suitability maps allowed marketing efforts to target the best suited regions of China
- Grass seed exports to China increased dramatically in years following the study

# Suitability Mapping Applied to Crop Insurance

**China Model Updated and Improved**

**Semi-Monthly Water Balance Simulation**



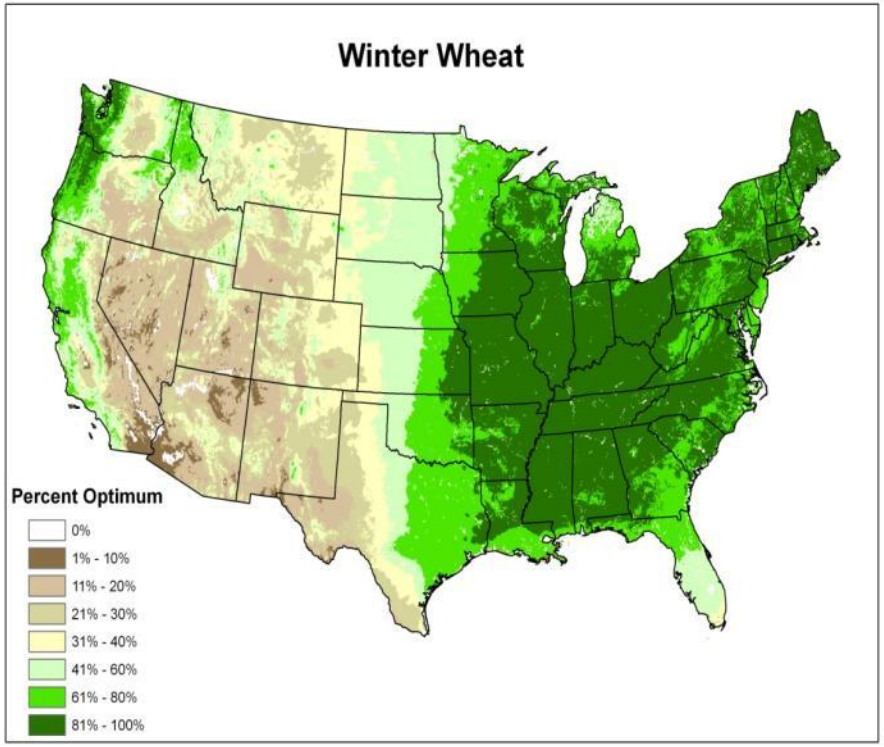
# Nationwide Crop Suitability Mapping

## Dryland Winter Wheat

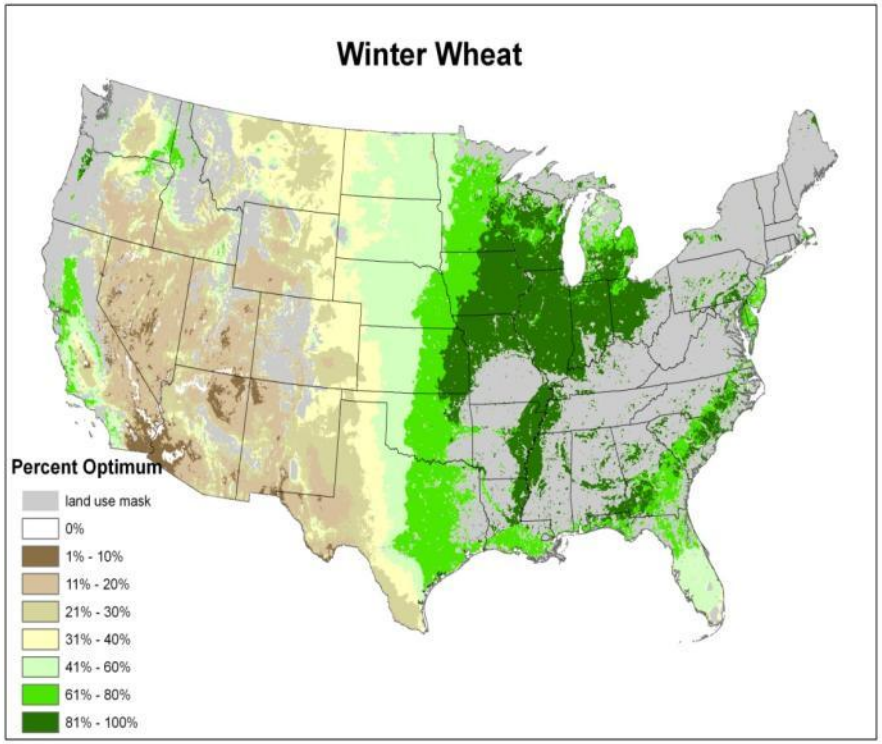
