2015 ESS/SAES/ARD Meeting and Workshop Ballantyne Hotel, Charlotte, NC

September 28 - Oct 1,2015 Schedule

Monday, September 28, 2015	
Registration	2:00 PM-7:00PM
Regional Meetings	3:00 PM - 6:00 PM
Reception	6:30 PM - 8:30 PM
Tuesday, September 29, 2015	
Breakfast	6:30 AM - 7:45 AM
Welcome to North Carolina - Shirley Hymon-Parker, Interim Dean, School of Agriculture and Environmental Sciences, NC A&T State Univ	8:00 AM - 8:15 AM
Workshop Session 1 - Public-Private Partnerships • NC Research campus in Kannapolis - Leonard Williams, NC A&T State Univ	8:15 AM- 10:00 AM
Break and Boarding of Buses	10:00 AM- 10:30 AM
Travel to Kannapolis, NC	10:30 AM - 11:30 AM
Lunch and presentation from Dole Executives on NC public-private partnerships at the Kannapolis Research Campus	11:45 AM - 1:15 PM
Tour of Kannapolis research projects	1:15 PM- 3:15PM
Return to Charlotte	3:30 PM- 4:30 PM
Dinner on your own	
Wednesday, September 30	
Breakfast	6:30 AM - 7:45 AM
Workshop Session 2: Water Security: Quality, Quantity, and Policy • Irrigation efficiency and conservation, Dan Devlin, Kansas State University • **Drought Tolerant Germplasm** - John Cushman, University of Nevada Reno • **Drought in the West** - Doug Parker, Director California Water Resources Research Institute, University of California • **Climate and water** - Lois Morton, Iowa State University • Water Policy - Reagan Waskom, Director Colorado Water Institute, Colorado State University • Synthesis and Key Messages; Call to Action - Mike Harrington, WAAESD	8:00 AM - 10:00 AM
Break	10:00 AM - 10:30 AM
ESS Business Meeting	10:30 AM- Noon
Lunch	Noon - 1:30 PM

ESS Business Meeting	1:30 - 3:00 PM
Break	3:00PM- 3:30 PM
Workshop session 3: Future of Plant Breeding • **USDA Perspective** - Ann Marie Thro, NPL Plant Breeding and Genetic Resources, USDA/NIFA • Links to the USDA Roadmap for Plant Breeding and Plant Breeding Listening Session notes can be found at http://www.usda.gov/wps/portal/usda/usdahome?navid=OCS • **University Perspective** - David Francis, NAPB President and Professor, Horticulture & Crop Science, The Ohio State University	

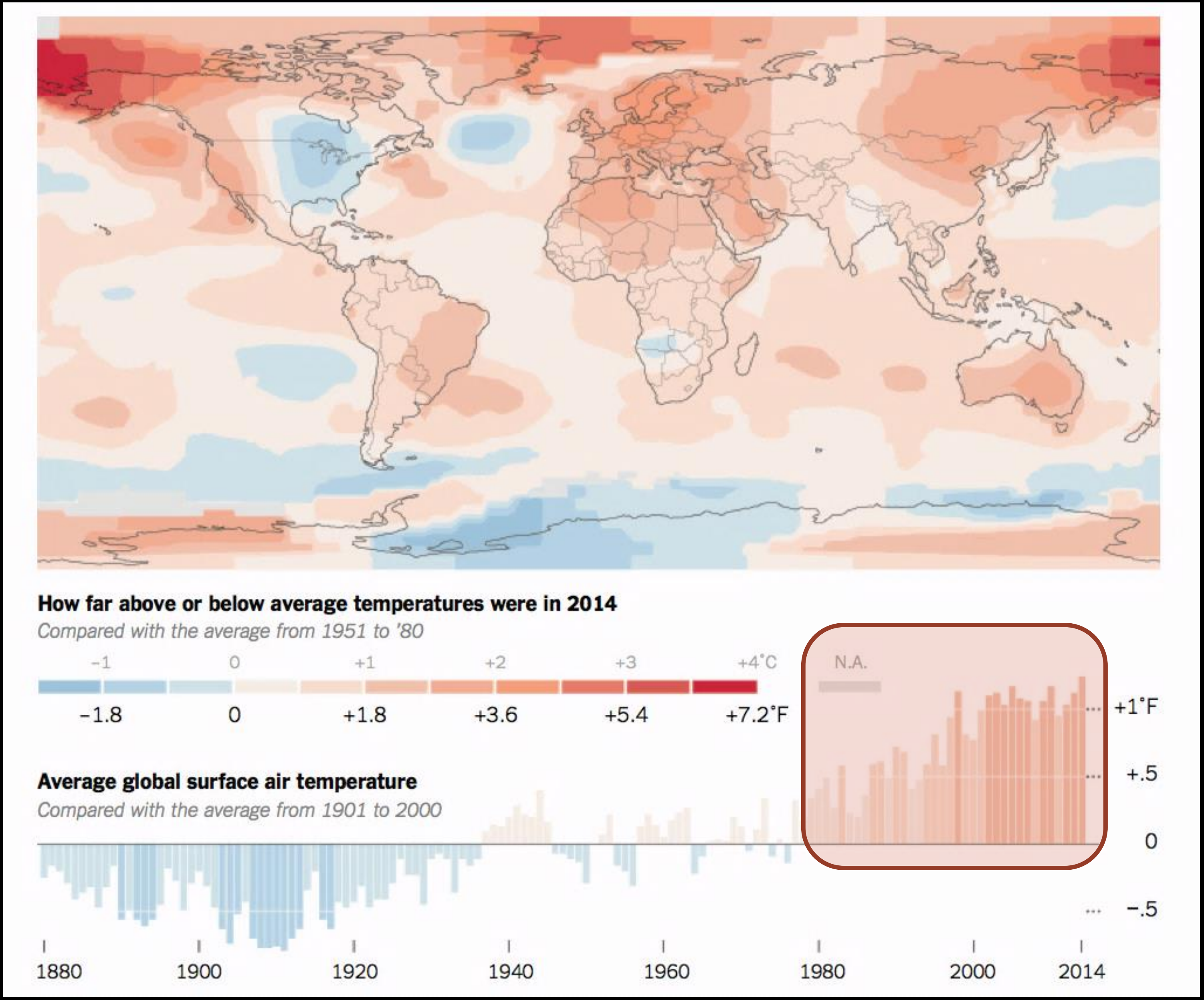
• **Industry Perspective** - Jane DeMarchi, Vice President, Government and Regulatory Affairs, ASTA	3:30 PM - 5:00 PM
Closing Dinner	6:00 PM- 8:30 PM
Thursday, October 1, 2015	
Science and Technology Committee Meeting	8:00 AM - noon

Drought-tolerant Germplasm Options for Agriculture

John C. Cushman – University of Nevada – Reno
Nevada Agricultural Experiment Station

WAAESD – Charlotte, NC
September 30, 2015

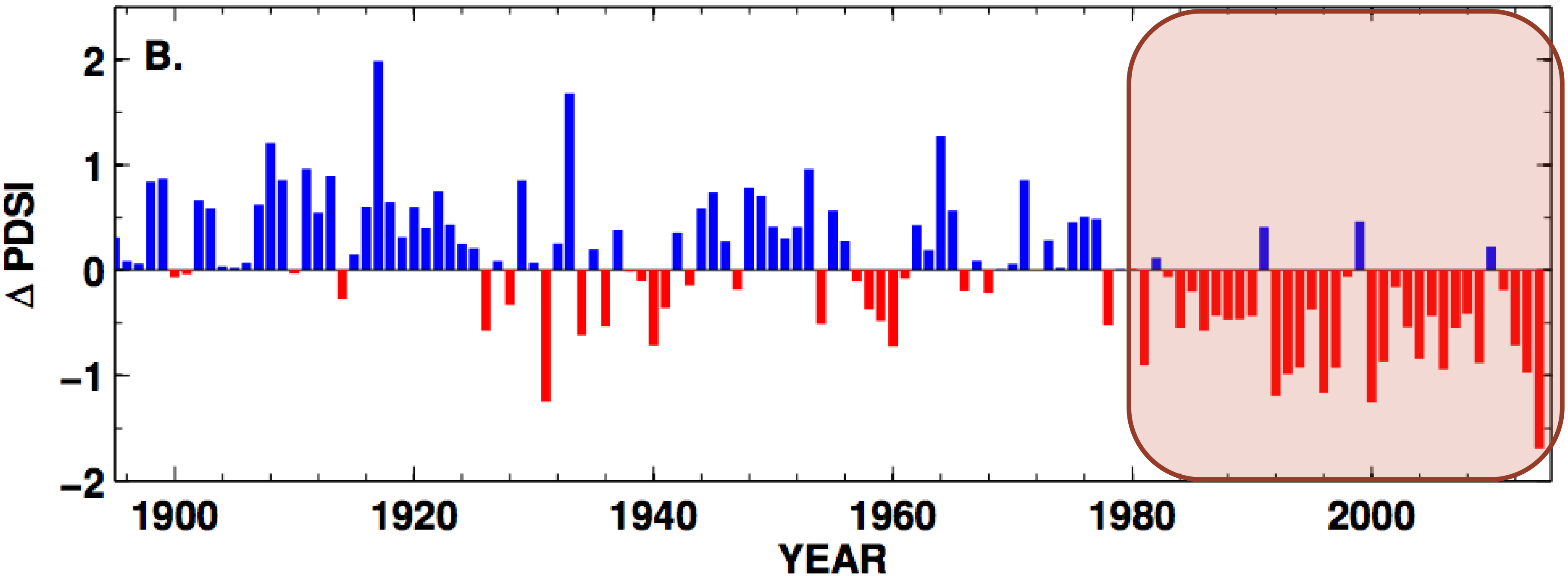
2014: Warmest Year on Record



New York Times Source: NASA; NOAA: 1951-1980 Average (top), 1901-2000 Average (bottom)

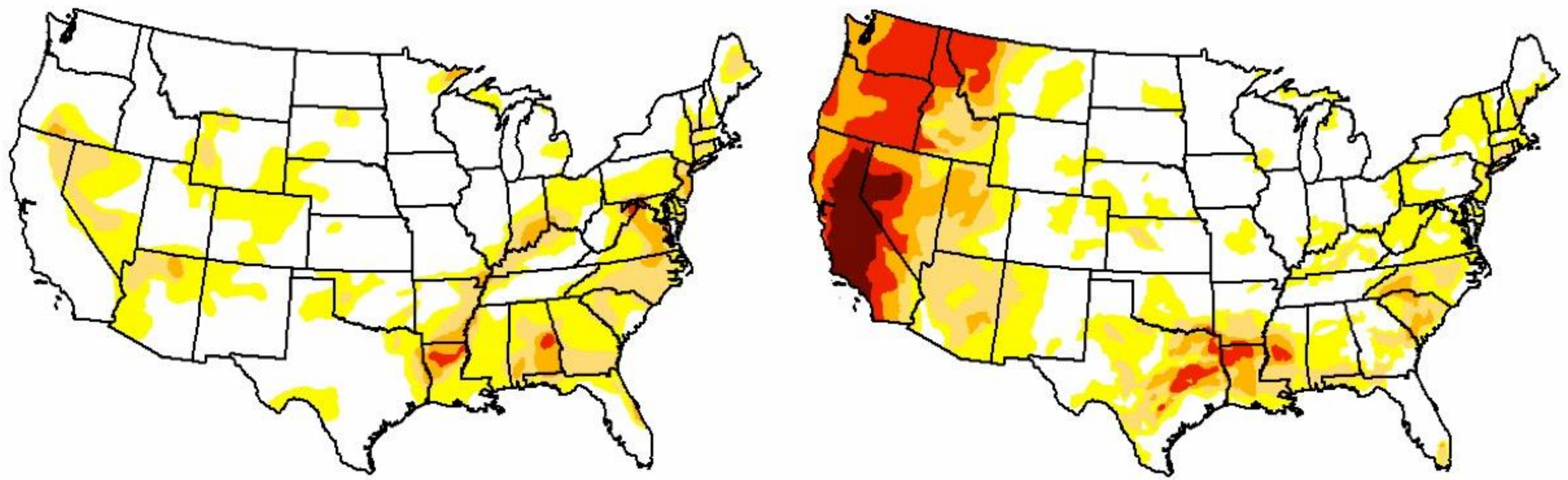
California 2014: Worst Drought in the Last Century

- Change in Palmer Drought Severity Index (ΔPDSI)
- Reduced precipitation (although not unprecedented) and record high temperatures are driving PDSI values more negative (accumulated moisture deficits worst in last 1200 years).



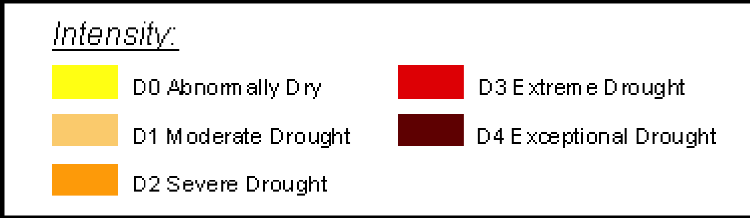
Griffin & Anchukaitus (2014) Geophys. Res. Lett. DOI: 10.1002/2014GL062433

Drought Monitor: 2010 *vs.* 2015



D2 = Crop/pasture losses likely; water shortages common; water restrictions imposed.

D4 = "Exceptional and widespread pasture/crop losses; shortages of water in reservoirs, streams, and wells creating water emergencies"



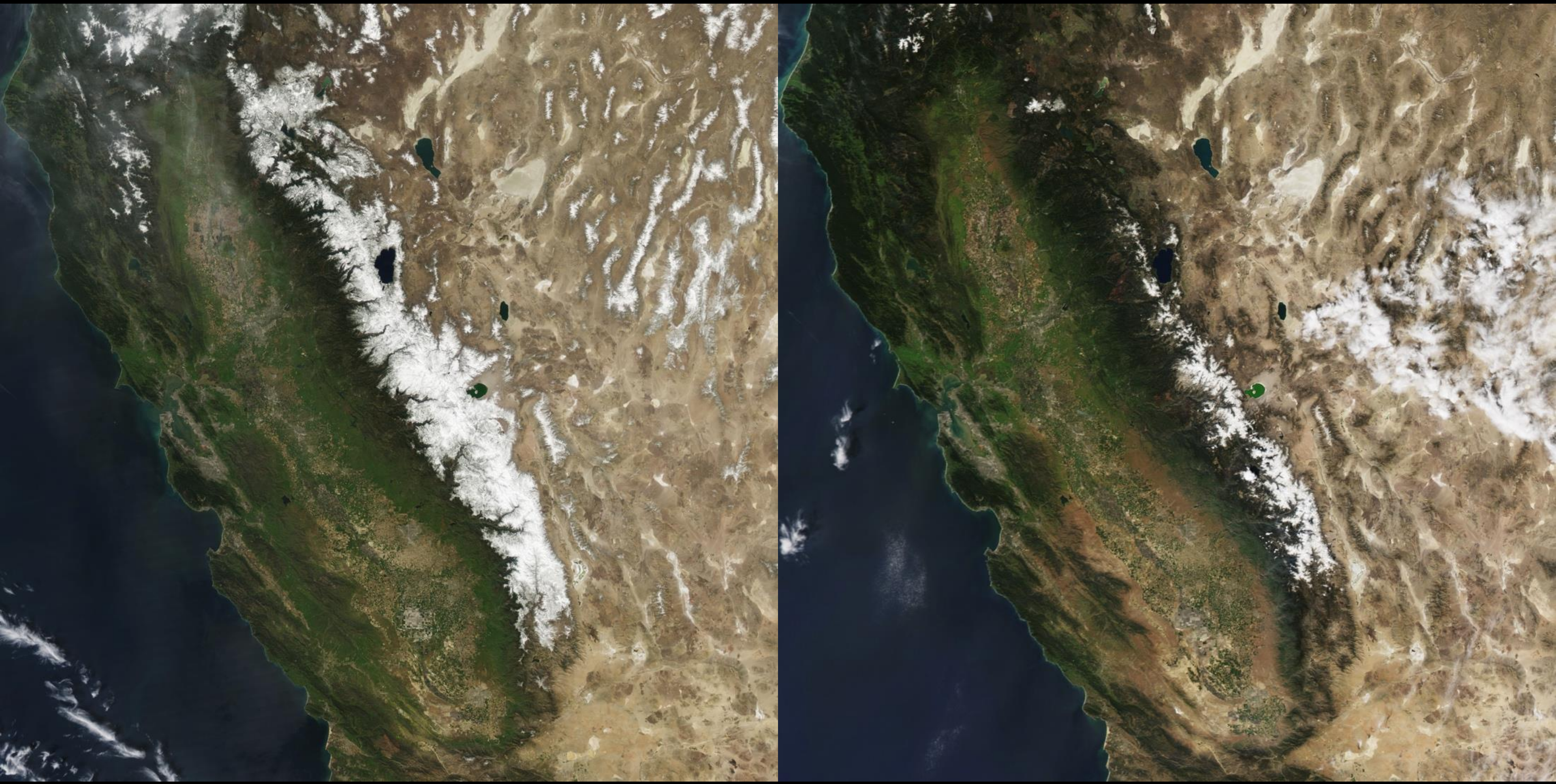
Source: http://droughtmonitor.unl.edu/

Sierra Snowpack: 2010 *vs.* 2015

- **2015 lowest recorded snowpack (6% of average) in last century**

March 27, 2010

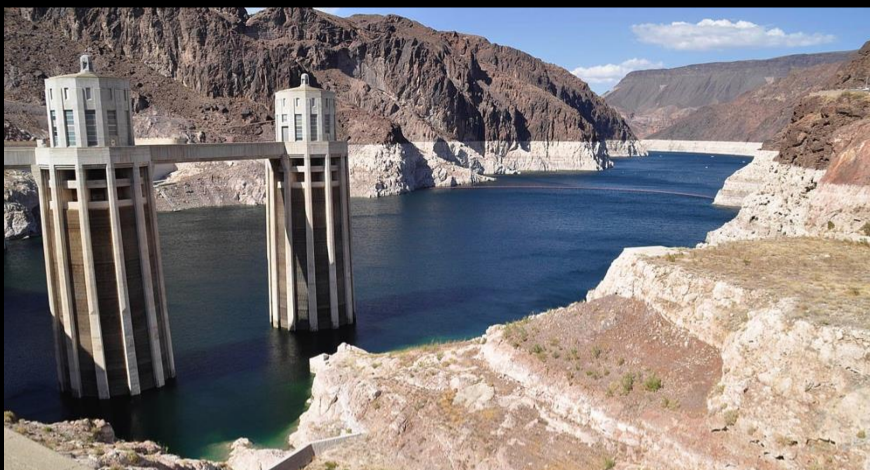
March 29, 2015

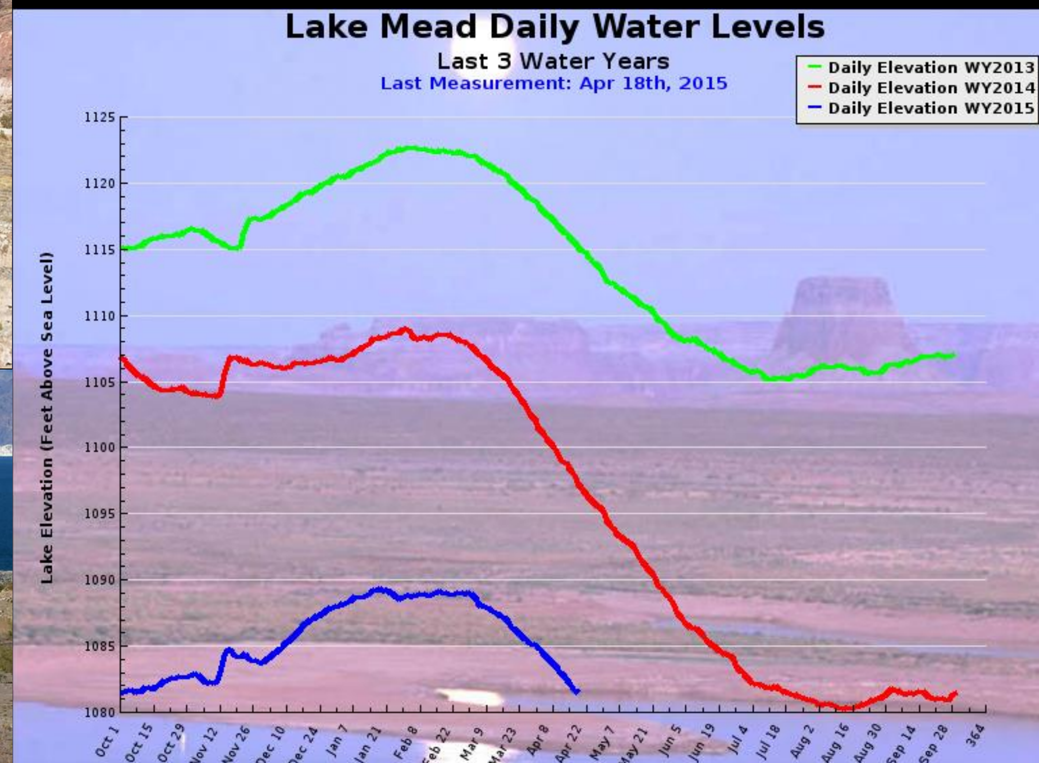


Source: NASA Earth Observatory. Credit: Jesse Allen

Lake Mead Drops to All Time Low

- 1080 ft. level is lowest level since construction in 1930s (full pool = 1,229 ft.).
- LVWA is spending $1.5 billion to add water intake pipes at 850 ft.

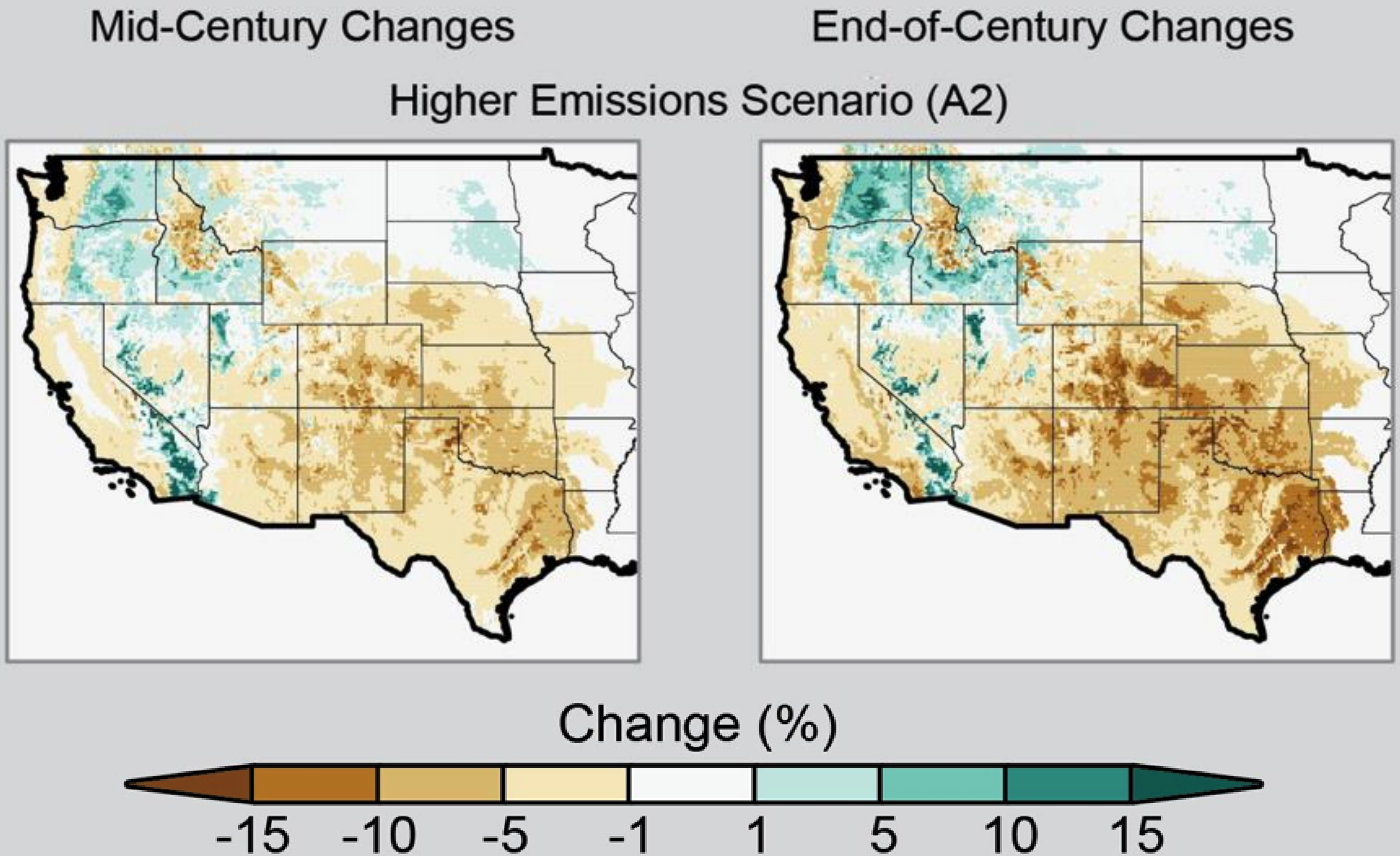




Lake Mead, NV http://zimbio.com and http://thepoog.com

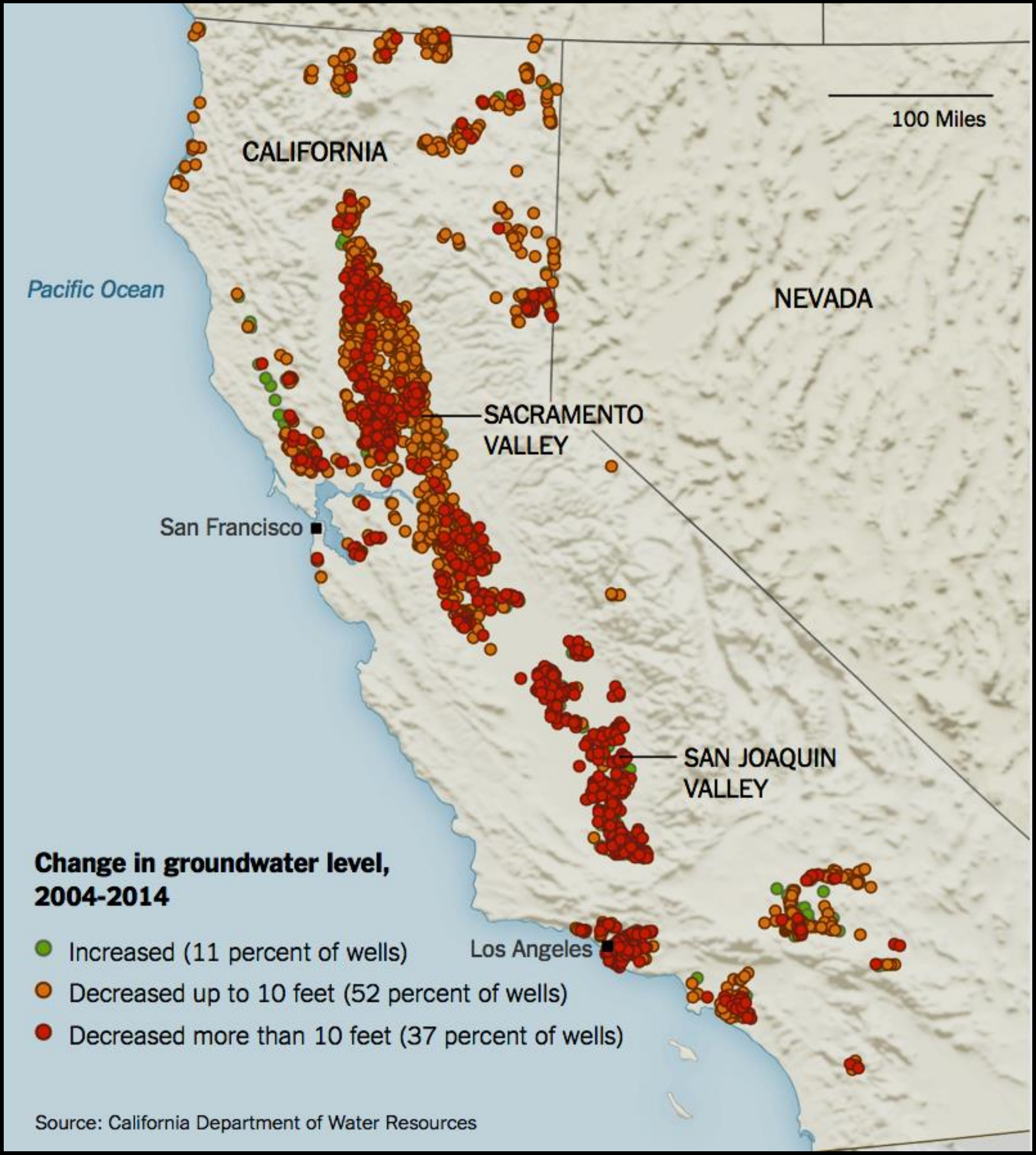
Lake Mead, NV http://Graphs.water-data.com/lakemead

Predicted Soil Drying Trends in the Future



Source: NOAA/NCDC

Groundwater Depletion: California



New York Times Source: California Department of Water Resources: 2004-2014

How can we make better use of our limited water resources?

Alternative crops with improved drought tolerance and water-use efficiency…

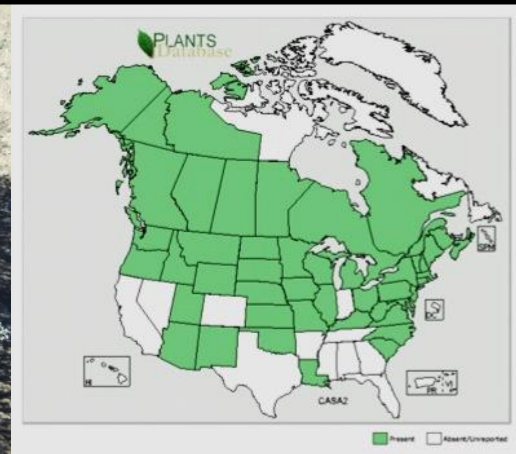
Drought-tolerant Germplasm Options





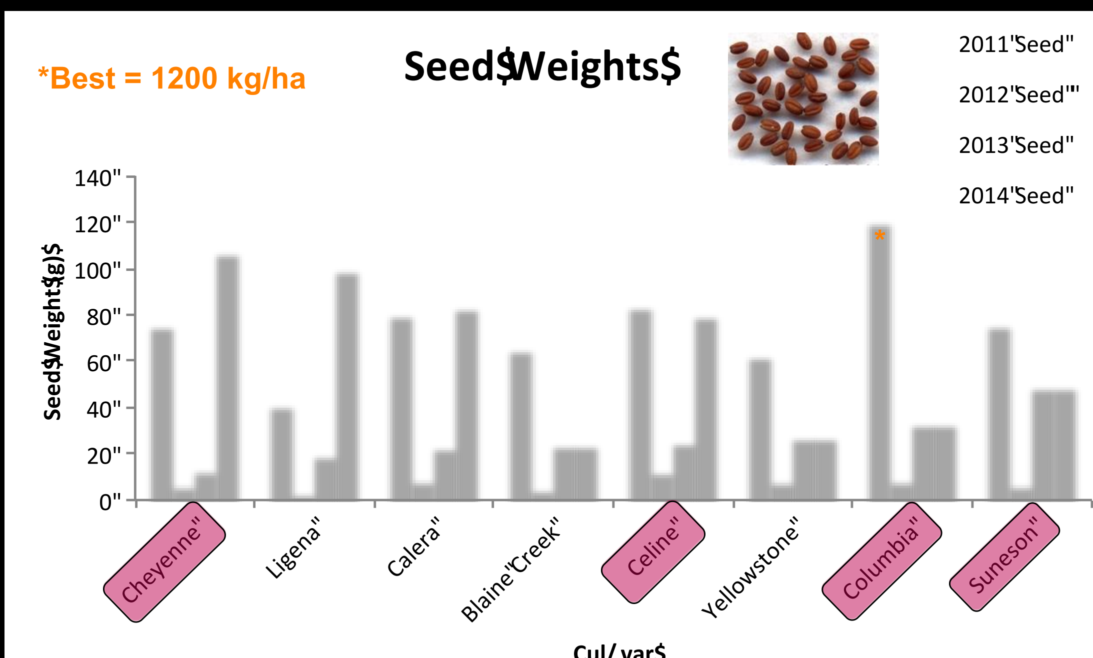

- *Camelina*
- *Sporobolus*
- Gumweed
- Rabbitbrush
- *Agave*
- *Opuntia*

Drought-tolerant Germplasm *Options: Camelina*



http://plants.usda.gov/; USDA-NRCS PLANTS Database

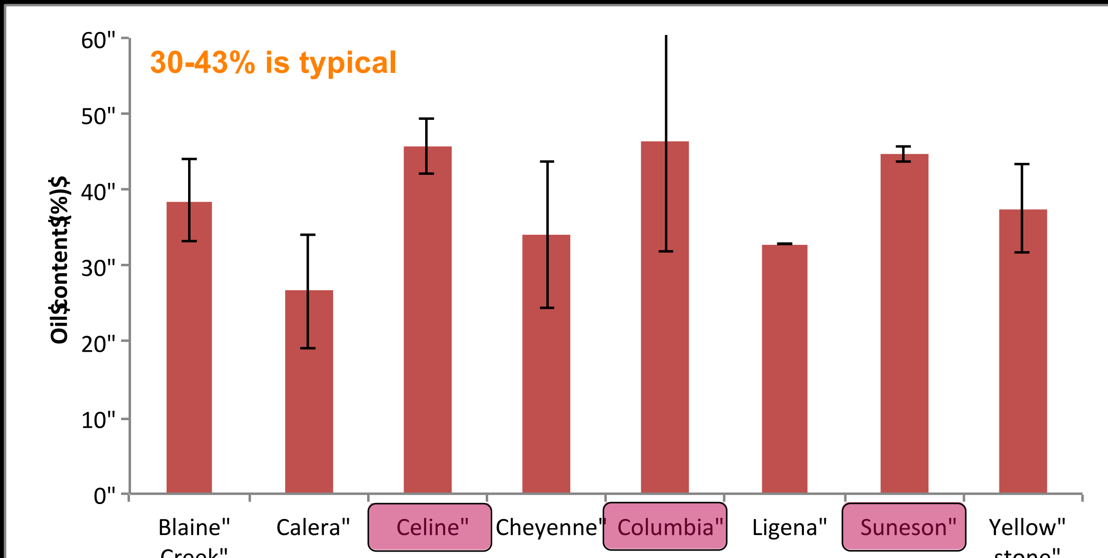
False flax (*Camelina sativa*)



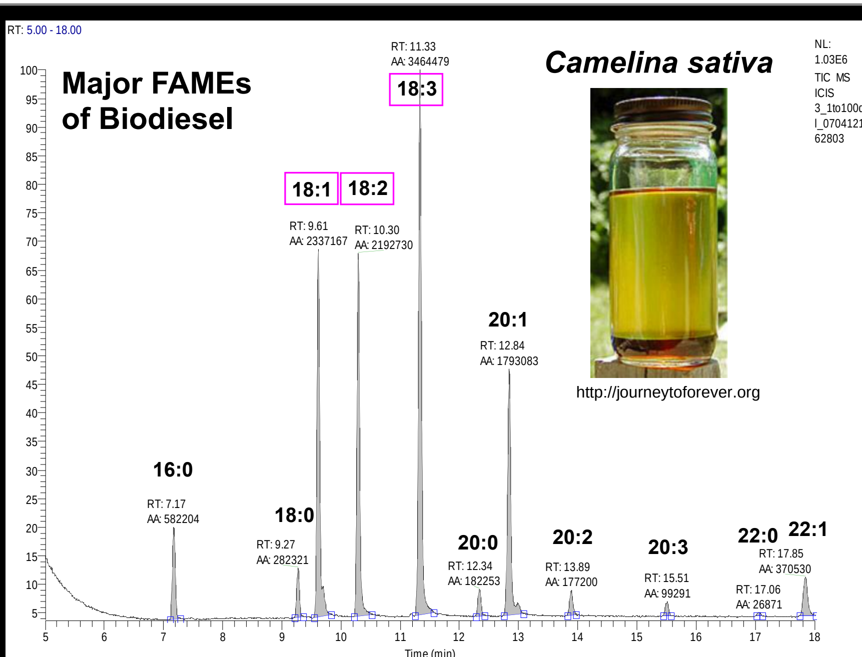
Jason Caudill, Juri Kubac, Karmen Swanson, Richard Lohaus

- Generally more drought and salt tolerant than canola
- Requires low water (400 mm) and fertilizer inputs
- Inexpensive to grow (~$80/ha)
- Rapid growth cycle (85-100 days)
- Can be winter seeded; rotation or intercrop
- Oilseed production: 1,200 kg/ha

Drought-tolerant Germplasm *Options: Camelina*



Tapas Acharjee, Norman Groves



- High seed oil content: 30-47% oil
- Predominantly C18:1 (oleic), C18:2 (linoleic), and C18:3 (α-linolenic) fatty acids
- Suitable for biodiesel; Oil rich in polyunsaturated fatty acids
- Meal contains 45-47% crude protein, 10-11% fiber
- Erucic acid (C22:1) and glucosinolate contents should be reduced to improve edible oil quality

Drought-tolerant Germplasm *Options: Camelina*

- Analysis of transgenic *C. sativa (*Celine) P_{SARK}::IPT with improved drought tolerance and delayed leaf senescence.

