Comparison of Vegetation Cover vs. Precipitation on a Reclaimed Coal Mine in Northeastern Wyoming

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Purpose

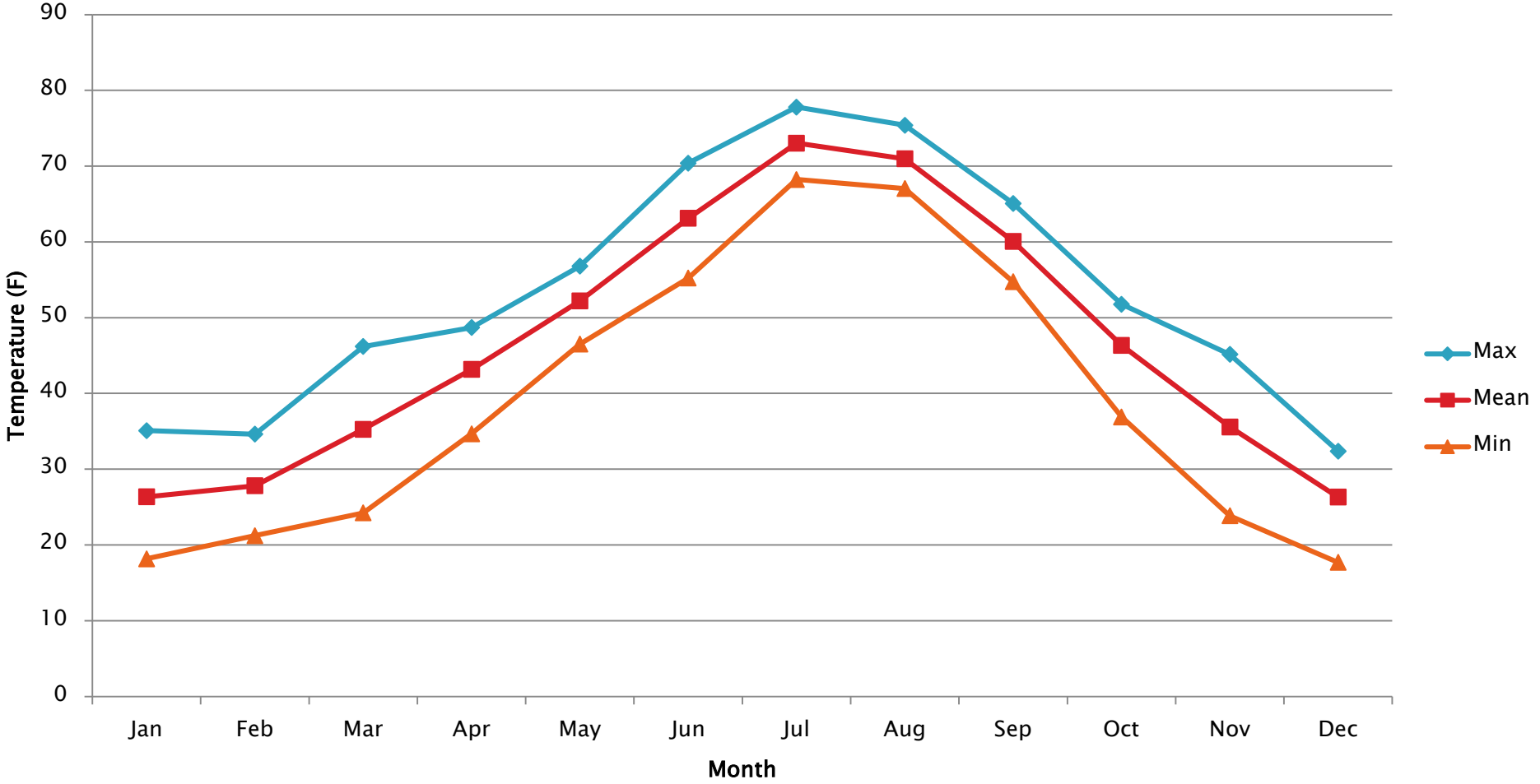
- Vegetation cover on reclaimed areas varies due to multiple factors
  - Do meteorological factors have a statistically significant impact on total vegetation or lifeform cover over the 18 year time frame?
  - If so, which lifeform is most influenced?
  - If not, are there any trends that may not be apparent at this time?
  - What main factors may be missing in the analysis?