**Draft**

**Support: DOE Sun Grant, RMA**

### All Land




### Non-Forest Land




**Assumes Amended Soils - Liming (pH) and Tiling (Drainage)**

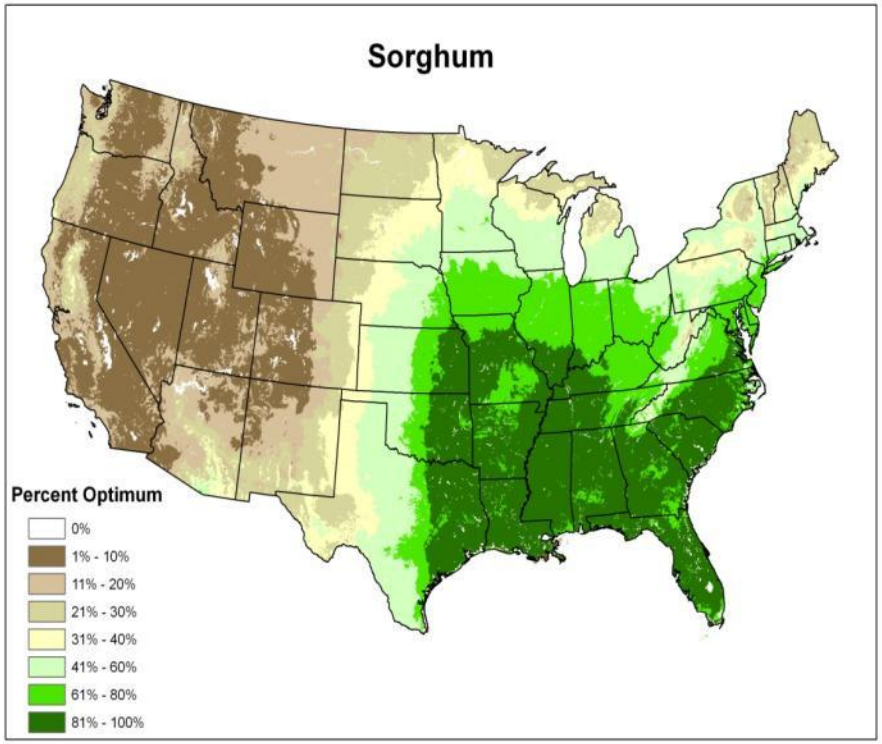
# Nationwide Crop Suitability Mapping

## Dryland Sorghum

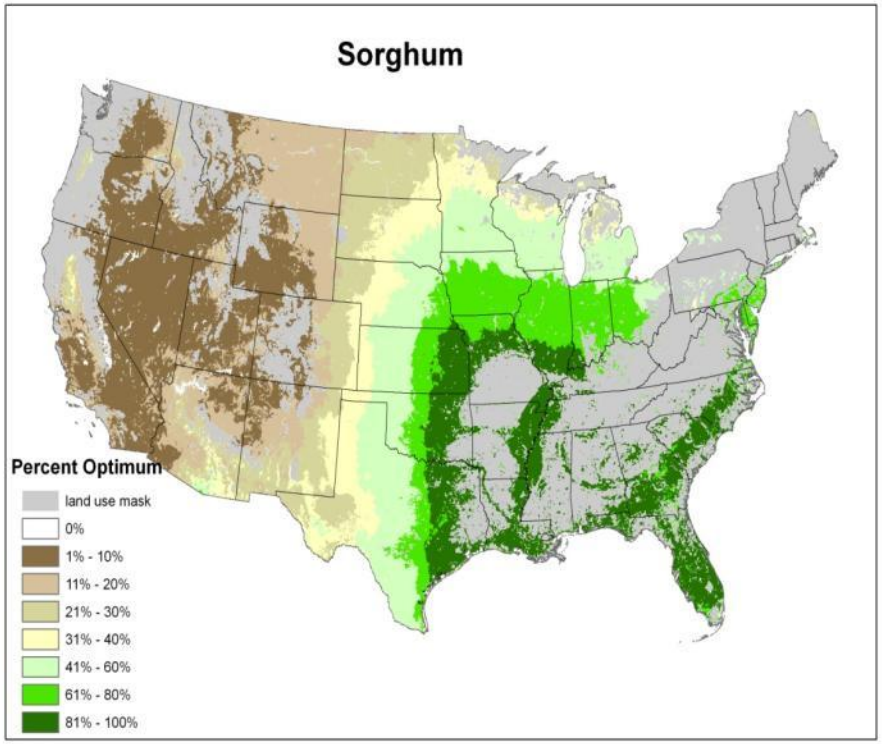
**Draft**

**Support: DOE Sun Grant, RMA**

### All Land




### Non-Forest Land




**Assumes Amended Soils - Liming (pH) and Tiling (Drainage)**

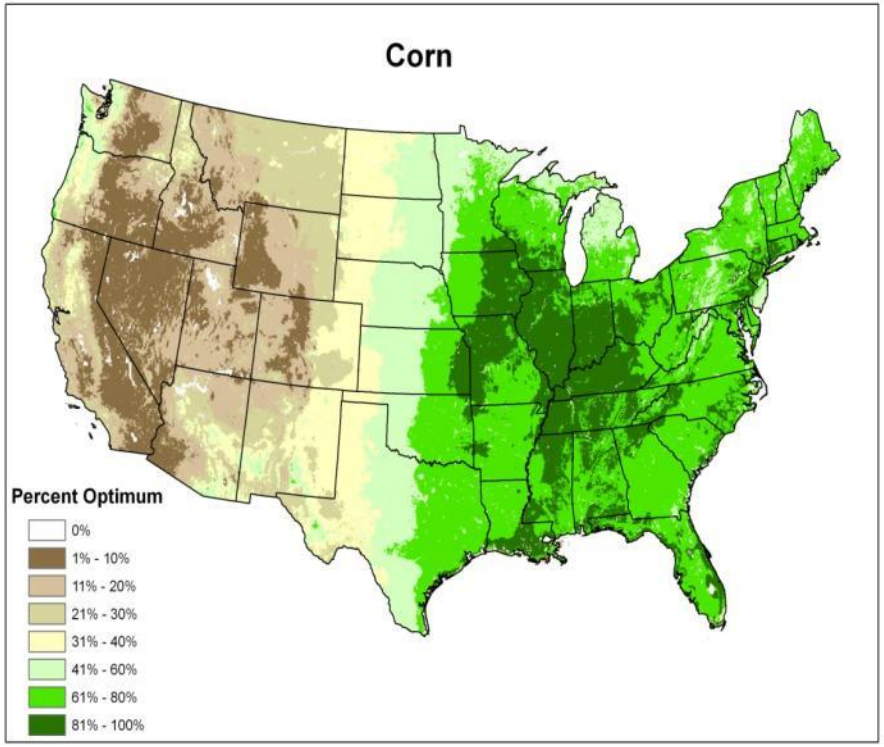
