6th Annual TAWC
Water College

January 23, 2020
Lubbock Civic Center
Lubbock, TX

The TAWC project was made possible through a grant from the
6th Annual Water College

January 23, 2020
Lubbock Memorial Civic Center
Lubbock, TX

Morning Sessions:
8:30 am  Registration & Visit Booths

8:50 am  Welcome & Introductions

Dr. Glen Ritchie, Department Chair and Professor of Plant & Soil Science, Texas Tech University
Cameron Turner, Manager, Agricultural Water Conservation Program, TWDB

9:00 am  Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

Kevin Brinkley, President and CEO Plains Cotton Cooperative Association

9:40 am  Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Kris Verett, Lubbock Texas Producer

10:30 am  Break & Visit Booths

10:50 am  Real Farm Data – Using Irrigation Management Technology to Conserve Water and Gain Profitability

Lloyd Arthur, TAWC Producer
Jeff Miller, Forefront Agronomy

11:50 am  Update from the Texas Water Development Board

Brooke Paup, Texas Water Development Board (TWDB)

The TAWC project was made possible through a grant from the Texas Water Development Board.
**Afternoon Sessions:**

12:15 pm  **Lunch & Visit Booths**

12:30 pm  **Keynote Address**

*Jodey Arrington*, U.S. Representative, District 19 Congressional District

1:30 pm  **Upcoming Weather Patterns – What is in store?**

*Brian Bledsoe*, Chief Meteorologist/Climatologist, Colorado Springs, CO

2:00 pm  **Hot Topics of Texas Water Law**

*Tiffany Dowell Lashmet J.D.*, Extension Specialist Agricultural Law, Texas A&M AgriLife Extension

2:40 pm  **Break & Visit Booths**

3:10 pm  **US Cotton Trust Protocol – What Farmers Need to Know**

*Ken Burton*, Executive Director of U.S. Cotton Trust Protocol National Cotton Council

3:40 pm  **The Future of Cotton Genetics and Weed Control**

*Dr. Luis Herrera-Estrella*, President’s Distinguished Professor of Plant Genomics and Director of the Center for Functional Genomics of Abiotic Stress, Texas Tech University

4:30 pm  **Close**

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*The TAWC project was made possible through a grant from the Texas Water Development Board*
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If questions/needs ask any of these TAWC Personnel:

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The TAWC project was made possible through a grant from the Texas Water Development Board.
Welcome, Moderator and Presenters for
2020 TAWC Water College

Dr. Glen Ritchie is Chair of the Department of Plant and Soil Science at Texas Tech University (TTU). Dr. Ritchie received his B.S. degree from Utah State University in Crop Science in 2000, his M.S. degree from Utah State University in Crop Science in 2003, and his Ph.D. degree from the University of Georgia in Agronomy in 2007. He joined the Texas Tech Faculty in 2011 as an Associate Professor of Crop Physiology. His responsibilities at Texas Tech include teaching Crop Physiology and Plant Water Relations. Dr. Ritchie has completed approximately 20 Master of Science and PhD. students. Dr. Ritchie has an active research program examining plant water relations in cotton and sorghum.

Research interests include developing effective and economical water management strategies for crop production in the Southern High Plains. Current projects include research on cultivar selection, irrigation management, and the effects of persistent and episodic drought on crop growth, morphology, yield, and quality.

Cameron Turner is the Manager of the Agricultural Water Conservation Program at the Texas Water Development Board. His duties include managing grant projects, developing statewide irrigation estimates, and providing outreach and education to the public.

He was raised on a family farm with operations in parts of Deaf Smith, Parmer, Bailey, and Lamb counties. His rural upbringing fuels his passion for conservation as a means to preserve rural economies, livelihoods, and the prosperity of agriculture in rural Texas.

Cameron attended Texas A&M University where he received a degree in Agricultural Economics with a focus on Farm and Ranch Management. He now lives in Cedar Park with his wife and two children.

The TAWC project was made possible through a grant from the
**Kevin Brinkley** is the president and chief executive officer of Plains Cotton Cooperative Association headquartered in Lubbock, Texas. PCCA is a grower-owned marketing cooperative supplying cotton from Texas, Oklahoma and Kansas to textile mills around the world.

Originally from Burnet, Texas, Brinkley graduated from Texas Tech University with bachelor’s and master’s degrees in agricultural economics. Upon graduation, he joined the staff of the National Cotton Council until 2000, when he joined The Seam. Brinkley was named chairman and chief executive officer of The Seam in January 2015.

Brinkley has spent the last 30 years in the cotton industry, using his knowledge and experience to promote U.S. cotton and ensure the success of American cotton farmers around the globe. He serves as an advisor on trade policy to Secretary of Agriculture Sonny Perdue and United States Trade Representative Robert Lighthizer.

**Kris Verett** is a fourth-generation operator of Verett Farms in Ralls, TX, where cotton and multi-species covers comprise the majority of the operation.

Kris grew up working on the farm and grew to love all things farming. He continued his passion by completing a degree in agronomy and entomology at Texas A&M, followed by a masters in agronomy at Texas Tech. Upon completing school, Kris knew he wanted to return to the farm to employ his knowledge.

After attending R.N. and Ronnie Hopper’s no-till meeting in 2013, Kris became interested in implementing the system into his operation. Today nearly every acre follows a rotation of cotton followed by multi-species covers. Kris looks forward to continuing to better utilize our resources and leave the farm better than he found it for his two boys, Charley and Luke.

**Lloyd Arthur** is a fifth-generation farmer living in Ralls, Texas with his wife Angela.

They have four children, and together the family has created a farming operation that has received awards and recognition such as Crosby County Agriculturist of the Year, Ralls Chamber of Commerce Mr. & Mrs. Cotton Boll and Texas Farm Bureau District II Outstanding Young Farmer and Rancher. Field to Market Farmer Spotlight, and Outstanding Friend of Extension Specialists Award. Lloyd has served in numerous leadership roles including the boards of Rio Blanco Soil

The TAWC project was made possible through a grant from the Texas Water Development Board.
The TAWC project was made possible through a grant from the Texas Water Development Board, Cotton Incorporated, and Texas Farm Bureau (just to name a few).