Wild-type

P_{SARK}::IPT

28 days optimal growth conditions

↓

Water-deficit stress for 14-20 days

↓

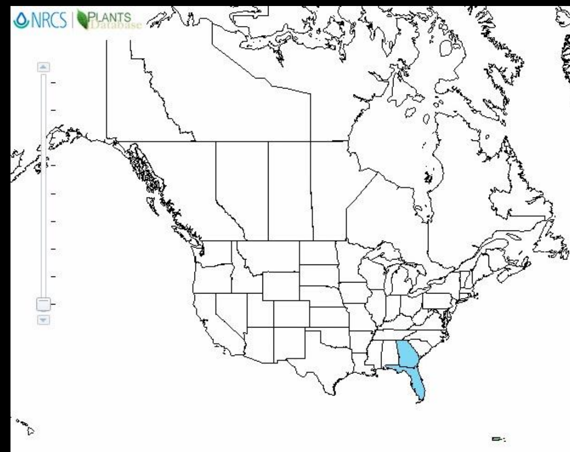
Rewater

↓

Assess drought tolerance performance

James Davis

Drought-tolerant Germplasm *Options: Sporobolus*



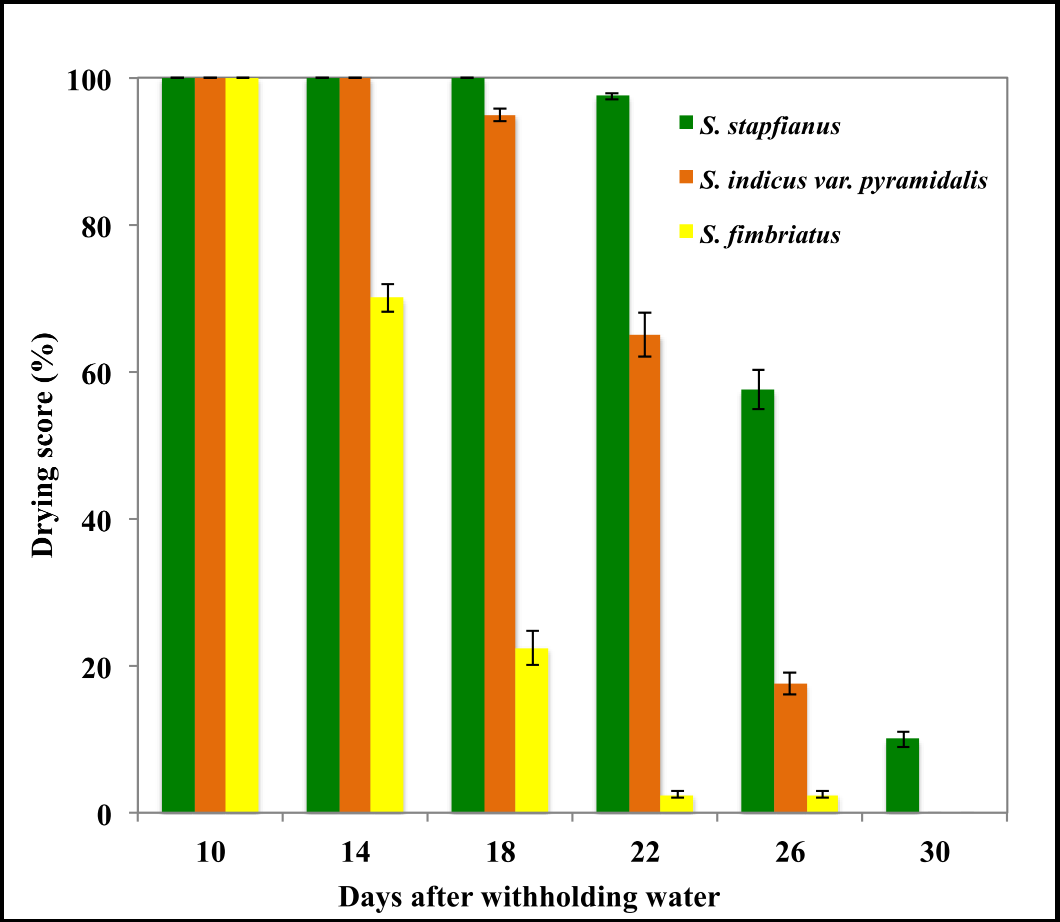
http://plants.usda.gov/; USDA-NRCS PLANTS Database.

West Indian Dropseed (*Sporobolus indicus pyrimidalis*)

- *S. stapfianus (Poacea)* DT native to South Africa, Kenya, Somalia, Nigeria, and Ethiopia
- Survives complete desiccation, resurrects within hours

- ***S. indica cv.pyrimidalis*** desiccation sensitive DS sister species introduced to FL, GA
- *S. fimbriatus* desiccation sensitive DS sister species
- Potential as low-water input forage grasses

Chronic Water-deficit Stress: Drying Scores



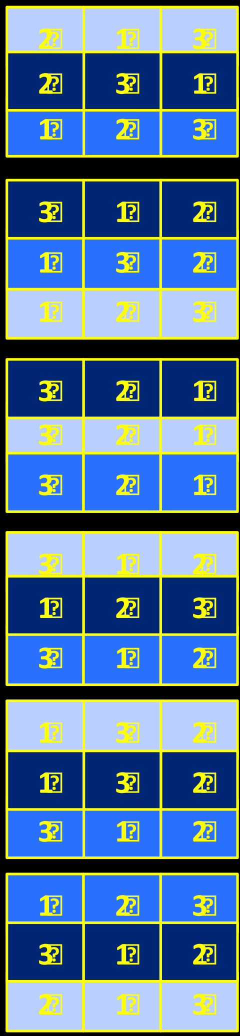
2 month old plants; *n* = 40 per species; *n* = 120 total

- After day 22 of withholding water, 5% of *S. fimbriatus survived,* in contrast, 99% of *S. stapfianus* were still green (do not die -> enter dry state).

Yobi et al., 2013

Sporobolus: 2008 & 2009 Field Trials

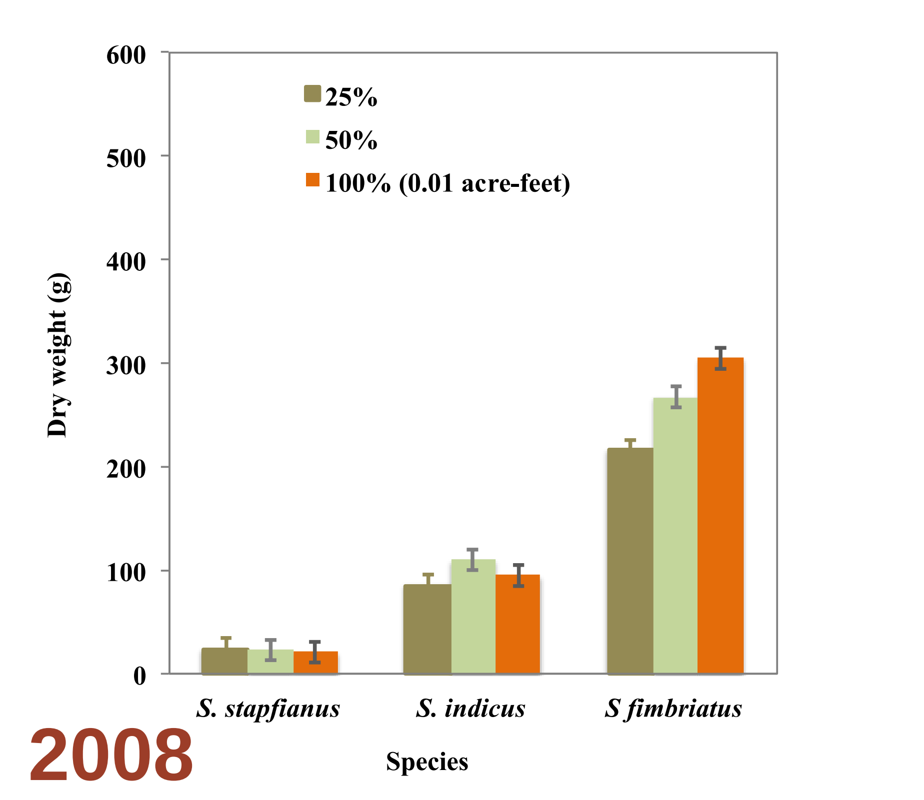
S. fimbriatus (3) *S. pyrimidalis* (2) *S. stapfianus* (1)

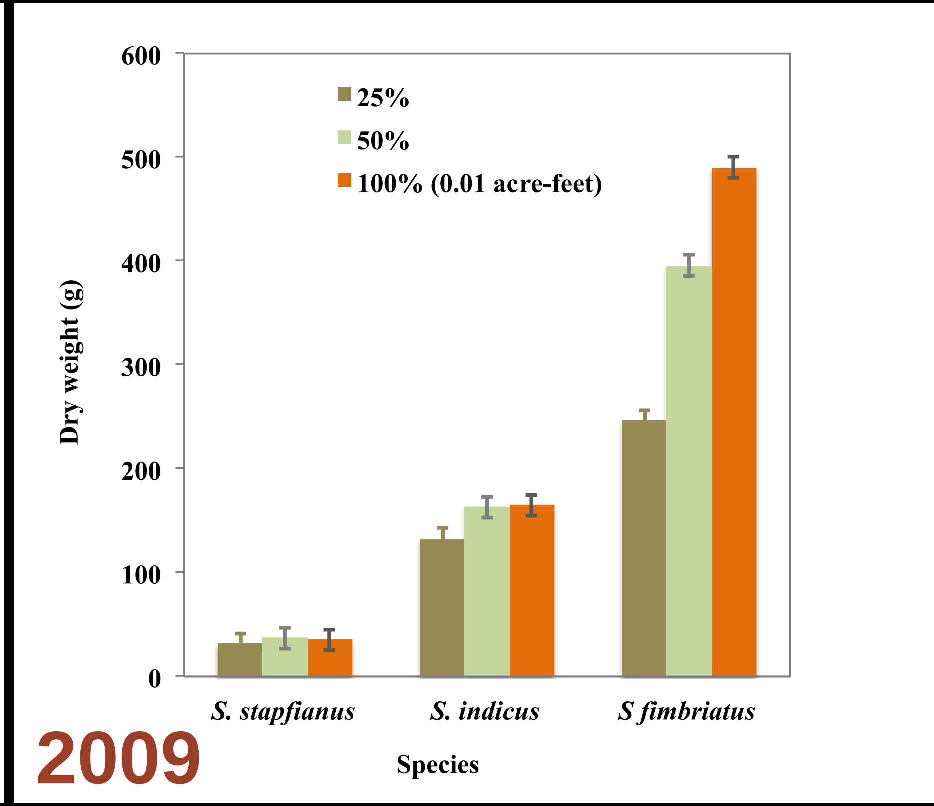


Irrigation Regime: 0.1 acre ft (dark blue) *0.05 acre ft* (blue) *0.025 acre ft* (light blue)

Yobi et al., 2013

Biomass Production: Dry weight



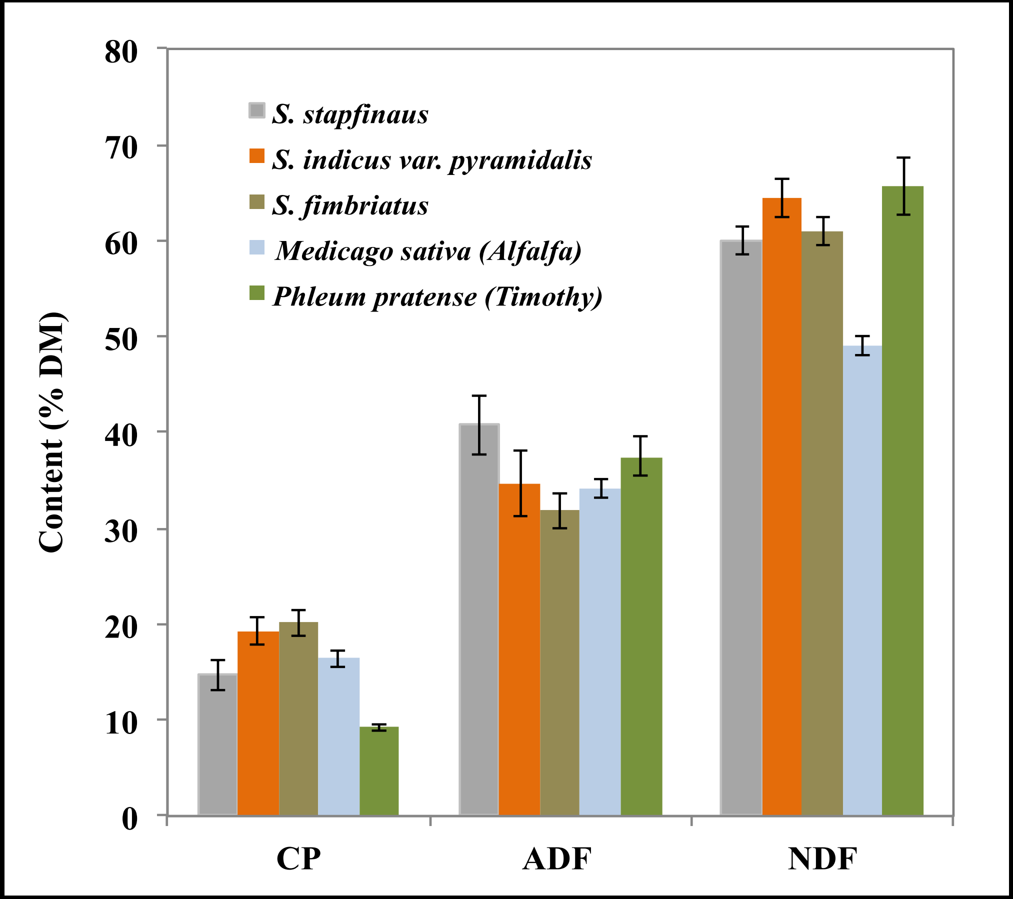


- Biomass production: *S. stapfianus* << *S. indicus* < *S. fimbriatus.* do not increase biomass production in response to increasing water inputs.
- Require 500-fold less water than the commonly used forages such as alfalfa (0.01 *vs* 5 acre-feet).

Yobi et al., 2013

Drought-tolerant Germplasm *Options: Sporobolus*

- *Sporobolus* species tested have mineral and forage qualities comparable to other forage grasses and alfalfa, but can be grown with far less water.



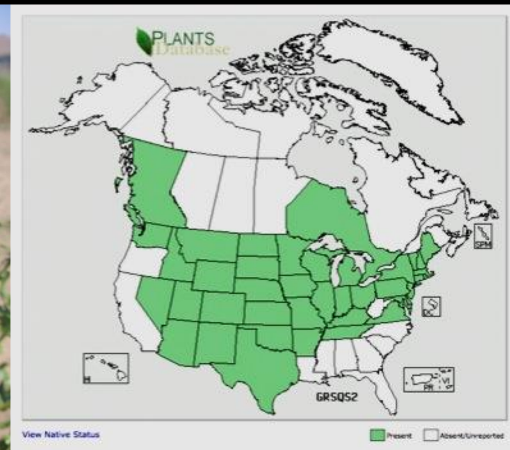
- *Sporobolus stapfianus* can be used as a low-water input and drought-durable ornamental landscape clump grass for arid areas.

- Interspecific *Sporobolus* hybrids might provide intermediate biomass producing genotypes with the DT trait.

Yobi et al., 2013

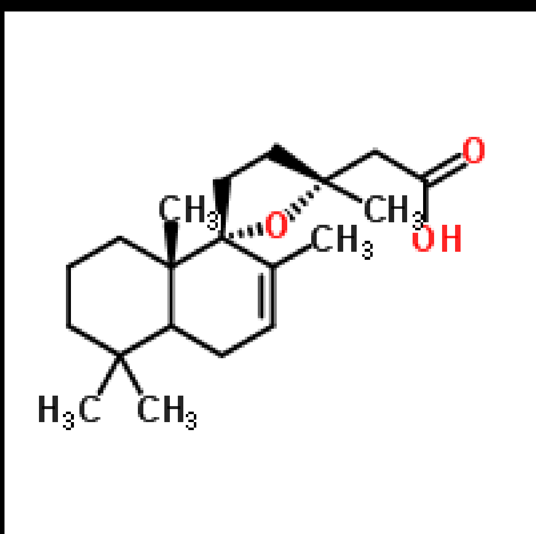
Drought-tolerant Germplasm Options: *Gumweed*

Photo credit: Glenn Miller



http://plants.usda.gov/; USDA-NRCS PLANTS Database.

Gumweed (*Grindelia squarosa*)



Grindelic acid

Photo credit: Glenn Miller

- Native species that requires little water and fertilizer inputs
- Vegetative and floral tissues contain 11-13% “biocrude” resin by dry weight
- Hydrocarbons are C_{20} grindelic acid plus (55% by weight in the biocrude) plus other C_{10-20} terpenoids.
- Biocrude resin production: 900-1200 kg/ha (used as B20).

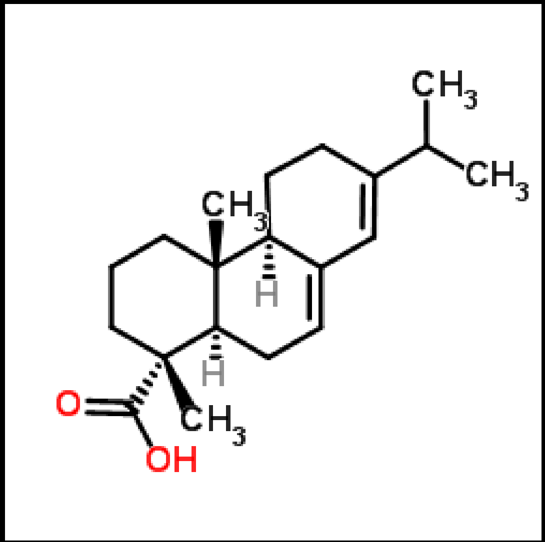
Glenn Miller

Drought-tolerant Germplasm Options: *Gumweed*

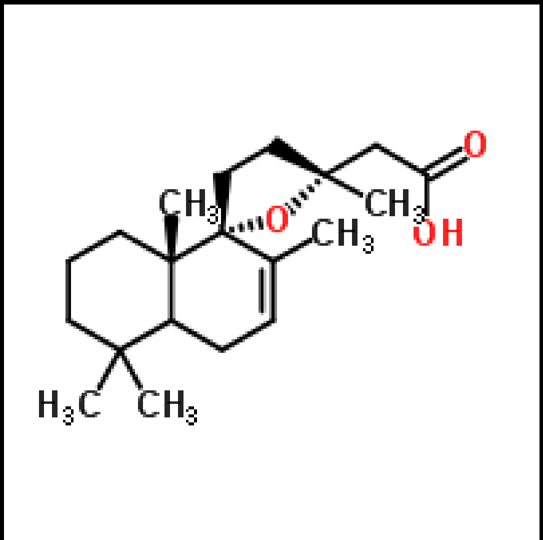
- Gumweed can provide a substitute for abietic acid (wood resin) as grindelic acid has a similar structure.

- Abietic acid is in high demand for making paper, ester gums, and various paints, varnishes, and lacquers and is currently derived from tree stumps (mostly imported).

- Distillation of extract (acid extract of gumweed over alumina) converts 50% to highly branched, high-energy, C_{15} two-ring hydrocarbons that are suitable for use as a jet fuel.



Abietic acid (wood rosin)



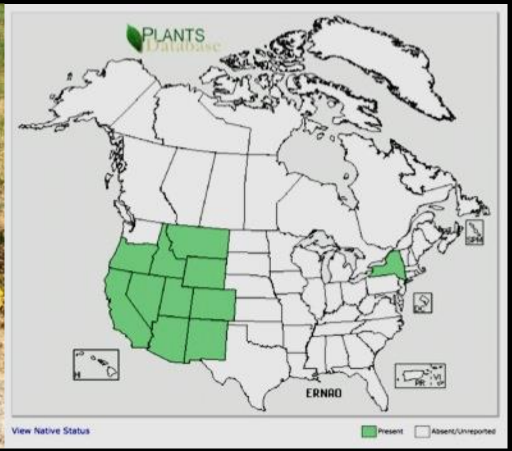
Grindelic acid

Jet fuel

Glenn Miller

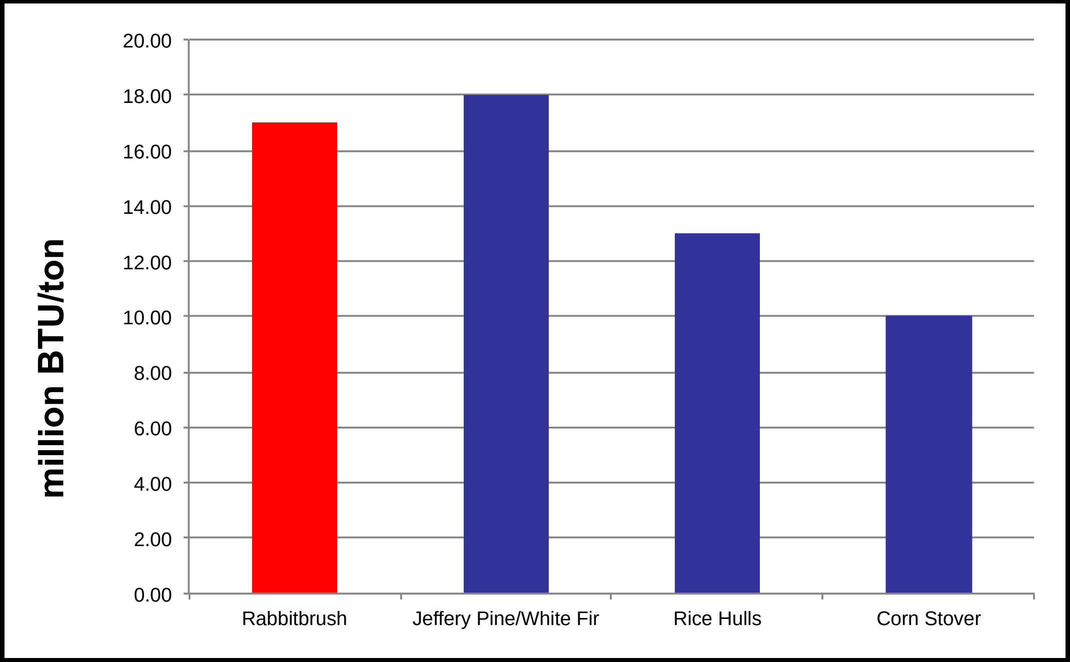
Drought-tolerant Germplasm Options: *Rabbitbrush*

Photo credit: John Cushman



http://plants.usda.gov/; USDA-NRCS PLANTS Database.

Rabbitbrush (*Ericameria nauseosa*)



- **Native species that requires little water and fertilizer inputs**
- **Produces 40 Mg/ha dry biomass; High energy content ~17 M BTU/Mg**
- **Vegetative and floral tissues contain 20% resin by dry weight**
- **Hydrocarbons are $C_{5\text{-}20}$** terpenoids.
- Biocrude resin production: 2600 L/ha (used as B20).

David Shintani

Drought-tolerant Germplasm Options: *Rabbitbrush*

- Rabbitbrush shoots contain 2-6% rubber by dry weight

- High molecular weight rubber comparable to Guayule and Hevea
  (RB 995,800 dal; Guayule 1,143,000 dal; Hevea 1,143,000 dal)

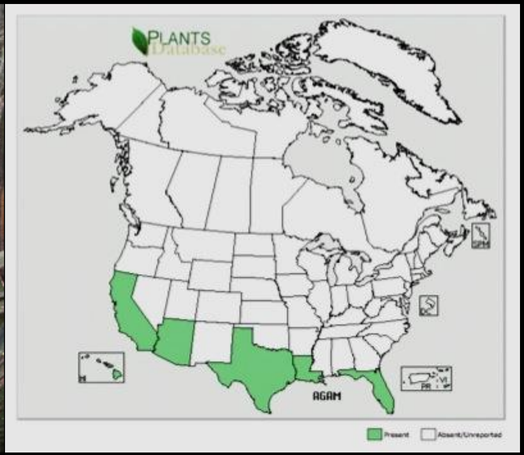
- Good thermostability
  (Plasticity Retention Index: RB 73; Guayule 77.1; Hevea 60)

- Excellent hypoallergenic qualities
  (mg protein/g rubber : RB = ~6.0; Guayule = ~6.7; Hevea; ~13,350)

Rabbitbrush rubber

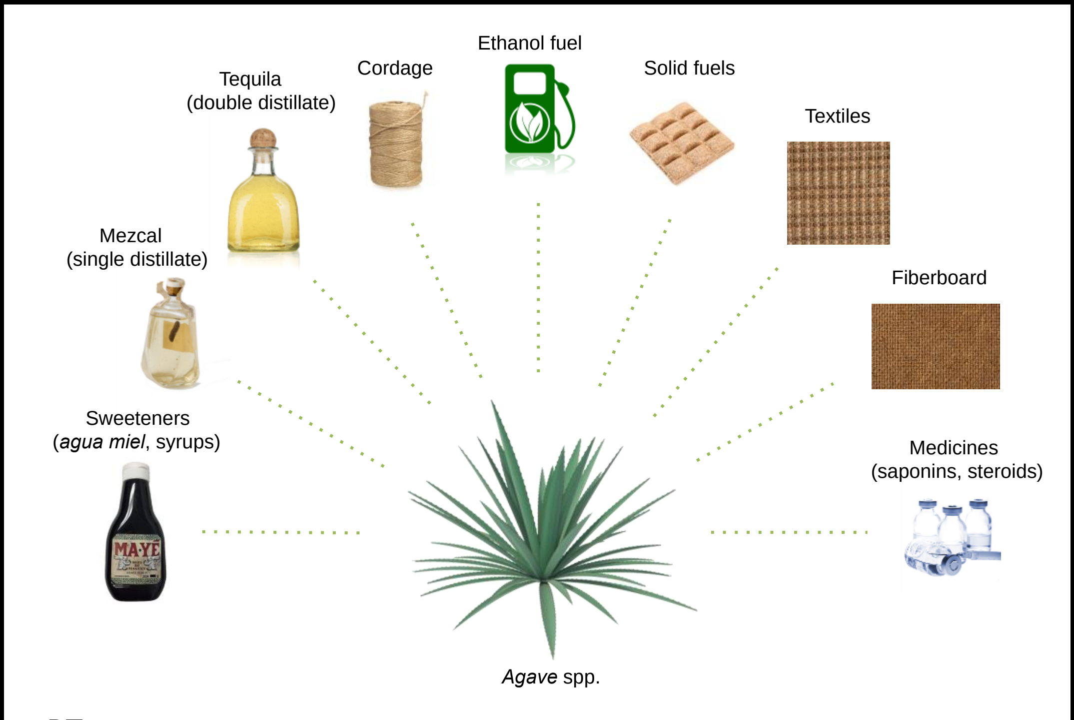
David Shintani

Drought-tolerant Germplasm Options: *Agave*



http://plants.usda.gov/; USDA-NRCS PLANTS Database.

Agave (*Agave americana*)



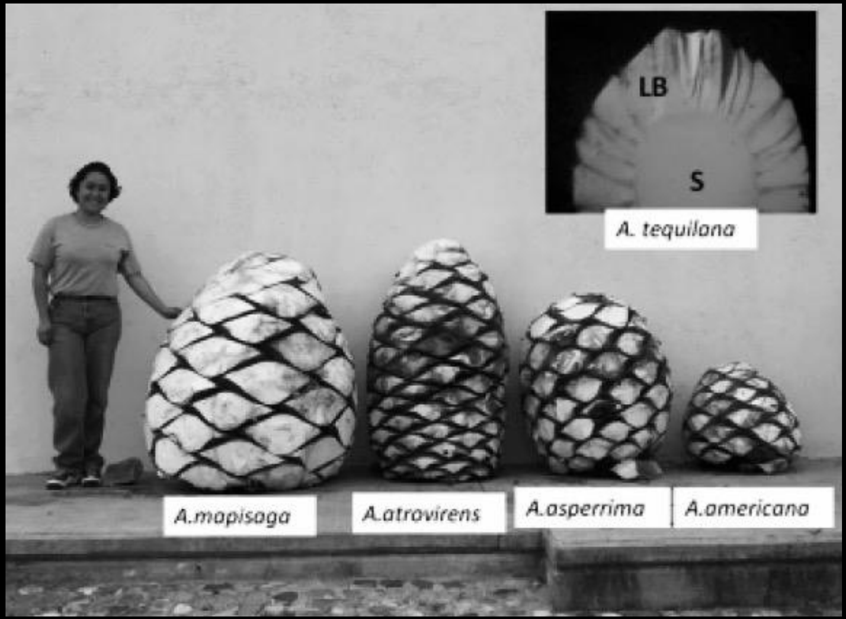
- Water inputs only 20% of traditional crops
- High biomass producers (10-34 Mg/ha/year)
- Leaves and stems contain fermentable sugars with low lignin content for ethanol production
- Various uses

Cushman et al., (2015) J. Exp. Bot.

Drought-tolerant Germplasm Options: *Agave*

- *Agave* worldwide cultivation >500,000 ha (low input, 5-8 year life cycle)
- Large Agave species used for alcoholic beverage production (27-38% sugar leaves/stems)
- Ethanol production well developed:
  - ✓ 14,000 l ha^{-1} (1246 gal ac^{-1}) ethanol plus
  - ✓ 33,650 l ha^{-1} (3598 gal ac^{-1}) cellulosic ethanol (bagasse waste products)

Agave tequilana



Simpson et al., 2011 Global Change Biology: Bioenergy 3: 25-36.

Drought-tolerant Germplasm Options: *Agave*

- *Agave* worldwide cultivation >500,000 Ha

- Large Agave species used for fiber production:
  - *A. sisalana* (sisal) 246 x 10^3 Mg
  - *A. fourcroydes* (henequin) 22 x 10^3 Mg

Agave sisalana

Sisal fibers

Drought-tolerant Germplasm Options: *Agave*

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Energy &
Environmental Science

Cite this: *Energy Environ. Sci.*, 2011, **4**, 3110

www.rsc.org/ees

ANALYSIS

Life cycle energy and greenhouse gas analysis for agave-derived bioethanol

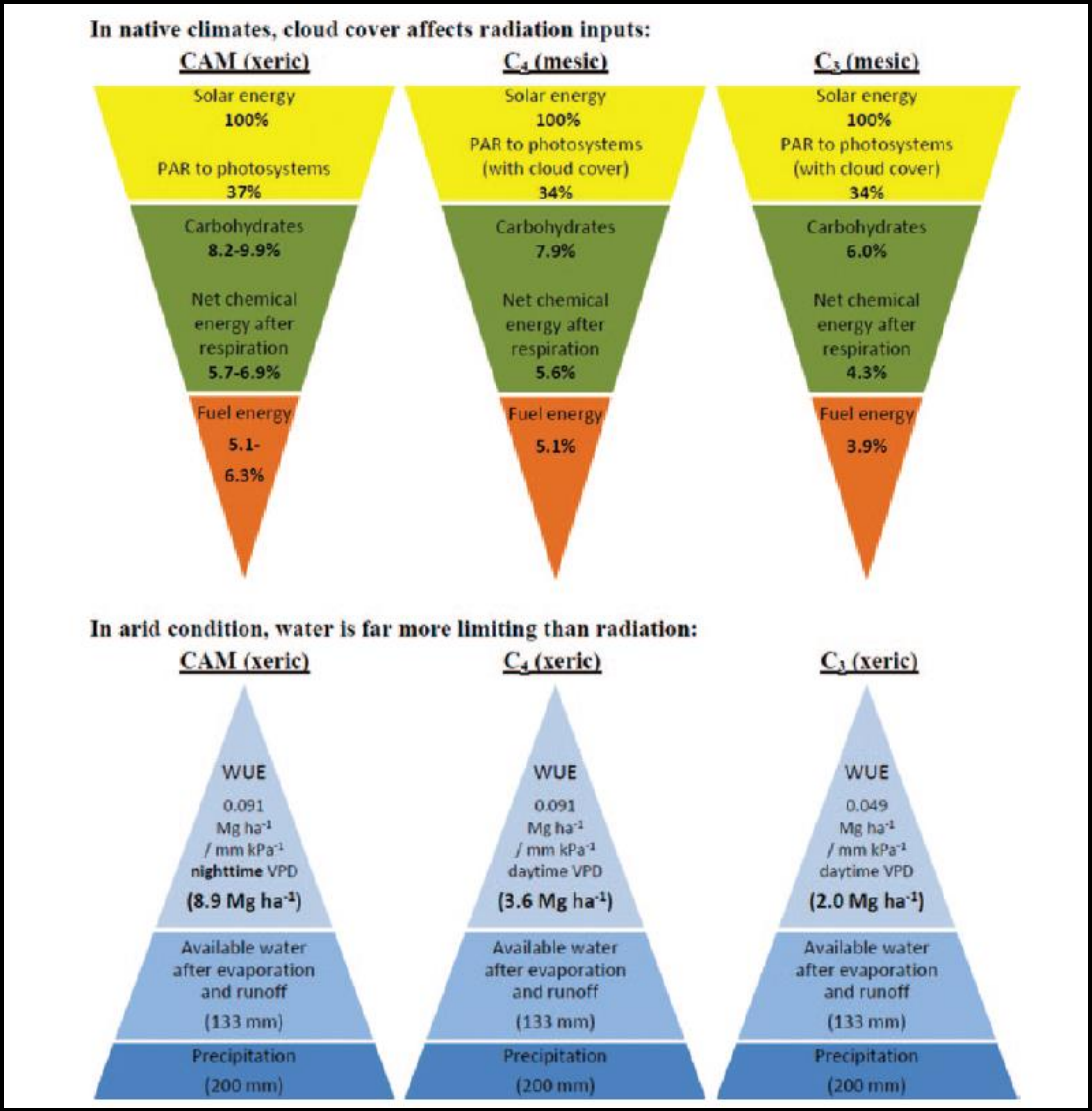
Xiaoyu Yan,*[a] Daniel K. Y. Tan,[bc] Oliver R. Inderwildi,[a] J. A. C. Smith*[b] and David A. King[a]

Received 29th January 2011, Accepted 24th June 2011
DOI: 10.1039/c1ee01107c

"Life cycle energy and greenhouse gas (GHG) analysis of agave-derived ethanol … suggests that ethanol derived from agave is likely to be superior, or at least comparable to that from corn, switchgrass, and sugarcane, in terms of the energy balance and GHG balances…ethanol output and … net GHG offset "

Yan et al., 2011 Energy Environ. Sci. 4: 3110.