Northeastern Wyoming Climate

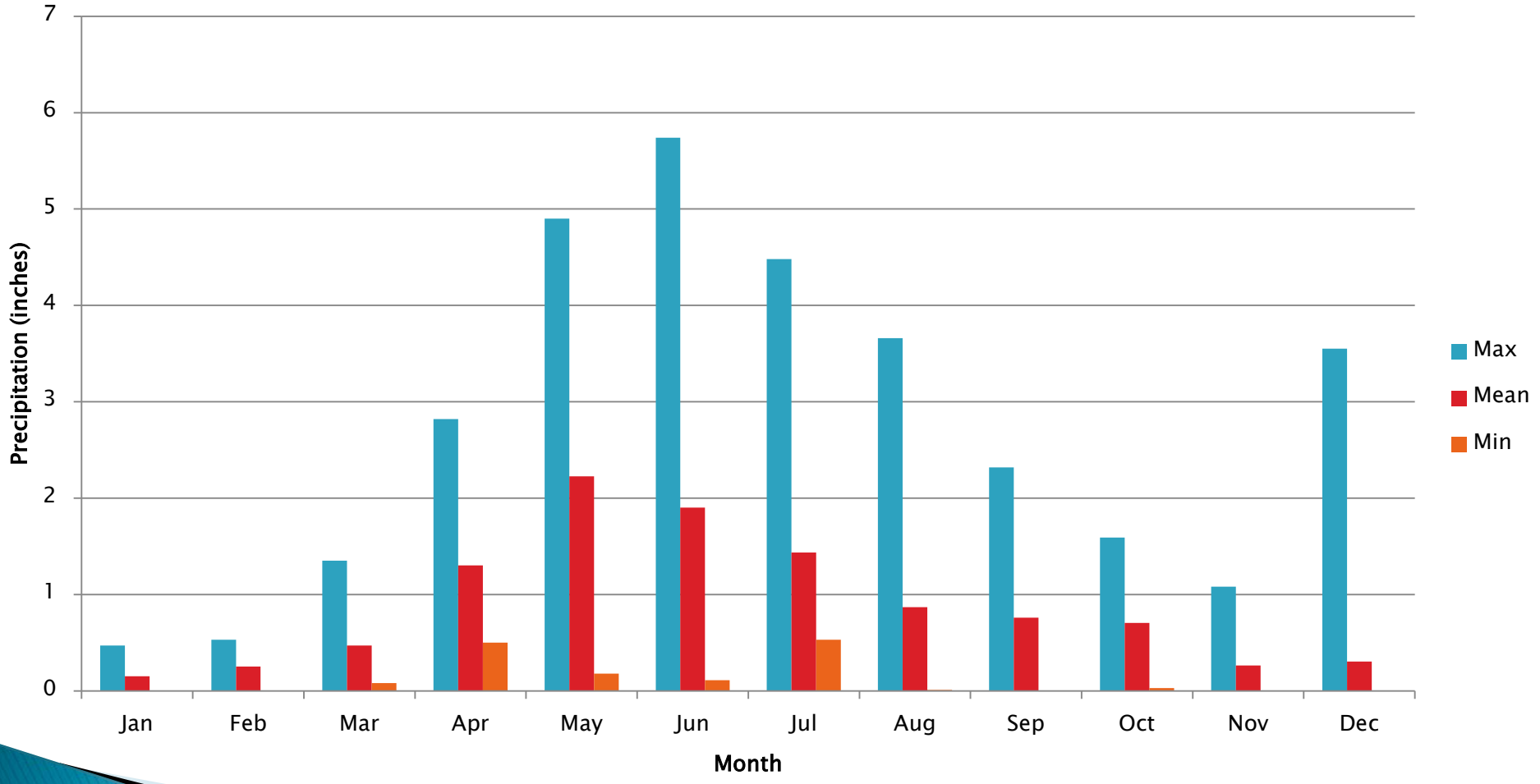
- Semi-arid, continental climate
  - Cold winter
  - Warm/hot summer
  - Majority of precipitation Apr-July
  - Variable summer thunderstorms
- Transition between prairie and sagebrush steppe
- Avg. min. precip.: 12.5”
- Avg. max. precip: 15.3”
- Avg. temp.: 47°F
- Avg. max. temp.: 59°F
  - Record high: 111°F
- Avg. min. temp.: 34
  - Record low: -49°F