**Jeff Miller** was born and raised in Plainview, TX and has been involved in agriculture his whole life. Jeff holds a BS in Integrated Pest Management from Texas Tech and an MS in Crop Physiology from Texas Tech. Jeff is married to Kate and has 4 beautiful children. Jeff worked for 10 years with Deltapine/Monsanto in product development and worked 8 years with Pioneer in drought research, sales, and agronomy.

He founded Forefront Agronomy in 2017 to provide leading edge individualized agronomy insight and support to the growers of West Texas. There are many challenges in agriculture and by utilizing our partnerships with DuPont Pioneer, CropMetrics, and 360 Yield Center we have the best support behind us to tackle these challenges and strive for profitability.

**Brooke Paup** was appointed to the Texas Water Development Board by Governor Greg Abbott on February 22, 2018 and reappointed to a new term on February 6, 2019.

Prior to her appointment to the Board, Paup served as the director of legislative affairs for the Texas Comptroller of Public Accounts for the previous three years. While there, she led a team of legislative professionals to address statutory tax reforms.

Paup is formerly the deputy division chief of intergovernmental relations and former special assistant for policy and research for the Office of the Attorney General, where she worked on legislative issues, special litigation, and public finance—notably House Bill 4 and Senate Joint Resolution 1 in the 83rd Legislative Session, which created the State Water Implementation Fund for Texas (SWIFT) and the State Water Implementation Revenue Fund for Texas (SWIRFT). Paup has 13 years of state government experience.

She is a member of the State Bar of Texas, Symphony League, Wine and Food Foundation of Texas Auction Committee, and Doss PTA. Paup earned a Bachelor of Arts from Texas A&M University and a juris doctor from Texas Tech School of Law. She lives in Austin with her husband, Spivey, and their two children, Henry and Heidi.
Keynote Address

Congressman Jodey Arrington was raised in Plainview, Texas, the son of a tractor salesman and a school teacher. Jodey graduated from Texas Tech and his passion of public service took him to Austin, Texas where he worked for Governor George W. Bush. He was then tapped by President Bush to join the White House as a senior advisor before being appointed as Chief of Staff to the Federal Deposit Insurance Corporation. In 2007, he returned to West Texas where he was Vice Chancellor of the Texas Tech University System before taking the helm as President of a healthcare innovation company in Lubbock.

In January of 2017, Jodey became only the fifth person to represent Texas’ 19th Congressional District since its formation in 1935. In Congress, Jodey has been an outspoken advocate for reining in the federal government, promoting agriculture and energy, strengthening national security, and respecting the Constitution.

In his first term, Jodey served as a member of the Agriculture, Budget and Veterans’ Affairs committees. He was also appointed by the Speaker as the only freshman member to serve on the Joint Select Committee on Budget and Appropriations Reform.

Upon entering the 116th Congress, Jodey was selected to serve on the Committee on Ways and Means. The oldest Congressional Committee, Ways and Means also has the broadest legislative jurisdiction including tax, trade, healthcare, social security, and welfare. As a new member on the Committee, prioritizing rural America’s most critical issues – agriculture, energy, and healthcare, will remain his driving force.

He is grateful to serve and is especially thankful for the tremendous sacrifice and support of his wife, Anne, and their three children.
The TAWC project was made possible through a grant from the
Texas Water Development Board.

Brian Bledsoe is the Chief Meteorologist/Climatologist for KKTV 11 News in Colorado Springs, Colorado.

Brian's goal is to help AG producers make their business more successful, by using accurate weather forecasts, both short term and long term. His strong background in agriculture is important, as he recognizes the need for good common-sense weather forecasting that can be readily used by farmers and ranchers. Brian has several private clients scattered around Colorado, and the whole United States. He frequently speaks all across the region about weather and the importance of using long range forecasting to help your business.

Tiffany Dowell Lashmet, J.D. is an Associate Professor and Extension Specialist in Agricultural Law with Texas A&M AgriLife Extension. Tiffany grew up on a family farm and ranch in Eastern New Mexico, received her Bachelor of Science in Agribusiness (Farm and Ranch Management) *summa cum laude* at Oklahoma State University, and her law degree *summa cum laude* at the University of New Mexico.

Prior to joining Texas A&M AgriLife Extension, Tiffany worked for 4 years at a law firm in Albuquerque practicing civil litigation. She is licensed to practice law in New Mexico and Texas. She lives in the Texas Panhandle with her husband, son, and daughter.

In 2016, Tiffany was named the State Specialist of the Year for Texas Agriculture by the Texas County Agricultural Agents Association. In 2019, she won the Excellence in Agricultural Law Award for Academia from the American Agricultural Law Association.

Ken Burton is the Executive Director of the U.S. Cotton Trust Protocol. Ken is responsible for the overall development and operation of the U.S. Cotton Trust Protocol. He works with producers and other cotton industry members to enroll participants in the Trust Protocol, as well as interact with textile brands/retailers and civil societies in the development, acceptance and use of the program.

A graduate of Auburn University, Ken has 28 years of experience in the cotton industry, most recently serving as Vice President of Loeb and Company, Inc. He has built strong relationships with industry participants throughout the
The TAWC project was made possible through a grant from the supply chain from growers to textile manufacturers. Ken coordinated all aspects of Loeb and Company’s participation in the Better Cotton Initiative.

Ken is happily married to his wife, Laura for 27 years. They have three children: Madeline (22), William (20), and Kristen (17).

Dr. Luis Rafael Herrera-Estrella's research focuses on the molecular mechanisms that allow plants to cope with a continuously changing environment. In particular, he has studied the two fundamental processes of molecular responses to light as a source of energy and a developmental signal, and nutrient availability.

Herrera-Estrella identified DNA regulatory elements that allow plants to activate genes in response to light stimuli and the protein sequence present in many corresponding gene products that ultimately allow participation in the photosynthesis process. A holder of 15 patents, Herrera-Estrella has published more than 180 research papers and 47 book chapters and other reviews while having delivered more than 200 presentations on his work. He served as a senior international research scholar at the Howard Hughes Biomedical Institute from 2012 to 2017 and earned the Dr. Luis Federico Leloir Award in 2012 from the Argentinian Ministry of Science, Technology and Innovation.