# Nationwide Crop Suitability Mapping

## Dryland Corn

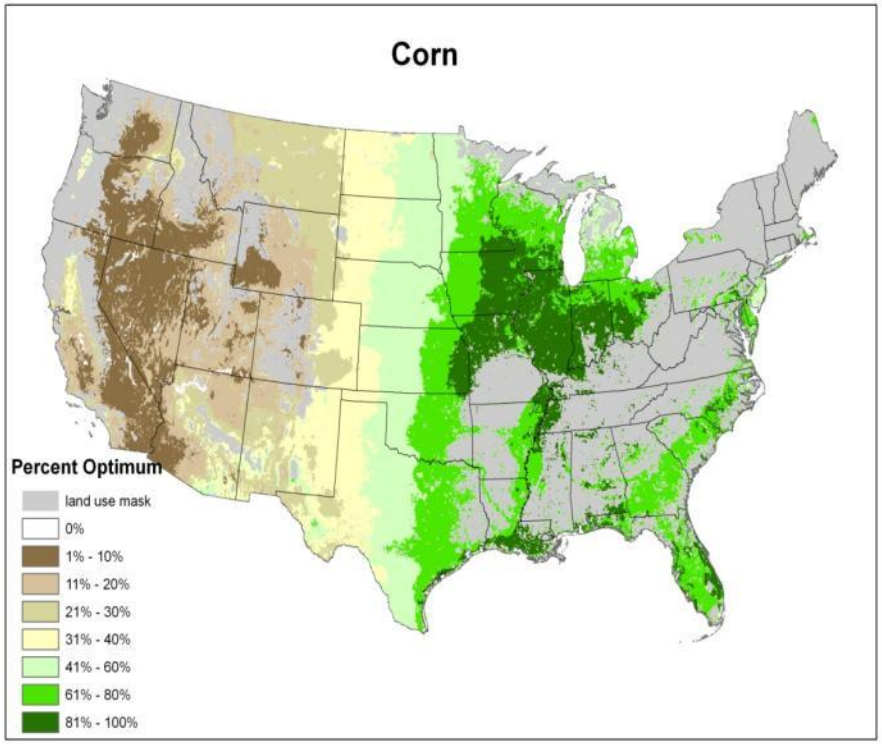
**Draft**

**Support: DOE Sun Grant, RMA**

### All Land




### Non-Forest Land




**Assumes Amended Soils - Liming (pH) and Tiling (Drainage)**

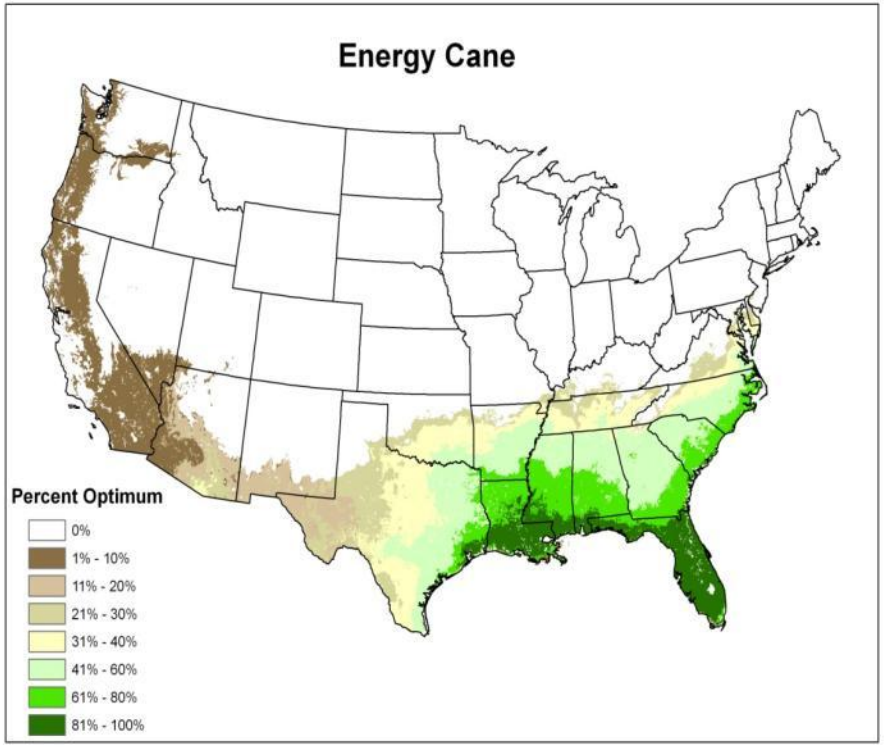
# Nationwide Crop Suitability Mapping

## Energy Cane

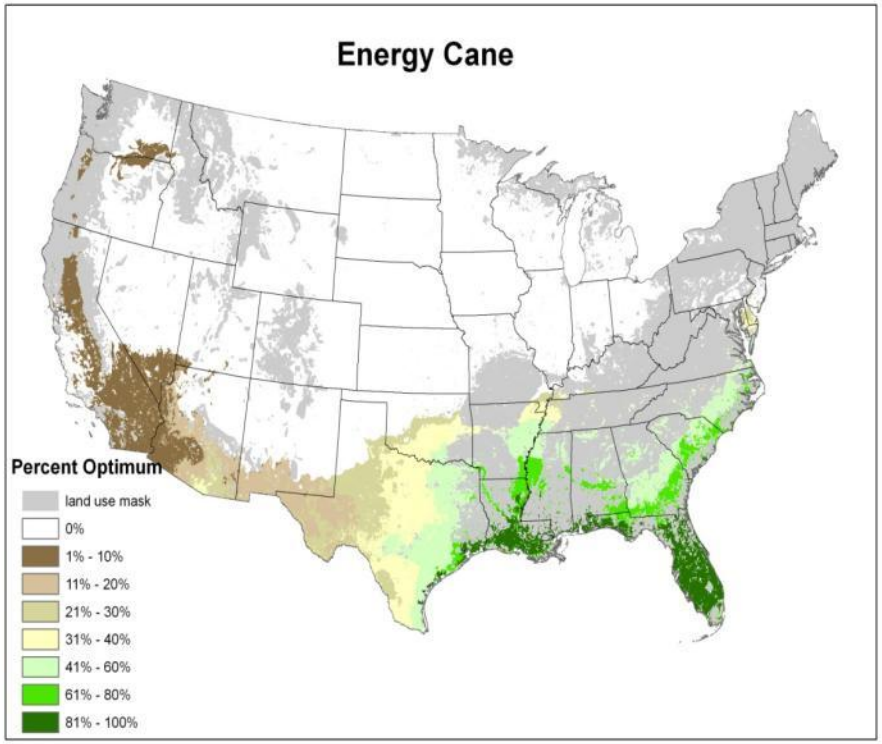
**Draft**

**Support: DOE Sun Grant, RMA**

### All Land




### Non-Forest Land




**Assumes Amended Soils - Liming (pH) and Tiling (Drainage)**

# 2012 USDA Plant Hardiness Zone Map

USDA Agricultural Research Service

United States Department of Agriculture

Mapping by PRISM Climate Group - Oregon State University

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Home | View Maps | About | Map & Data Downloads | Interactive Map | Help