NOAA Dull Center Station (482725), 1918-2004

Study Area – Temperature 1995–2012

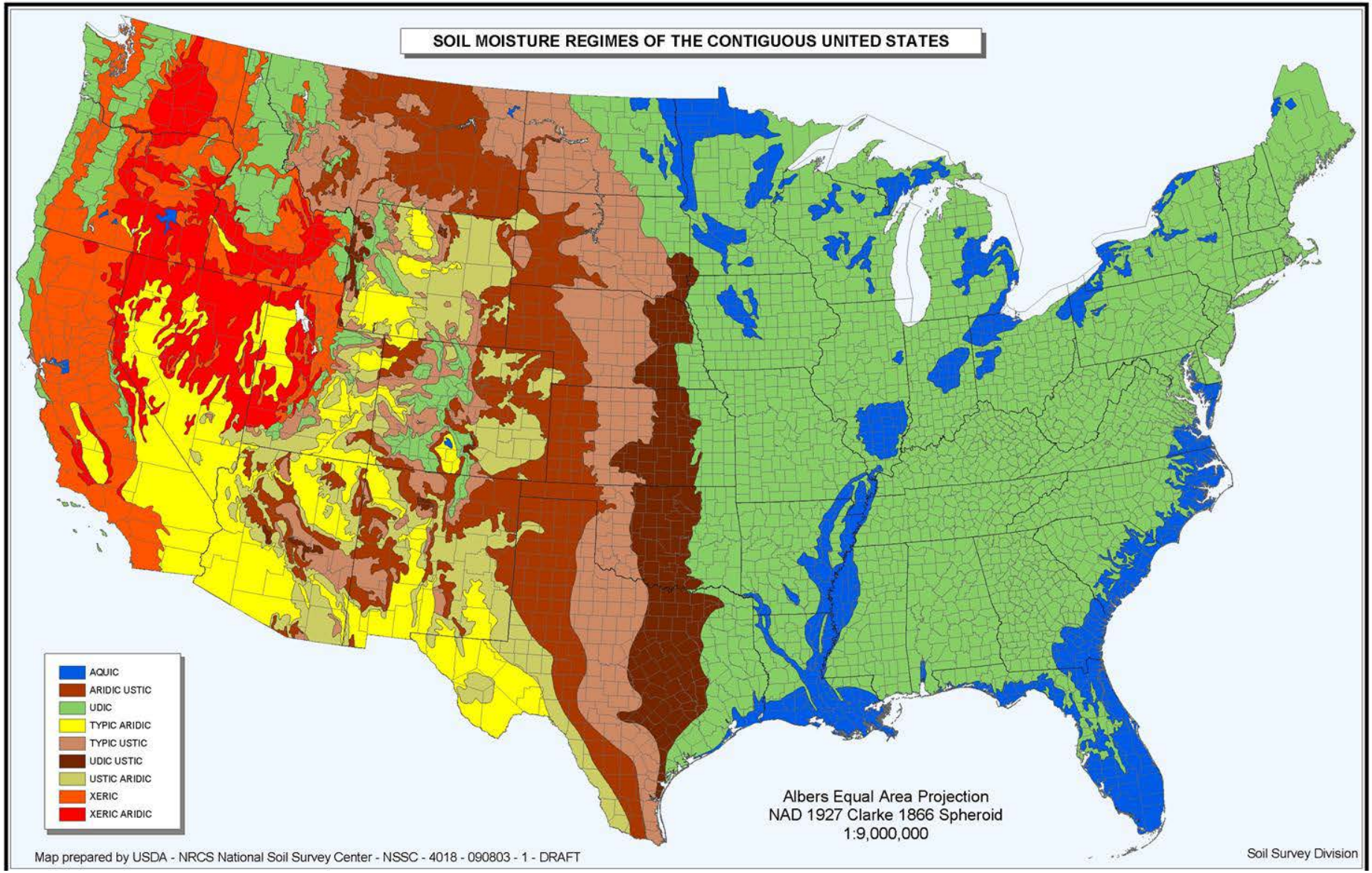


Study Area – Precipitation 1995–2012



Climatic Challenges for Reclamation in Northeastern Wyoming

- Unreliable, Variable Precipitation
- Unreliable, Variable Temperature Extremes
- Relatively Short Growing Season
- Wind Desiccation