Drought-tolerant Germplasm Options: *Agave*



- Under native conditions, CAM (*Agave*) species have comparable fuel energy content to C_4 bioenergy crops.
- Under arid, water-limiting conditions, *Agave* has yield potentials that are 147% greater than C_4 species.

Davis et al. 2014 J. Exp. Bot 65:3471-3478.

Drought-tolerant Germplasm Options: *Opuntia*

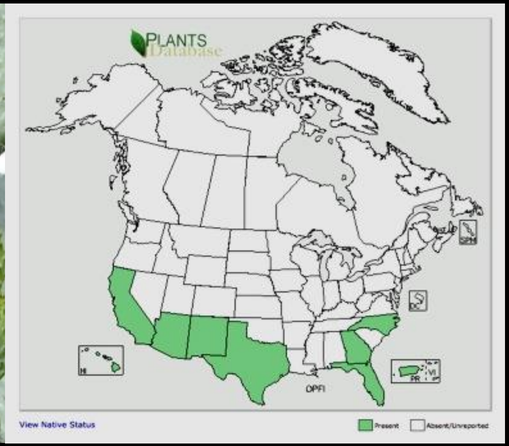
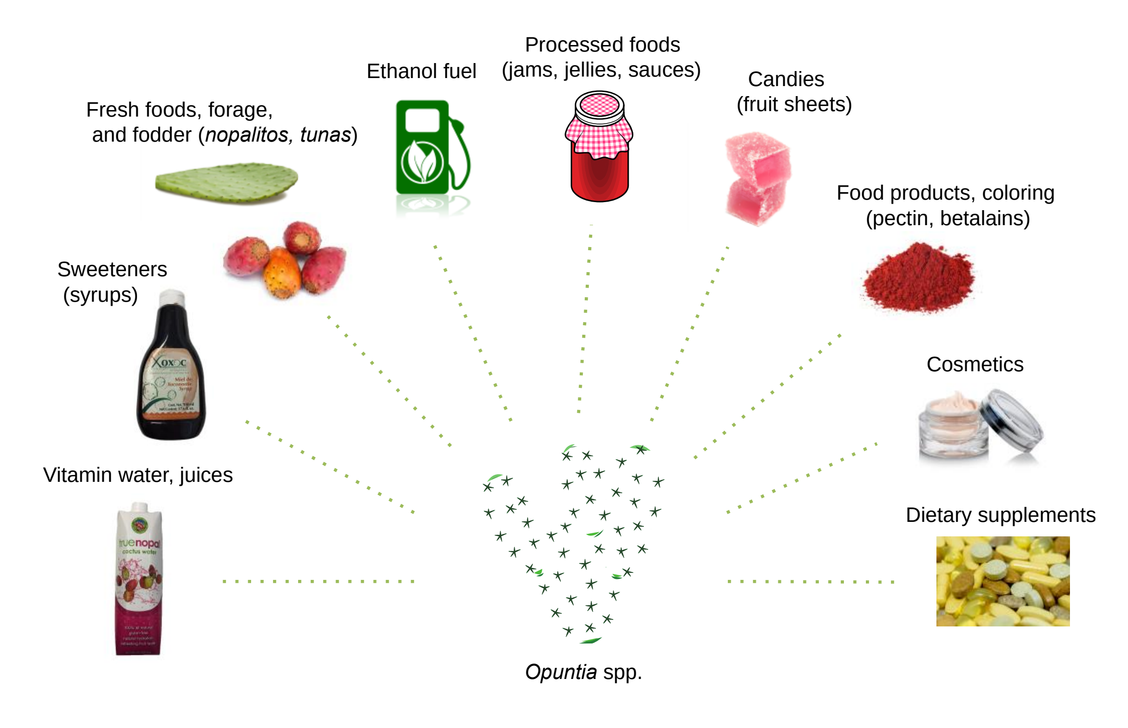


Photo credit: J.S. Peterson @ USDA-NRCS PLANTS Database

http://plants.usda.gov/; USDA-NRCS PLANTS Database.

Prickly Pear Cactus (*Opuntia ficus-indica*)



- Water inputs only 20% of traditional crops
- High biomass producers (10-47 Mg/ha/year)
- Leaves and fruits are edible by humans/livestock and fermentable for ethanol and biogas production
- Various uses

Cushman et al., (2015) J. Exp. Bot.

Drought-tolerant Germplasm Options: *Opuntia*

- *Opuntia* worldwide cultivation >1,000,000 ha

- Large *Opuntia* species used for food as young cladodes (nopalitos) and fruits (tunas) and forage

Paterson **et al., (2008)** Trop. Plant Biol. 1**: 3-19**

Drought-tolerant Germplasm Options: *Opuntia*

World J Microbiol Biotechnol
DOI 10.1007/s11274-014-1745-6

ORIGINAL PAPER

Opuntia ficus-indica cladodes as feedstock for ethanol production by *Kluyveromyces marxianus* and *Saccharomyces cerevisiae*

Olukayode O. Kuloyo · James C. du Preez ·
Maria del Prado García-Aparicio · Stephanus G. Kilian ·
Laurinda Steyn · Johann Görgens

- Separate hydrolysis & fermentation (SHF) and simultaneous saccharification (enzymatic hydrolysis) and fermentation (SSF) conditions tested.
- Only 2.6% ethanol yield; 4% needed for economic viability.
- Low fermentable sugar (Glu, Gal, Fru, Man) content limits commercial viability.

Kuloyo et al., 2014 World J. Microbiol. Biotechnol.

Drought-tolerant Germplasm Options: *Opuntia*

- Prickly pear "spears" added as the sole carbon source using minimal media.

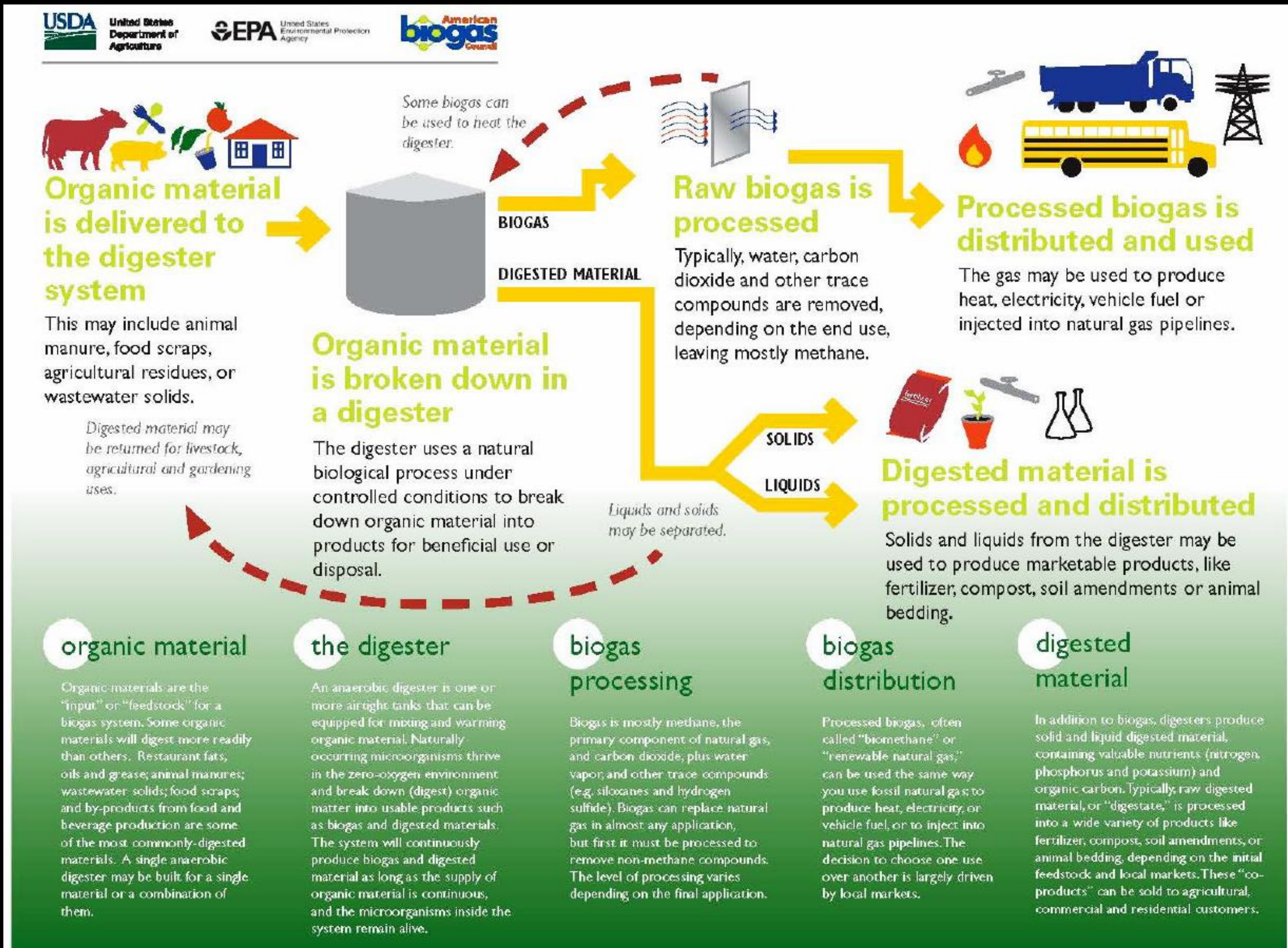
- Soil consortium of microbes resulted in hydrolysis within 5 days.

- More complete release of fermentable sugar should improve utility as a biofuel feedstock.

Soil Consortium | Control

Brian Fox Lab (Univ. Wisconsin)

Biogas Opportunities Roadmap (2014)



Drought-tolerant Germplasm Options: *Opuntia*

- *Opuntia* plantation in Chile for biogas production.

Photo credit: Rodrigo Wayland Morales, Elqui Global Energy, La Serena, Chile

CAM Bioenergy Crops: *Opuntia & Euphorbia*

Fig. 2 Ten-month-old *Opuntia ficus-indica* in Laikipia, Kenya (photo credit George Francis).

Opuntia ficus-indica

Fig. 3 *Euphorbia tirucalli* under test in Laikipia, Kenya (photo credit George Francis).

Euphorbia tirucalli

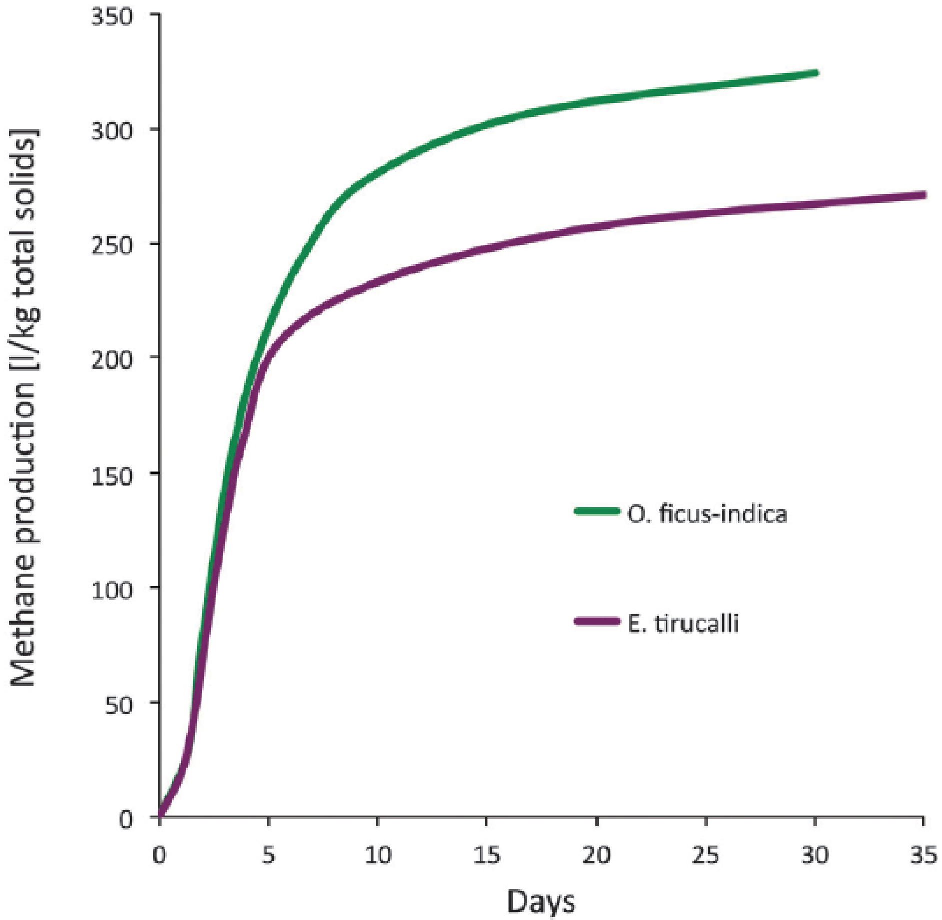


Fig. 6 Digestion rate of *Opuntia ficus-indica* and *Euphorbia tirucalli* grown in Laikipia, Kenya.[46]

Mason et al., 2015 Energy & Environmental Science

CAM Bioenergy Crops: *Opuntia & Euphorbia*

Energy & Environmental Science

ROYAL SOCIETY OF CHEMISTRY

ANALYSIS

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Cite this: DOI: 10.1039/c5ee00242g

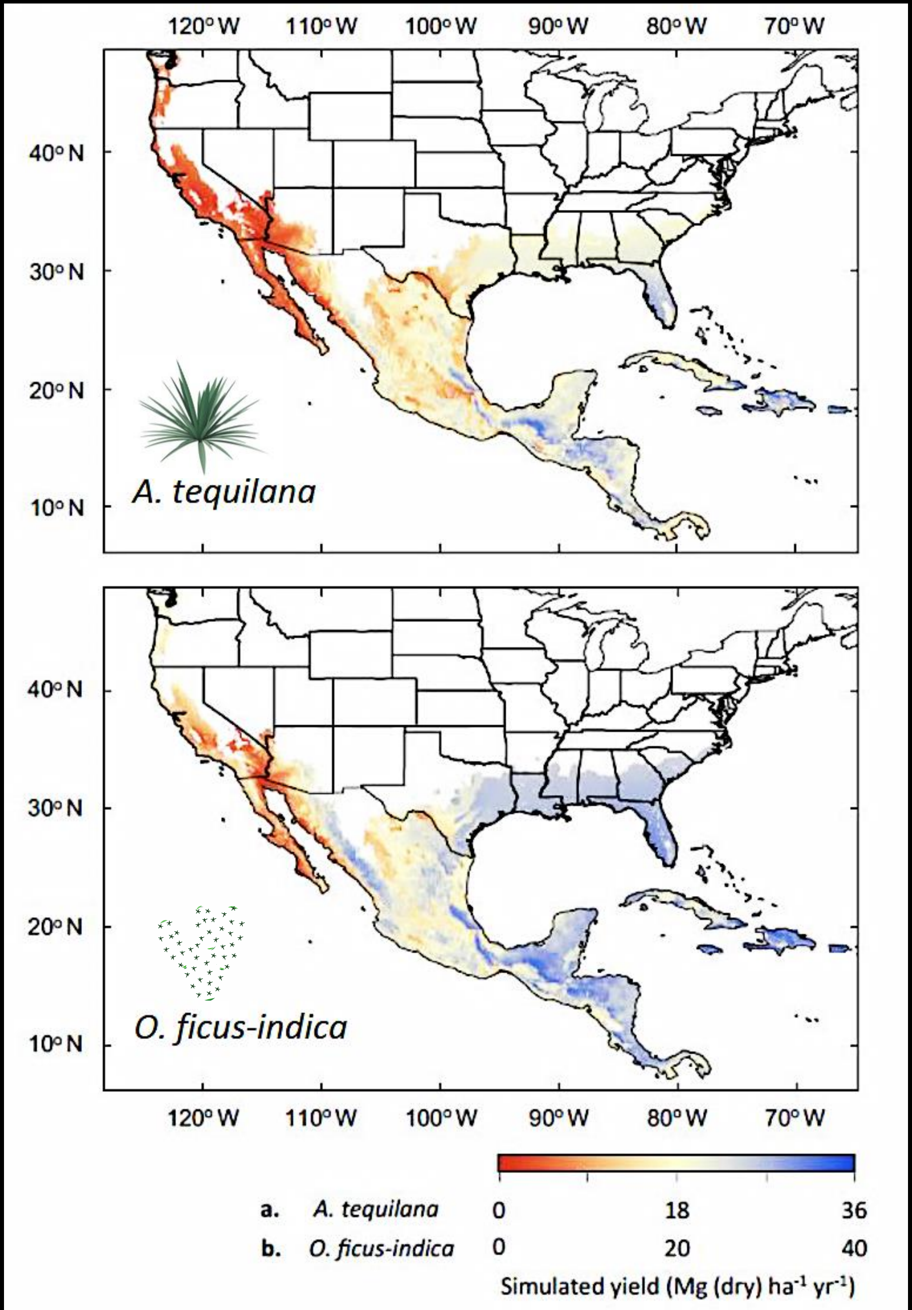
The potential of CAM crops as a globally significant bioenergy resource: moving from 'fuel or food' to 'fuel and more food'†

P. Michael Mason,*[ab] Katherine Glover,[b] J. Andrew C. Smith,[c] Kathy J. Willis,[d] Jeremy Woods[e] and Ian P. Thompson[a]

- *Opuntia ficus-indica* and *Euphorbia tirucalli* are highly drought-tolerance CAM bioenergy crops that can be grown on semi-arid lands.
- Anaerobic digestion of biomass to produce biogas.
- Global power generation = 5 PW h per year; 100-380 M ha or 4-15% of potential land area (2.5 B ha total semi-arid lands).

Mason et al., 2015 Energy & Environmental Science

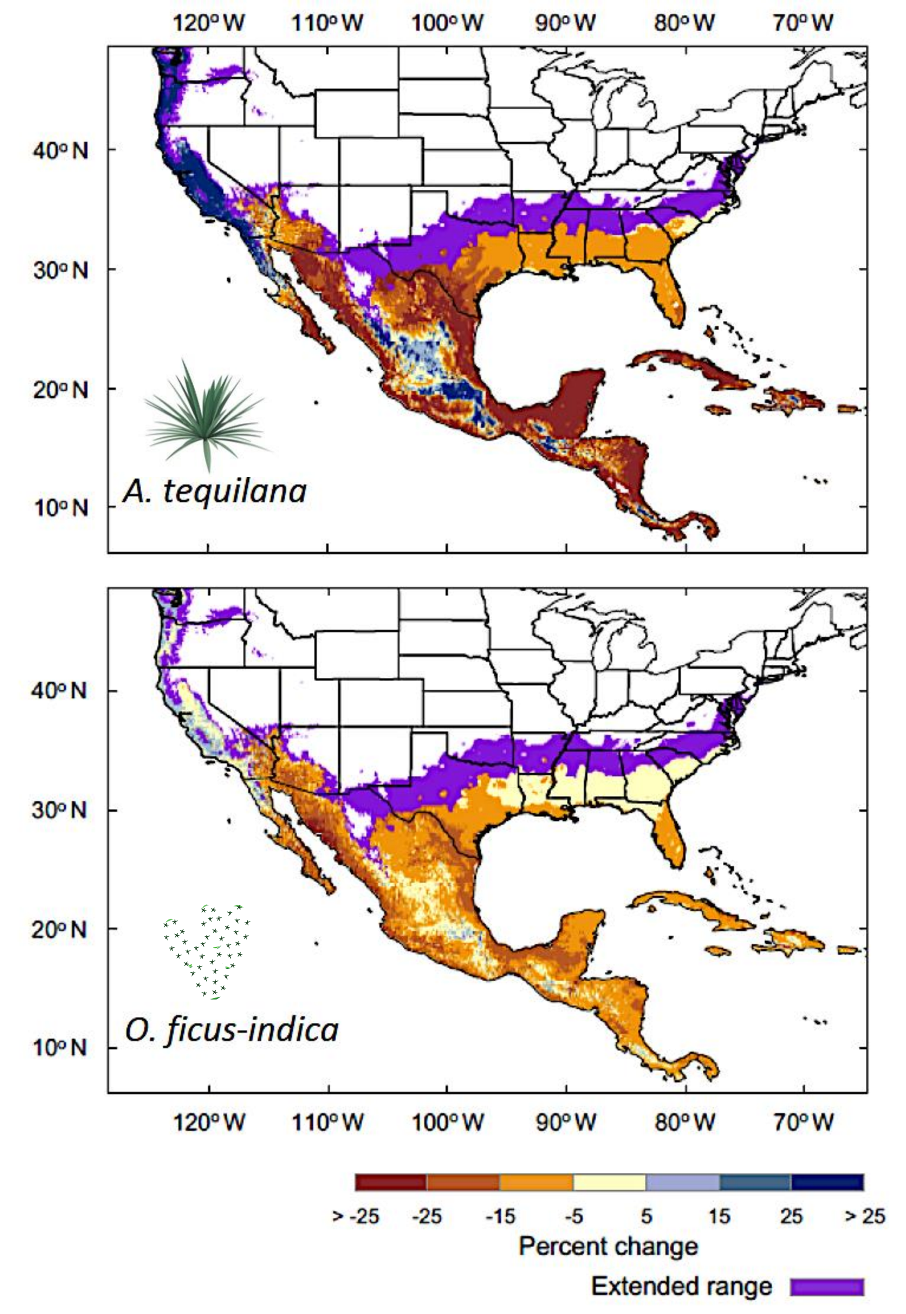
Yield Productivity under Current Climate Conditions



- Highly productive regions in Southeastern states.
- *O. ficus-indica* outperforms *A. tequila* in most parts of North America.
- Monthly isotherm set to 0 ° C. *O. ficus-indica* can survive to -9 ° C.
- Annualize productivity of *O. ficus-indica* expected to increase from rising CO_2 concentrations (Nobel 1991).

Nick Owen: Yang et al., (2015) New Phytologist

Simulated Yield under Future Climate Conditions



- Comparison of present conditions with worst-case climate change scenario in 2070.
- Productive range likely to double for both species (purple).
- *A. tequilana* will perform better in mountainous regions (dark blue).
- *O. ficus-indica* shows greater resilience to climate change.

Nick Owen: Yang et al., (2015) New Phytologist

Opuntia Field Production Trial in U.S.

- 0.25 ha (0.6 acre) field site in Logandale, NV
- Three (spineless) varieties:
  - *Opuntia ficus-indica*
  - *Opuntia cochenillifera*
  - *Opuntia streptacantha*

Opuntia Field Production in U.S.

- 3 Varieties:
  - *Opuntia ficus-indica*
  - *Opuntia cochillifera*
  - *Opuntia streptacantha*

- 3 watering regimes:
  - *200 mm*
  - *400 mm*
  - *800 mm*

  (local = 108 mm)

- 4 Replicates:
  - *7 plants/block*
  - *Pseudo-random design*

Opuntia Field Production in U.S.

- 3 Varieties:
  - *Opuntia ficus-indica*
  - *Opuntia cochillifera*
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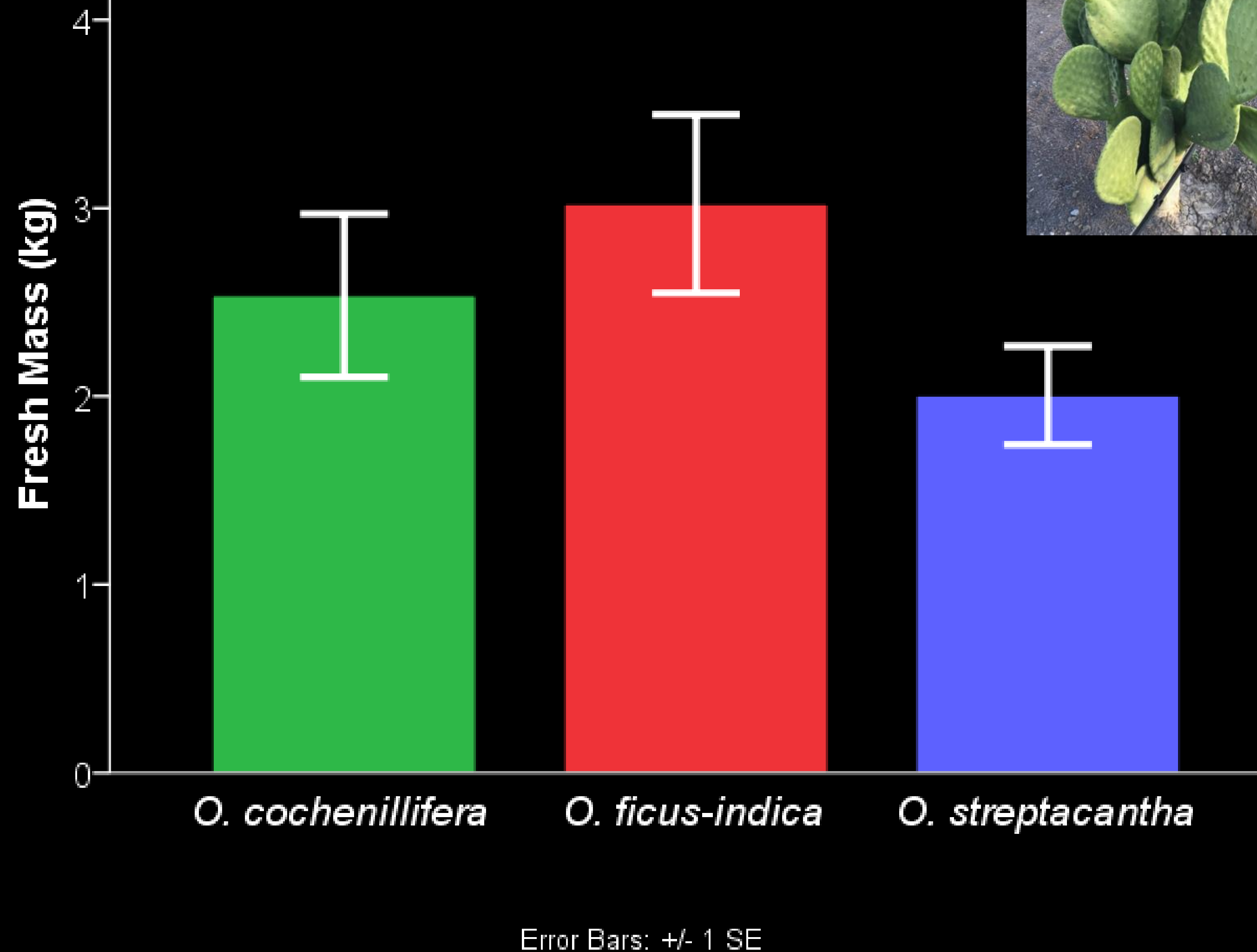
  - *800 mm*

  (local = 108 mm)

- 4 Replicates:
  - *7 plants/block*
  - *Pseudo-random design*

Opuntia Field Production Year 1

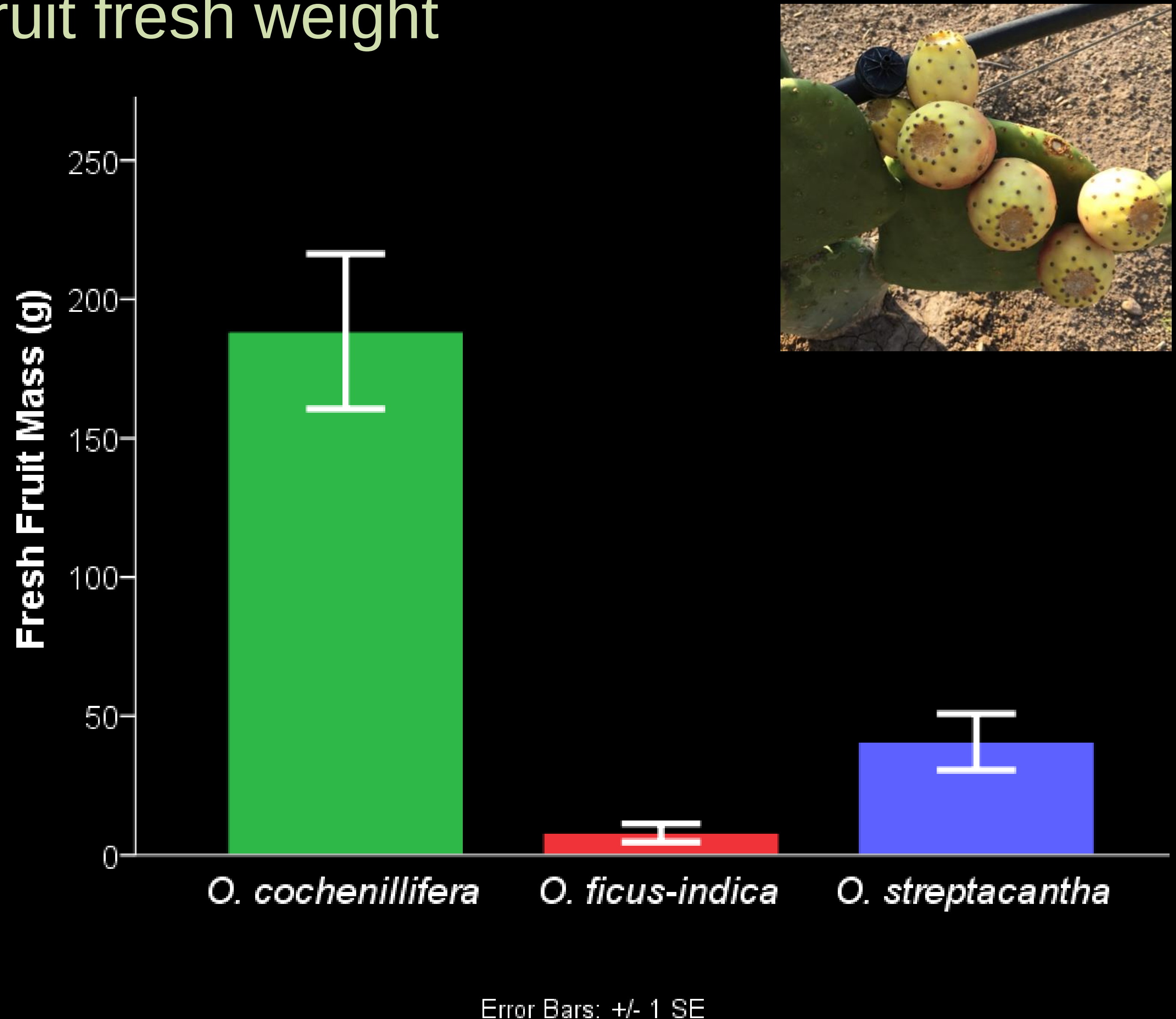
- Cladode fresh weight



Jesse Mayer

Opuntia Field Production Year 1

- Fruit fresh weight



Jesse Mayer

Drought-tolerant Germplasm Options






- *Camelina*
- *Sporobolus*
- Gumweed
- Rabbitbrush
- *Agave*
- *Opuntia*

Drought-tolerant Germplasm Options

- More water-use efficient crops will be needed in the future due to warmer, drier climate, particularly in the western US.

- Water limitations will likely force greater reliance on crops that use less water.

- Productive areas for some species (*Agave* and *Opuntia*) will double in the US over the next 50 years.

- Expanded use of these species has the potential to increase production while reclaiming abandoned or underutilized semi-arid agricultural lands.