A native of Mexico, Herrera-Estrella also has served as the president of the International Society of Plant Molecular Biology (2001-2003), and in 2000, earned the gold medal from the World Intellectual Property Organization as one of the most distinguished inventors in Mexico, one of only three Mexican citizens to receive this honor.

Herrera-Estrella earned his doctoral and postdoctoral degrees in genetics from the State University of Ghent, Belgium. He received his master's degree in genetics and molecular biology from the Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, and his bachelor's degree from Escuela Nacional de Ciencias Biológicas Instituto Politécnico Nacional.
Future Trends in World Demographics and Agriculture

The Effect of Population Changes on the American Farmer

Current global political and economic conditions are the darkest in history.

True or False

What percent of the world lives in poverty?

A.) 61%  B.) 54%  C.) 35%  D.) 28%
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

For most of the world's population, the human condition has improved.

**What are the implications for the future of agriculture?**

**A Shifting Population**

Population projection by the UN, 2015

**Population Growth**

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Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

China’s Aging Population

Billions of People

Percent Over 65

0% 5% 10% 15% 20% 25% 30% 40%

What does population growth mean to agriculture?

Gap = Production Minus Consumption

Population vs. GDP

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Future Trends in World Demographics and 
Ag: The Effect of Population Changes on the 
American Farmer

What percent of the world lives in poverty?
A.) 61% B.) 54% C.) 35% D.) 28%

Poverty is rapidly declining
Percent of World Living on $1.90/day or Less

Nearly 80% percent of the world’s poor
live in rural areas, and many depend on
farming for their livelihood.

Source: World Bank

Global Income Distribution

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Corn Production Gap-Africa

Wheat Production Gap-Africa

Cotton Production Gap-Africa
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

Brazil’s Deforestation

<table>
<thead>
<tr>
<th>Year</th>
<th>Thousand Square Miles</th>
</tr>
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<tbody>
<tr>
<td>2005</td>
<td>7.3</td>
</tr>
<tr>
<td>2006</td>
<td>5.5</td>
</tr>
<tr>
<td>2007</td>
<td>4.5</td>
</tr>
<tr>
<td>2008</td>
<td>8.0</td>
</tr>
<tr>
<td>2009</td>
<td>2.9</td>
</tr>
<tr>
<td>2010</td>
<td>2.7</td>
</tr>
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<td>2011</td>
<td>2.5</td>
</tr>
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<td>2012</td>
<td>1.8</td>
</tr>
<tr>
<td>2013</td>
<td>2.3</td>
</tr>
<tr>
<td>2014</td>
<td>1.9</td>
</tr>
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<td>2015</td>
<td>2.4</td>
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<td>2016</td>
<td>3.0</td>
</tr>
<tr>
<td>2017</td>
<td>2.7</td>
</tr>
<tr>
<td>2018</td>
<td>3.1</td>
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Competitors of the Future?

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent of Land in Agriculture</th>
</tr>
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<tbody>
<tr>
<td>1970</td>
<td>37%</td>
</tr>
<tr>
<td>1975</td>
<td>37%</td>
</tr>
<tr>
<td>1980</td>
<td>37%</td>
</tr>
<tr>
<td>1985</td>
<td>37%</td>
</tr>
<tr>
<td>1990</td>
<td>37%</td>
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<tr>
<td>1995</td>
<td>37%</td>
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<td>2000</td>
<td>37%</td>
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<tr>
<td>2005</td>
<td>37%</td>
</tr>
<tr>
<td>2010</td>
<td>37%</td>
</tr>
<tr>
<td>2015</td>
<td>37%</td>
</tr>
</tbody>
</table>

Lesser Developed Nations Needs

- Money
- Infrastructure
- Education
- Time
- Political Stability

Source: Instituto Nacional de Pesquisas Espaciais

Source: World Bank

Sub-Saharan Africa

Lesser Developed Nations Needs

• Money
• Infrastructure
• Education
• Time
• Political Stability

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Access to Electricity

Quality of Port Infrastructure

Workforce Skills

Only 68% of Sub-Saharan Africa has completed a primary education
Current global political and economic conditions are the darkest in history.

True or False

What does all of this mean for our farmers?

Trade
In 1980, President Jimmy Carter embargoed U.S. grain sales to the U.S.S.R.

Did it permanently impact our market?
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

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**Free Trade Works for Ag**

Ag Exports in $ Billions in 5 Years Before and After FTAs

Before vs. After FTAs

---

**China vs. India**

Net Agricultural Trade

Production: China 22% vs. India 33%
Consumption: China 33% vs. India 22%
Imports: China 23% vs. India 22%
World Stocks: China 41% vs. India 22%

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**China Dominates World Market**

22% Production
33% Consumption
23% Imports
41% World Stocks
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

What About the Near Term?

Summary

Demand Drivers
- Global population growth
- Income Improvements
- Lack of production capacity in highly populated areas

Supplier Advantages
- Limited land means productivity is critical
- Infrastructure investments
- FTAs work for agriculture

What do we do until demand starts to improve?
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

U.S. Farm Working Capital

Opportunities for Change?

Focus Areas for Growers

- Reduce costs per unit of production
- Add value through innovative marketing
- Advocate for appropriate federal support
Future Trends in World Demographics and Ag: The Effect of Population Changes on the American Farmer

<table>
<thead>
<tr>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Nations</td>
</tr>
<tr>
<td>World Bank</td>
</tr>
<tr>
<td>USDA</td>
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<tr>
<td>CoBank</td>
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<tr>
<td>Plains Cotton Cooperative Association</td>
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</table>

1/23/2020

Kevin Brinkley - 2020 TAWC Water College
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Kris Verett

Overview
- Verett Farms background
- Why no-till & covers?
- Rotational sequence
- Cover progression
- Planting & setup
- Weed control strategies
- Budget comparison
- Questions

Verett Farms Background
- Location: Ralls, TX
- Acres: approximately 4,000
- Primary crops:
  - Cotton
  - Multi-species covers
- Cows?
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Why No-Till & Covers?