SOIL MOISTURE REGIMES OF THE CONTIGUOUS UNITED STATES
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Albers Equal Area Projection
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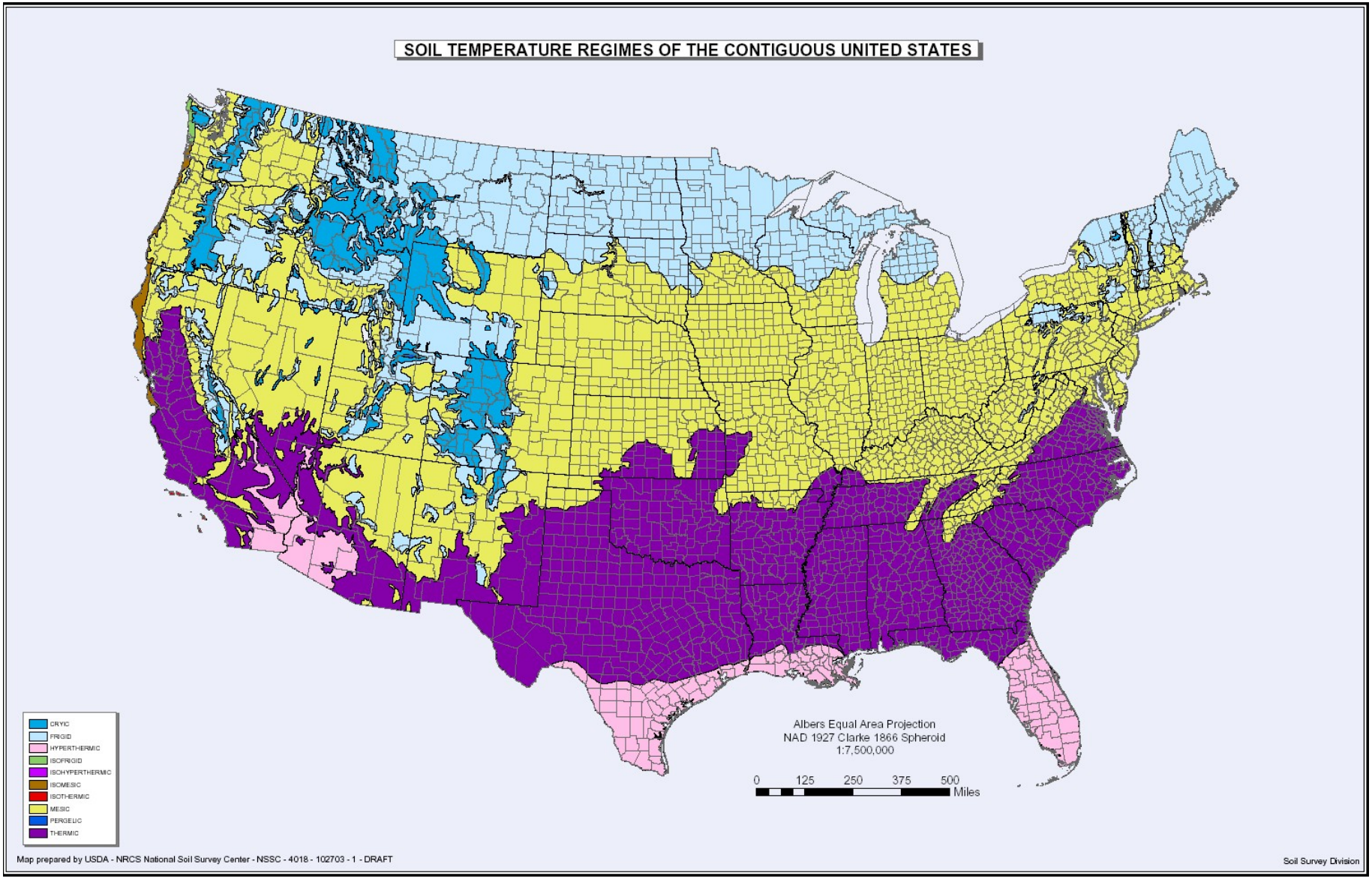
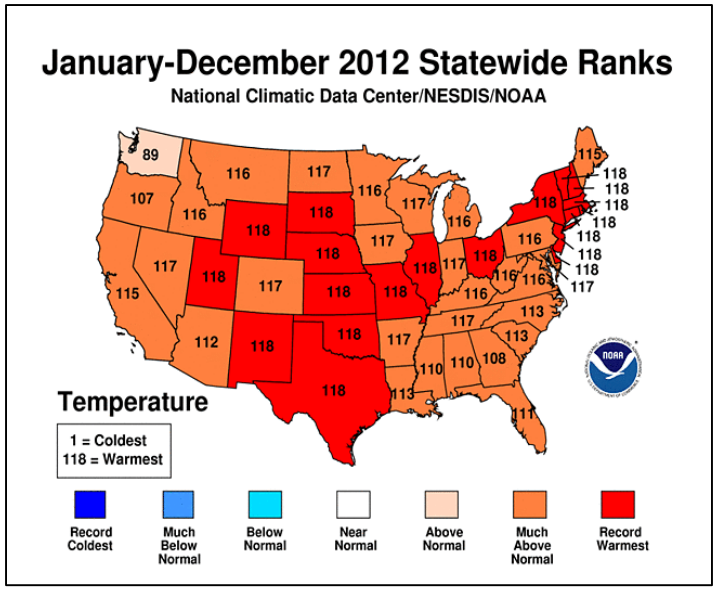
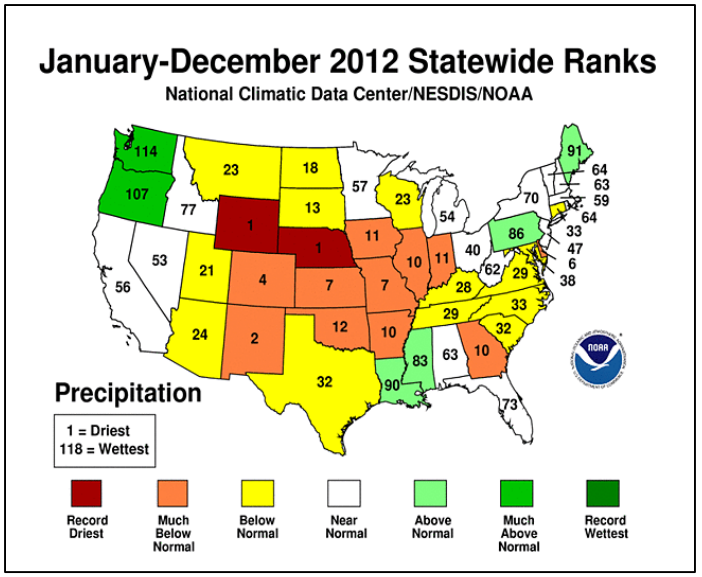
Map prepared by USDA - NRCS National Soil Survey Center - NSSC - 4018 - 090803 - 1 - DRAFT
Soil Survey Division