Acknowledgements and Project Support

UNR:
Abou Yobi
SangHo Kang
Jesse Mayer
Richard Lohaus
George Fernandez
Barry Perryman
David Shintani
Glenn Miller
Jeffery Harper
Carol Bishop

Undergraduate Students

Mel Oliver

Nevada Agricultural Experiment Station

National Research Initiative Competitive Grants Program (2007-02007)

Nevada Agricultural Foundation

Drought in the West

Doug Parker
Director, California Institute for Water Resources
Strategic Initiative Leader, UC ANR Water Initiative
doug.parker@ucop.edu
ciwr.ucanr.edu | @ucanrwater

University *of* California
Agriculture and Natural Resources | California Institute for Water Resources

Precipitation

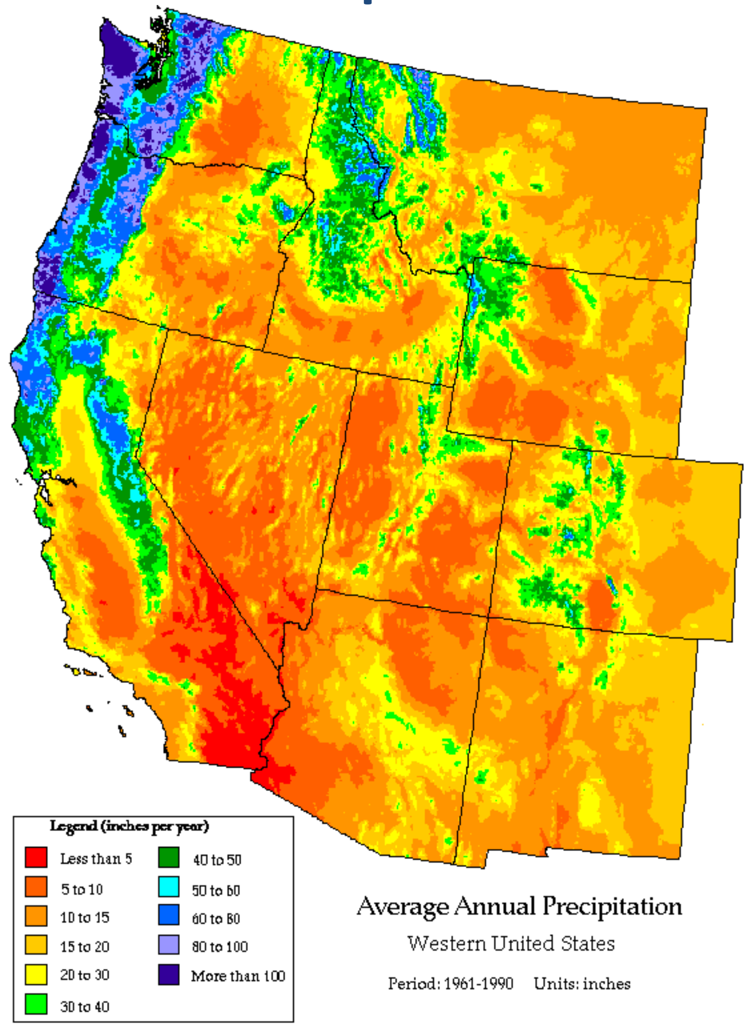
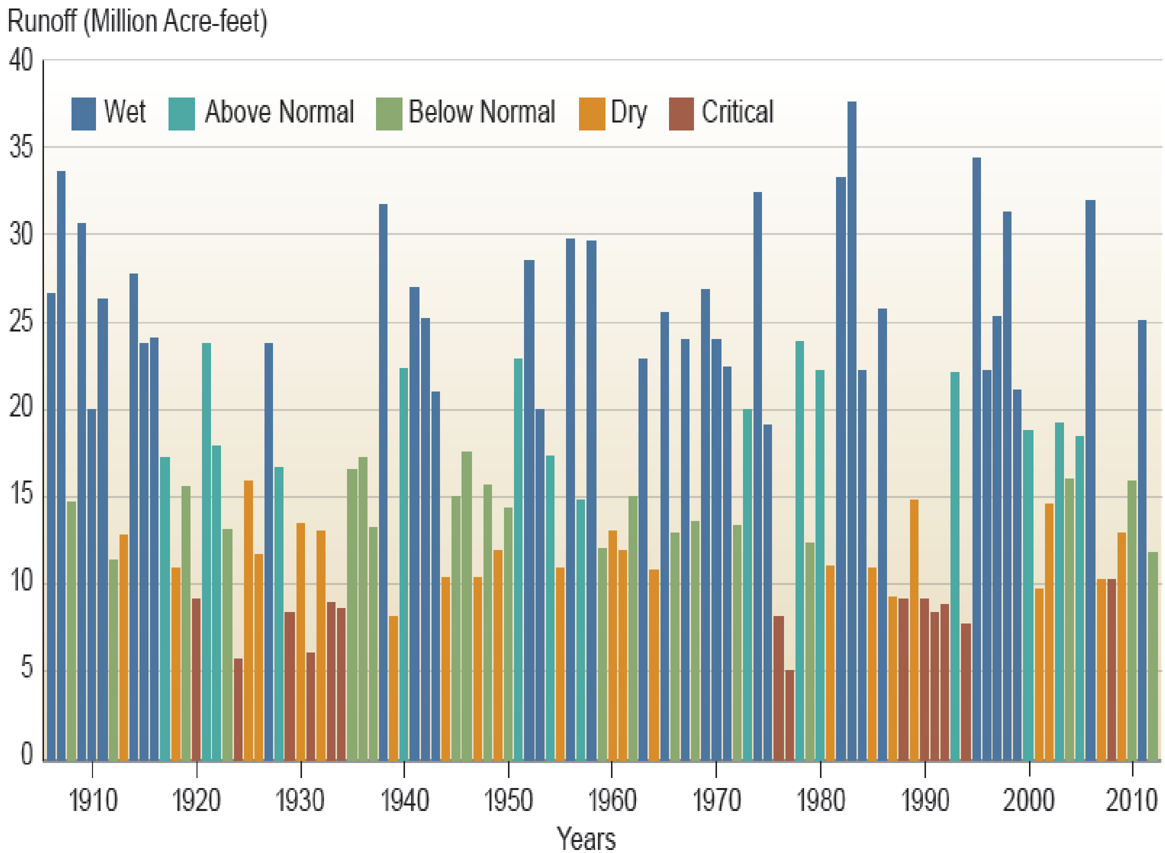


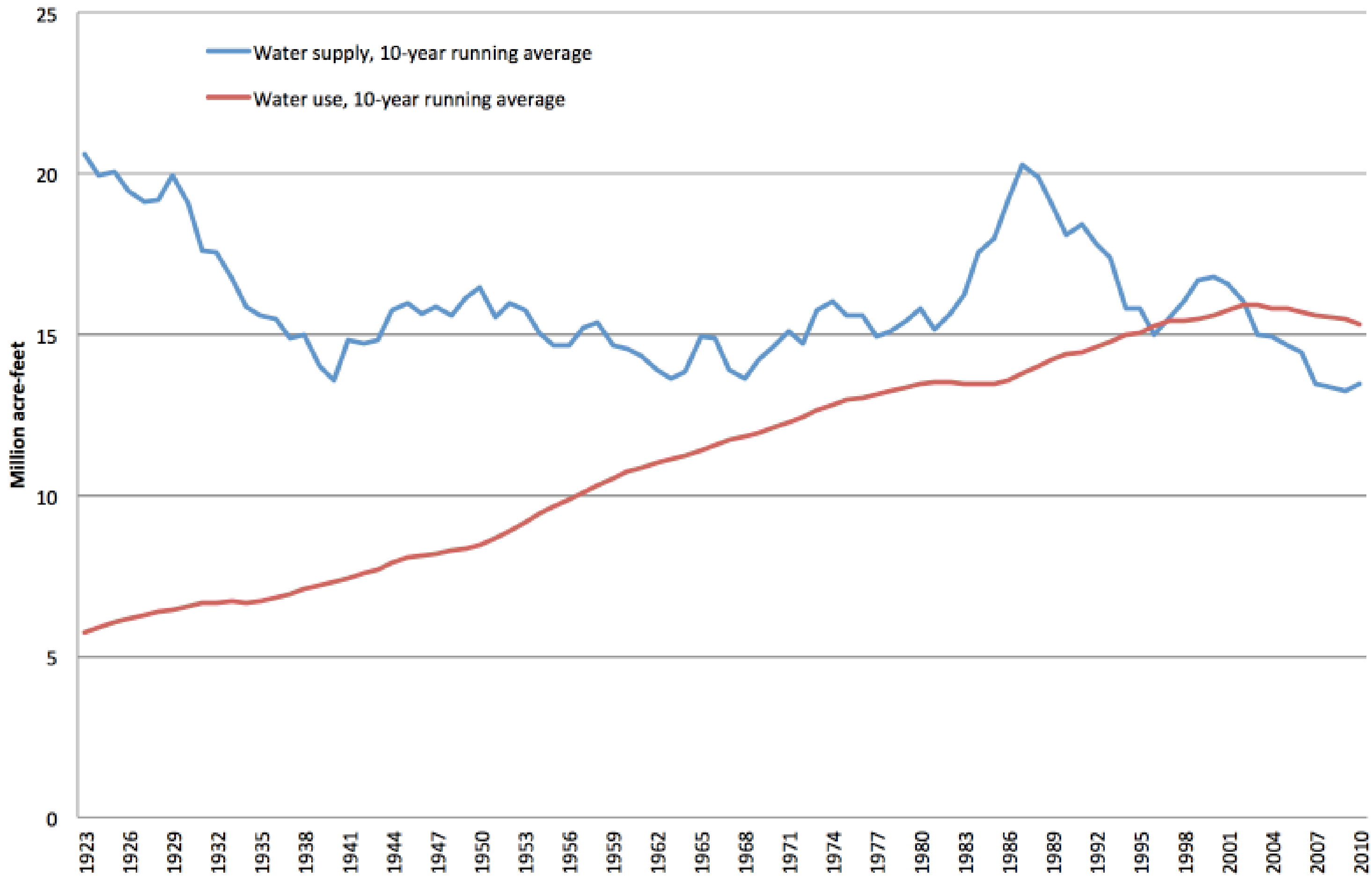
Figure 3-7 Sacramento Four Rivers Unimpaired Runoff, 1906-2012



Note: The Sacramento Four Rivers are Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Lake Oroville; Yuba River at Smartville; American River inflow to Folsom Lake.

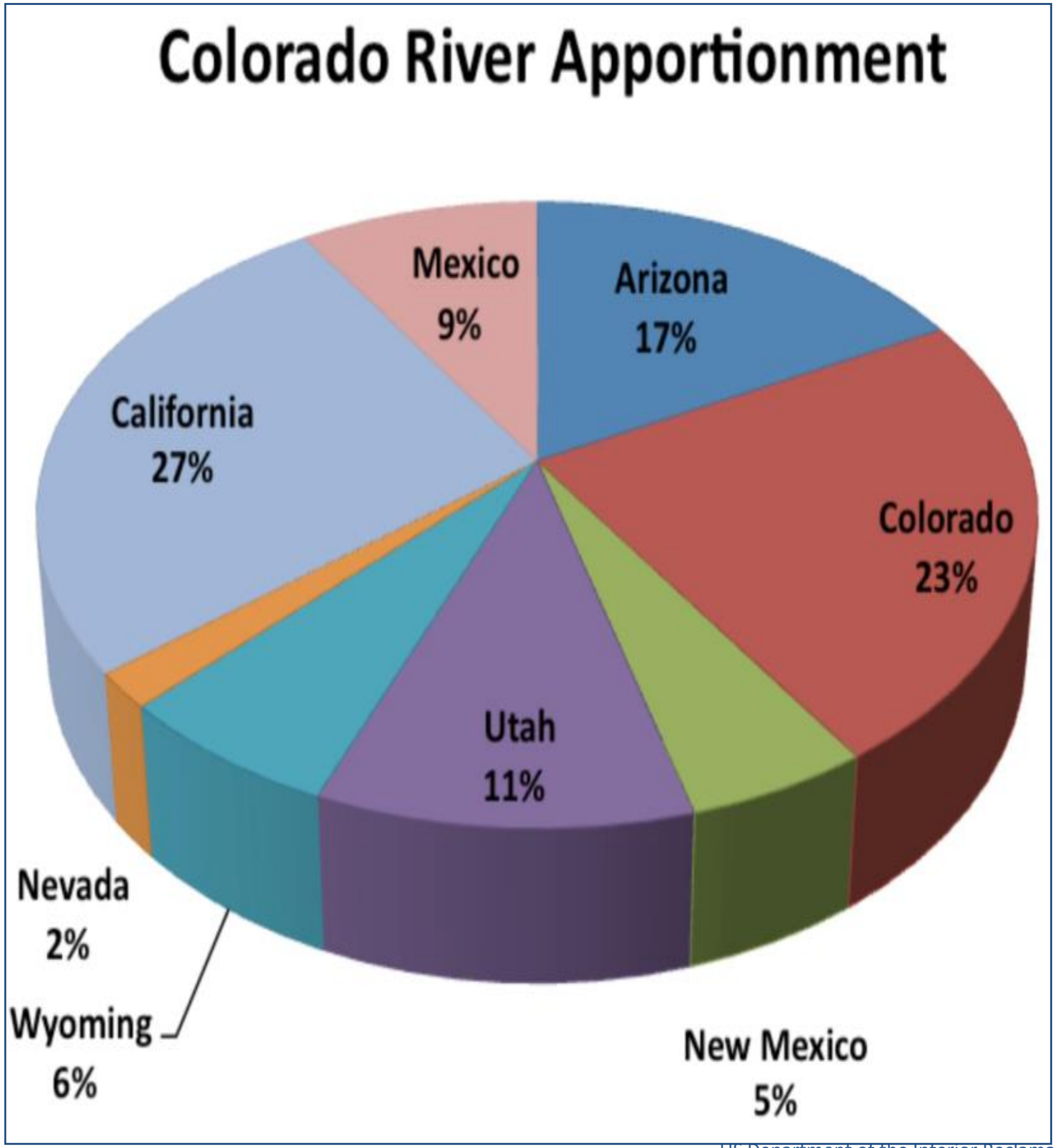
California Water Plan Update 2013

Water supply and water use in the Colorado River Basin



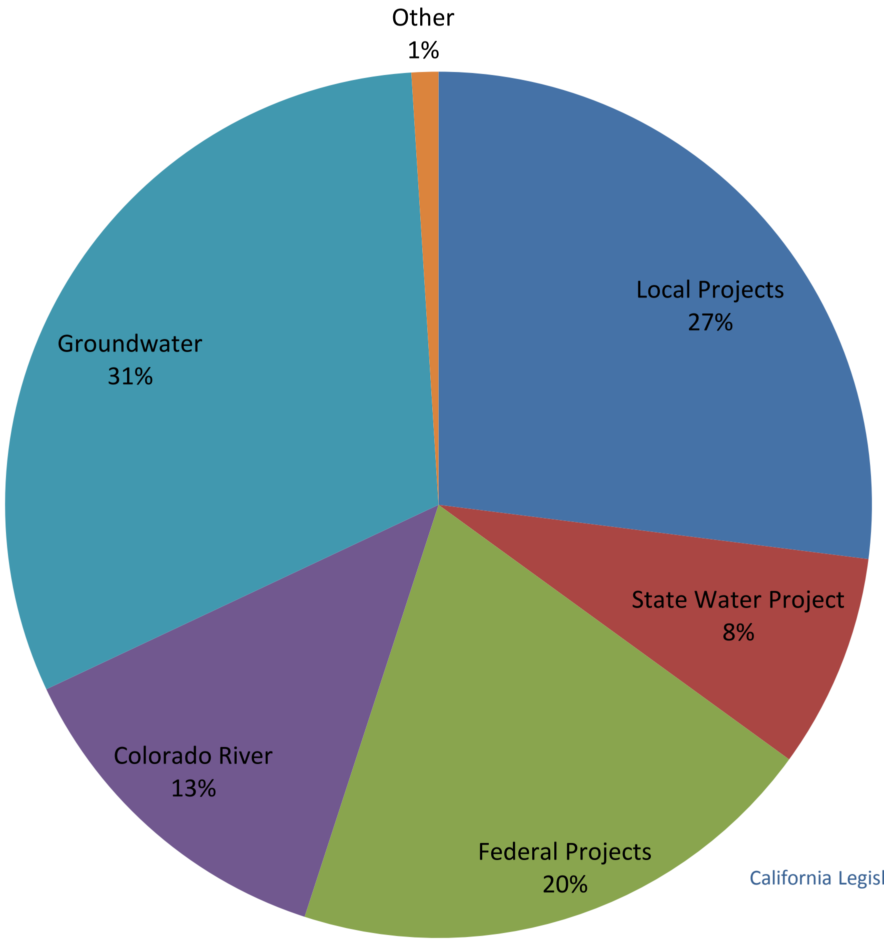
http://palm.mydesert.com/2014Projects/2014ClimateChange/WaterSupplyUse800.png

Colorado River Basin- MAP- CRBC- Chris Harris.jpg



US Department of the Interior Reclamation Bureau, 1971 - 2005

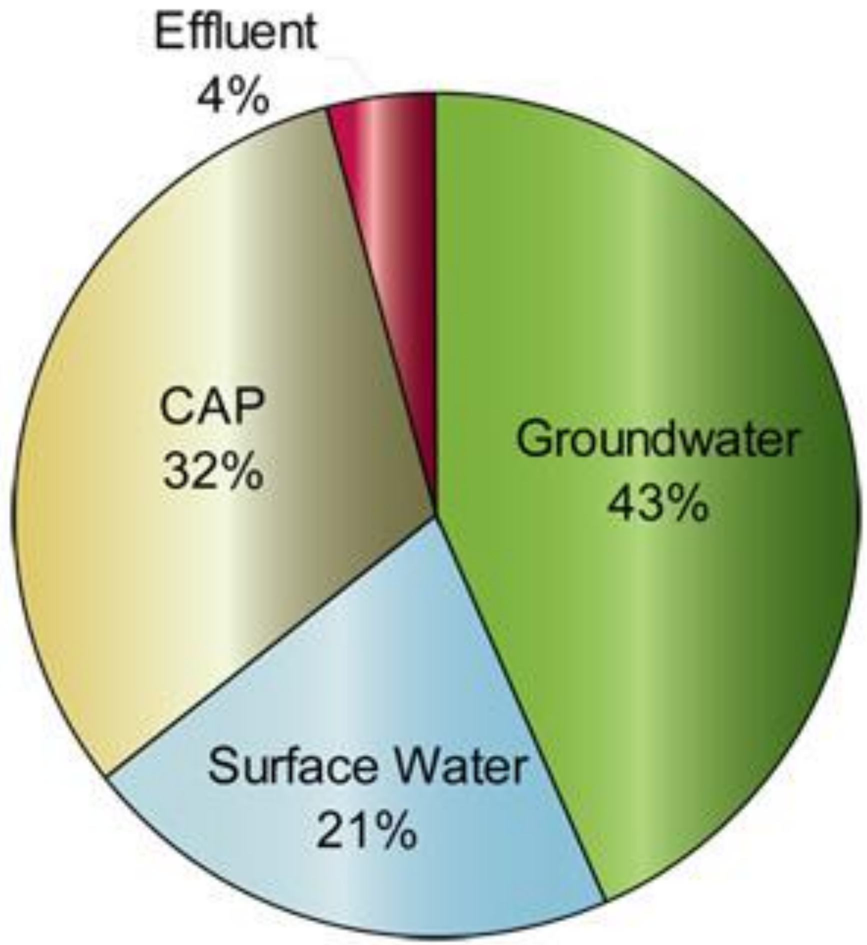
California's Water Sources



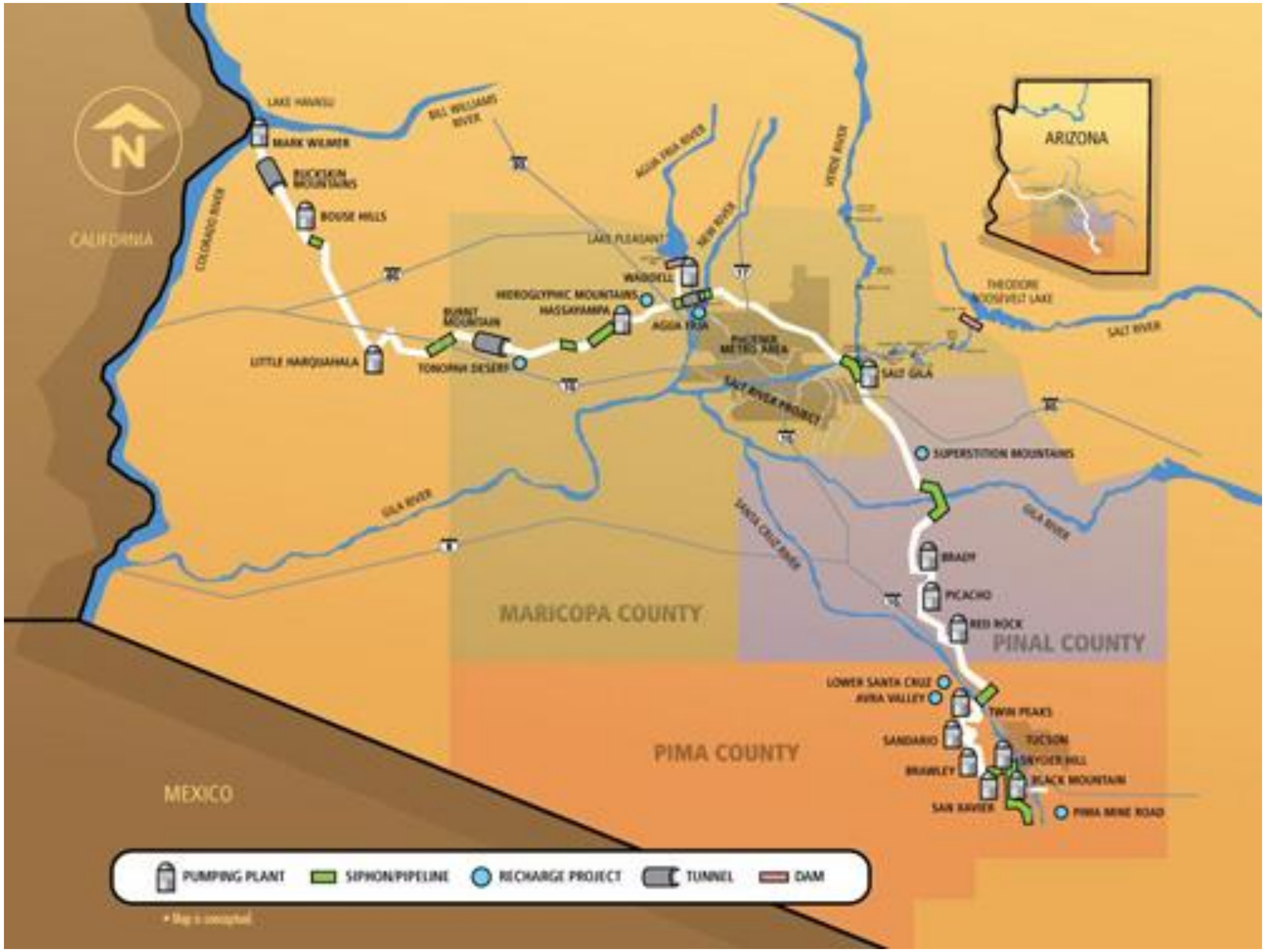
California Legislative Analyst's Office, September 8, 1999

California Water Plan Update 2013

AMA Water Supplies



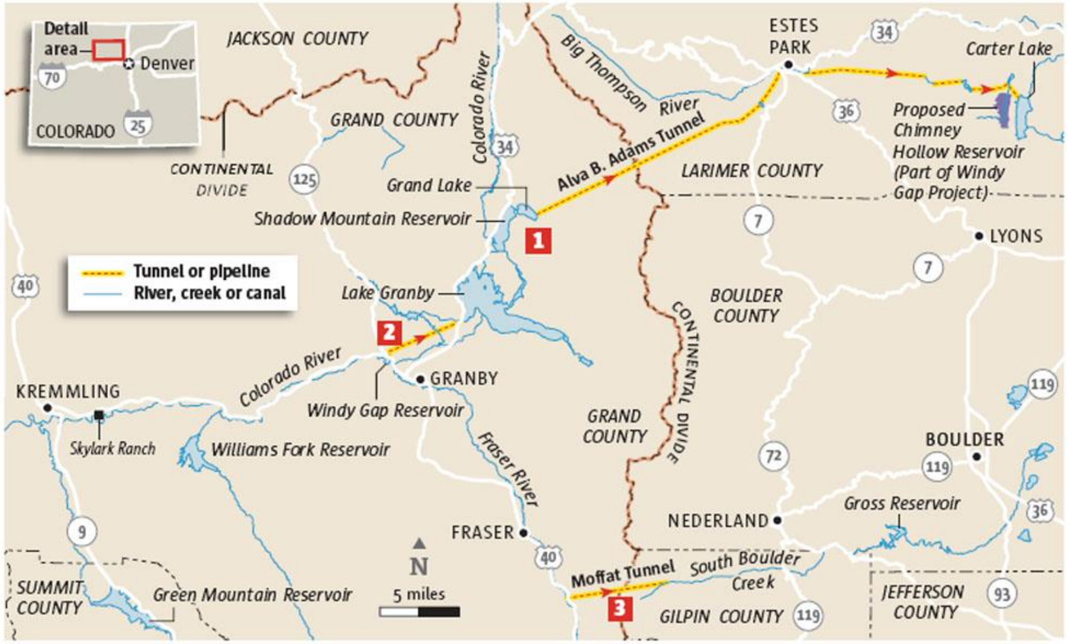
Central Arizona Project



Colorado Water Supply

Shipping water east

The Northern Colorado Water Conservancy District and Denver Water have built reservoirs, pipelines and dams in the Grand County headwaters of the Colorado River to ship water to the Front Range. About 60 percent of the water — measured at the confluence of the Fraser and Colorado rivers — is sent over the mountains to cities and suburbs. New projects by the two utilities would send another 10 percent east, according to the Northwest Colorado Council of Governments.



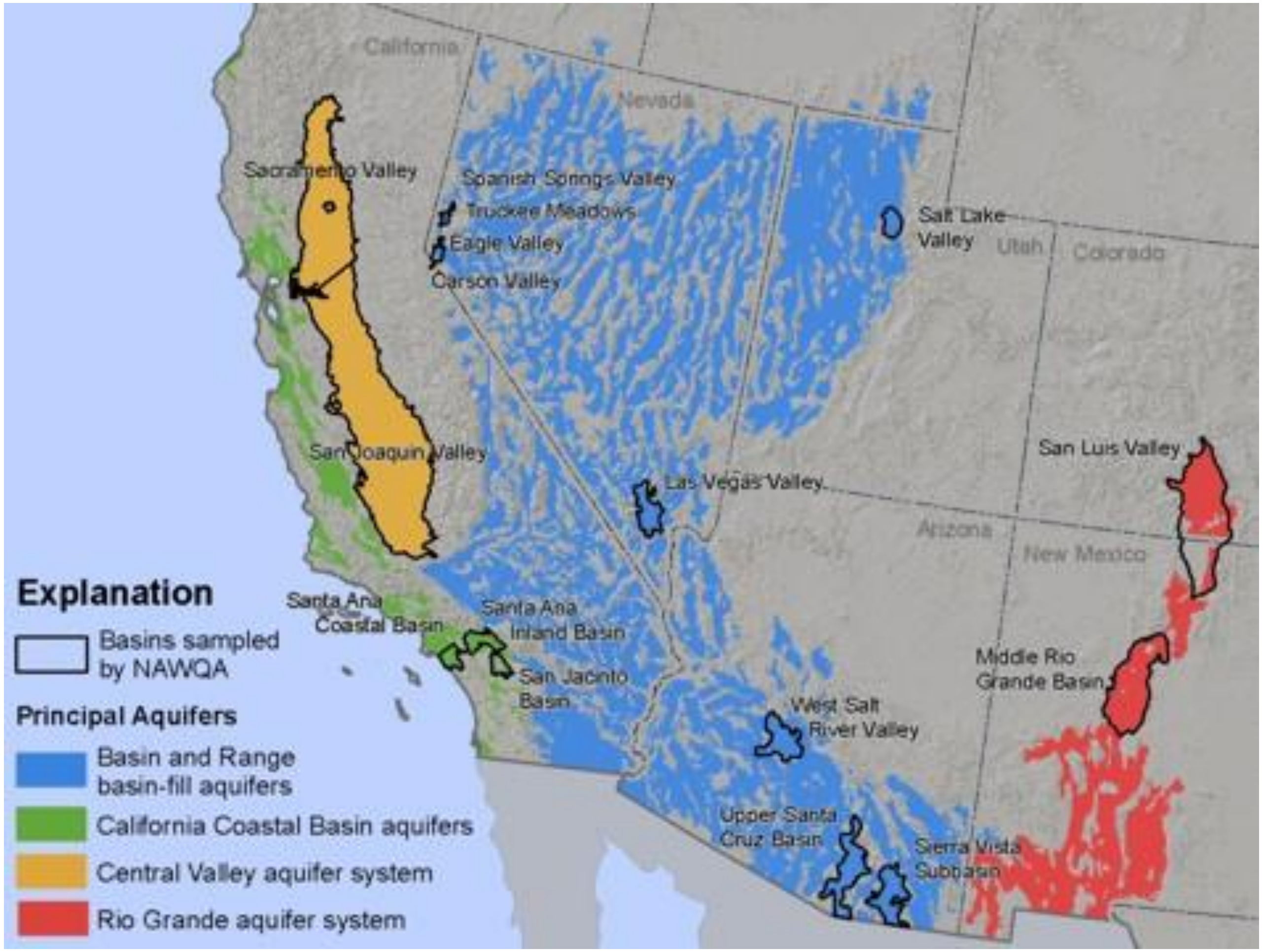
1 **The Colorado-Big Thompson Project** delivers about 213,000 acre-feet of water a year, using Lake Granby and the Alva B. Adams Tunnel, to 35 northeastern Colorado municipalities and agricultural and industrial users.

2 **The Windy Gap Project** delivers about 48,000 acre-feet annually to 13 water providers and the Platte River Power Authority between Denver and Fort Collins. The project has to ship water through the reservoirs and pipelines owned by the Colorado-Big Thompson Project when there is available capacity.

3 **The Moffat Collector System** provided 85,444 acre-feet of water to Denver Water's 1.3 million customers in 2007.

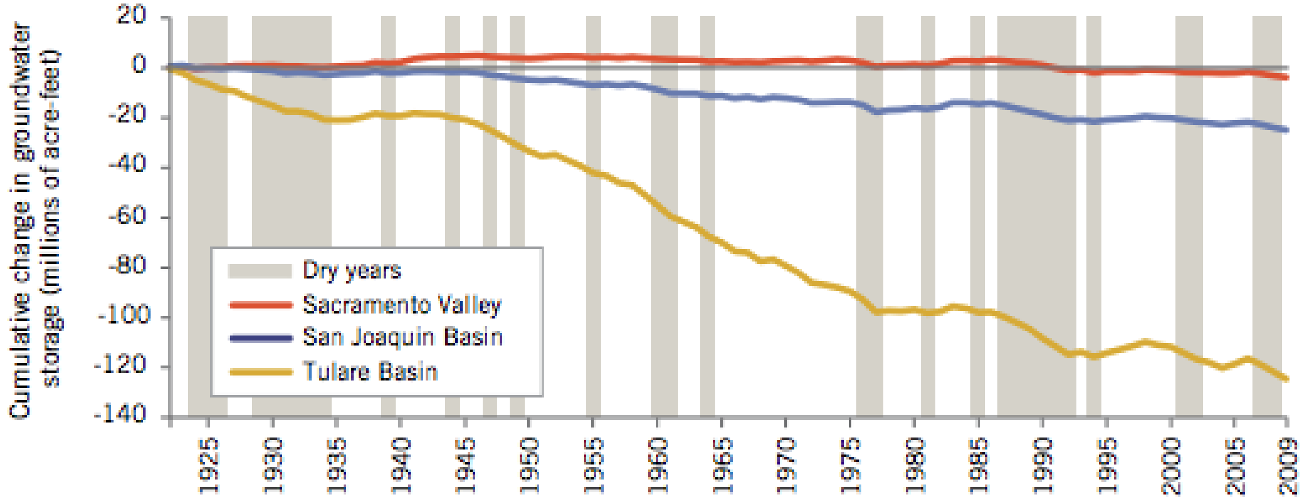
Sources: U.S. Geological Survey; Denver Water; Northern Colorado Water Conservancy District *Mark Jaffe and Thomas McKay, The Denver Post*

Groundwater Basins



Groundwater Levels

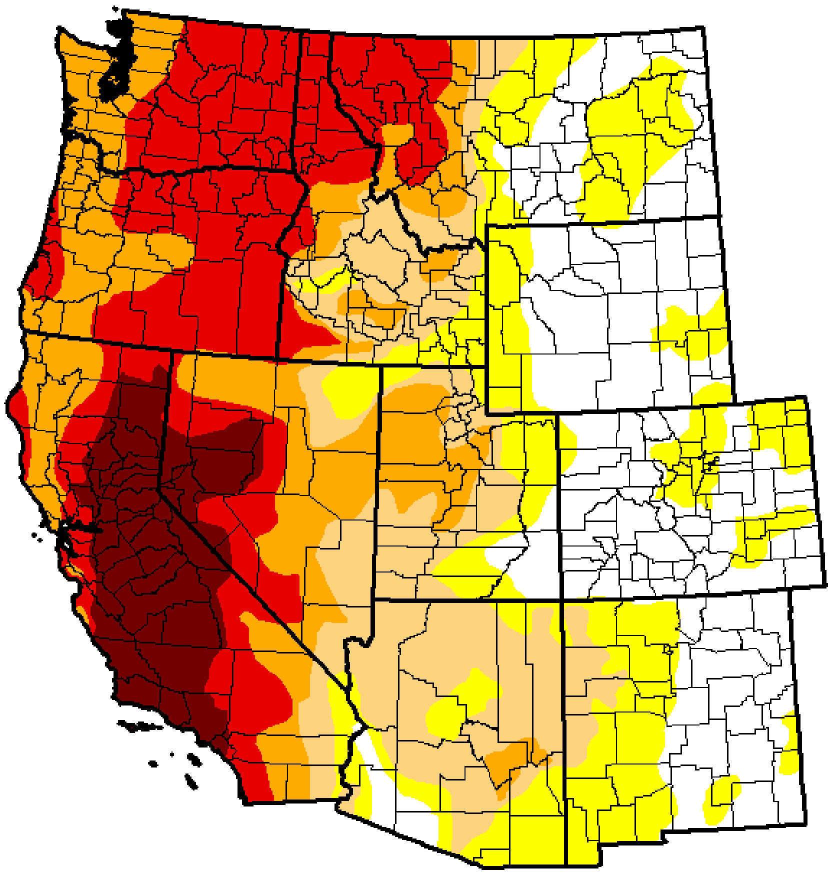
UNSUSTAINABLE GROUNDWATER PUMPING IS DEPLETING RESERVES IN THE CENTRAL VALLEY



SOURCE: The Nature Conservancy, using California Department of Water Resources data and models.

NOTES: Dry years are those classified as critical or dry in the Sacramento Valley based on the California Cooperative Snow Survey.