- Less soil erosion
- Cost savings
  - Fuel: using 60% less
  - Maintenance
  - Wear & tear
- Less employee burnout
- Less soil erosion
- Cost savings
  - Fuel: using 60% less
  - Maintenance
  - Wear & tear
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Kris Verett - 2020 TAWC Water College
Why No-Till & Covers?

- Less soil erosion
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  - Maintenance
  - Wear & Tear
- Less employee burnout
- Better water infiltration
- Collecting unruly precipitation
- Less evaporation
- Keeps ground cooler
Why No-Till & Covers?

- Less soil erosion
- Cost savings
- Fuel: using 60% less
- Maintenance
- Wear & tear
- Less employee burnout
- Better water infiltration
- Collecting un-harvested
- Less evaporation
- Keep ground cooler
- Soil health benefits
- Less compaction
- Firmer seed beds

Rotational Sequence

Drilling Rye

- Tontiness
- Planting rate
- Rye
- Radishes
- Minimal soil disturbance
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

**Multi-Species Mix**

<table>
<thead>
<tr>
<th>Seed</th>
<th>Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckwheat</td>
<td>0.5</td>
</tr>
<tr>
<td>Daikon Radish</td>
<td>0.5</td>
</tr>
<tr>
<td>Purple Top Turnip</td>
<td>0.5</td>
</tr>
<tr>
<td>Teff Wheat</td>
<td>1.0</td>
</tr>
<tr>
<td>Japanese Wheat</td>
<td>1.0</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>1.0</td>
</tr>
<tr>
<td>Sorghum Sudan</td>
<td>4.0</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>1.0</td>
</tr>
<tr>
<td>Rye Grass</td>
<td>1.0</td>
</tr>
<tr>
<td>Sunn Hemp</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Planting Multi-Species into Rye**

**Cover Progression – Wideman Pivot – April 25th**

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Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Cover Progression – Wideman Pivot – June 15th

Cover Progression – Wideman Pivot – June 24th

Cover Progression – Wideman Pivot – July 9th
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Cover Progression – Wideman Pivot – August 29th

Cover Progression – Wideman Pivot – September 23rd & 30th

Cover Progression – Wideman Pivot – November 19th
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

**Cotton Planting Setup**
- Case IH Planter
- Yetter finger-style trash whippers, with depth band
- Martin spiked closing wheels

**Planting Cotton Behind Cover**

**Emergence Progression Pics**
Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Cover Degradation – Starting Point – September 10th

Cover Degradation – You Can’t Have Enough!

<table>
<thead>
<tr>
<th>Timing</th>
<th>Herbicide Mix</th>
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<tbody>
<tr>
<td>Late February</td>
<td>8 oz Weedmaster + 1 qt Roundup</td>
</tr>
<tr>
<td>April</td>
<td>24 oz Weedmaster + 1 qt Roundup</td>
</tr>
<tr>
<td>Behind planter</td>
<td>2 oz Staple + 1 lb Dires + 32 oz Gramoxone</td>
</tr>
<tr>
<td>Early-mid post</td>
<td>Dual or Warrant + 40 oz Liberty + 1 qt Roundup</td>
</tr>
<tr>
<td>Post-directed leyby</td>
<td>1 lb Dires + 1 qt Roundup</td>
</tr>
</tbody>
</table>

Weed Control Strategies

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Using Cover Crops to Manage Soil and Weed Control While Being Economically Sustainable

Justifying Herbicide Expense

- Cultivation not an option
- Reseeding weeds
- Increased soil erosion
- Poor water infiltration
- Preventing emergence of resistant weeds
- Fibermulch varieties
- Less annual weed pressure over time

Budget Comparison - Irrigated

<table>
<thead>
<tr>
<th>120 Acres Irrigated Cotton 2 gpa/acre</th>
<th>100% yield potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>120</td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
</tr>
<tr>
<td>Net for 120 Acres</td>
<td>$36,900</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>60 Acres Irrigated Cotton 4 gpa/acre</th>
<th>150% yield potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>60</td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
</tr>
<tr>
<td>Net for 60 Acres</td>
<td>$42,000</td>
</tr>
</tbody>
</table>

Budget Comparison - Dryland

<table>
<thead>
<tr>
<th>120 Acres Dryland Cotton 400#</th>
<th>65% yield potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>120</td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
</tr>
<tr>
<td>Net for 120 Acres</td>
<td>$10,200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>60 Acres Dryland Cotton 650#</th>
<th>65% yield potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>60</td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
</tr>
<tr>
<td>Net for 60 Acres</td>
<td>$13,650</td>
</tr>
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</table>

https://southplainsprofit.tamu.edu

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Questions?
Hindsight

- We have many technologies available to look back on past performance
  - Yield Monitor - yield Data
  - Soil Moisture
  - Historical Weather Data
  - Soil Information
  - EC Data

Insight

- Having the ability to look at what is happening now.
  - Soil Moisture Probes - plant water use, rooting depth, available moisture
  - Imagery
  - Tissue/Soil Testing
  - Crop Scouting
Foresight

- The ability to predict what may happen and give us the chance to make adjustments before it happens
  - Soil Moisture Crop Modeling
  - Fertility Modeling
  - Weather Forecasting
  - Sap Analysis
  - Biological Soil Testing

Confidence is found in systems

The opportunity is in the Variability

- It’s because of the variables that we need to plan
- If you fail to plan, you will plan to fail
  - Plan to fail - when and where to abandon or move water to best parts of the field
  - Identify the 50% best part of the farm we have to make money
- Manage the fixed variable that are known
- Unknown variables
  - Depleting wells, weather, commodity price
Variable Rate Irrigation Basics

Speed Control VRI
- Application rate is varied by changing the speed of the pivot
- Irrigation Management Zones are "pie sliced"
- Relatively inexpensive - most pivot panels can operate without added investment
- No special hardware on sprinklers
- If spatial variation lines up well with pie slices
- Varying application based on topography, varying application on one split if it lines up with pie slices
- Multiple crops or varieties under one pivot

Optimize Every Acre
in Every Field
Every Time!