SOIL TEMPERATURE REGIMES OF THE CONTIGUOUS UNITED STATES
CRYIC
FRIGID
HYPERTHERMIC
ISOFRIGID
ISOHYPERTHERMIC
ISOMESIC
ISOTHERMIC
MESIC
PERGELIC
THERMIC
Albers Equal Area Projection
NAD 1927 Clarke 1866 Spheroid
1:7,500,000
0 125 250 375 500
Miles
Map prepared by USDA - NRCS National Soil Survey Center - NSSC - 4018 - 102703 - 1 - DRAFT
Soil Survey Division

2012 Drought

- Wyoming
  - Warmest year on record
  - Driest year on record





The U.S. Drought Monitor is produced in partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

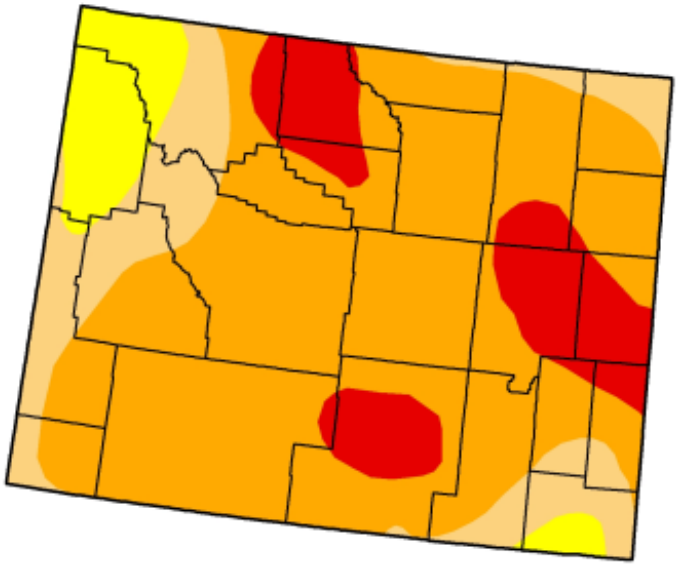
U.S. Drought Monitor

May 28, 2013
Valid 7 a.m. EST

Wyoming

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	92.55	77.14	13.87	0.00
Last Week (05/21/2013 map)	0.00	100.00	92.55	77.14	13.87	0.00
3 Months Ago (02/26/2013 map)	0.00	100.00	93.56	83.64	56.71	10.10
Start of Calendar Year (01/01/2013 map)	0.00	100.00	96.15	86.03	64.23	10.51
Start of Water Year (09/25/2012 map)	0.00	100.00	98.01	87.30	58.34	2.72
One Year Ago (05/22/2012 map)	21.81	78.19	33.83	0.70	0.00	0.00



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu

USDA National Drought Mitigation Center

Released Thursday, May 30, 2013
Brad Rippey, U.S. Department of Agriculture

The U.S. Drought Monitor is produced in partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

Specific Revegetation Challenges

- Warm season grass establishment
- Perennial forb establishment
- Shrub establishment
- Cool season grass establishment…usually not a problem as long as soil chemistry isn't an issue
- Competition with invasive species
- Reduction of cheatgrass impacts

Short-term Impacts of Drought on Reclamation Efforts

- Seeding failure
- Grazing
- Productivity
- Cover
- Succession
- Invasive spp.

Reclamation Efforts in NE WY

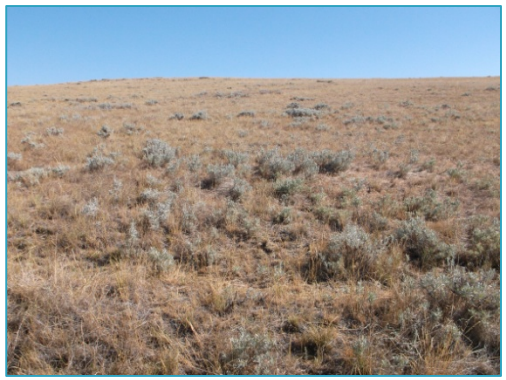
- Topsoil salvage
- Seeding in the fall is most conducive to establishment
  - Late winter/early spring most historically, reliable precipitation
  - Late fall moisture of the previous year is important too
- **Open winters make ground susceptible to wind erosion**
  - Bare ground without some form of snow catchment reduces moisture availability the following spring
- Minimize Impacts
  - Drought
  - Extreme precipitation events
  - Grazing practices