U.S. Drought Monitor
West



September 22, 2015
(Released Thursday, Sep. 24, 2015)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

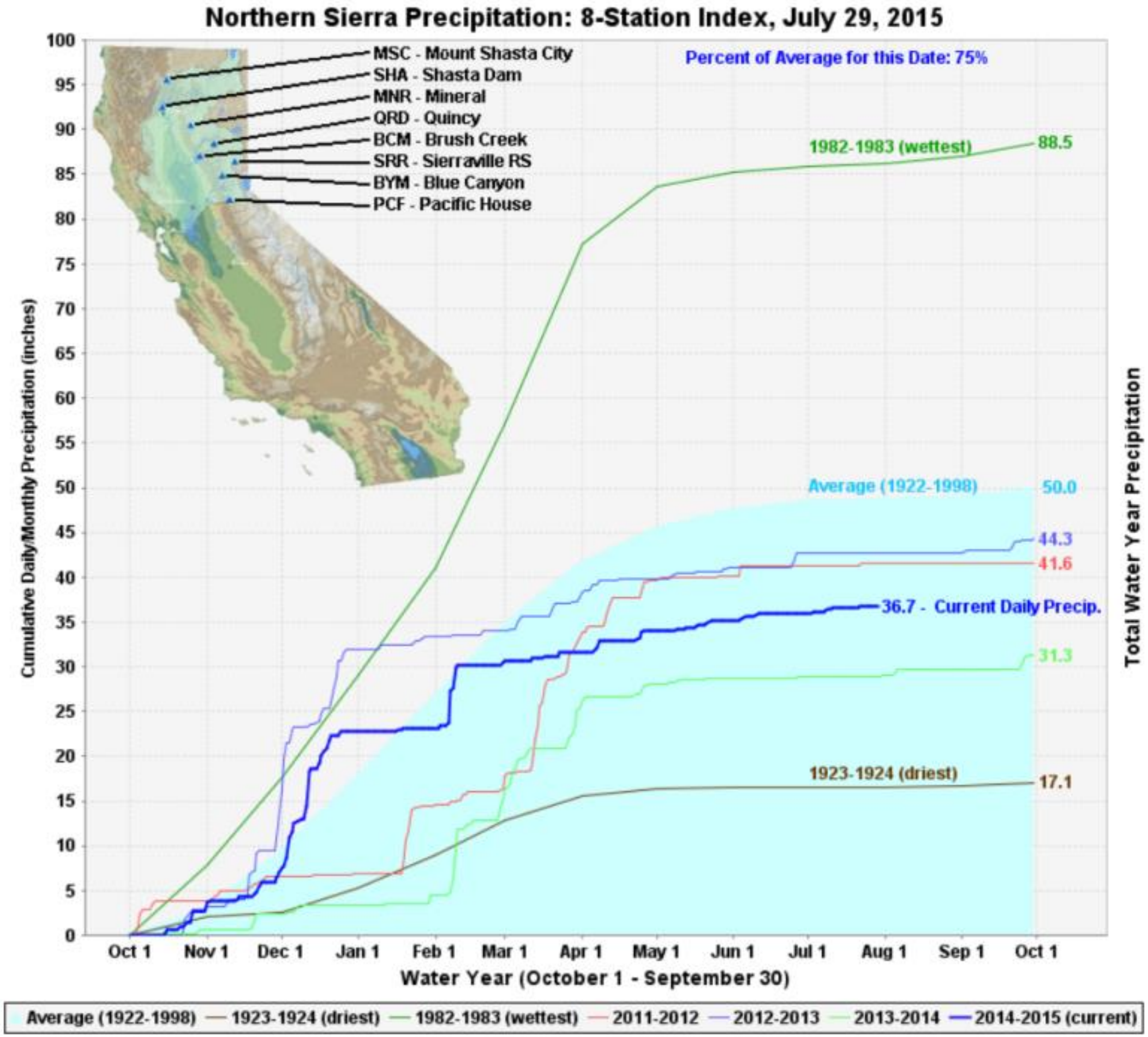
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	22.79	77.21	58.18	42.49	26.73	7.62
Last Week 9/15/2015	24.68	75.32	59.66	42.69	26.73	7.62
3 Months Ago 6/23/2015	23.93	76.07	57.86	35.88	17.13	7.26
Start of Calendar Year 12/30/2014	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year 9/30/2014	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 9/23/2014	31.18	68.82	56.42	35.96	20.00	8.90

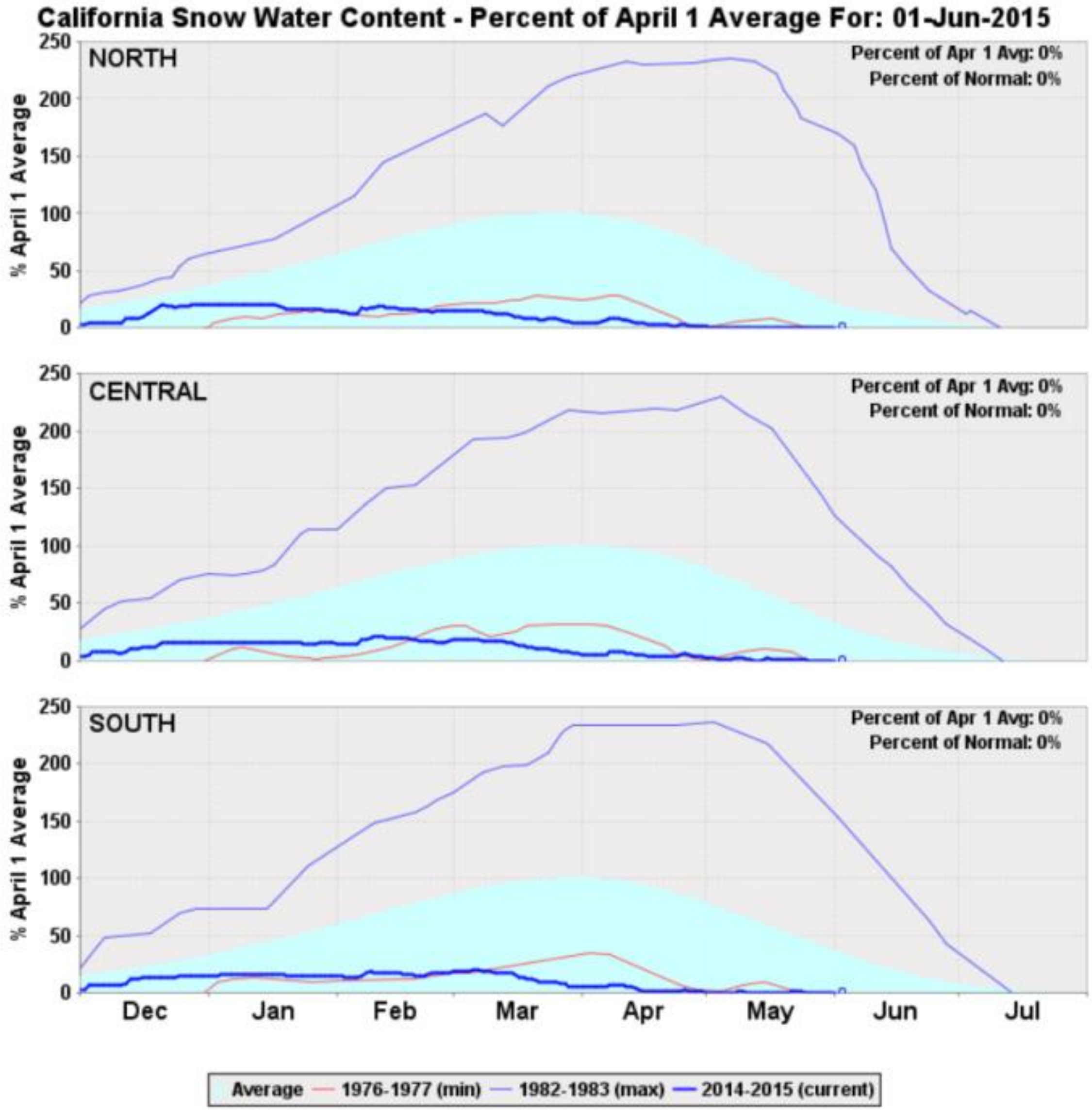
Intensity:
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

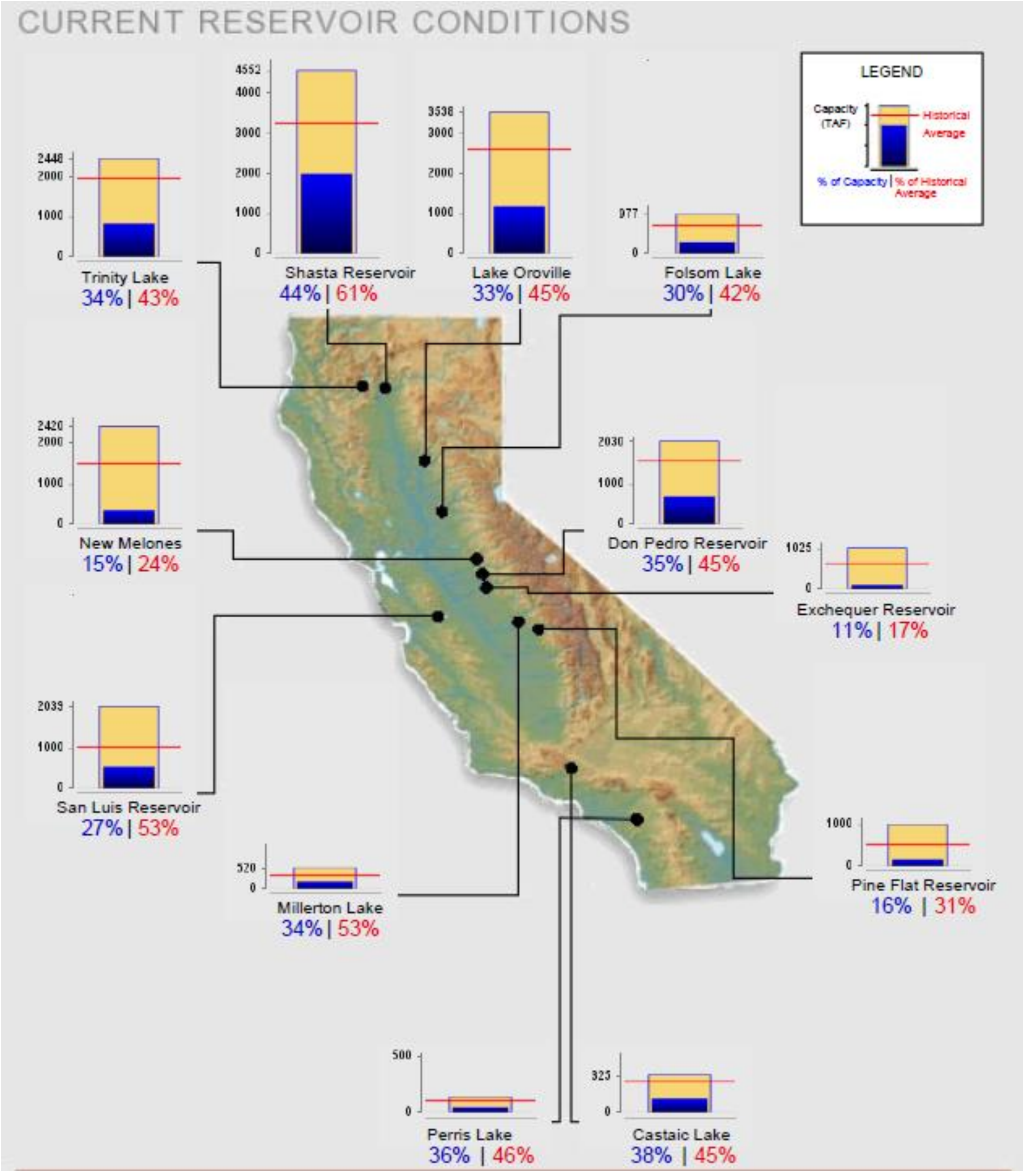
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Eric Luebehusen
U.S. Department of Agriculture

http://droughtmonitor.unl.edu/


Northern Sierra Precipitation: 8-Station Index, July 29, 2015
Percent of Average for this Date: 75%
MSC - Mount Shasta City
SHA - Shasta Dam
MNR - Mineral
QRD - Quincy
BCM - Brush Creek
SRR - Sierraville RS
BYM - Blue Canyon
PCF - Pacific House
1982-1983 (wettest)
88.5
Average (1922-1998)
50.0
44.3
41.6
36.7 - Current Daily Precip.
31.3
1923-1924 (driest)
17.1
Cumulative Daily/Monthly Precipitation (inches)
Total Water Year Precipitation
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Water Year (October 1 - September 30)
Average (1922-1998)
1923-1924 (driest)
1982-1983 (wettest)
2011-2012
2012-2013
2013-2014
2014-2015 (current)


California Snow Water Content - Percent of April 1 Average For: 01-Jun-2015
NORTH
CENTRAL
SOUTH
Percent of Apr 1 Avg: 0%
Percent of Normal: 0%
% April 1 Average
0
50
100
150
200
250
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Average
1976-1977 (min)
1982-1983 (max)
2014-2015 (current)


CURRENT RESERVOIR CONDITIONS
LEGEND
Capacity (TAF)
Historical Average
% of Capacity | % of Historical Average
Trinity Lake
34% | 43%
Shasta Reservoir
44% | 61%
Lake Oroville
33% | 45%
Folsom Lake
30% | 42%
New Melones
15% | 24%
Don Pedro Reservoir
35% | 45%
Exchequer Reservoir
11% | 17%
San Luis Reservoir
27% | 53%
Millerton Lake
34% | 53%
Pine Flat Reservoir
16% | 31%
Perris Lake
36% | 46%
Castaic Lake
38% | 45%

Severity of California Drought

- Worst 4 consecutive years in 1,200 years
- Worst snowpack in 500 years
- Over 2,000 wells gone dry
- Severe areas of subsidence

Drought Impacts

- Fallow crop land
- Import feed for livestock and dairy
- Cull herds
- Increase wildfire
- Impact ecosystem health
- Impact ecosystem restoration efforts
- Residential and urban water conservation

2014 Impact to California
$2.2 billion Statewide Impact
17,100 Lost Jobs 500,000 Fallowed Acres

Land-Grant University Response to Drought

- Drought not new to the West
- 135+ years of research and outreach
  - Irrigation efficiency/management
  - Crop Breeding/Health
  - Rangeland management
  - Managed Aquifer Recharge
  - Recycling/reuse
  - Desalination
  - Master Gardener
  - Stormwater capture and recharge
  - Real-time monitoring stream and snowpack

Current Drought Resources

Web: ucanr.edu/drought for up-to-date resources

Twitter: @ucanrwater for daily updates

Thank You

Web: ucanr.edu/drought Twitter: @ucanrwater

Climate * Water

Lois Wright Morton
Professor Sociology, Iowa State University
Director USDA-NIFA Climate & Corn-based Cropping System
Coordinated Agricultural Project (CAP)

2015 September 30th Water Security: Quality, Quantity, and Policy
Association of Public & Land Grant Universities,
Experiment Station and Research Directors Annual Meeting

This research is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190:
Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems
Project Web site: sustainablecorn.org

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

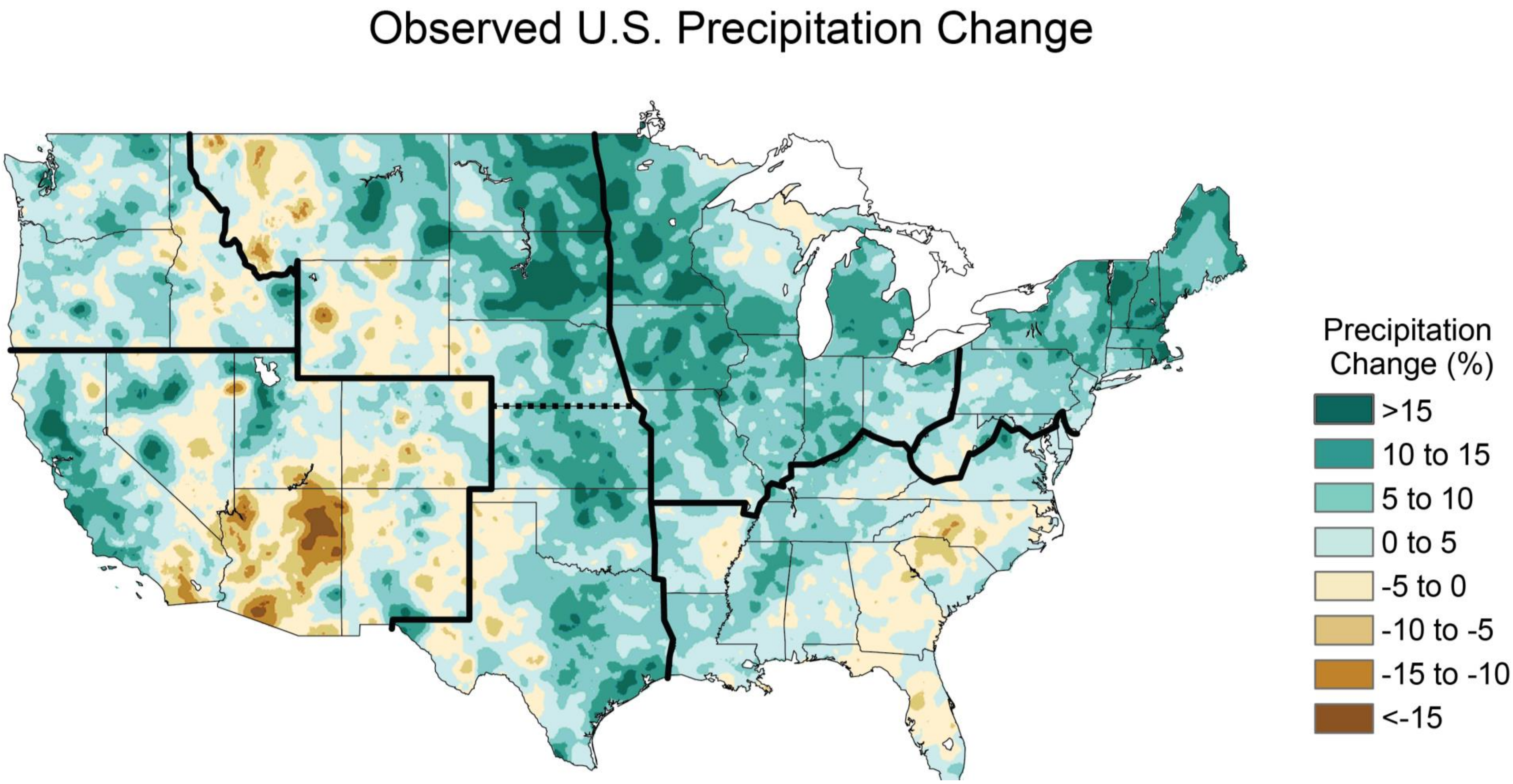
SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

Water is the visible impact of extreme and variable climate conditions






Geography matters

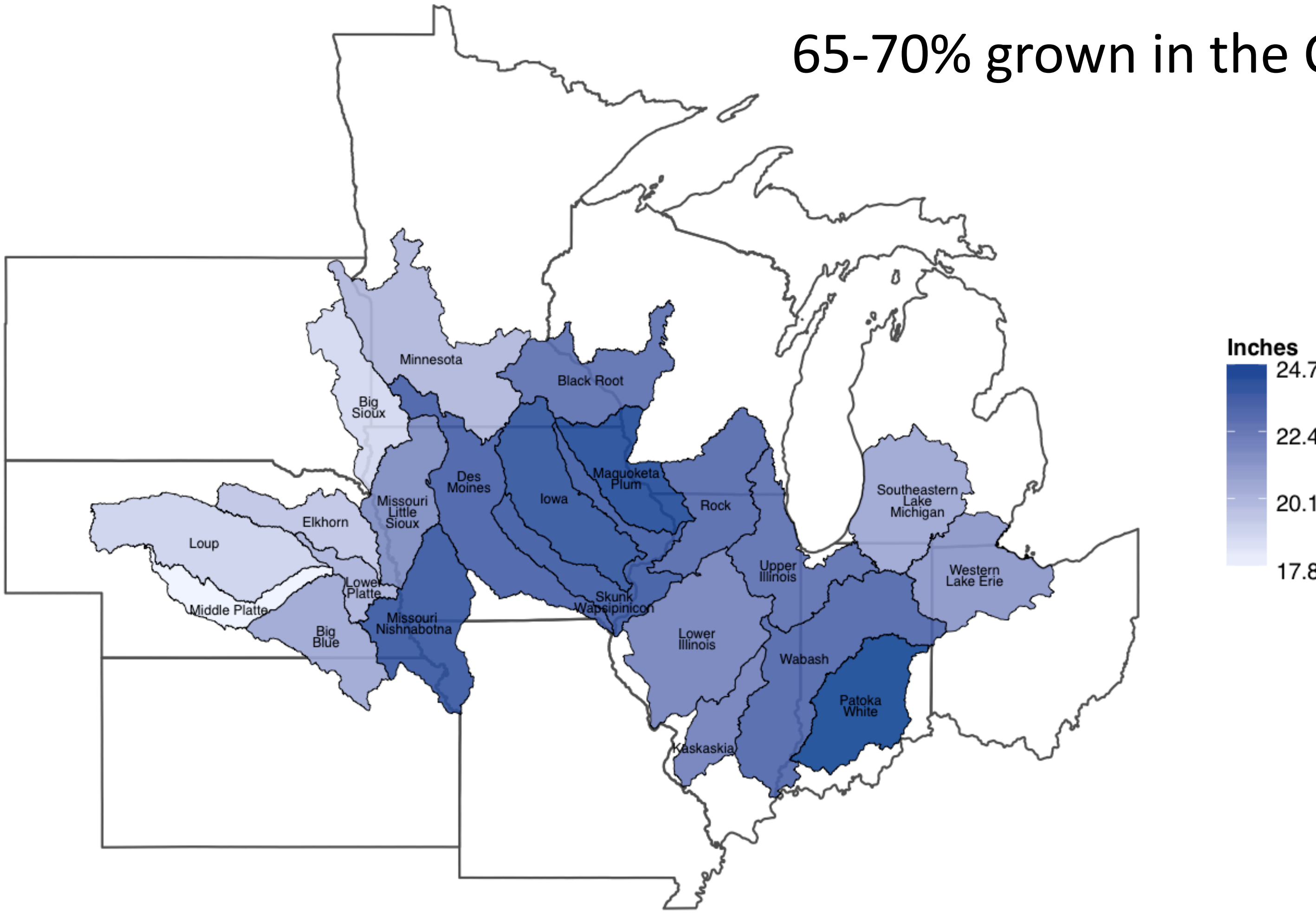


Annual total precipitation changes for 1991 to 2012 compared to 1901 to 1960
(Third US Climate Assessment report, Melillo et al. 2014)

~400,000 US farms grow corn; ¼ of all harvested crop acres

~$80 billion commodity   US world leader in production

65-70% grown in the Corn belt



Corn belt median seasonal precipitation (April 1-Sept 30 1971-2011)

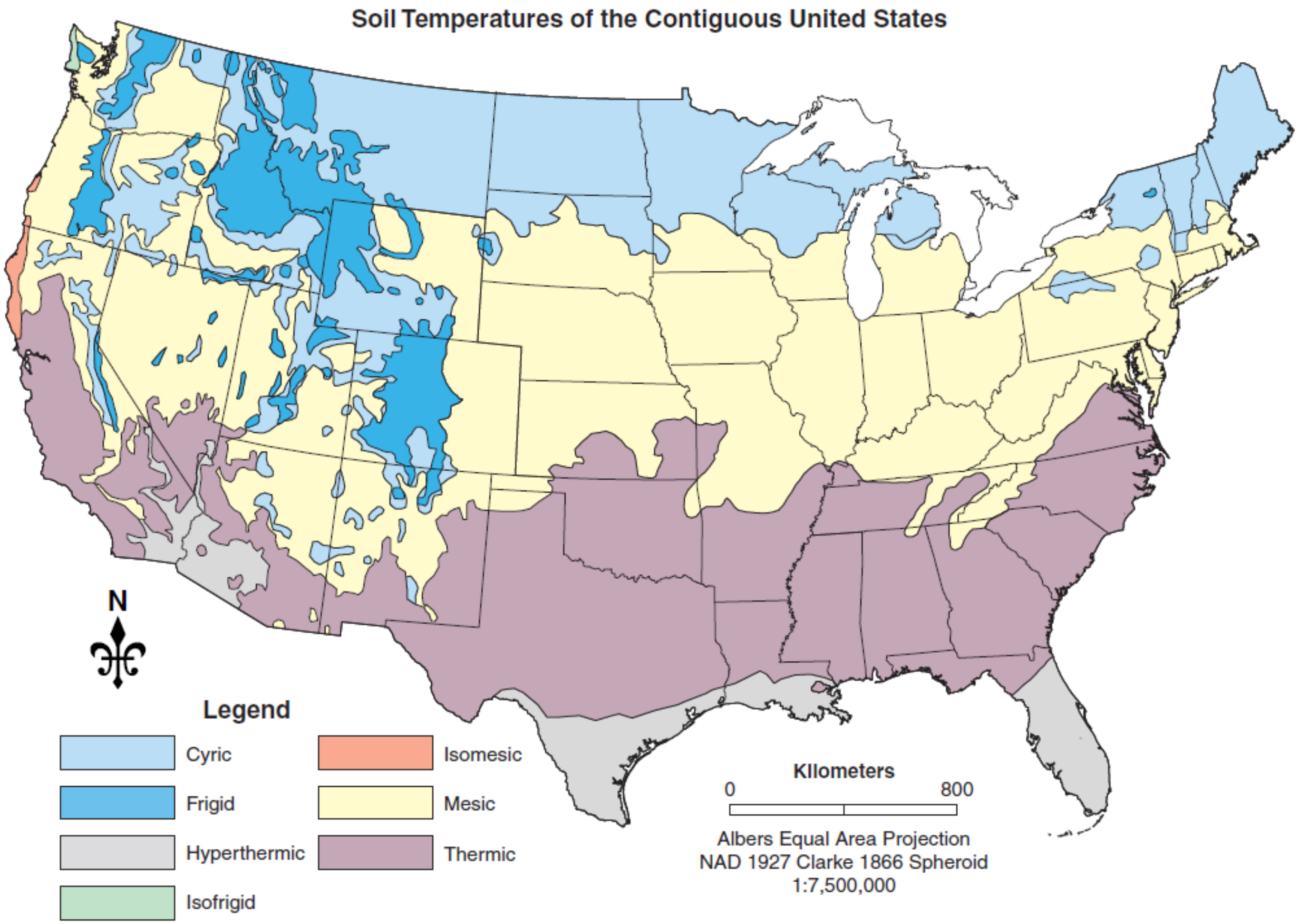
USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Agriculture & Weather Variability in the Corn belt: A Survey of Corn belt Farmers Statistical Atlas 2013
Arbuckle, Loy, Hobbs, Wright Morton, Tyndall

SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

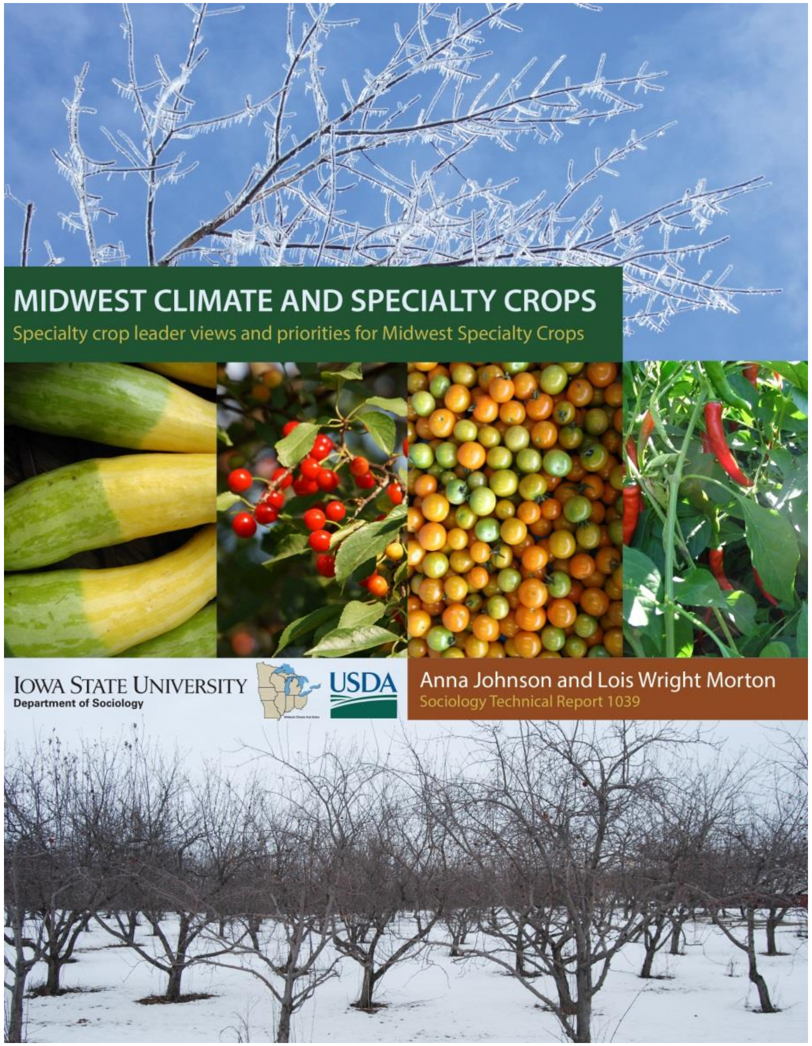
Water * temperature interactions affect cropping systems

shifts in the US mesic-frigid boundary



The science of variable climate and agroecosystem management 2014. L.W. Morton
Journal Soil & Water Conservation 696:207A-212A

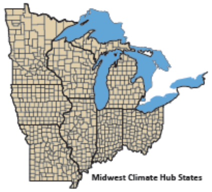
Midwest Climate and Specialty Crops:
Specialty crop leader views and priorities for Midwest specialty crops (2014)



Midwest Climate Hub
Priority areas for specialty crops

1. Pest and disease
2. Marketing and risk
3. **Water**
4. **Climate and weather**
5. Farming as a livelihood
6. Labor
7. Changes in operations
8. Changing opportunities & vulnerabilities
9. Production-consumer-research nexus

USDA



This research, North Central Fruit, Vegetable and Wine Growers' Assessment of Soil and Water Vulnerability Under Changing Climate Conditions and Extreme Weather Events funded by USDA-Agricultural Research Service (ARS) Midwest Climate Hub.

Johnson, A. and L.W. Morton 2015. Midwest Climate & Specialty Crops. Midwest Climate Hub Sociology Technical Report 1039. Iowa State University Ames, IA

Some of the underlying issues associated with climate, water and agriculture

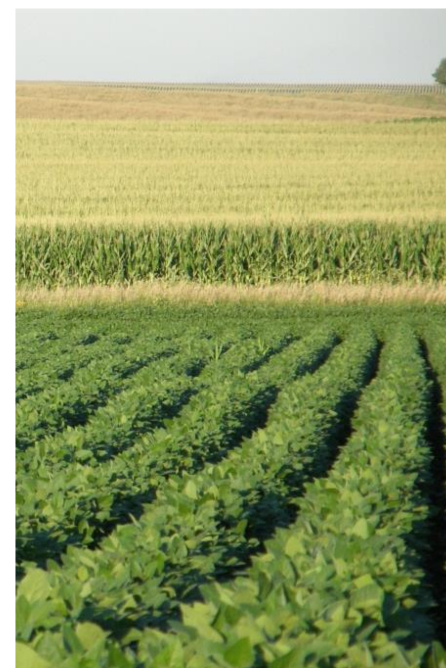
*How much change can specific cropping systems absorb and still retain core functions: productivity, profitability &ecosystem integrity?

*What are the characteristics of specific cropping systems that offer increased capacity to adapt to changing and variable climates?

*What characteristics reduce and limit capacity to adapt and mitigate water challenges under increasingly variable and unpredictable climatic conditions?

Land Grant University science is critical
if we are to build a knowledge base,
effectively address water*climate issues and
develop strategies and capacities that
help our stakeholders adapt to risk and
uncertainties associated with continual change



Key Challenges

1. Fragmentation in how we engage water science

2. Regional exchange & learning

3. AES directors are key investors

4. US water resource science needs cohesive leadership and partners

1. Fragmentation in how we engage water science

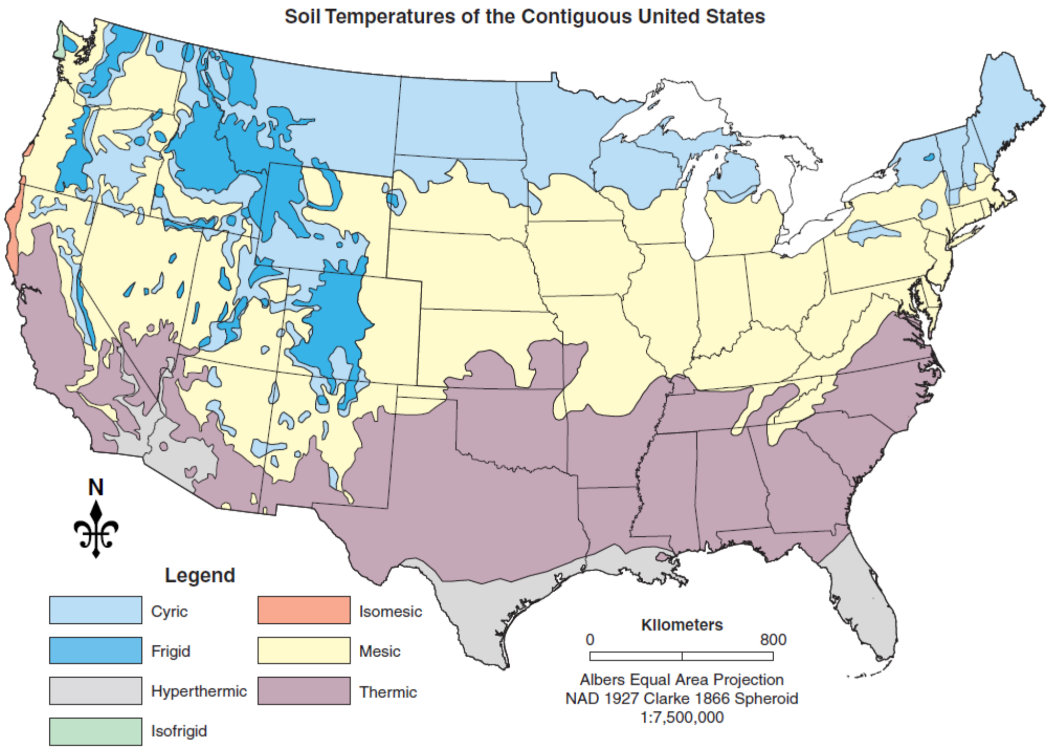
The water cycle has no social, geo-political boundaries

Ecosystems and agriculture are intimately connected

Coupled human-natural systems

2. Regional exchange & learning

What one region has learned could be critical science for another entering/experiencing drought or flooding/excess water



shifts in the US mesic-frigid boundary

3. AES & research directors are key investors

…able to construct collaborative partnerships to leverage and expand scarce financial, institutional and human resources across geography

1) Coupled human-natural systems research
2) Long term observational experiments
3) Shared data for synthesis and integration

4.US water resource science needs cohesive leadership and partners

Plan to guide
priority investments
in US water resources

Multi-pronged agenda for sustainable agricultural systems research

1. Institutional infrastructure; shared data bases
2. Field & landscape level trials across geography & crops (innovation & standardized protocols)
3. Sociology and economics (primary & secondary data)
4. Synthesis and integration of data; modeling climate, water, and humans (coupled human-natural systems)
5. Purposeful feedback loops among scientists, farmers, industry, policy-makers, & non-governmental organizations

a microcosm of what is possible among Land Grant Universities

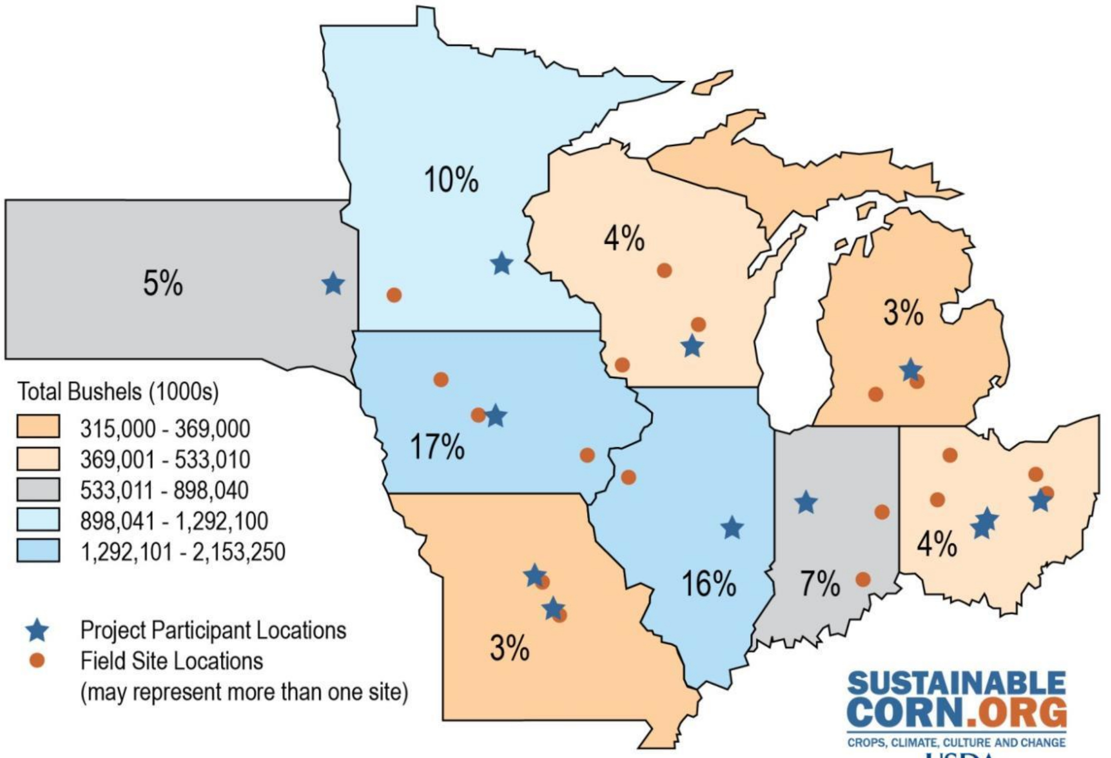
Climate Change, Mitigation & Adaptation in Corn-based Cropping Systems Coordinated Agricultural Project (CAP)