Types of VRI Irrigation Prescriptions

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Limitation</th>
<th>Example Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>Prescription stays the same or changes only a few times during the season</td>
<td>Relatively simple to apply. Does not account for changes in spatial variability over the season</td>
<td>Avoiding irrigation on uncrossed areas. Mining differences in soil available water capacity Windshield Wiper pivot with little spatial variability</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Prescription changes frequently during the season, possibly for each irrigation event</td>
<td>May be complicated and increase management efforts. May provide maximum gross benefit</td>
<td>Varying irrigation to each part of the field as needed and adjusting areas as needs change during the season</td>
</tr>
</tbody>
</table>
Possible VRI Uses - Thinking outside the box of Soil Variability

<table>
<thead>
<tr>
<th>Uses</th>
<th>Prescription Type</th>
<th>Management Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid application in uncrossed areas</td>
<td>Static</td>
<td>Low</td>
</tr>
<tr>
<td>Avoid overlapping pivots for improved efficiency</td>
<td>Static &amp; Dynamic</td>
<td>Low</td>
</tr>
<tr>
<td>Reduce application in wet areas to avoid waterlogging or leaching</td>
<td>Static &amp; Dynamic</td>
<td>Medium</td>
</tr>
<tr>
<td>Irrigate lighter soils when needed while heavier soils use water</td>
<td>Static Medium</td>
<td>Medium High</td>
</tr>
<tr>
<td>Reduce application rate to avoid runoff in part of a field</td>
<td>Static Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Apply extra water to sloping areas to compensate for runoff after heavy rain</td>
<td>Static &amp; Dynamic</td>
<td>Medium High</td>
</tr>
<tr>
<td>Irrigate each part of the field as needed by precipitation, runoff, evapotranspiration, wind, and/or drainage</td>
<td>Dynamic</td>
<td>High</td>
</tr>
</tbody>
</table>

Steps for Implementing a VRI Strategy

1. Measure field variability via a soil electrical conductivity survey (EC)
2. Build the VRI prescription layer
3. Schedule irrigation
4. Monitor the field during the season

Keep Eyes Focused Forward to move the needle

- Performance is PAST
- Potential is FUTURE
  - What's interesting is that 2.5 bales may be all that piece of ground is going to produce but with current inputs for 3 bales we are limiting the 3.5 and 4 bale regions (Who knows where the upper limit is)
Real Farm Data - Using Irrigation Management Technology to conserve Water and Gain Profitability

Why Variable Rate Works
Precision Farming is MODERN DAY FARMING - letting the DATA lead us in that direction

Field Goal: 1250 lbs/ha

Precision Farming is MODERN DAY FARMING - letting the DATA lead us in that direction

24/7 alerts and monitoring from your phone

24/7 alerts and monitoring from your phone

Lloyd Arthur & Jeff Miller - 2020 TAWC Water College
Real Farm Data - Using Irrigation Management Technology to conserve Water and Gain Profitability

CropMetrics VO
Jill Miller - ForeFront Agronomy
Soil Moisture Probes

Lloyd Arthur - Ralls, TX

<table>
<thead>
<tr>
<th>Irrigation Scheme</th>
<th>Avg Application/Pas s</th>
<th>Total inches applied inseason</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRI</td>
<td>0.935</td>
<td>7.20</td>
</tr>
<tr>
<td>Flat Rate</td>
<td>1.000</td>
<td>7.60</td>
</tr>
</tbody>
</table>

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Real Farm Data - Using Irrigation Management Technology to conserve Water and Gain Profitability

VRI Farm 12

Flat Rate vs VRI Yield Comparison 3 yr – Arthur Farms

Flat Rate vs VRI Loan Rate Comparisons 3yr – Arthur Farms

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<table>
<thead>
<tr>
<th>Sector</th>
<th>Yield</th>
<th>Lint</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Rate</td>
<td>777.2</td>
<td>$0.5173</td>
<td>$402.04</td>
</tr>
<tr>
<td>VRI</td>
<td>892.2</td>
<td>$0.5284</td>
<td>$471.41</td>
</tr>
<tr>
<td>VRI Advantage</td>
<td>115.0</td>
<td>$0.0111</td>
<td>$69.37</td>
</tr>
<tr>
<td>Probe Cost</td>
<td>-</td>
<td>-13.3/A</td>
<td></td>
</tr>
<tr>
<td>VRI Cost</td>
<td>-</td>
<td>-5/A</td>
<td></td>
</tr>
<tr>
<td>Controller Cost</td>
<td>-</td>
<td>-5.46/A</td>
<td></td>
</tr>
<tr>
<td>Water savings of 0.4” @ $8/inch</td>
<td>$3.20</td>
<td>$48.81</td>
<td></td>
</tr>
</tbody>
</table>

Water savings of 0.4” @ $8/inch $3.20 $48.81
Nozzle Spacing Differences

80" drop spacing  40" drop spacing
Nozzle Spacing Comparison

<table>
<thead>
<tr>
<th>Irrigation Type</th>
<th>Yield</th>
<th>Loan</th>
<th>$/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>40” Drop Spacing</td>
<td>731.6</td>
<td>$0.5161</td>
<td>$377.55</td>
</tr>
<tr>
<td>80” Drop Spacing</td>
<td>563.1</td>
<td>$0.5048</td>
<td>$284.20</td>
</tr>
</tbody>
</table>

2 yr Avg - 10.4” of irrigation in season
Other Uses for VRI

Water on turn rows/how many gallons wasted?
Variable Rate Irrigation to address Wiper or Split Pivots

- Constant Speed at 1.5"
- 26 bu/AC yield difference between N side and S side
Variable Rate Irrigation

For wind stress, VR prescriptions can be easily programmed to increase irrigation to any edge of the field that shows crop damage or potential yield loss as determined by visual observation.

Variable Rate Irrigation

Variable Rate Seeding

For optimal variable rate seeding prescriptions, VR prescriptions can more precisely match irrigation to increased or decreased seed densities to further optimize yields.