Seed Mixes

- Developed for each approved post mining land use
  - Grazing
  - Agricultural
  - Wildlife habitat
- Mix of perennial native cool and warm season perennial grass, forbs, and shrubs
- Introduced species are only allowed if
  - Additional herbaceous species are needed
  - Suitable native species are unavailable
  - Cropland/Pastureland
  - Quick, temporary stabilization

Seed Mixes

	Grassland	Sagebrush Grassland	Big Sagebrush Shrubland
Cool season perennial grass	59%	42%	12%
Warm season perennial grass	14%	9%	9%
Forbs	21%	14%	11%
Shrubs	6%	34%	68%



WDEQ-LQD Requirements

- Permanent reclaimed areas must be monitored before and after grazing at intervals throughout the 10 year bond responsibility period
  - Cannot graze for first two years of bond period
- Sample for two consecutive years for bond release

Interim Reclamation Monitoring

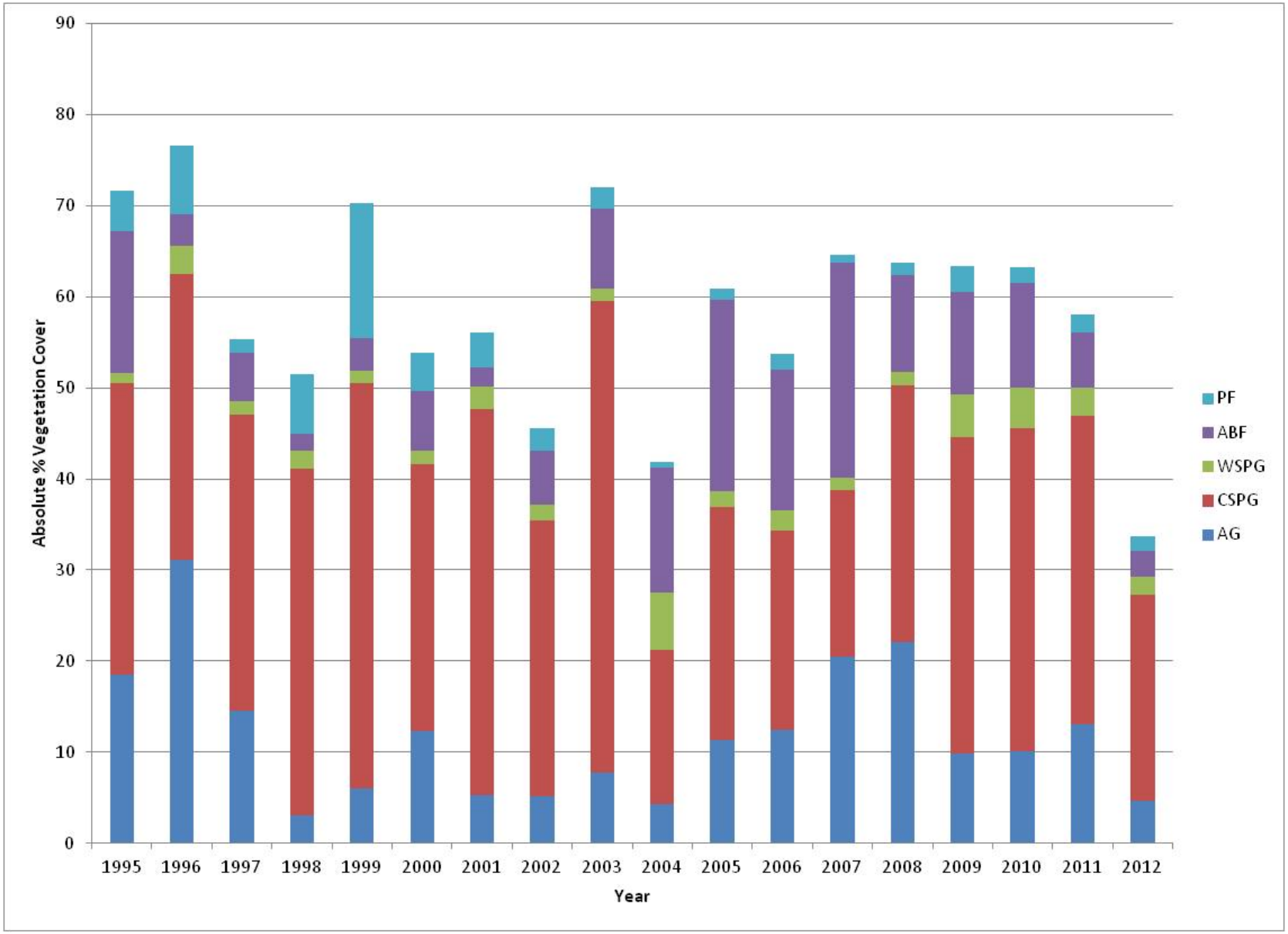
- Characterize and describe vegetation data
- Explain deviations from permit commitments
- Comparisons
  - Reclaimed vs. reclaimed
  - Reclaimed vs. reference areas
- Trends
- Problems areas
- Bond release