36 research sites, field experiments
14 sites, GHG measurements

9 Upper Midwest states
10 Land Grant Universities
USDA-ARS
~140 faculty, graduate students, post docs, & technical staff

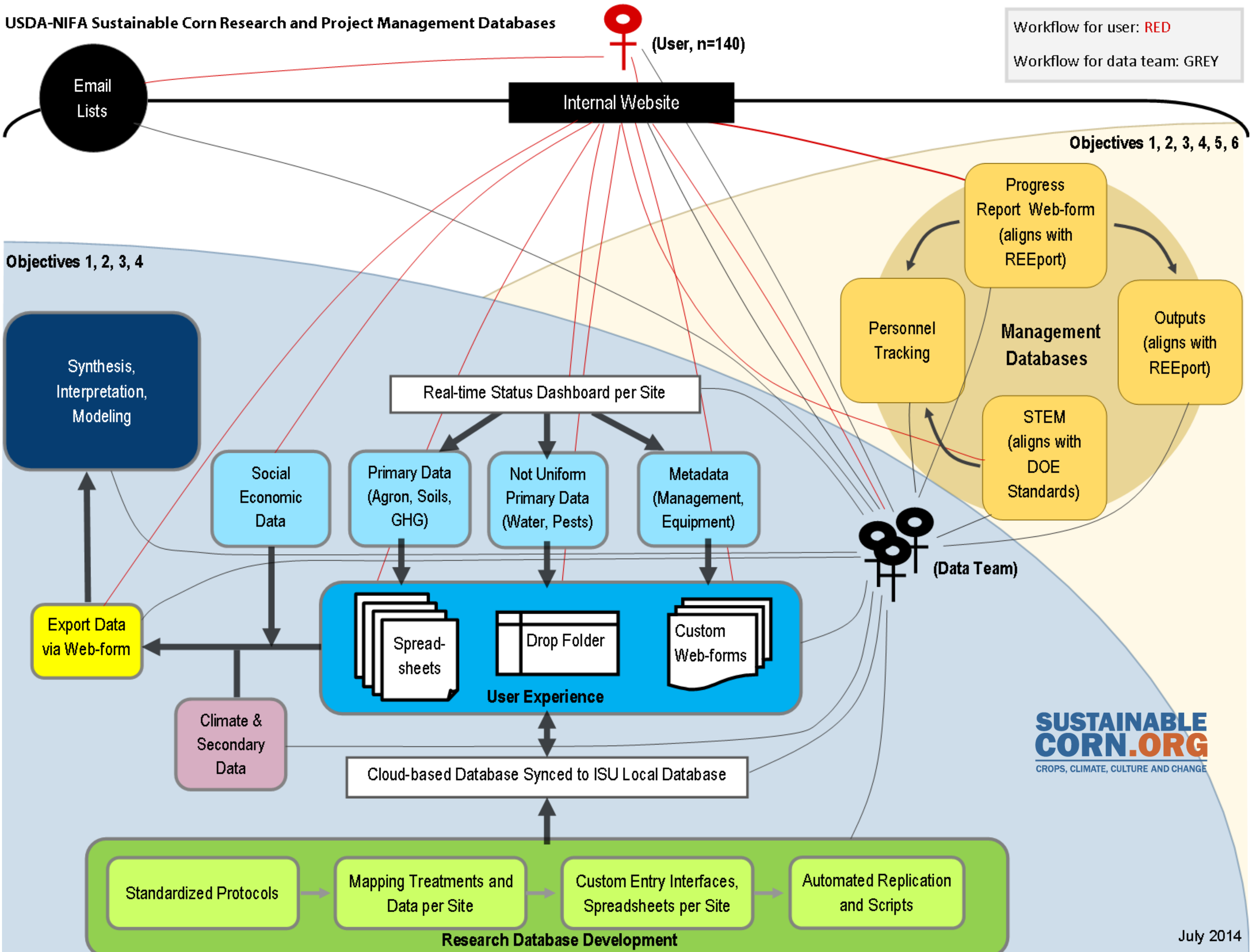
~200 farmers
Advisory board of industry, NGO, agencies, farmers & educators

Project Participants and Field Sites
and 2010 Percent of U.S. Total Grain Harvest



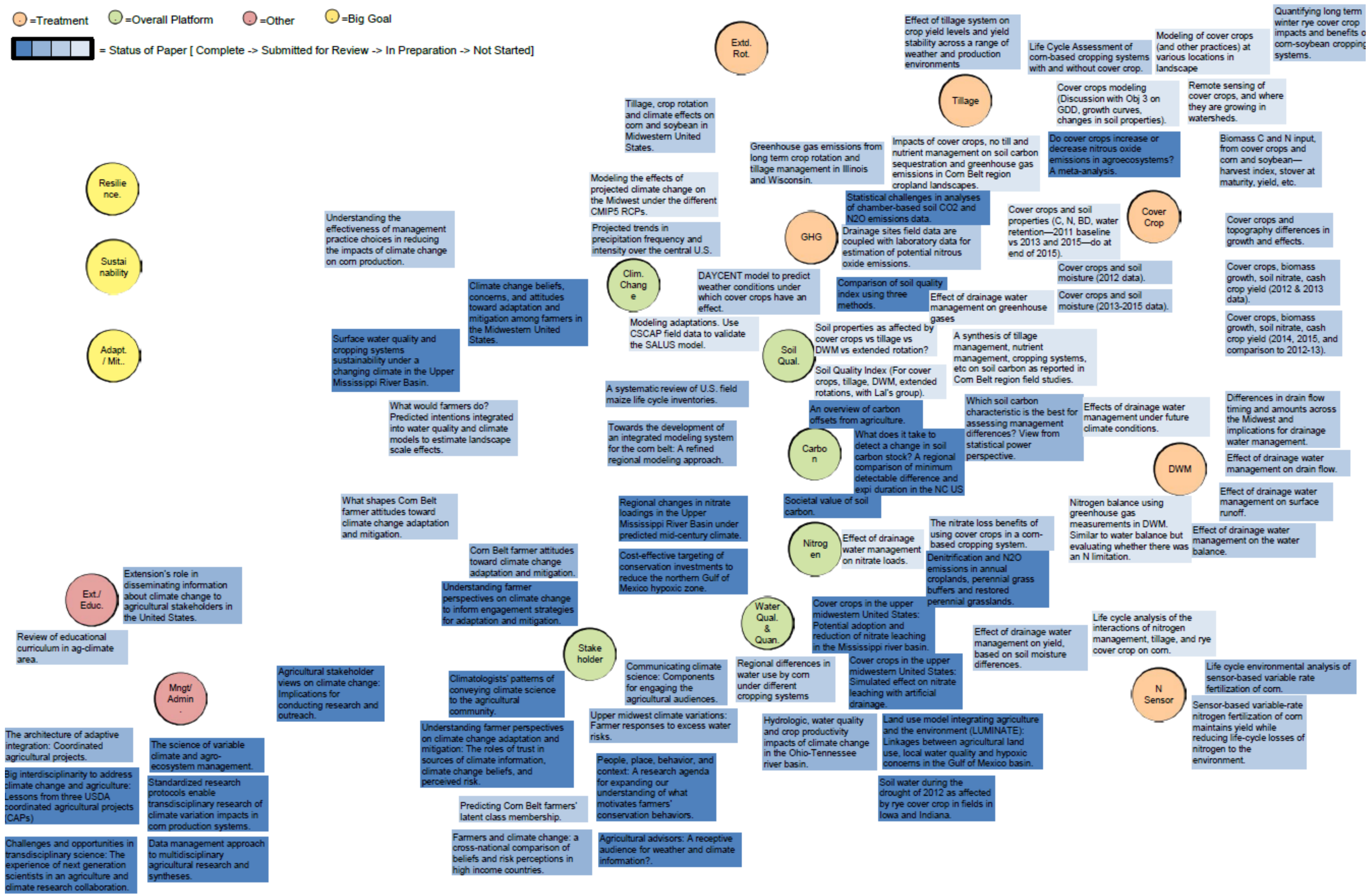
SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE
USDA
United States Department of Agriculture
National Institute of Food and Agriculture

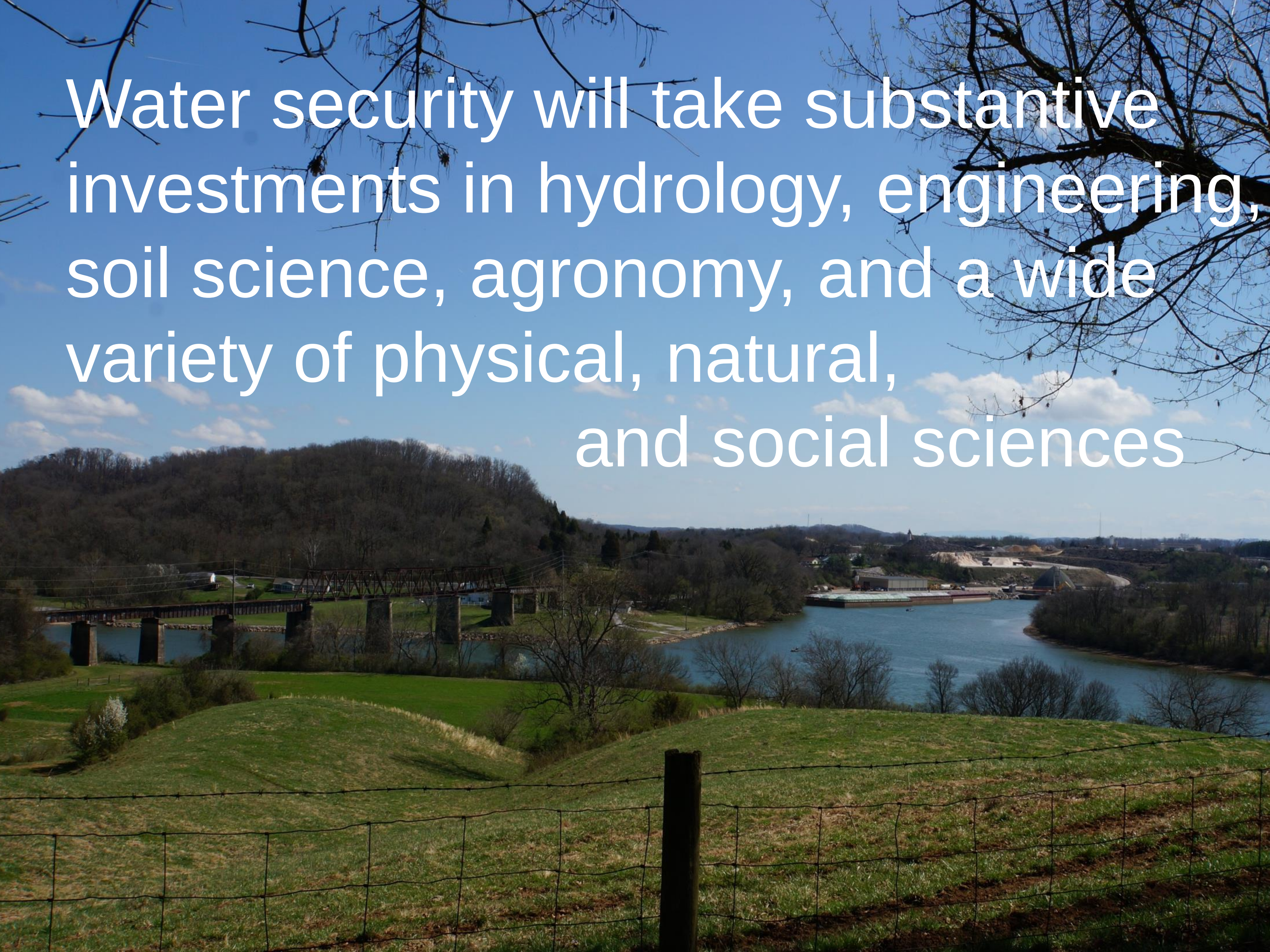
The 11 institutions comprising the project team include the following Land Grant Universities and USDA Agricultural Research Service (ARS): Iowa State University, Lincoln University, Michigan State University, The Ohio State University, Purdue University, South Dakota State University, University of Illinois, University of Minnesota, University of Missouri, University of Wisconsin, and USDA-ARS Columbus, Ohio.


USDA-NIFA Sustainable Corn Research and Project Management Databases
(User, n=140)
Workflow for user: RED
Workflow for data team: GREY
Email Lists
Internal Website
Objectives 1, 2, 3, 4, 5, 6
Progress Report Web-form (aligns with REEport)
Personnel Tracking
Management Databases
Outputs (aligns with REEport)
STEM (aligns with DOE Standards)
Objectives 1, 2, 3, 4
Synthesis, Interpretation, Modeling
Real-time Status Dashboard per Site
Social Economic Data
Primary Data (Agron, Soils, GHG)
Not Uniform Primary Data (Water, Pests)
Metadata (Management, Equipment)
(Data Team)
Export Data via Web-form
Spread-sheets
Drop Folder
Custom Web-forms
User Experience
Climate & Secondary Data
Cloud-based Database Synced to ISU Local Database
SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE
Standardized Protocols
Mapping Treatments and Data per Site
Custom Entry Interfaces, Spreadsheets per Site
Automated Replication and Scripts
Research Database Development
July 2014

Synthesis & integration of sciences

203 papers; 82 are integrative in nature




Water security will take substantive investments in hydrology, engineering, soil science, agronomy, and a wide variety of physical, natural,
and social sciences

USDA's Plant Breeding Roadmap

Presented to ESS/AES/ARD
Sept 2015

USDA Office of the Chief Scientist

Ann Marie Thro, Sr. Advisor

Plant Health, Production, and Plant Products

7/29/2015

USDA

United States Department of Agriculture
Office of the Chief Scientist

Background:
USDA's Office of the Chief Scientist, **OCS**

2008 'farm bill': USDA Chief Scientist,
Under Secr'y for Research, Education, & Economics (REE)
presently Dr. Catherine Woteki

OCS: Supports and advises Chief Scientist and Secretary; Fosters collaboration and coordination among USDA science agencies

OCS staff includes Director plus senior advisors in six areas:

Plant Health, Production & Products // Animal Health, Production & Products // Natural Resources & Environment incl. Bioenergy // Food Safety & Nutrition // Agricultural Systems incl. Climate Change // Agricultural Economics & Rural Communities

Five USDA Agencies *Conduct* or *Support* Plant Breeding

Plant breeding, genetic resources, and related biological research:

- Agricultural Research Service (**ARS**)
- Forest Service (**FS**)
- Natural Resource Conservation Service (**NRCS**)

Economic and policy analyses

- Economic Research Service (**ERS**)

***Capacity* and *competitive* funds for Research, Education, and Extension** (i.e. *extramural* plant breeding)

- National Institute for Food and Agriculture (**NIFA**)

United States Department of Agriculture
Office of the Chief Scientist

What is Plant Breeding?

"Human-aided development of plant cultivars with needed characteristics"

The *organizing principle* of breeding is the genetic gain equation:

$$\Delta G = h^2 S$$

Gain in a desired trait (ΔG, or "delta-G") is a function of

- the *heritability* of *that trait* (h^2)
- the *intensity of selection (S)*

Plant breeding "puts it all together", using different resources, tools, and methods to maximize gain, ΔG.

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Role of USDA Plant Breeding

To provide plant breeding outcomes *that are needed to achieve USDA's Strategic Goals*,

…*When* these have the nature of *"public goods*":

E.g.,

- Breeding for long–term horizons -- too distant for private investment
- Important goals but probability of success is low or unknown
- Market size is small

Increase in Stakeholder Attention to Plant Breeding

New groups; national meetings, including:

- Land-grant-univ. Plant Breeding Coordinating Committee *2007*
- National Association of Plant Breeders (NAPB) *(publ+priv)* *2009*
- American Seed Research Summit *(private-sector organized)* *2008*
- USDA ARS stakeholder workshops *2011*
- PCAST: Ag Preparedness & the Ag. Research Enterprise *2012*
- Seeds & Breeds for 21st Century Agric. *(organic/sustainable)* *2014*

.

Increasing number of stakeholders, incl. organic sector, engaging w/USDA officials to present plant breeding needs & priorities

(since ~2010)

USDA Response:

- Plant Breeding Working Group (PBWG) *2012*
  - *Support to USDA Chief Scientist (REE UnderSecr.)*
    - *Interagency coordination; advise re issues & priorities*
- Public Plant Breeding Listening Session *2013*
- USDA Plant Breeding Roadmap *2014/15*

Both documents posted at:

http://www.usda.gov/wps/portal/usda/usdahome?navid=OCS

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What We've Learned

What stakeholders—*both public and private*—
see as USDA's <u>core</u> contributions to plant breeding:

- **The National Plant Germplasm System collections** (NPGS) incl.
  - Collection, curation, rejuvenation, characterization, and pre-breeding
  - Genetic Resources Information Network (GRIN):
    GRIN is an *Information management system f*or genetic resources:
    Inventory, images, rejuvenation status, IPR status, requests/order status
    - GRIN-Global: USDA ARS with co-funding from Global Ag Diversity Trust
      Collaboration with Bioversity International
      For global needs: multiple languages
      Open-source software; scale-able databases (laptop version)

What We've Learned, con't.

Additional core contributions -- as seen by stakeholders:

USDA's breadth of geographic coverage, through partnerships including:

- USDA sites (e.g. ARS, FS, and NRCS)
- Land-Grant Universities and State Agricultural Experiment Stations
    - ESS and ARD; co-funded through USDA
- Others, e.g.
- Long Term Agricultural Research sites (LTAR) (multi-partner)

USDA United States Department of Agriculture
Office of the Chief Scientist

What We've Learned, cont'd.

<u>Deliverables "by and for" public plant breeding</u>
cited by stakeholders as <u>*needed from* USDA</u>:

Intramural

- **Cultivars** (varieties) for "public-goods situations"
- **New tools & methods**, publically available for any breeder to help maximize gain, ΔG.
  - E.g. new tools / methods to :
    - Incorporate new genetic & biological understanding
    - Reduce breeding cycle time (from cross-to-variety release)

Extramural

- Adequate and appropriate funding mechanisms,
  - for the long-term nature of plant breeding;
  - for education

USDA United States Department of Agriculture
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What We've Learned, cont'd.

Heard from stakeholders: concerns about…

External funding thru' USDA

- Low total funding + many proposals leads to low success rates in compet. programs (<10%, sometimes <5%)
- Short-duration (2-4 yrs); non-renewable

Education

- Few funding opportunities for student stipends
- Even fewer for faculty to develop contemporary plant breeding curricula

Challenges for USDA's response

- Not enough competitive funding to respond to stakeholder concerns
- Plant breeding needs longer-term funding cycles

Solution?

- Rely on intramural USDA plant breeding?

… **leads to more questions:**

- Loss of university plant breeding?
- Loss of closeness to needs and opportunities of local farming?
- Whence opportunities for educating future breeders -- *within active breeding context*?

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National Institute of Food & Agriculture, NIFA is USDA's extramural funding agency.

NIFA funding programs that can include plant breeding :

Capacity programs

Hatch	1862 state land-grant univ's.
Evans-Allen	1890 land-grant univ's.
McIntire-Stennis	State forestry schools

Competitive programs

AFRI Agriculture & Food Research Initiative
OREI Organic Agriculture Research & Extension Initiative (started 2005)
SCRI Specialty Crops Research Initiative (2008)
BRDI Biomass Research & Development Initiative (2009)
SBIR Small Business Innovation Research

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How USDA plans to respond

Next Steps in Plant Breeding

Agricultural Research Service (ARS)

As foreseen in next 5-10 years

Strengthening the NPGS and its use → Researching new breeding tools and methods → Continue breeding improved cultivars → ARS Post-Doc & other Fellowships

Strengthening the NPGS and its use

- Additional collections
- Efficient germplasm management and characterization
- Capacity to store and analyze massive datasets
- Pre-breeding with NPGS materials

Researching new breeding tools and methods

- E.g., methods to increase speed and precision (genomic select'n., gene editing, others coming…)
- Cross-dataset coordination with other progr's./entities
- Transgenic research when critical

Continue breeding improved cultivars

- When situations require public investment

ARS Post-Doc & other Fellowships

- Lab and field experience

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Next Steps in Plant Breeding: *Forest Service (FS)*

As foreseen in next 5-10 years

- **Genetics** of critical forest-tree traits
  - For faster, more accurate breeding progress
- **Germplasm resources**
  - How to conserve diversity of those tree species that cannot be stored as seeds?
- **Data curation**
- **Collaboration** with ARS

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Next Steps in Plant Breeding:
Natural Resource Conservation Service (NRCS)

As foreseen in next 5-10 years

- **Landscape and ecosystem services**; cover crops; wildlife and pollinator habitat
- **Increasing needs** for selected plant material from NRCS Plant Material Centers
- **Collaboration** with ARS, FS, and Bureau of Land Management (BLM) e.g. Plant Conservation Alliance

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Next Steps in Plant Breeding: *Economic Research Service (ERS)*

Using crop genetic resources to help agriculture adapt to climate change:

Economics and policy.

(EIB-139, Heisey & Day-Rubenstein, 2015)

Other topics in progress, *including*
Implications of international agreements in the area of plant genetic resources

Looking Further Ahead (> 10 yrs)

Some anticipated future priorities for USDA plant breeding :

Plant germplasm – anticipated to remain a top priority for USDA

Plant breeding *per se*:

- Transfer of ***new knowledge*** to plant breeding
    - Knowledge to increase speed and accuracy, lower costs
    - New horizons … e.g. phytobiome…
    - New strategies, e.g. for phenotypic or participatory breeding
- Identification of ***new traits***, e.g.
    - *Adaptation* to new environments, climates, and practices
    - Traits for *coexistence* of IP or organic crops, w/GE or others
    - Interactions between food, nutrition, and human *health*
- Breeding for ***new situations*** and ***new crops***:
    - Varieties /traits for:
        - Organic systems / small farms / urban food systems
        - Perennial crops; trees;
        - Long-term ecosystem services

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Also from the Roadmap process:
Issues broader than USDA

Recruit / Educate

- Encourage more young people to be interested in plant breeding
- Education: K-12, CC's, undergrad.; grad.

IPR

- Optimal understanding and use of intellectual property rights (IPR) and tech transfer mechanisms?

Public / Private

- Most favorable balance of investment in plant breeding?

Funding the model

- A joint endeavor: intra/extramural; capacity/competitive; public/private
- Funding the training pipeline

What are ways that USDA can respond?

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RAISING THE PROFILE OF AGRICULTURAL SCIENCE AND EDUCATION INCLUDING PLANT BREEDING:

BASED ON USDA'S WORK IN THE PLANT BREEDING ROADMAP,
THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY
PLANS A PROFILE-RAISING EVENT
ANTICIPATED FOR EARLY DECEMBER 2015 AND JAN/FEB 2016

OSTP ARE KEENLY INTERESTED IN LEARNING ABOUT OTHERS PLANNING NEW OR EXPANDED INITIATIVES IN THIS AREA.

IF INTERESTED IN LEARNING MORE:

PLEASE GET IN TOUCH WITH :

ANNMARIE.THRO@OSEC.USDA.GOV
ELIZABETH_R_STULBERG@OSTP..EOP.GOV

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Thank You For Your Attention

So many genomes, so little time: the future of plant breeding

(apologies to Webb Miller, Nature Biotechnology 18:148 - 149 (2000))

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

National Association of Plant Breeders
NAPB
Improving Plants to Improve Lives

Future of plant breeding (public plant breeder's perspective)

National Association of Plant Breeders (NAPB) Strategic Plan

A Brief "Ask" concerning the OSTP White House Event on Ag. Sciences Research and Education

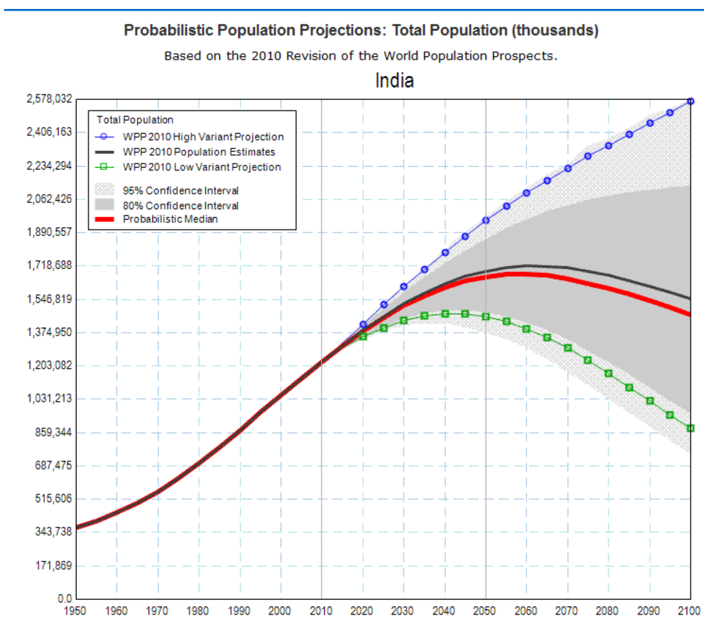
Shameless promotion of plant breeding

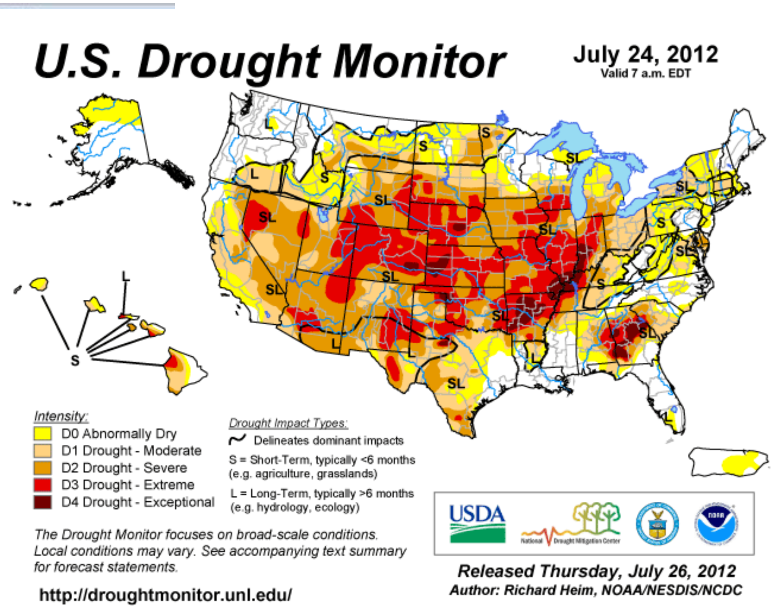
Not because other disciplines in the Ag. Sciences are less important but because:

- Translational potential for investment in genomics
- Serves as a key node in multi-disciplinary teams
- Record of solving problems
- Ability to mitigate risk (diversity of crops and diversity within crops)
- Position in University IP portfolios
- Projected needs in domestic Ag. Science hires

Examples from OSU research

The issue: How do we harness the power of science and education to develop and produce high quality crops that contribute to sustainable agricultural production and human health in the face of population growth and climate instability?





http://esa.un.org/unpd/ppp/index.htm

Bayesian Probabilistic Population Projections for 2045 =

median: 9.0 billion; 95% interval: 7.8-10.3 billion

Response includes expertise in getting water off of fields and getting water on to fields. “It took a while to learn how to do that…”




$\Delta G = \boldsymbol{k}^* \, \boldsymbol{\sigma_P}^* \, \mathbf{h^2}$ **Plant breeder's approach: Gain under selection**

K, σ_P, h^2 are all subject to disruptive technologies; these are embraced as a way to improve the efficiency of selection

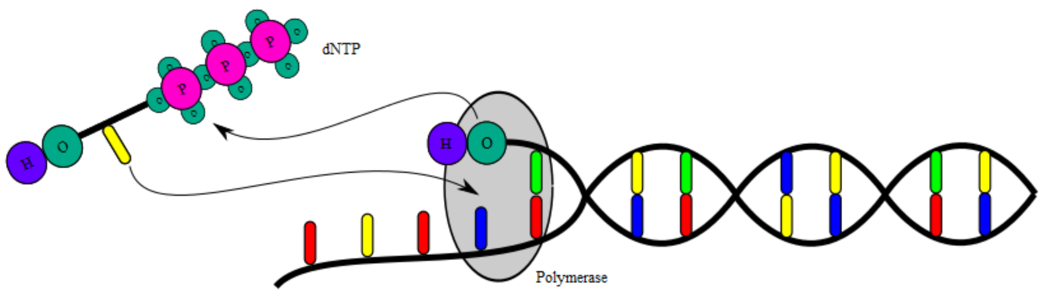
Efficiency
ΔG
Cost
Time

So many genomes…

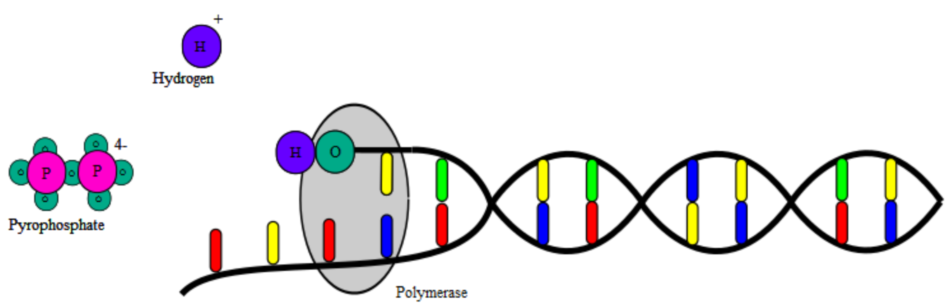
Disruptive technologies: sequencing by synthesis and parallel detection of hydrogen or pyrophosphate

1) Discovery of new alleles

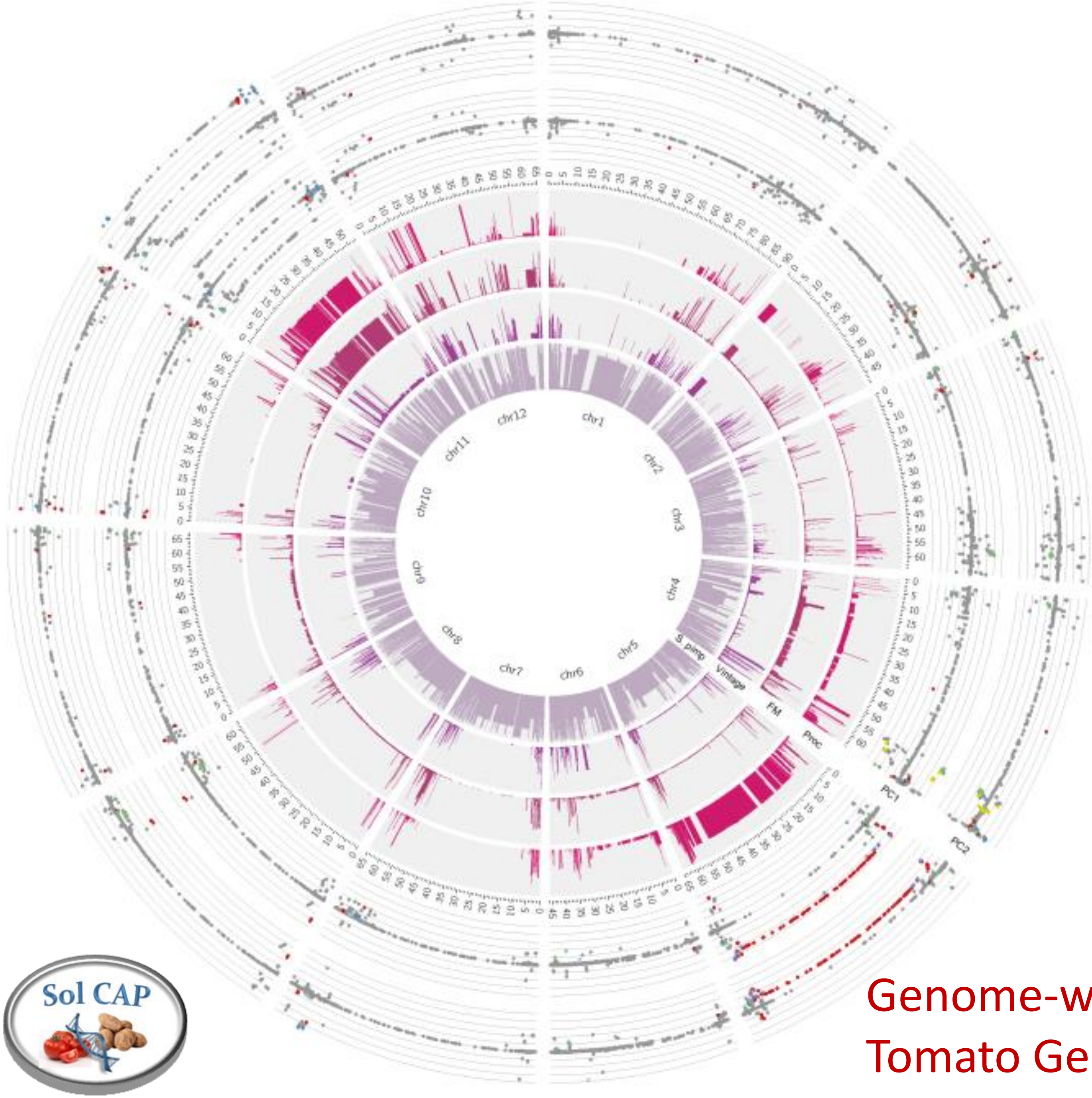
2) Predict performance based on genotype



Polymerase integrates a nucleotide.



Hydrogen and pyrophosphate are released.