Jeff Miller
ForeFront Agronomy LLC
(806) 787-6954
forefrontagronomy@gmail.com
https://forefrontagronomy.com

Lloyd Arthur & Jeff Miller - 2020 TAWC Water College
Don’t Mess with Texas: Water Edition

Director Brooke T. Paup
Texas Water Development Board

TAWC Water College
January 23, 2020

Mission

The mission of TWDB is to provide:
• Leadership
• Information
• Education
• Support for planning, financial assistance, and outreach

For the conservation and responsible development of water for Texas.
Legislative Update

Groundwater bills
- HB 720 (Larson) – Appropriations of water for aquifer storage & recovery projects (ASR)
- HB 721 (Larson) – TWDB studies on ASR projects
- SB 1041 (Taylor) – Extend HB 30 deadline to designate brackish groundwater production zones

Update Water Availability Models
- HB 723 by Larson (Perry)
- For the following rivers:
  - Brazos  – Red
  - Neches  – Rio Grande
Update from the Texas Water Development Board  1/23/2020

Water Planning

• HB 807 by Larson (Buckingham)
  – Requires TWDB to create an inter-regional planning council
  – For the following purposes:
    • Improve coordination among regional planning groups
    • Improve coordination between each regional group and the TWDB
    • Facilitate dialogue on water management strategies that could affect multiple planning areas
  – Regional planning groups encouraged to make legislative recommendations

SB 7

Financing Flood Mitigation

Senate Bill 7

• Relating to:
  – Flood planning
  – Mitigation
  – Infrastructure projects

• Creates two funds
  – Flood Infrastructure Fund
  – Texas Infrastructure Resiliency Fund

Brooke Paup - 2020 TAWC Water College
**Senate Bill 7**

- Stated goal is to “encourage development of structural and non-structural flood mitigation”
  - Structural: physical barriers near rivers, coastline
  - Non-structural: policies or naturally-existing
- Recognizes financial need: preference for counties whose median income is lower than 85% of state median income

**Flood Infrastructure Fund**

- Use of the fund
  - Loans (potentially below market rates) for:
    - Construction of flood projects
    - Costs for planning, design, regulatory approval
  - Grants for:
    - Matching funds for federal flood programs
    - Political subdivisions who would have difficulty repaying a loan
    - Flood projects outside of metro areas

**Additional requirements**

- Political subdivisions must “act cooperatively” with other nearby political subdivisions
- All political subdivisions “substantially affected by a proposed flood project” must participate in planning process
- Public meetings required
- Must analyze whether a proposed flood mitigation project could capture floodwater for water supply purposes
Texas Infrastructure Resiliency Fund

Four accounts comprise the TIRF:
- Floodplain Management Account
- Hurricane Harvey Account
- Federal Matching Account
- Flood Plan Implementation Account

Floodplain Management Account

- Money in this account to be used for:
  - Collecting and analyzing flood-related data
  - Public outreach and education
  - Evaluating responses to flood events
- Funded by insurance taxes – about $3.05 million each fiscal year
- The existing money in Floodplain Management Account #330 will be transferred and re-allocated as one of the 4 TIRF accounts

Hurricane Harvey Account

- This account to provide money to TDEM to finance Harvey-related projects
  - Grants to provide matching funds for:
    - TDEM or FEMA hazard mitigation projects
    - TDEM or FEMA public assistance projects
  - Loans for planning/design, permitting, construction
- TWDB will develop a point system with TDEM to properly prioritize projects
- Highest priority to projects that:
  - Recommended by Director of TDEM
  - Meet emergency need in Governor-declared disaster area
Federal Matching Account

- TWDB can only use these funds to meet matching requirements for federal projects
  - This includes US Army Corps of Engineers projects
- TWDB may also make subsidized loans to political subdivisions to provide the local share of a federal ship channel improvement project

Flood Plan Implementation Account

- This account will take center stage once the first State Flood Plan is adopted in 2024
- TWDB may only use money in this account to fund projects in the State Flood Plan, much like current SWIFT structure
- Other three accounts will finance projects over the next 4-5 years
- Money may be awarded to several political subdivisions for a single flood project

TIRF Advisory Committee

- Composed much like the existing SWIFT Advisory Committee
- 3 House members: Phelan, Metcalf, Walle
- 3 Senate members: Perry, Hinojosa, Kolkhorst
- 1 Comptroller’s Office / 1 TDEM
- Can hold hearings, work sessions, meetings
- Committee will review operation, function, and structure of the TIRF
- TWDB will provide annual reports to committee
**SB 8**

Statewide Planning for Flood Mitigation

- TWDB shall prepare and adopt a comprehensive state flood plan
  - Composed of several regional plans
  - Guide to state and local flood control policy
  - Contribute to water supply where possible

**Senate Bill 8**

- Relating to state and regional flood planning
- TWDB shall prepare and adopt a comprehensive state flood plan
  - Composed of several regional plans
  - Guide to state and local flood control policy
  - Contribute to water supply where possible

**Senate Bill 8**

- What is included in the State Flood Plan?
  - Evaluation of existing flood infrastructure
  - Statewide ranked list of ongoing and proposed flood control projects
  - Analysis of completed, ongoing, proposed flood projects (starting with second plan in 2029)
  - Analysis of development in the 100-year floodplain
  - Legislative recommendations
Senate Bill 8

- Who will participate in the process?
- TWDB will adopt guidance principles with:
  - Texas Commission on Environmental Quality
  - Texas Department of Agriculture
  - General Land Office
  - Texas Parks and Wildlife Department
  - Texas Department of Emergency Management
  - State Soil and Water Conservation Board

Regional Flood Planning

- TWDB will first designate flood planning regions that correspond to river basins
  - Some river basins are so big that TWDB may subdivide those into multiple planning regions
- TWDB will provide financial and technical assistance to these regional planning groups
- Composed of the same interest groups that do regional planning for SWIFT

Regional Flood Planning

- Regional plans must:
  - Use information based on hard science and updated mapping
  - Describe existing flood infrastructure
  - Describe changes in land use and population increases that could have an effect on flooding
  - Indicate whether a proposed project:
    - Meets emergency need
    - Uses federal money as a funding source
    - Has water supply benefits
Regional Flood Planning