General Monitoring Data

- Vegetation cover
  - Species
  - Lifeforms
  - Total
- Production
- Shrub density
- Species diversity

Evaluation –Vegetation

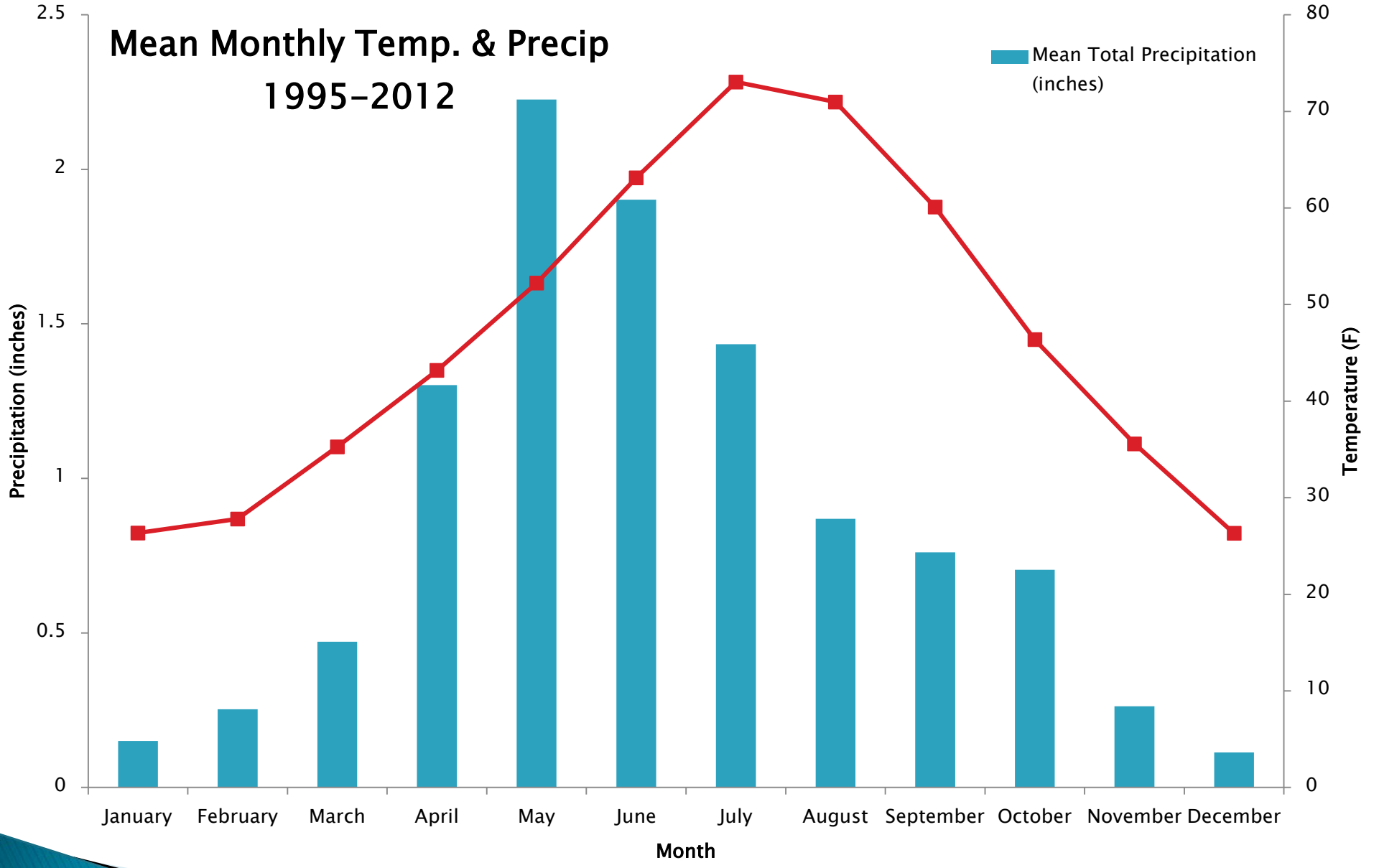
- Vegetation data
  - 303 reclaimed areas
  - Seeded from 1985-2008
  - Seeded with nine seed mixes
  - Sampled from 1995-2012
  - 5-74 reclaimed areas sampled/year
- Vegetation lifeform cover
  - Annual forb (AF)
  - Cool season perennial grass (CSPG)
  - Warm season perennial grass (WSPG)
  - Annual/Biennial forb (ABF)
  - Perennial forb (PF)