**Find Your Plant Hardiness Zone**

Enter ZIP Code: Find

**View Your State Map**

For a static map of your state, click on the map below or Select a State

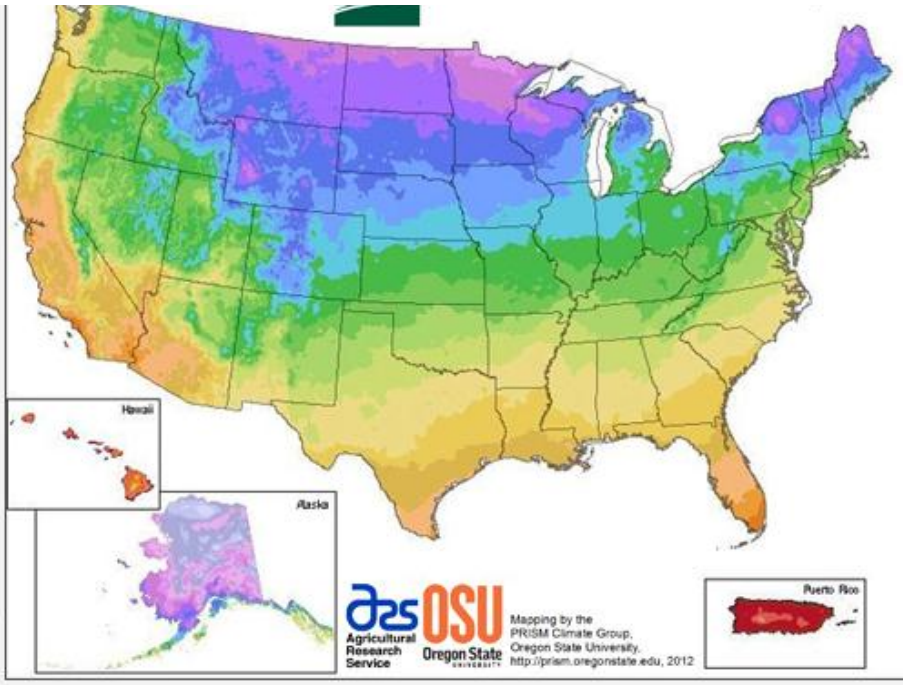
planthardiness.ars.usda.gov

**USDA Plant Hardiness**

The 2012 USDA Plant Hardiness Zone Map is the standard by which gardeners and growers can determine which plants are most likely to thrive at a location. The map is based on the average annual minimum winter temperature, divided into 10-degree F zones.

For the first time, the map is available as an interactive GIS-based map, for which a broadband Internet connection is recommended, and as static images for those with slower Internet access. Users may also simply type in a ZIP Code and find the hardiness zone for that area.

No posters of the USDA Plant Hardiness Zone Map have been printed. But state, regional, and national images of the map can be downloaded and printed in a variety of sizes and resolutions.




erage Annual Extreme
inimum Temperature
1976-2005

| Temp (F) | Zone | Temp (C) |
|---|---|---|
| -60 to -55 | 1a | -51.1 to -48.3 |
| -55 to -50 | 1b | -48.3 to -45.6 |
| -50 to -45 | 2a | -45.6 to -42.8 |
| -45 to -40 | 2b | -42.8 to -40 |
| -40 to -35 | 3a | -40 to -37.2 |
| -35 to -30 | 3b | -37.2 to -34.4 |
| -30 to -25 | 4a | -34.4 to -31.7 |
| -25 to -20 | 4b | -31.7 to -28.9 |
| -20 to -15 | 5a | -28.9 to -26.1 |
| -15 to -10 | 5b | -26.1 to -23.3 |
| -10 to -5 | 6a | -23.3 to -20.6 |
| -5 to 0 | 6b | -20.6 to -17.8 |
| 0 to 5 | 7a | -17.8 to -15 |
| 5 to 10 | 7b | -15 to -12.2 |
| 10 to 15 | 8a | -12.2 to -9.4 |
| 15 to 20 | 8b | -9.4 to -6.7 |
| 20 to 25 | 9a | -6.7 to -3.9 |
| 25 to 30 | 9b | -3.9 to -1.1 |
| 30 to 35 | 10a | -1.1 to 1.7 |
| 35 to 40 | 10b | 1.7 to 4.4 |
| 40 to 45 | 11a | 4.4 to 7.2 |
| 45 to 50 | 11b | 7.2 to 10 |
| 50 to 55 | 12a | 10 to 12.8 |
| 55 to 60 | 12b | 12.8 to 15.6 |
| 60 to 65 | 13a | 15.6 to 18.3 |
| 65 to 70 | 13b | 18.3 to 21.1 |