MAF

- Processing
- Fresh Market
- Vintage
- S. pimpinellifolium

Loci under selection

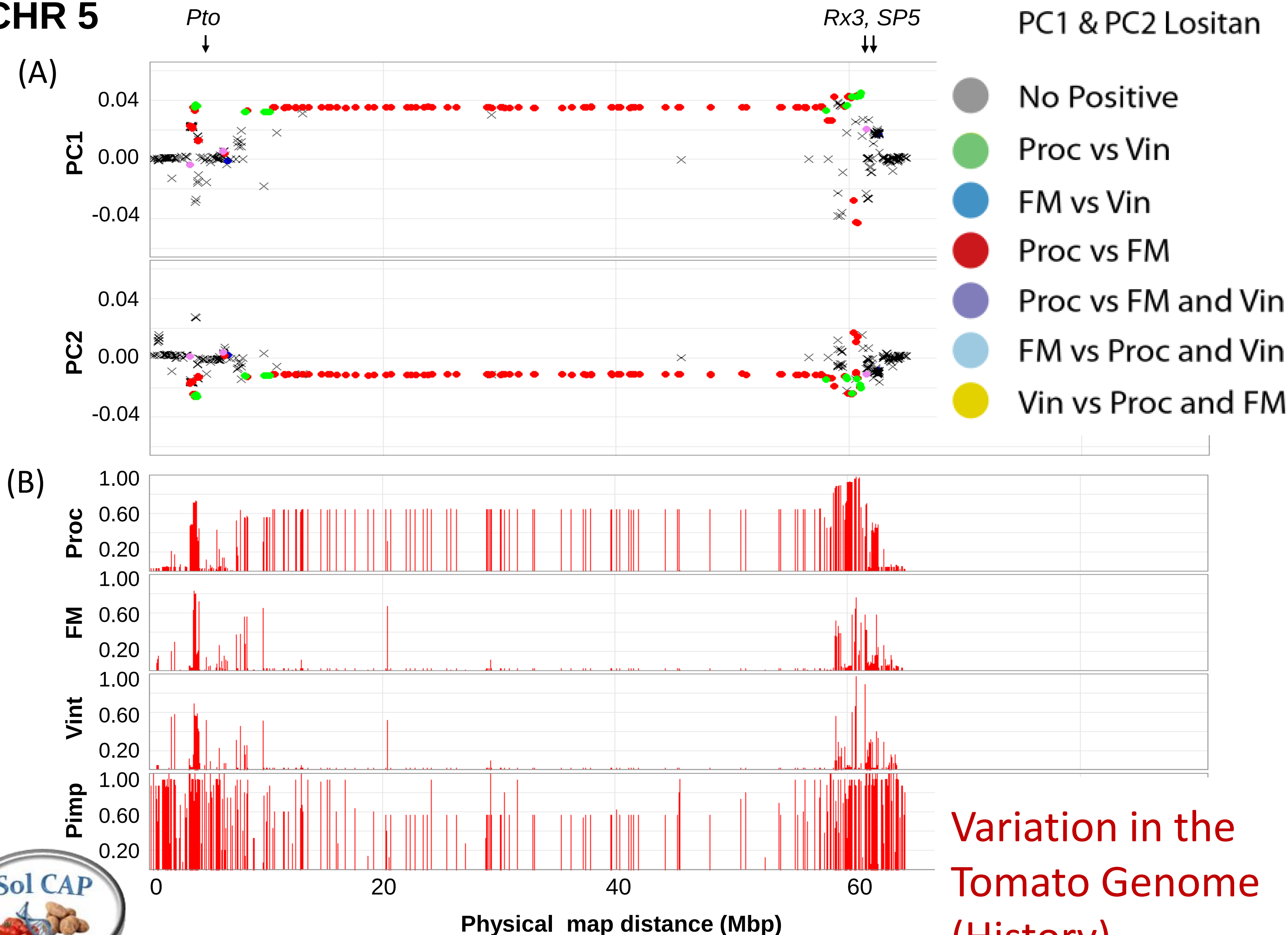
PC1 & PC2 Lositan

- No Positive
- Proc vs Vin
- FM vs Vin
- Proc vs FM
- Proc vs FM and Vin
- FM vs Proc and Vin
- Vin vs Proc and FM

Sol CAP

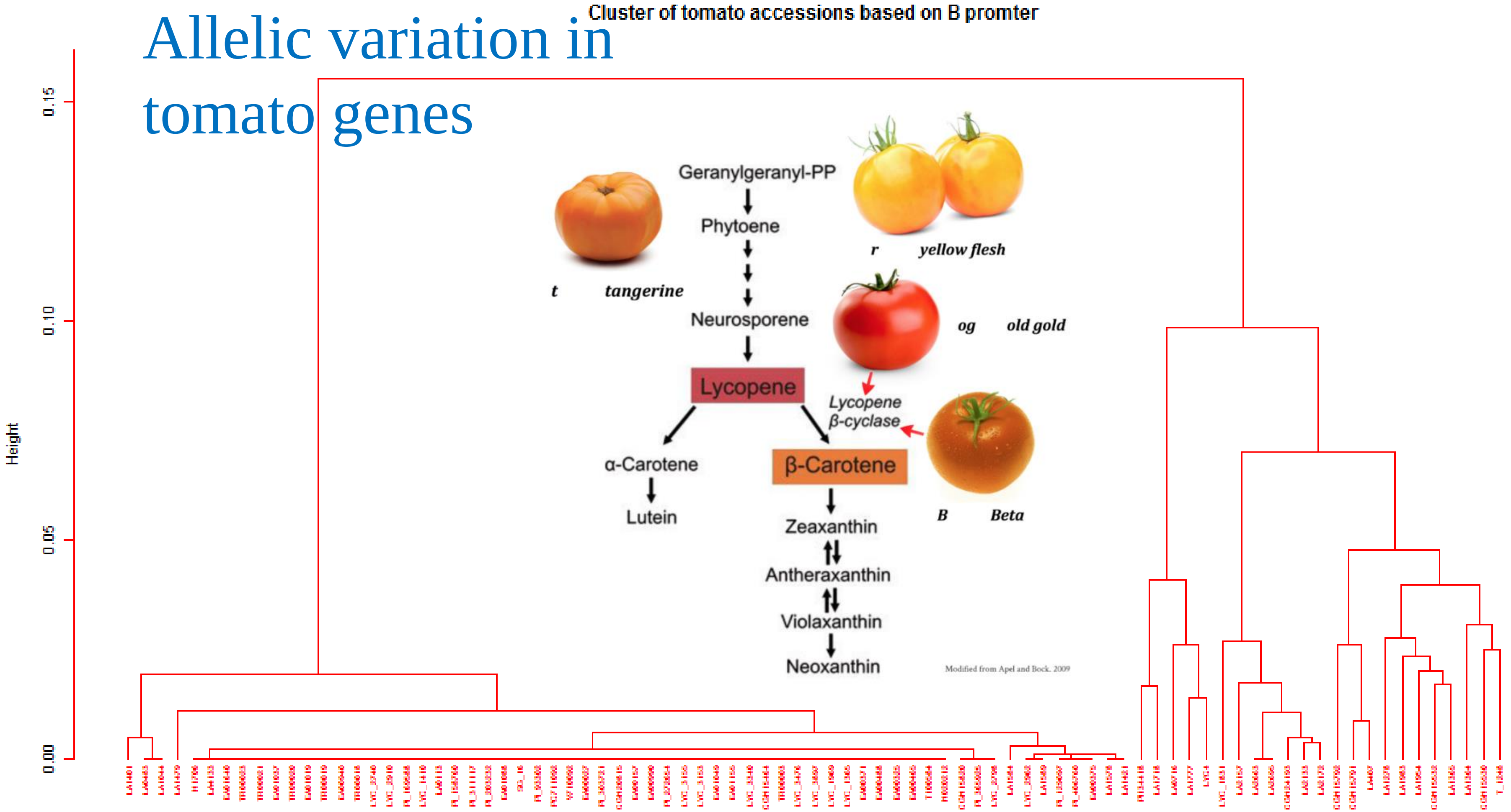
Genome-wide variation in the Tomato Genome (History)

CHR 5



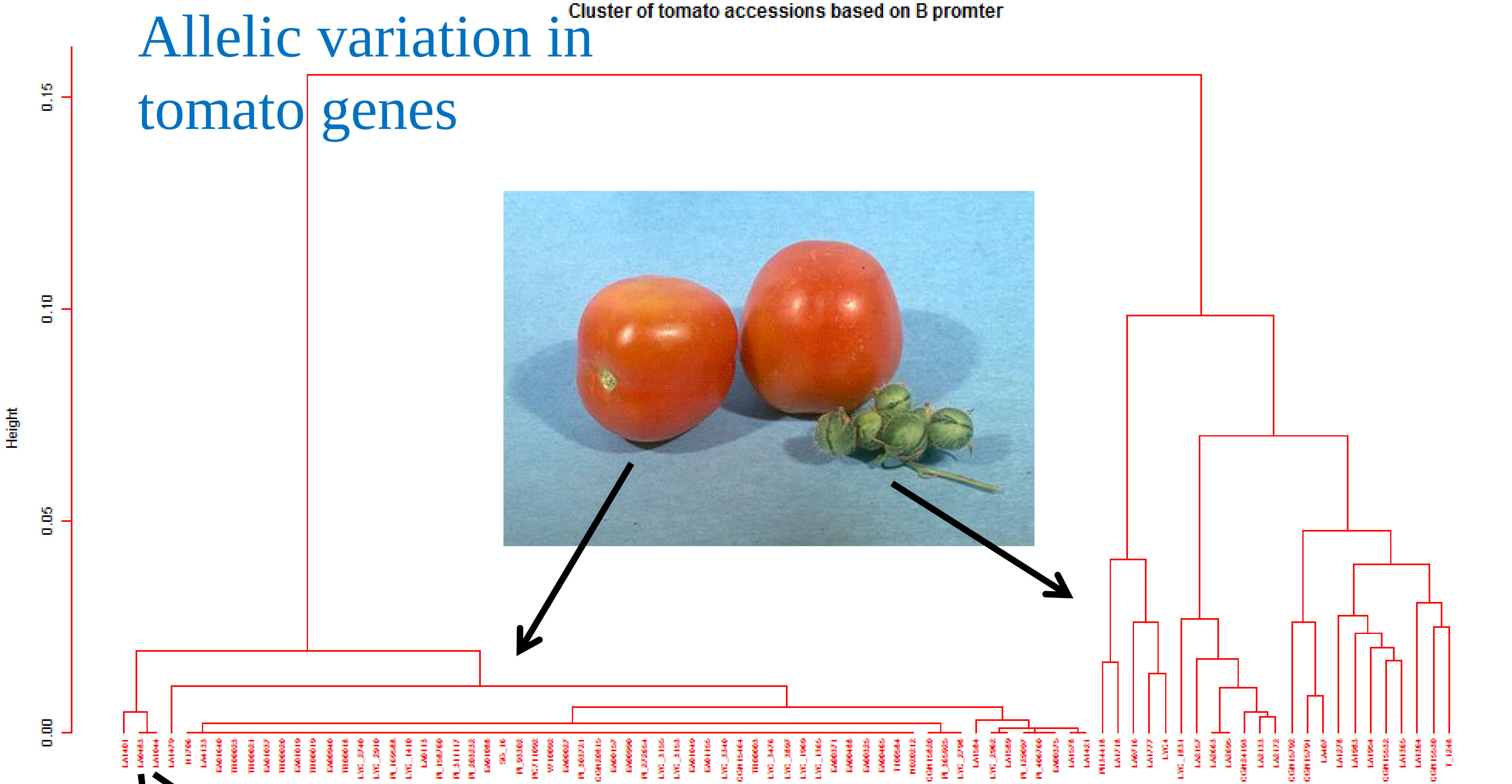
Variation in the Tomato Genome (History)

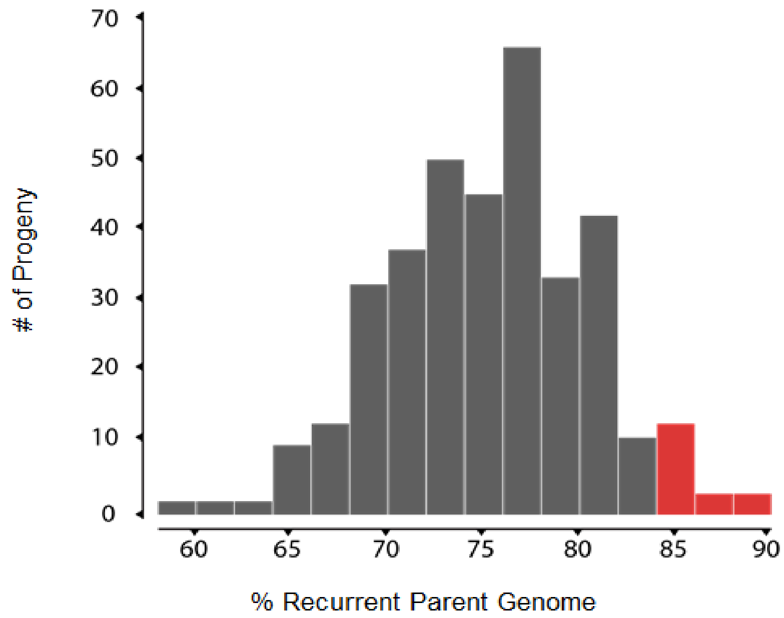
Allelic variation in tomato genes

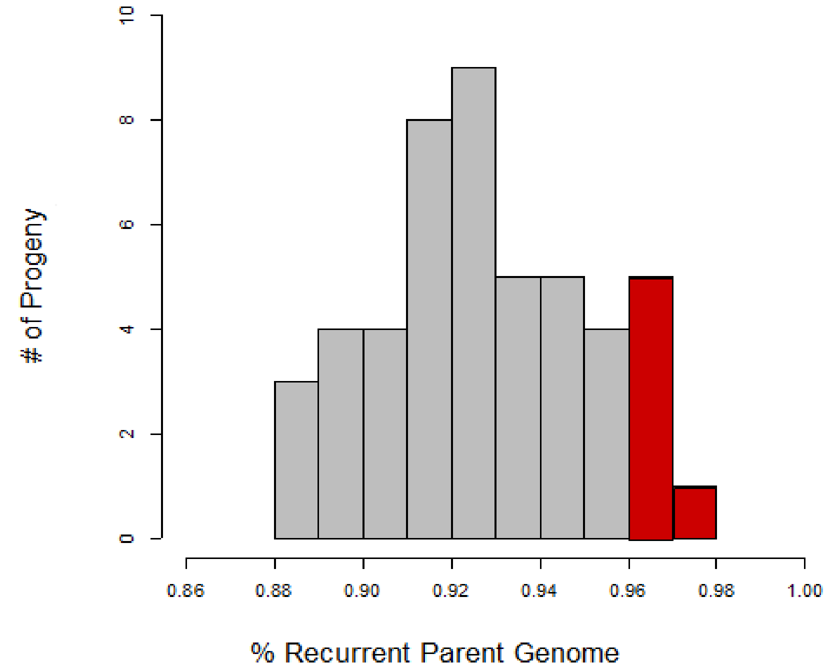


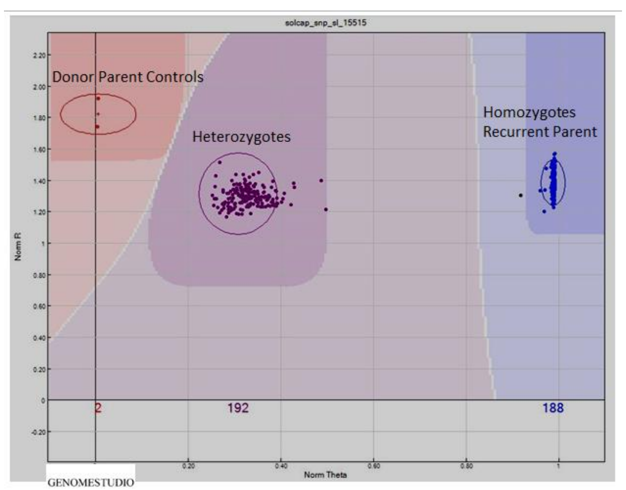
- Variation in tomato genes (future)
- 30 or more alleles within structural genes
- 30 or more alleles within 5’ untranslated regions

Allelic variation in tomato genes

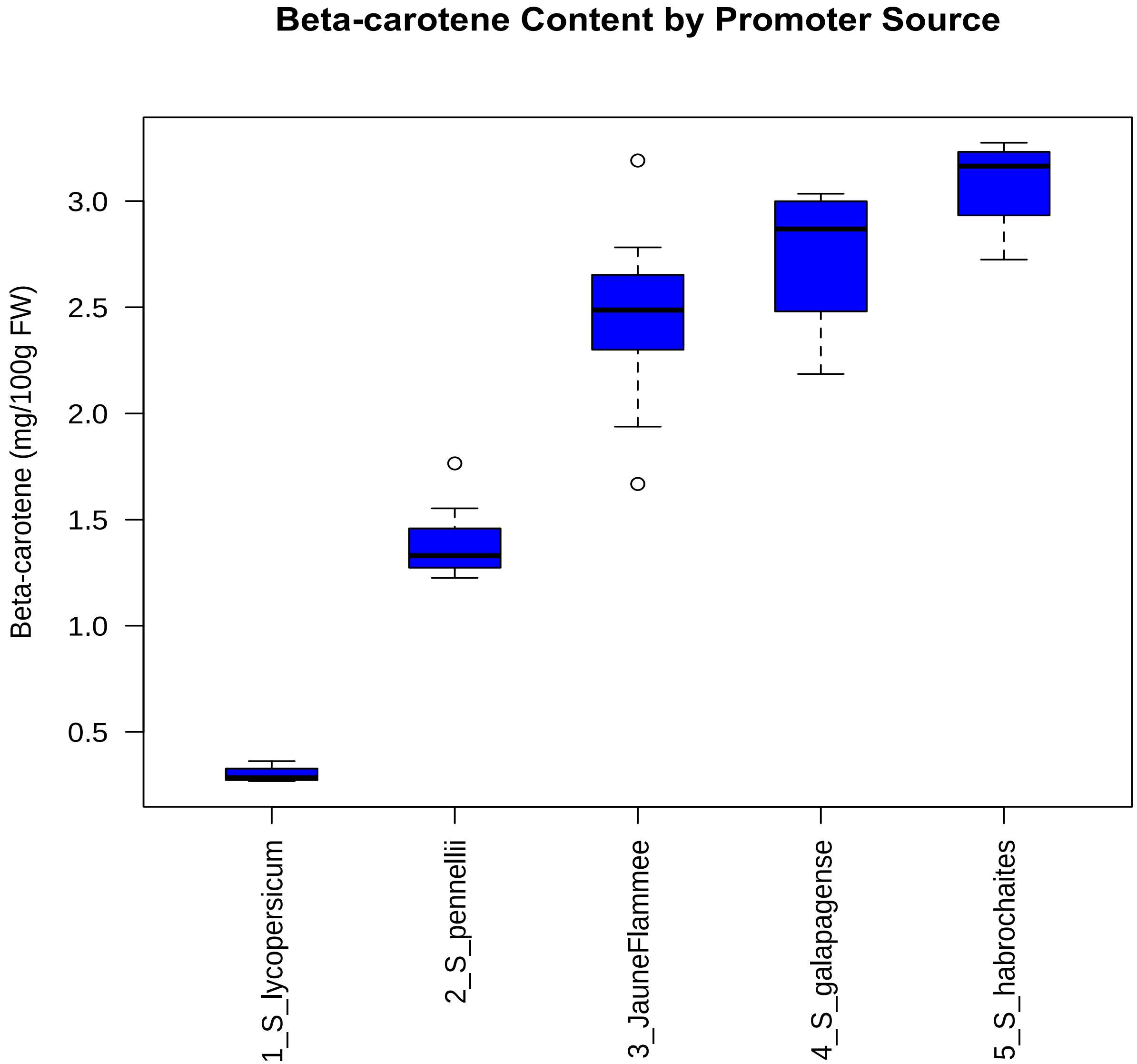








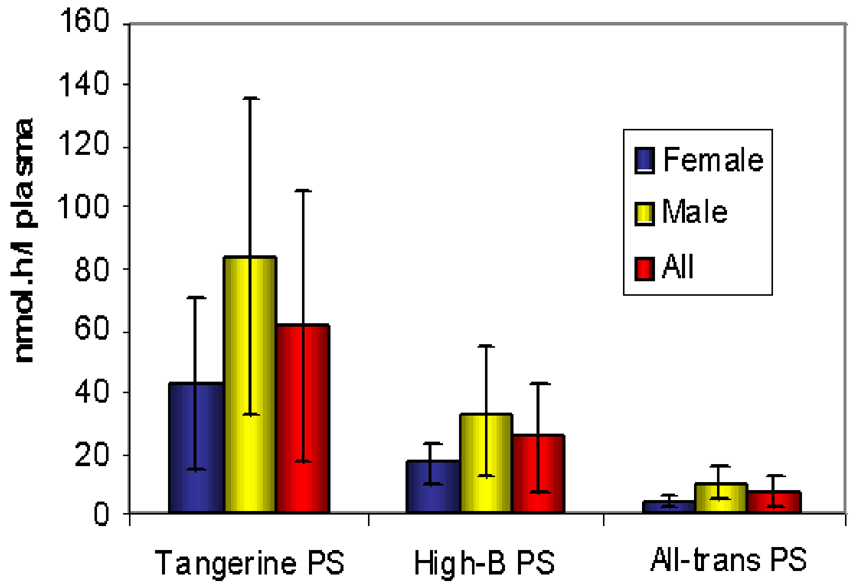
SolCAP team (sequence resources); HCS Greenhouses; OARDC branch farms; FST Pilot Plant; Schwartz lab at OSU; Clinton lab at OSU; Illumina; LGC Genomics;



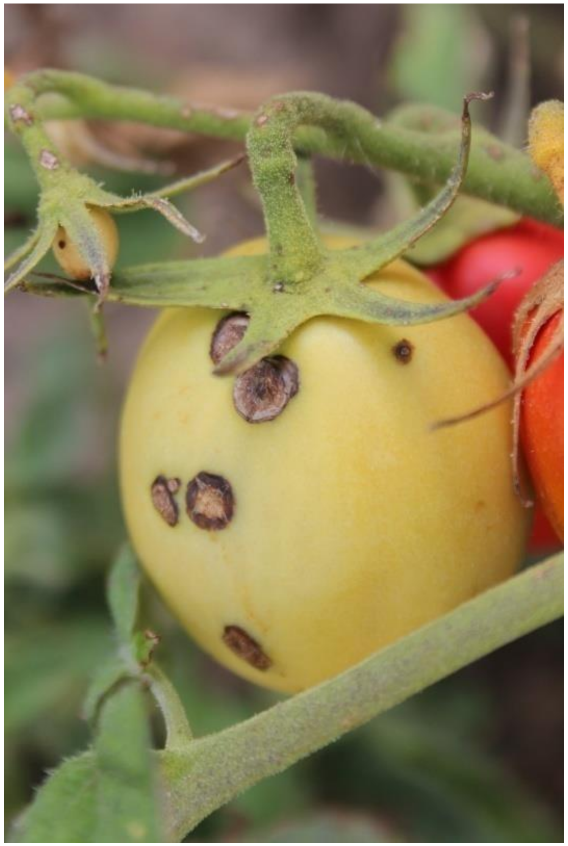
Conclusion:

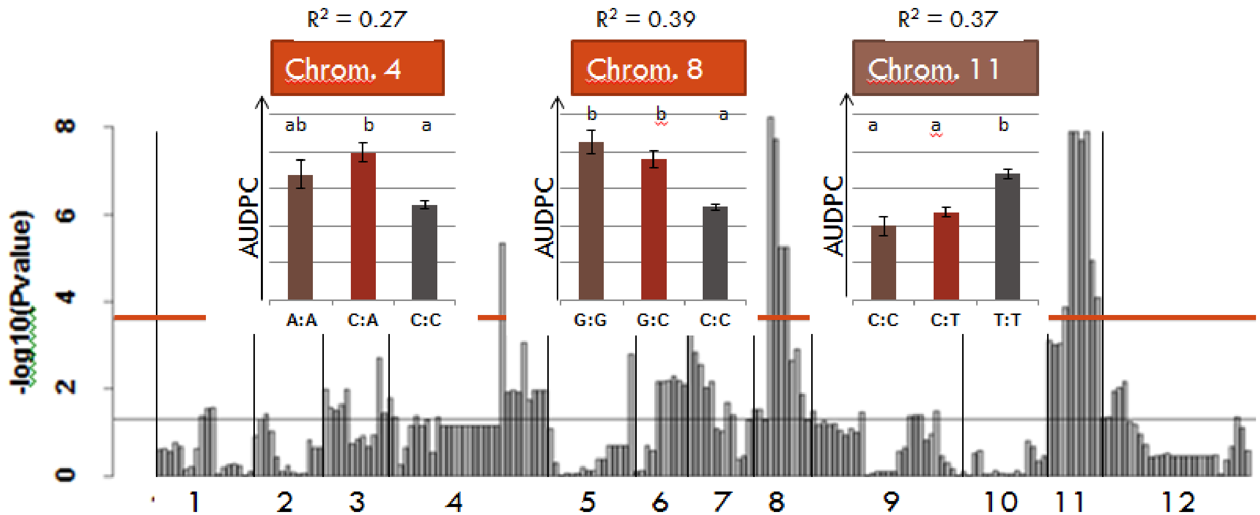
Within the context of a MS, new alleles can be identified, bred into cultivated background, and evaluated for function.

Result: 1) Plant genetic resources with novel high beta-carotene alleles to study carotenoid availability and efficacy in animal and human trials; 2) Association of putative causal SNPs with phenotype.



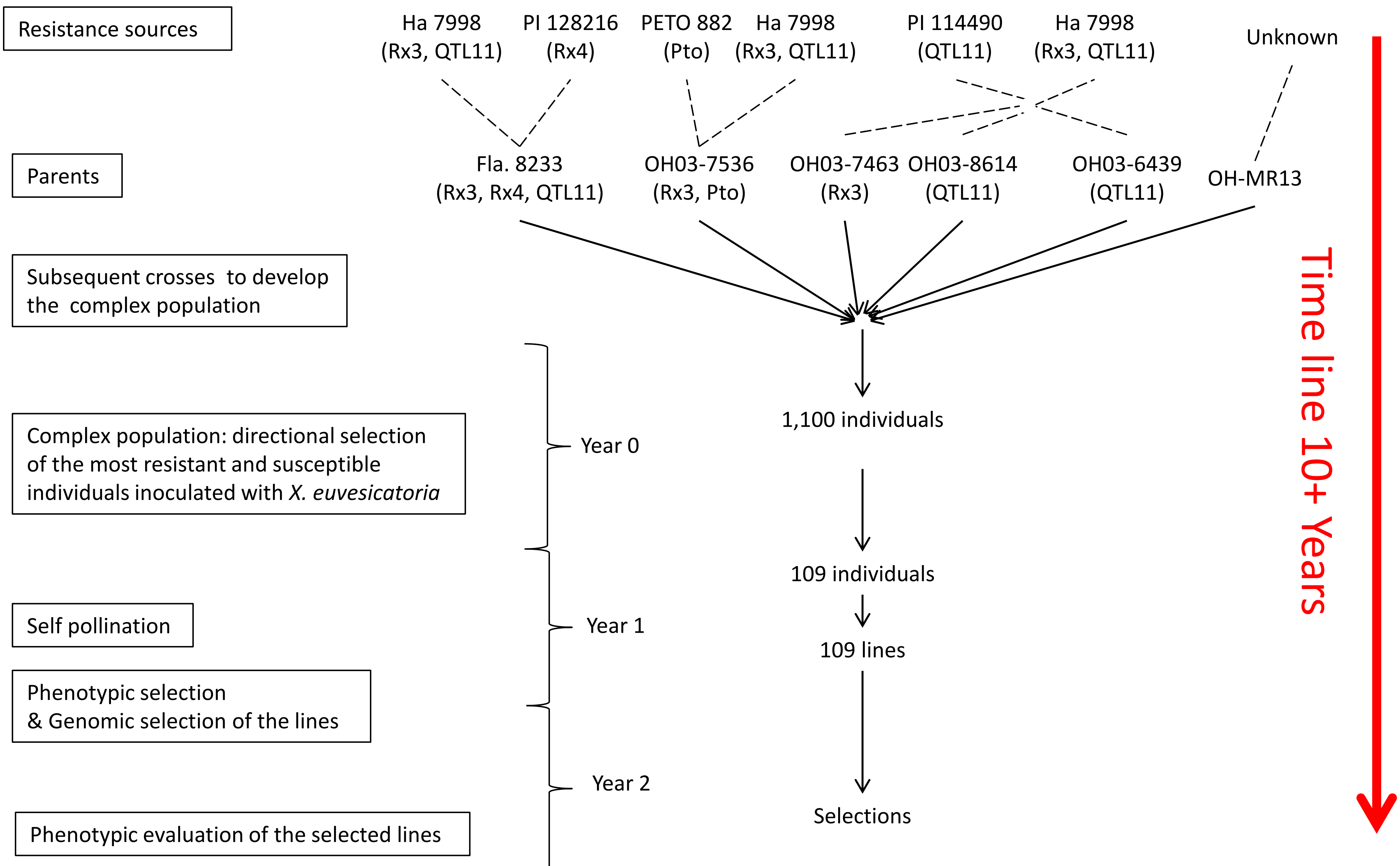
Disease Resistance (Emerging disease "Black Spot" *Xanthomonas gardneri*, 2009): Predicting performance – an empirical validation of genomic selection models



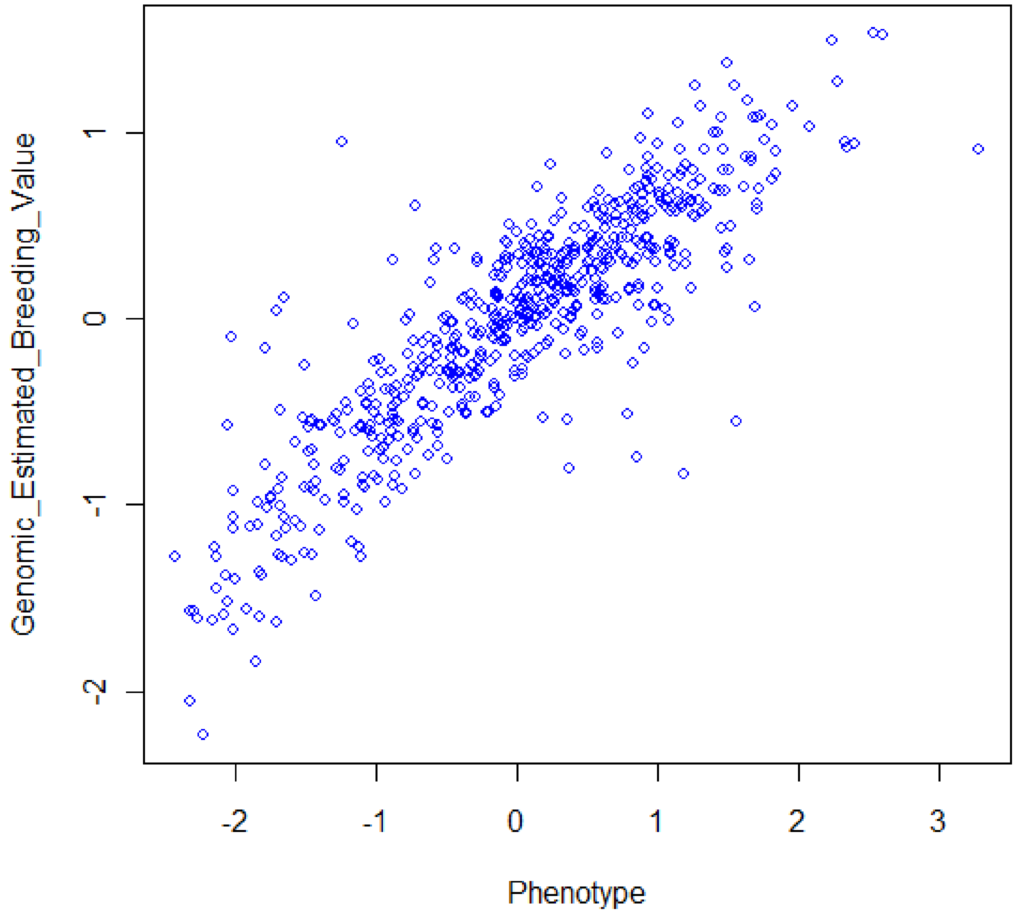


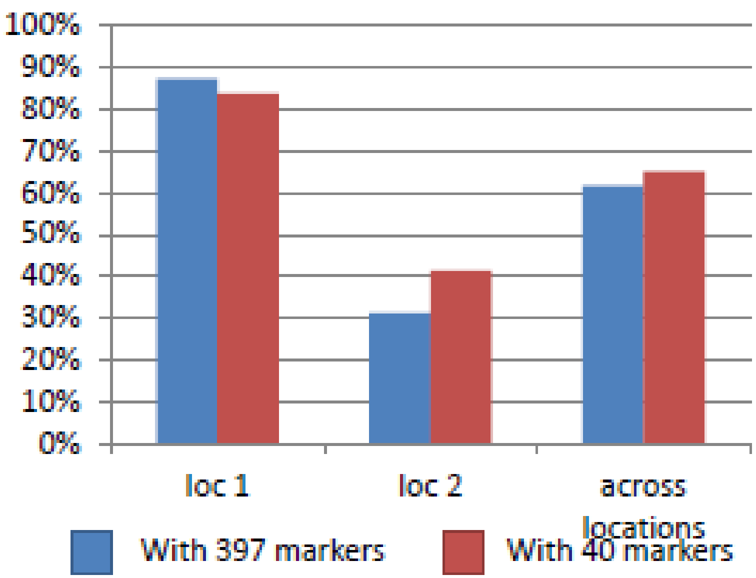
SolCAP team (sequence resources); HCS Greenhouses; OARDC branch farms; Miller lab at OSU; Scott group at UFL; Illumina; LGC Genomics;

Population and workflow



Disruptive Technologies: Computational power, open source software, statistical innovations. When coupled to highly efficient genotyping = power to predict progeny performance (Genomic Selection)





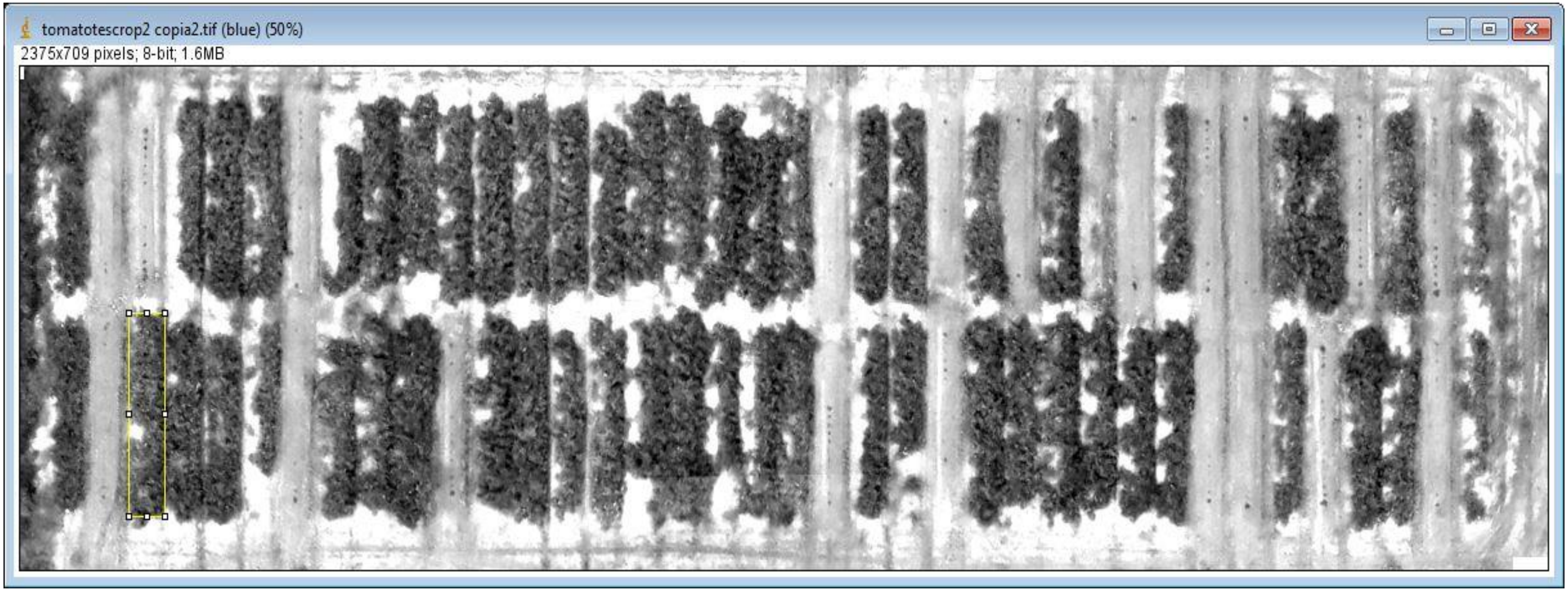
Result: 1) Plant genetic resources to address a problem (inbred parents and hybrids evaluated at commercial scale); 2) Accurate knowledge of genome position for effective alleles; 3) Models for off-season selection.

Other Disruptive Technologies:

Biological (Doubled haploids and Genome Editing)

Engineering (biological assessment through remote sensing and image analysis)

IP (open source seeds initiative)



The Future of Plant Breeding

The Future of Plant Breeding

Look hard at what needs to be done “in house” and what can be outsourced (core service providers)

We do less wet-lab work despite increasing sequencing and genotyping 100x

Computational (bioinformatic and statistical genetics) demands have increased.