- Regions must hold open meetings that allow for substantive public comment
- Posting and notice requirements like most other political subdivisions
- TWDB then determines the following before the region adopts its plan:
  - Satisfies all statutory requirements
  - Whether proposed projects affect neighboring areas
  - If so, then TWDB would help coordinate a solution that accommodates all affected areas

Advisory Committee

- Composition of committee
  - Chair of Senate Water and Rural Affairs
  - Chair of House Natural Resources
  - Chair of Senate Finance
  - Chair of House Appropriations
  - Representative from TDEM
  - Representative from State Soil and Water Conservation Board
- Committee will oversee the implementation of the State Flood Plan

Agricultural Conservation Grants
Agricultural Conservation Grants

• Eligible applicants
  – Groundwater districts
  – University systems
  – Other political subdivisions

• Eligible participants
  – Ag producers
  – Crop consultants
  – Equipment dealers
  – Non-profit organizations

Agricultural Conservation Grants

• $1.2 million available this year
  – Amount recently doubled by the Legislature

• Focus this year
  – Improving soil health
  – Promoting irrigation conservation

• Applications due: February 19th, 2020

New TWDB Initiatives
Asset Management Program for Small Systems

- Assist smaller utilities in operating proactively
- Help utilities create a plan to keep them technologically and financially sustainable
- Utilizes management tools developed by TCEQ
- No local match requirement, just 80 staff hours of “sweat equity” to develop the plan
- Initial round SFY19: $450,000 / 6 small systems
- Any entity (not just small systems) now eligible to borrow up to $75,000 at 0% interest to prepare similar asset management/financial planning tools

CPA to Go Initiative

- Similar in concept to AMPSS
- CPAs provide technical assistance services
- Targets systems in need of special assistance to maintain adequate SRF compliance
- 2 broad categories
  – Regulatory and financial assistance covenant compliance procedures
  – Professional services
Securing Safe Water Initiative

- EPA Strategic Plan goal: significantly reduce the number of systems with health violations
- April 2019: 261 public water systems in Texas had unresolved health issues
- Special allocations: Very Small Systems, Urgent Need, Disadvantaged, Small/Rural
- Outreach and determining need
- Technical assistance
- Track outcomes

Program Updates

SWIFT Update

- September 24th, 2019 bond sale
- Will provide approximately $972 million for financing new state water plan projects
- Estimated savings of approximately $170 million for these ten SWIFT borrowers
- Brings total savings to over $1 billion since the first funding cycle in 2015
- SWIFT 2020 funding cycle is now open. Abridged SWIFT applications are due February 3rd
Flood Update

• SB 7: Flood Infrastructure Fund
  – Draft rule comment period: Closed January 13th
  – Special board meeting: January 30th
  – Adopt final rules: End of February

• SB 8: Guidance principles/Designate planning areas
  – Draft rule comment period: Closes February 3rd
  – Adopt final rules: End of March
Upcoming Weather Patterns - What is in store?

1/23/2020

**Precipitation +/- Inches of “Normal” Past 90 Days**

**Objective Short-Term Drought Indicator Blend Percentiles**

**ENSO Update**

Sea Surface Temperature Anomalies 1/21/20

Brian Bledsoe - 2020 TAWC Water College
Neutral to weak Modoki El Niño...

Possible Legit El Niño Brewing?

ENSO Plumes Ensemble Favors Neutral ENSO Conditions
Upcoming Weather Patterns - What is in store?

1/23/2020

Weak Modoki El Niño Likely Continues

• Goodbye Traditional El Niño
• Goodbye Modoki El Niño

JAMSTEC Modoki index

Traditional El Niño

Modoki El Niño
Upcoming Weather Patterns - What is in store?

1/23/2020

Brian Bledsoe - 2020 TAWC Water College
Upcoming Weather Patterns - What is in store?

Precipitation Differences With Different El Niños

• Traditional El Niño

• Modoki El Niño

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NMME Model Precipitation Forecast
Green = Wetter  Brown = Drier  White = “Average”

14

NMME Model Precipitation Forecast
Green = Wetter  Brown = Drier  White = “Average”

15
Upcoming Weather Patterns - What is in store?

NMME Model Precipitation Forecast
Green = Wetter Brown = Drier White = “Average"

JAMSTEC Model Precipitation Forecast
Green = Wetter Brown = Drier White = “Average”

1/23/2020
Upcoming Weather Patterns - What is in store?

1/23/2020

JAMSTEC Model Precipitation Forecast
Green = Wetter Brown = Drier White = “Average”

Predicted SON2018 temp2 anom. from 1Jul2018 (9-member)

Predicted JJA2020 temp2 anom. from 1Jan2020 (9-member)

Predicted DJF2018/2019 temp2 from 1Jul2018 (9-member)

Brian Bledsoe - 2020 TAWC Water College
Upcoming Weather Patterns - What is in store?

1/23/2020

JAMSTEC Model Precipitation Forecast
Green = Wetter  Brown = Drier  White = “Average”
Predicted SON2020 temp. anom. from 1jul2020 (9-member)

EURO Seasonal Model Precipitation Forecast
Green/Blue = Wetter  Yellow/Brown = Drier  White = “Average”
Anomaly monthly precipitation (in)
Upcoming Weather Patterns - What is in store?

EURO Seasonal Model Precipitation Forecast
Green/Blue = Wetter  Yellow/Brown = Drier  White = “Average”

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EURO Seasonal Model Precipitation Forecast
Green/Blue = Wetter  Yellow/Brown = Drier  White = “Average”

32

Pacific Northwest Regional Outlook

Drought currently an issue, especially northwest...and could worsen according to models and analogs. Dry signal isn’t strong for a prolonged stretch, but worth protecting against.
California/Nevada Outlook

Drought not an issue at this time. However, various models show the potential for the wetter than average at times, and much drier than average at times. The driest stretch could be Jan/Feb per models. Esp. if weak Modoki occurs...