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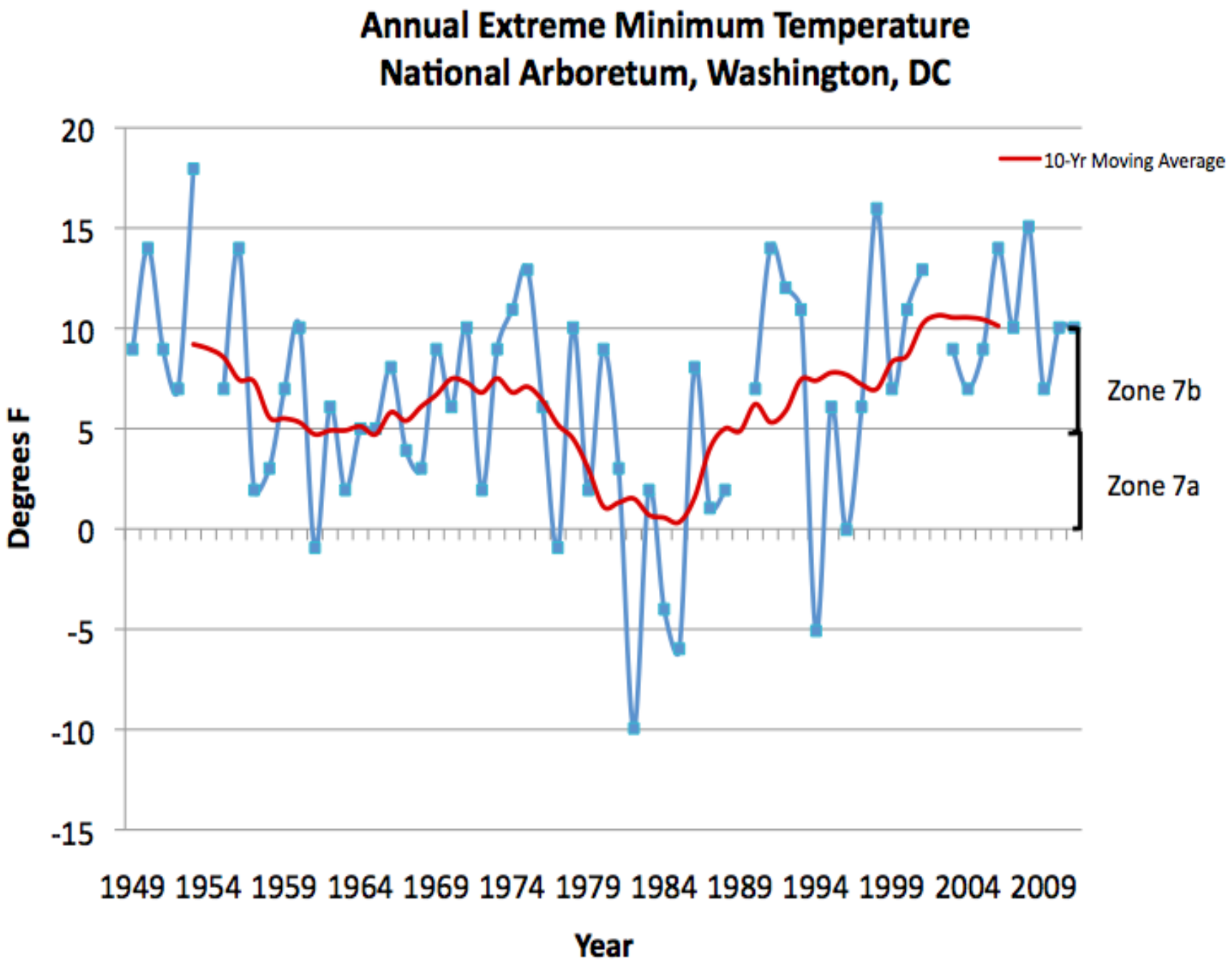
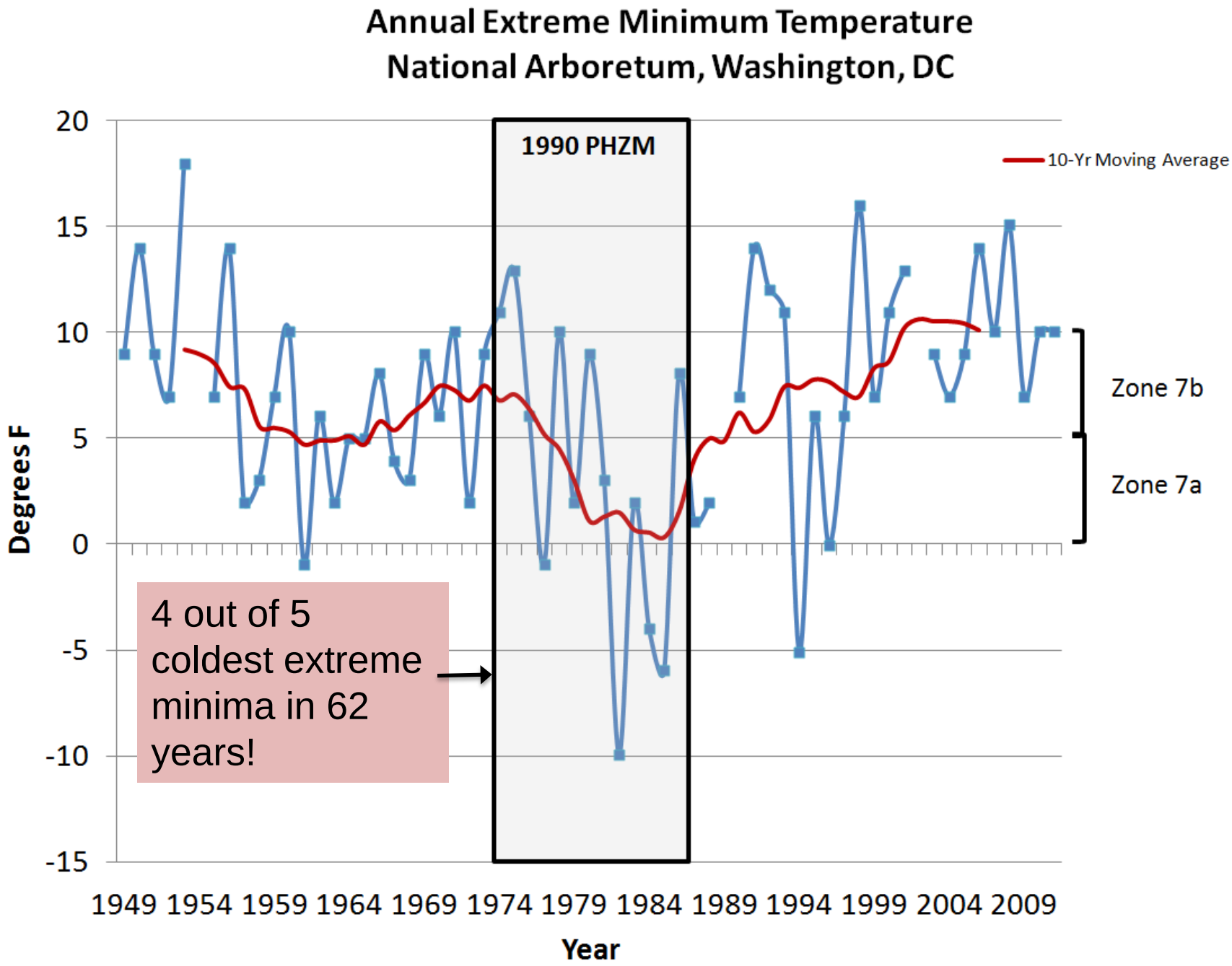
# 2012 USDA-ARS PHZM
## A 21st Century Product