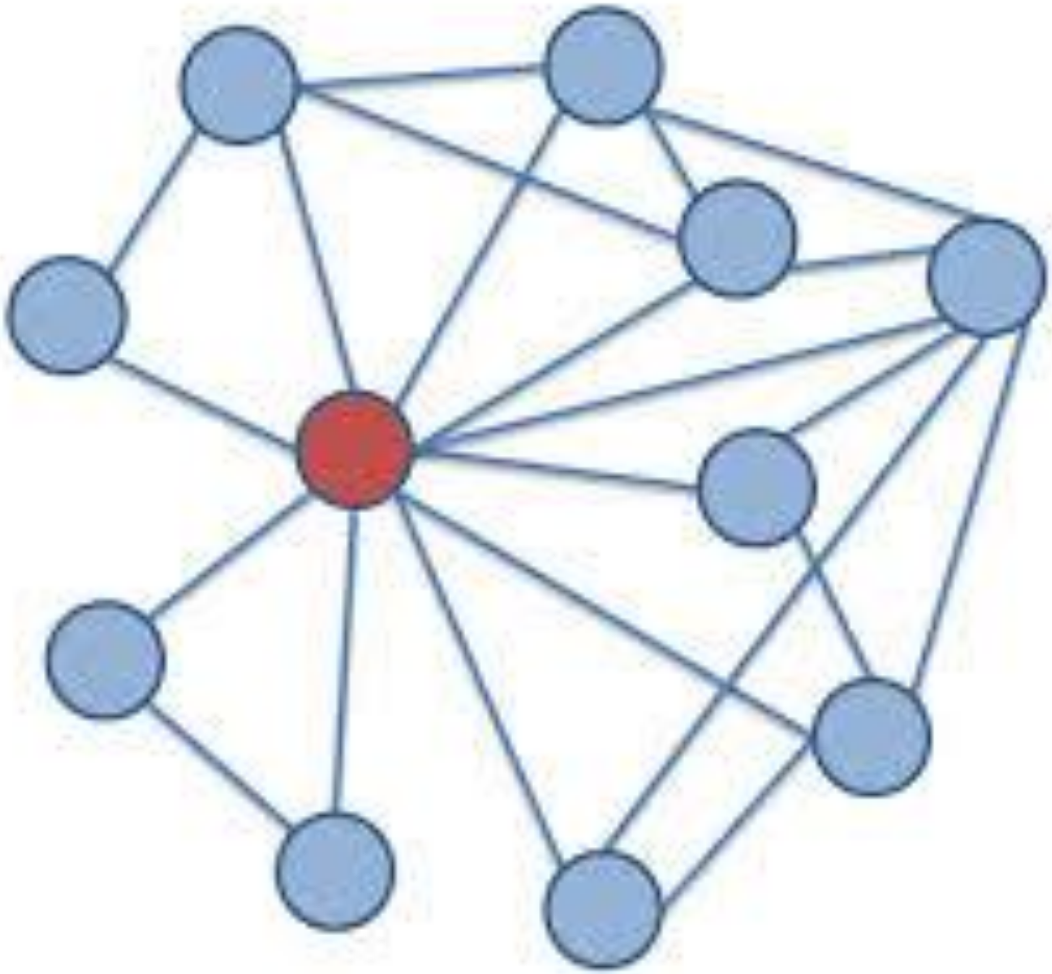
Our core strength – field and greenhouse capacity is more important than ever (> biological assessment capacity 80%)

The Future of Plant Breeding

"beyond mountains there are mountains“

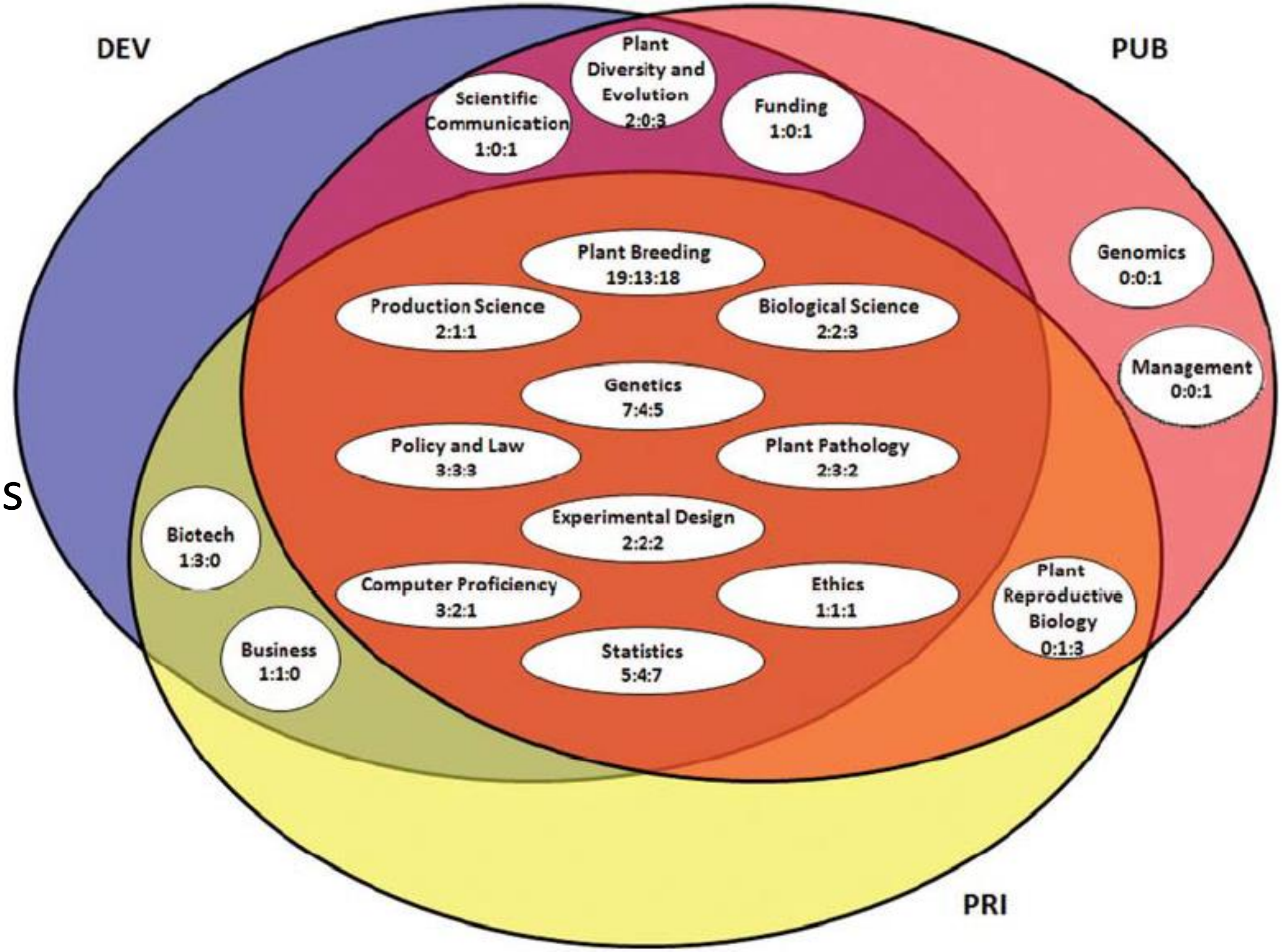
- Plant breeding requires:
  - development of multi-generation populations
  - evaluation under relevant conditions
  - a long-term endeavor

Educating the next generation of plant breeders

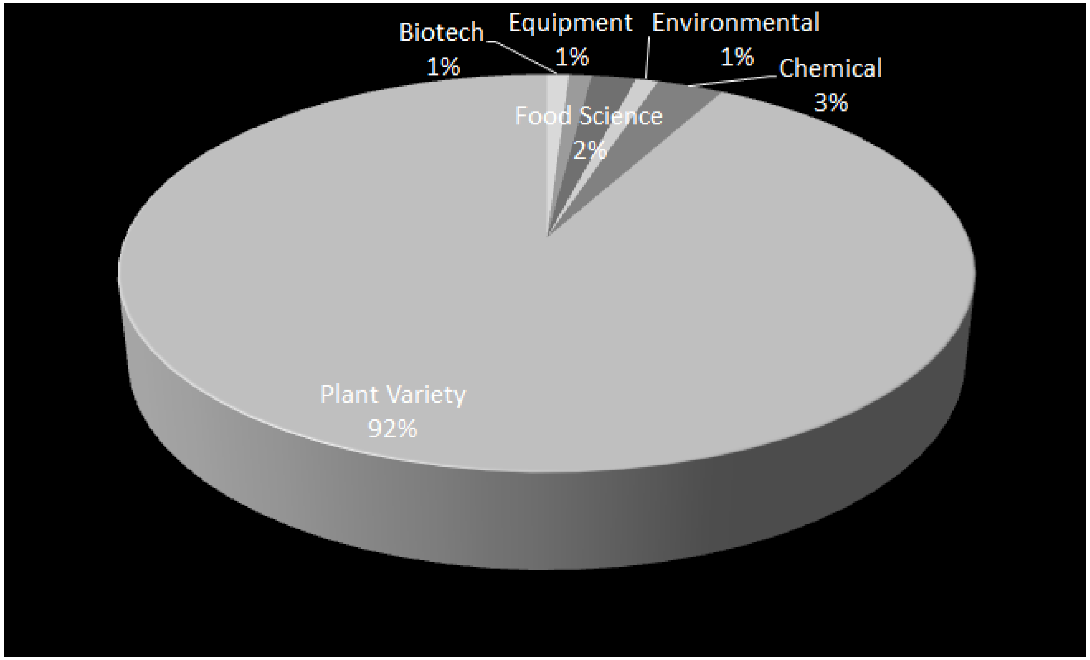


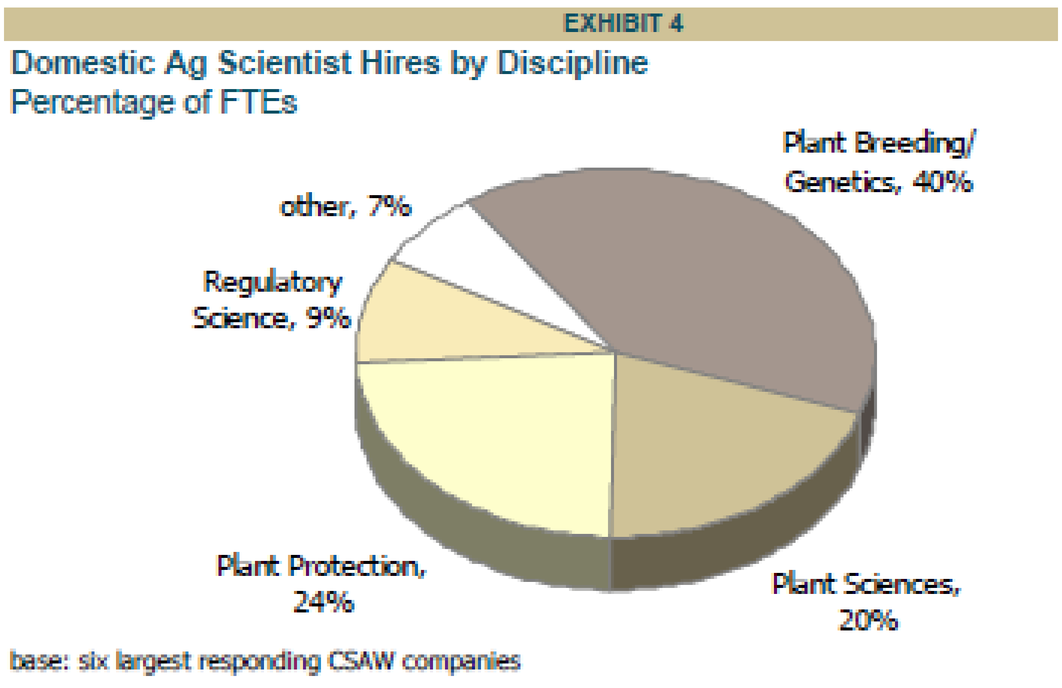
Plant breeding community has identified educational themes (Delphi study).

Several initiatives are moving forward (on-line courses, workshops, curriculum revisions)



Miller et al., 2011. Journal of Natural Resources & Life Sciences Education. Vol. 40 p. 82-90
Rapinski et al., 2011. Crop Science. vol. 51 p. 2325-2336





Justifying Continued Investment: Plant Varieties account for 20% of Land-Grant IP portfolios and 92% of royalty income; there are abundant jobs for graduates

Distribution of Land-Grant University Intellectual Property portfolios (A) and Royalty Income (B). Source: UC Compilation of IP for top tier Ag. Universities; 2012 Peer Review Survey (University of Florida); Coalition for a Sustainable Agricultural Workforce (CSAW)

Take home messages:

- Reason for optimism for the future of plant breeding
- New technology is invigorating the field
- Abundant Sequence data allows exploration of new alleles
- High-throughput genotyping permits efficient (time and cost) prediction and selection
- Plant Breeding is a nucleating discipline within the plant sciences; solving real-world problems requires an alliance of disciplines.
- Driver of technology and innovation in the agricultural sciences
- Risk mitigation through increased diversity of crops and genetic diversity within a crop
- Demand for students is high
- Requires development of multi-generation populations
- Requires evaluation under relevant conditions
- A long-term endeavor

National Association of Plant Breeders
NAPB
Improving Plants to Improve Lives

Plant Breeding Coordinating Committee

NAPB, PBCC Strategic Planning

History

2006	2007	2008	2009	2010	2011	2012	2013	2014

- Formation of the Plant Breeding Coordinating Committee (SSC080 also known as PBCC)
- The PBCC sponsored the first national Plant Breeding Workshop in Raleigh, NC
- Public outreach arm of the PBCC was named the National Association of Plant Breeders
- PBCC Survey of breeders research priorities and needed infrastructure
- Independent NAPB was created
- Two organizations began holding joint annual meetings
- NAPB begins developing organizational and governance policy
- Strategic Planning Began

NAPB Idea

NAPB Hatched

NAPB needs to fly

Participants

- Ellen Cull- Consultant
- Minneapolis Meeting: Liz Lee, Patrick Byrne, Jamie Sherman, Duke Pauli, Barry Tillman, David Francis, David Stelly, Shelly Jansky, Seth Murray,, Allen Van Deynze, Shelby Ellison, Heather Merk, Donn Cummings, Don Jones, Wayne Smith, Eric Young, Ann Marie Thro, Phillip Simon, Bill Tracy, Mike Gore, Thomas Luebberstedt
- Distilling Group: Jamie Sherman, Donn Cummings, Mike Gore, David Francis, Barry Tillman

Plant Breeding Coordinating Committee

National Association of Plant Breeders
NAPB
Improving Plants to Improve Lives

Joint strategic plan

NAPB strategic plan

Renewal of SSC-80

https://www.plantbreeding.org/about-us/

Distinctions

Structure and role well defined with distinct boundaries

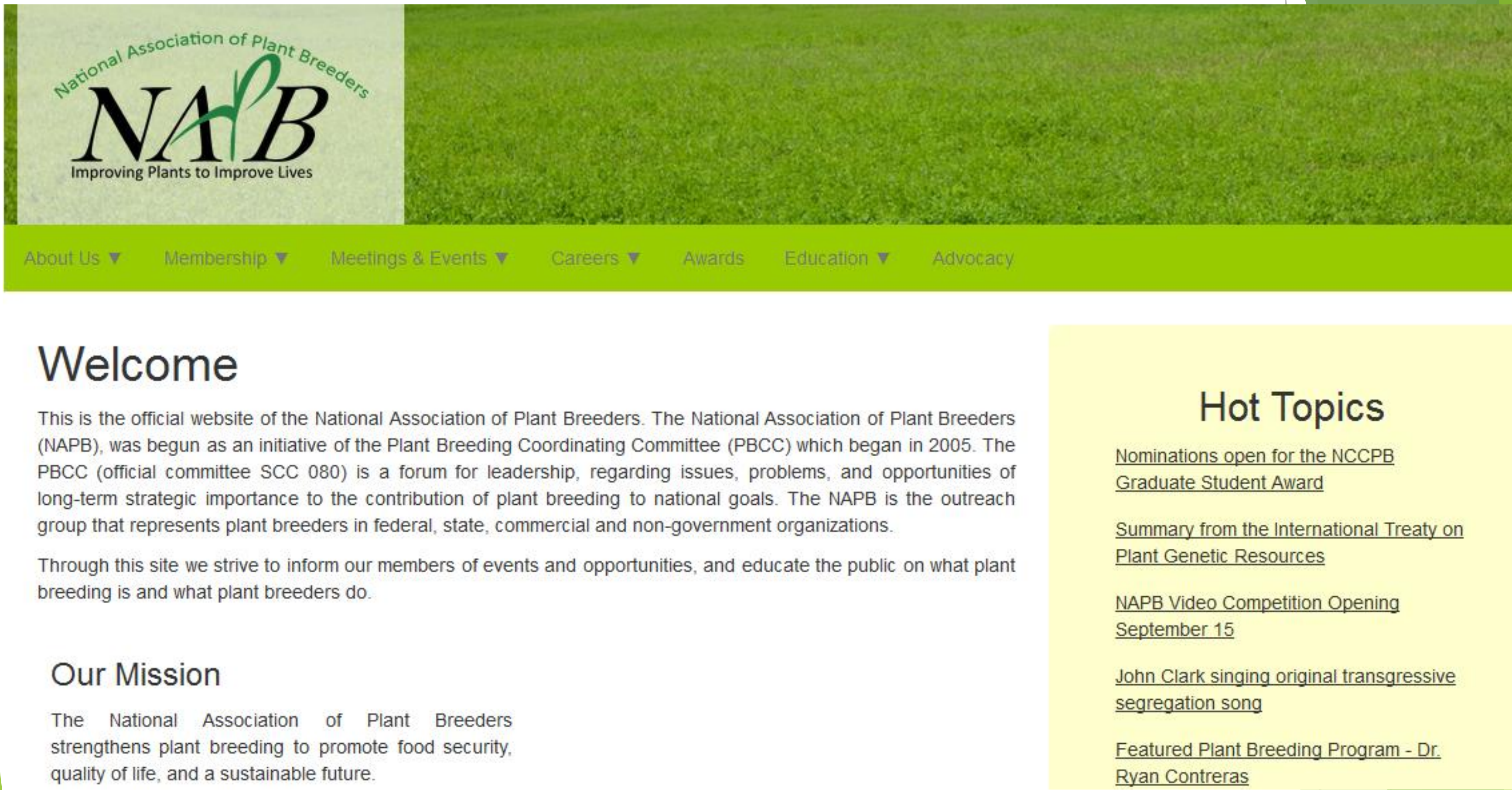
Criteria	PBCC	NAPB
Organization type	Multistate Activity	Professional Society
Established by	State Agricultural Experiment Stations and USDA-NIFA	Members
Ownership	Land Grant University System	Independent
Membership	One official per SAES designated by Director; anyone else by request	Anyone by registering through the web site. Recently rolled out paid membership.
Primary activity	Coordinate activities to solve plant breeding problems of common interest	Scientific exchange Advocate for plant breeding Recognize achievements
Recommendations are made to	Land grant university and USDA leaders; state and federal agencies; Congress ONLY if asked	State or federal legislators; any other federal, state, or private entity
NIFA may request comments	Directly through the National Program Leader representative member	Only in open public forum widely announced in advance
Educational targets	Everyone	Everyone

Products and goals

Products of the process

- A strategic plan that outlines:
  - Missions and roles of PBCC and NAPB
  - Five-year goals
  - Major initiatives / areas of focus to accomplish the goals in the next five years
- An action plan that outlines:
  - Initial steps to implement the goals in the subsequent one to two years
  - Clarification of lead responsibility for the actions

www.plantbreeding.org



Welcome

This is the official website of the National Association of Plant Breeders. The National Association of Plant Breeders (NAPB), was begun as an initiative of the Plant Breeding Coordinating Committee (PBCC) which began in 2005. The PBCC (official committee SCC 080) is a forum for leadership, regarding issues, problems, and opportunities of long-term strategic importance to the contribution of plant breeding to national goals. The NAPB is the outreach group that represents plant breeders in federal, state, commercial and non-government organizations.

Through this site we strive to inform our members of events and opportunities, and educate the public on what plant breeding is and what plant breeders do.

Our Mission

The National Association of Plant Breeders strengthens plant breeding to promote food security, quality of life, and a sustainable future.

Hot Topics

Nominations open for the NCCPB Graduate Student Award

Summary from the International Treaty on Plant Genetic Resources

NAPB Video Competition Opening September 15

John Clark singing original transgressive segregation song

Featured Plant Breeding Program - Dr. Ryan Contreras

Six objectives (https://www.plantbreeding.org/about-us/goals-and-objectives)

Six Goals of NAPB

1) Support for plant breeding:

Increase support for plant breeding among decision makers in the public and private sectors

2) Public plant breeding capacity:

Increase public and private support for cultivar development and germplasm improvement in public institutions

3) Education of plant breeding professionals:

Strengthen education for plant breeding professionals at all levels of experience

4) Public awareness:

Increase public awareness of plant breeding and what it contributes to the public good

5) Membership:

Strengthen and increase value provided to the membership

6) Organization:

Strengthen the NAPB organization

Strategic Plan Goal 3

Goal	Objectives - 5-year	Objectives- 10 to 15-year	Possible Measures
<u>Education of plant breeding professionals</u>: Strengthen education for plant breeding professionals at all levels of experience	• Identify and disseminate best practices for plant breeding education to include experiential learning as well as improved curriculum with increased focus on graduating upper level students who are field-ready. • Explore and implement public-private collaborations to recruit and support training of plant breeders. ○ Support for students – Expand public / private collaboration to provide support to plant breeding students for their training. ○ Recruitment of students – Develop and begin implementing public-private partnership program for recruitment	• Implement methods to encourage consistent, strong university curricula, possibly including: aggregating information on existing curricula, sharing curricula, developing curriculum standards, recommending strong curricula, and / or providing checklists of courses and content. • Continue to expand collaborations to recruit and support training of plant	• Number of plant breeding students who graduate with masters and Ph.D.s field-ready – they know how to work in the field, are able to do the field work of plant breeding • Amount of financial support available to graduate students • Student access to information leading to

NAPB “ASKs” Federal:

Increase AFRI competitive grant funding (4x)

Increase ARS NPGS funding for germplasm evaluation through CGCs (4x; represents only a slight increase in real funding given static levels over 25 years)

Maintain/Increase Hatch (let us know how we can help)

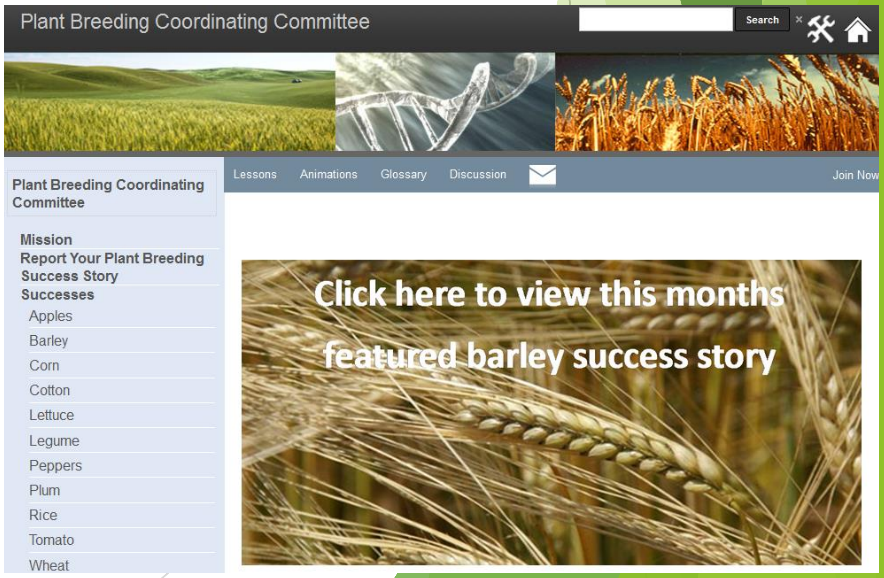
Work with us to develop a national plan based on eco-regions; commodity and specialty crops; emerging (both immediate and 10-year) issues. Goal is to **avoid planning by attrition.**

NAPB "ASKs" Land Grant Universities:

Maintain or even add faculty positions in plant sciences (NAPB recommendations parallel CSAW)

Participate in the Agricultural science research and education OSTP event (individually, regionally, as a whole)

How can we help you?



Example

The White House
Office of the Press Secretary

For Immediate Release June 12, 2015

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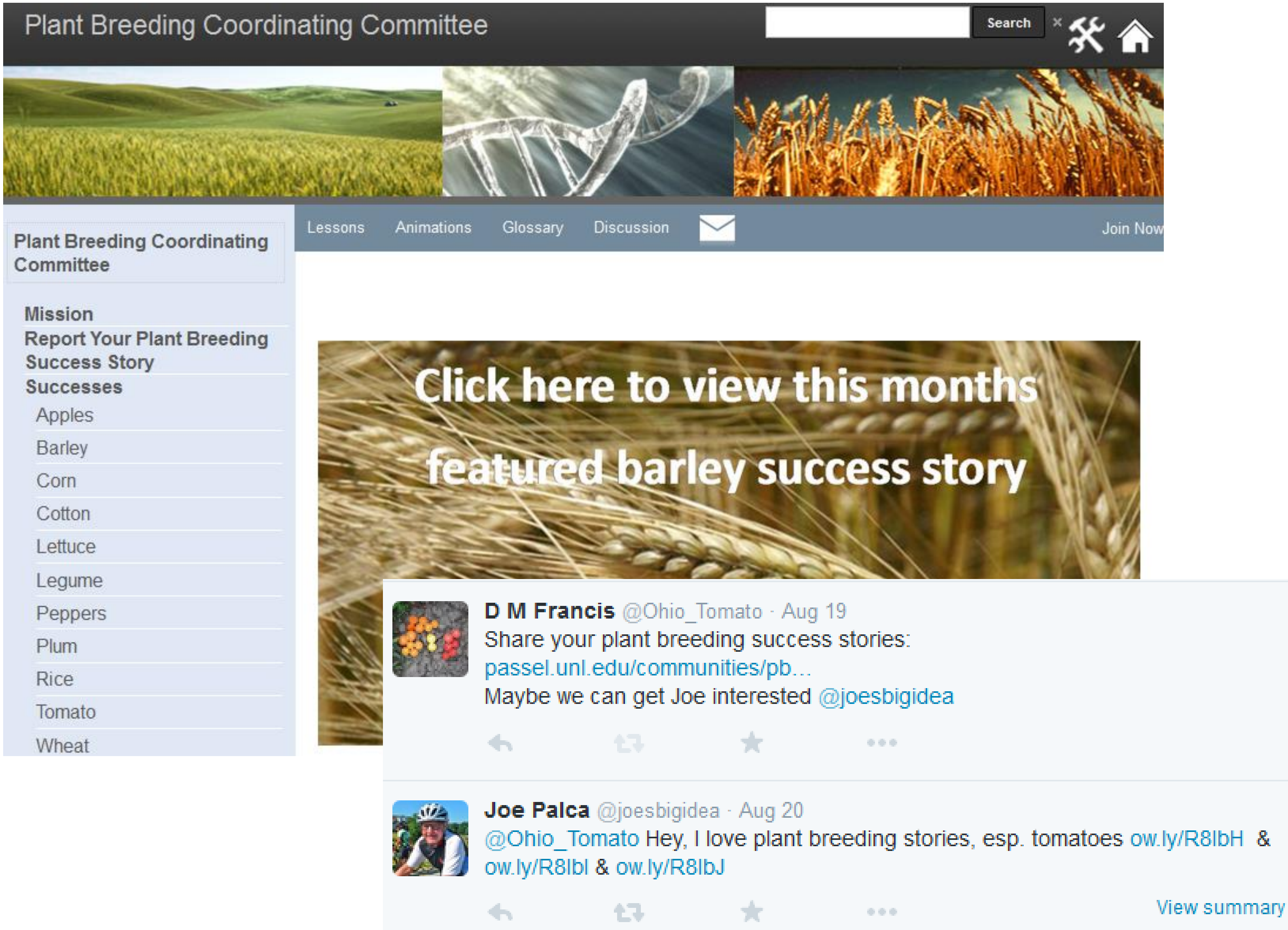
FACT SHEET: New Commitments in Support of the President's Nation of Makers Initiative

Joint letters and individual letters … committing to a response (see examples)

- More than 70 universities and colleges representing more than 1 million students, from Carnegie Mellon University to the University of Arizona, are doubling down on their efforts to expand Making on their campuses. These institutions, which include a diverse array of community colleges and public and private four-year universities of all sizes, in both **a joint letter and individual letters** to the President are each committing to expand their response to the President's call to action on making. For example:
  - *Bucknell* will open a central on-campus Bucknell MakerSpace, and host "maker jams" that will bring together students from engineering, arts, humanities and the social sciences.
  - *Case Western Reserve University* will open the first phase of a 50,000 square foot makerspace and innovation center – named think[box] – for students, while expanding cross-campus efforts to engage students and community members from different disciplines in making, such as involvement of its law school's intellectual property clinic.
  - *Cornell University's College of Engineering* will create a Makers' Projects website to connect all of the maker and maker-like activities across Cornell and are sponsoring the "Pitch your Prototype" and the Intel-Cornell Cup competitions.
  - *Lorain County Community College (LCCC)* will make its FabLab the forefront of its community-engagement strategy, and expand community access to its on-campus maker spaces.
  - *Santa Clara University* will expand its Maker Lab with new equipment and a larger workspace, incorporating the lab as a

Thank you for your time.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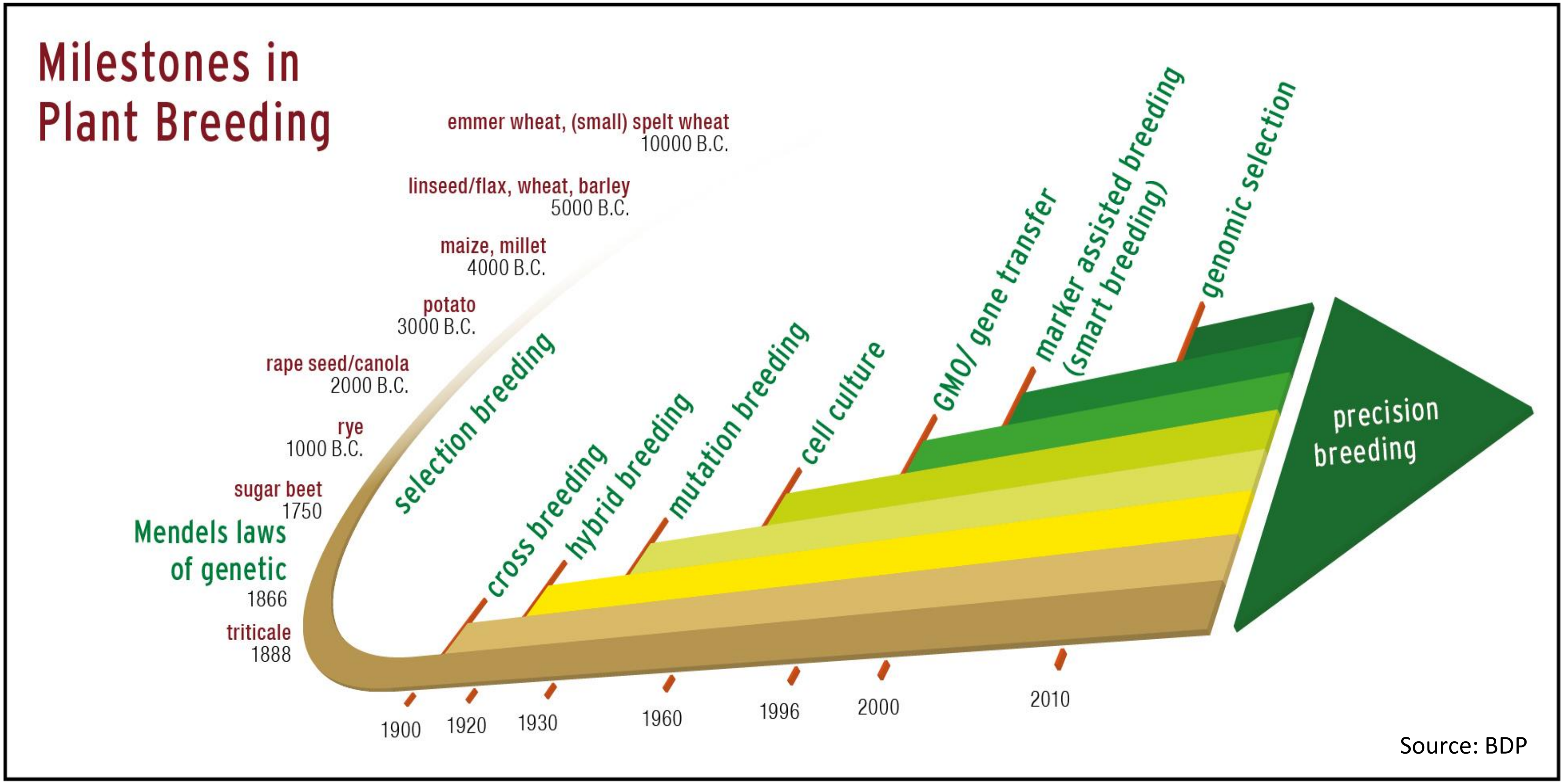
ow.ly/R8lbl & ow.ly/R8lbJ
View summary

The Future of Plant Breeding: Industry Perspective

Jane DeMarchi

Vice President of Government and Regulatory Affairs

The Goals of Plant Breeders Remain the Same


Milestones in
Plant Breeding
emmer wheat, (small) spelt wheat
10000 B.C.
linseed/flax, wheat, barley
5000 B.C.
maize, millet
4000 B.C.
potato
3000 B.C.
rape seed/canola
2000 B.C.
rye
1000 B.C.
sugar beet
1750
Mendels laws
of genetic
1866
triticale
1888
selection breeding
cross breeding
hybrid breeding
mutation breeding
cell culture
GMO/ gene transfer
marker assisted breeding
(smart breeding)
genomic selection
precision
breeding
1900
1920
1930
1960
1996
2000
2010
Source: BDP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Plant breeders today have access to an incredible array of genetic information from both commercial and wild plant varieties.

Genetic Variability: Fundamental to Plant Breeding

- Newer breeding methods also use genetic variability as source material
  - Very specific changes in existing plant genes
  - Ability to transfer defined pieces of plant's genetic material
- ***The plant varieties developed using these new tools could, in most cases, be developed through classical breeding***

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Importance to Plant Breeders

- Gene editing methods can be used across all agriculturally important crops
- Efficient and precise
  - Can reduce R&D and breeding time
  - Important for plants with long generation times
  - Important for crops with rapidly evolving diseases and pests
- Relatively inexpensive
  - Widely available to companies of all sizes and public breeders

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Impact of Public Policy

- Regulatory policy will determine utilization of methods across companies and across crops
- Overly high regulatory burden
  - Limit utilization to largest companies
  - Limit utilization to highest value crops (e.g., corn, soybeans) and to limited number of traits (e.g., herbicide tolerance)

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Impact of Public Policy

- Inconsistent policies
  - Make research collaborations difficult
  - Negative impact on commercial seed trade
  - Negative impact on trade in agricultural products
  - Competitive disadvantages on breeding innovation across countries
- Determine range of new varieties for farmers and new products for consumers
- Impact on overall innovation and agricultural development

Policy Goal

- Legal certainty in government policies
- Regulation grounded in science
- Government policies that facilitate innovation—unnecessary regulation will impede innovation
- Consistent policies for research, collaboration and trade

Policy Endpoints

- Question is <u>not</u> whether a new plant variety is adequately regulated
  - FDA already has oversight for all foods derived from plants
  - APHIS has ample authority to address risks posed by plant pests and noxious weeds
- Question is whether a special pre-market review and clearance process is warranted

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International Goal: Consistent Policy End Points

- Role of International Seed Federation
- Other countries
  - EU legal interpretation
  - Japan
  - Argentina
  - Australia
- Building Alliances

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Communication is Key

- Policy Makers
- Value Chain
- Public/consumers
- Domestic and International

Goal: To Have Entire Toolbox Available

Thank You