90
80
70
60
50
40
30
20
10
0
Absolute % Vegetation Cover
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year
PF
ABF
WSPG
CSPG
AG

Evaluation – Meteorological Data

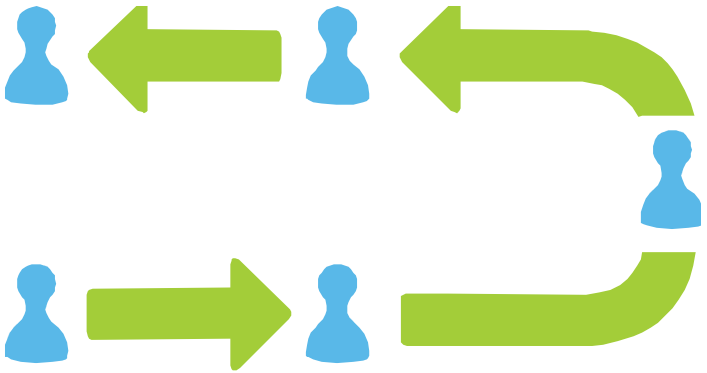
- Meteorological data
  - Collected from one met. station within the study area
  - 1995-2012
- Meteorological variables
  - Minimum monthly temperature
  - Maximum monthly temperature
  - Mean monthly temperature*
  - Total monthly precipitation*

* Variables analyzed


Mean Monthly Temp. & Precip
1995-2012
Mean Total Precipitation (inches)
Precipitation (inches)
Temperature (F)
2.5
2
1.5
1
0.5
0
80
70
60
50
40
30
20
10
0
January
February
March
April
May
June
July
August
September
October
November
December
Month

Statistical Analysis

- Factor Analysis
- Principal Component Analysis
- Multiple Regression
- Used all three to glean any significant relationships in dataset



General Methodology Considerations

- Initial Temp/Precip and combinations had 48 variables
- Conducted Factor Analysis to reduce high correlation among initial variables
- Transformation of these initial variables to produce 4 more meaningful factors used in further analysis in PCA, especially temperature
- These same 4 factors were then used to conduct regression analysis with various plant factors AGx, CSPGx, WSPGx, PFx, and TVx

Descriptive Statistics

Variable	Mean	SD	Communality
AG	12.4	5.7	0.88
CSPG	30.4	12.1	0.93
WSPG	2.2	2.1	0.84
ABF	9.4	6.6	0.89
PF	5.2	6.2	0.83
TV	52.4	11.1	0.85
Tempx	47.4	29.8	0.57
TotPrecp	1.3	1.4	0.89

- All cover categories in percentage
- The highest variation (SD) was within CSPG

Results of Statistical* Evaluation

- Total Vegetation Cover is correlated to:
  - AG cover (0.422)
  - CSPG cover (0.724)
- Correlation between PF and WSPG (0.496)
- Mean temp. is negatively correlated with
  - PF cover (-0.383)
  - TV cover (-0.445)
- Total precip. is negatively correlated with
  - PF cover (-0.399)
  - TV cover (-0.220)
- Negative relationship between CSPG and ABF with AG and total precip. (-0.239 and -0.257, respectively)

***Statistical significance at p=0.05**

Additional Thoughts

- Total ground cover (TV,L,R,BG) is best explained by MintFeb. Why? It looks like there might be some sort of temperature cue for the perennials, especially CSPG.
- ABF appear to be more influenced by later temperature cues (MintMarch). These are insect pollinated and do not invest in germination/growth until they can store resources closer to pollination time.
- WSPG being most affected by MintJune due to warm season grasses being affected by the warmer season temperatures.

Statistical Issues with Data

- Data sets (plant and environmental factors) for comparison did not have same number of sample numbers useful for multivariate analysis
- Some zeros in vegetation data, as well as precipitation
- Temp data highly correlated within months and thus, over months; e.g., Min, Max, and Avg temps/ day are highly correlated.
- Precip data are not correlated within/months, but are autocorrelated over successive months/yr.

Conclusions

- Lifeform cover does have some linear correlation with precipitation
- Meteorological factors have a statistically significant impact on TV and lifeform cover, but judged subjectively
- A more efficient field sampling design would likely reveal some lifeforms are closely related to both mean temp. and total precip.

Recommendations

- A more standardized sampling approach is required to better understand the linear relationships
- Additional variables to include in future analysis
  - Age of the reclaimed area
  - Timing of large precipitation events including the previous fall
  - Edaphic characteristics of the site (topography)
  - Collect soil data
    - Chemical
    - Physical
    - Soil moisture
  - Collect paired metrological and vegetation data
    - Analyze production data

Acknowledgement

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Questions

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