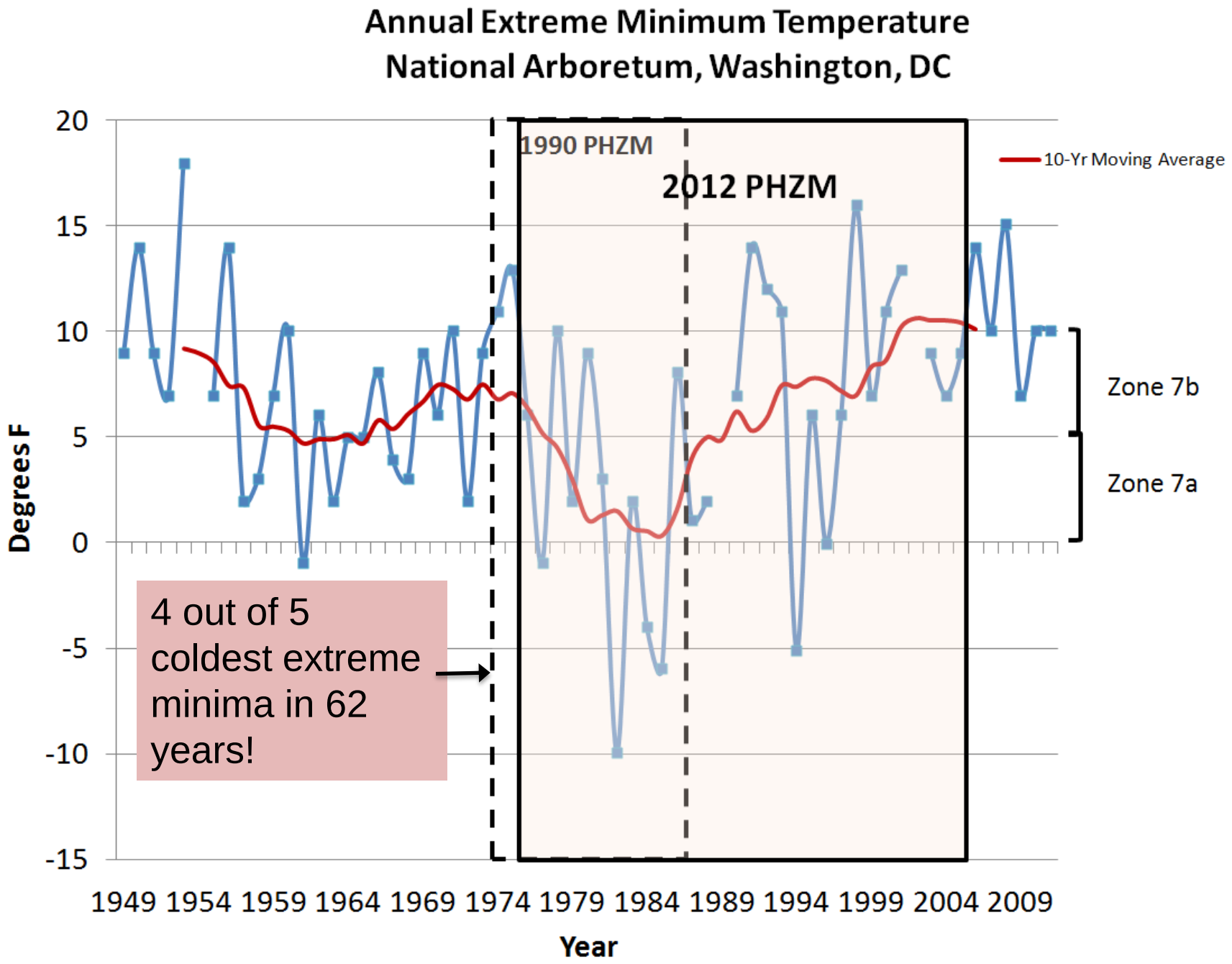
- Used PRISM - the most advanced climate mapping system
- Held to the highest scientific standards
  - Reviewed by experts nationwide
  - Documented in two peer-reviewed journal articles
- Unprecedented detail (1/2 mile pixel size)
- Produced digitally for the first time
  - Online-only product – no hard copies
  - ZIP code finder
  - Map images at various resolutions
  - Internet map server for close scrutiny
  - Map packages for graphic artists
  - Uses cloud computing to handle user load

# 1990 vs. 2012 USDA PHZM: Good Indicator of Climate Change?

- Climate change is measurable and real
- Average annual minimum temperatures have warmed over the last 100 years
- PHZM: average annual EXTREME minimum temperature, a volatile statistic
- 1990 map: 1974-1986, only 13 years
- 2012 map: 1976-2005, 30 years
- Can a comparison of a volatile statistic over such a short period say anything reliable about long-term trends?


Annual Extreme Minimum Temperature
National Arboretum, Washington, DC
10-Yr Moving Average
Zone 7b
Zone 7a
Degrees F
20
15
10
5
0
-5
-10
-15
1949 1954 1959 1964 1969 1974 1979 1984 1989 1994 1999 2004 2009
Year


Annual Extreme Minimum Temperature
National Arboretum, Washington, DC
1990 PHZM
10-Yr Moving Average
Zone 7b
Zone 7a
4 out of 5 coldest extreme minima in 62 years!
Degrees F
20
15
10
5
0
-5
-10
-15
1949 1954 1959 1964 1969 1974 1979 1984 1989 1994 1999 2004 2009
Year


Annual Extreme Minimum Temperature
National Arboretum, Washington, DC
1990 PHZM
2012 PHZM
10-Yr Moving Average
Zone 7b
Zone 7a
4 out of 5 coldest extreme minima in 62 years!
Degrees F
20
15
10
5
0
-5
-10
-15
1949 1954 1959 1964 1969 1974 1979 1984 1989 1994 1999 2004 2009
Year

# Need for Regular Updates to PHZM

- Users look to the USDA for guidance
  - But gardeners practice “zone denial” if map is poor or out of date
- Keeping up with the Curve
  - Last map was released 22 years ago
  - Climate is varying rapidly
- Ongoing update process
  - More cost effective than starting from scratch
  - Digital technology makes rapid updates possible
  - **Suggest 5-year “supplement” and 10-year full update**

# Summary

- The Importance of Climate in Crop Insurance
  - Provides a long-term context for assessing what is “unusual”
  - Historical context moves forward with time to capture climate changes as they occur
- Climate Mapping with PRISM
  - PRISM provides high-quality maps of both weather and climate
- PRISM RMA Weather and Climate Portal
  - Provides users with tools to quickly and easily access what they need
- How growers and others can contribute to our maps
  - Become a CoCoRAHS observer (cocorahs.org)

# Summary (concl.)

- Crop Suitability Mapping
  - Provides a reality check on whether a crop can be grown in a given location with acceptable risk
  - Can be used for both established crops and new crops, such as biofuel feedstocks (Sun Grant, RMA)
- The 2012 USDA Plant Hardiness Zone Map
  - Completely digital, best science
  - 1990-2012 comparison presents more questions than answers
  - Further study on long term trends and variations needed
  - Should be updated regularly (my opinion)