Four Corners Regional Outlook

Drought continues to expand due to monsoon season failure. May continue to worsen through the fall, before getting better through the winter and spring of 2020.

Southern Plains Regional Outlook

Drought has worsened in New Mexico and parts of Texas Panhandle. Drought has eased considerably farther east. Models optimistic for continued relief, especially east per Modoki. Less west...
**Plains/Midwest Regional Outlook**

Most areas not experiencing ANY drought. Models do not show stout dry signal for most areas. In fact, the winter/spring could be quite active for most of this region…esp. Northern Plains and Missouri Valley.

---

**My Thoughts…**

- ENSO neutral or weak Modoki El Niño continues…
- Drought not an issue for now…
- Models not exactly wet for spring, and it may take awhile to activate the pattern farther west. Cautious optimism for late spring moisture?
- Concerned about La Niña **POTENTIAL** late in 2020 into 2021…make sure you are prepared.

---

**Weather 5280**

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- Twitter @BrianBledsoe
- Need weather for your biz? Just ask for a quote…
- www.weather5280.com
Disclaimer

This presentation is for educational purposes only as well as to give general information and a general understanding of the law, not to provide specific legal advice. This presentation does not create an attorney/client relationship and should not be used as a substitute for the advice of a licensed attorney.

Road Map

• Quick overview of Texas water law
• State line water law clash
• Stratta case
• Groundwater as a conduit
Texas Water Law

- Applicable law depends on the type of water
  - Groundwater: water percolating in an aquifer
  - Surface water: water in a defined watercourse
  - Diffused surface water: storm runoff not yet in a defined watercourse

- Who owns the groundwater?
  - Landowner owns the water beneath his land.
  - Rule of capture, subject to limitations (common law & GCDs)
  - Exceptions from GCD permitting for domestic and livestock uses.
    - *Bragg v. Edwards Aquifer Authority*

Texas Water Law (cont.)

- Who owns the surface water?
  - State of Texas
  - Must obtain a permit for use from the TCEQ
  - Prior Appropriation
  - Exceptions to permit requirement: domestic and livestock uses

- Who owns the diffused surface water?
  - Landowner has right to use but cannot divert to damage neighbor.
“Navigable Streams”

- Classification matters for two reasons.
  - Exempt diversions allowed only on non-navigable streams.
  - Beds of navigable streams are owned by the state, meaning public can use the stream even if flowing across private land and the landowner may not fence or dam.

- Navigability tests
  - Navigable in fact: Can serve as “common highway for trade and travel.”
  - Navigable in law: Does streambed maintain average width of 30 feet from the mouth up?

State Line Water Law Clash

- Southeastern NM is major oil and gas country.
- NM water law requires a permit for groundwater use.
- Oil and gas companies have been refused fracking permits.
- So…across the state line they go.
- In TX, the landowner owns the groundwater.
  - Loving County, no GCD.
- Companies purchase water in TX, essentially run a hose across the line, use it in New Mexico.
- Former NMLC says this is theft of NM groundwater.
Prime Opportunity for This Issue…

**The Law of the Ogallala**

- SD: Prior appropriation
- NE: Reasonable use/correlative rights (in times of shortage)
- WY: Prior appropriation
- CO: Prior appropriation
- KS: Prior appropriation
- OK: Reasonable use/correlative rights (based on age)
- NM: Prior appropriation
- TX: Absolute dominion/rule of capture
Stratta Case

- Brazos Valley GCD uses formula to determine the number of acres required in order to for a certain amount of water to be pumped.

\[
(\text{Average Annual Discharge Rate} \times \text{District Service Area Size})^2 \times \pi = \text{Total number of equivalent acres needed to be assigned to the well site}
\]

43,560

Stratta Case (cont).

- City of Bryan owns 2.7 acres of land next to Fazzino.
  - Granted permit to drill well 3,000’ from property line to pump 3,000 gpm and 4,838 AF/year.
  - Ignored formula, which would have allowed 192 gpm and 315 AF/year.
- Fazzino owns 26 acres of land.
  - He seeks permit to drill a well pumping 3,000 gpm.
  - Apply formula to determine he is limited to 192 gpm and 315 AF/year.
- Fazzino files suit claiming taking, violation of equal protection.

Clean Water Act: Groundwater as a Conduit

- Clean Water Act says a federal NPDES permit is needed if:
  - Point source discharge
  - Pollutant
  - WOTUS
- Question has arisen: does the discharge have to be direct, or can groundwater serve as a conduit?
- Cases around the country have reached different results.
- SCOTUS heard argument in November.
Groundwater as a Conduit (cont.)

- Summary so far:
  - CWA does apply: 4th (twice); 9th
  - CWA does not apply: 6th (twice); trial court in 7th

- Three case examples:
  - County of Maui (9th Cir.): Disposal well for sewage goes into groundwater, out into Pacific Ocean. CWA does apply– “fairly traceable from point source to WOTUS.”
  - Upstate Forever (4th Cir.): Pipeline ruptures, gasoline seeps into groundwater and then 1,000' into WOTUS. “Sufficiently connected to navigable water.”
  - Kentucky Waterways (6th Cir.): Coal ash pond seeps into groundwater, ends up in lake. “Inconsistent with the text and structure of the CWA.”

Groundwater as a Conduit (cont.)

- Court seemed to struggle…
  - Concerned about “fairly traceable” test being far too broad.
  - Concerned about “directly into” test being far too narrow.

- Potential impacts for agriculture and for rural landowners.
Additional Resource

Other Programs...

• 2020 Ranchers Leasing Workshops
  - Palestine: January 16
  - Abilene: March 31
  - LaVernia (San Antonio area): April 24
  - Brenham: August 17
  - Fredericksburg (Bennett Trust Program): September 14

• 2020 Owning Your Piece of Texas
  - Amarillo: February 12
  - Conroe: March 16
  - Seguin: June 4
  - Burnet: September 15
U.S. Cotton's Journey To Sustainability

Cotton Producers
Increased Management and Environmental Practices

1970s +

Field to Market
Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of commodity crop production in the U.S.

2006

1/23/2020
U.S. Cotton Trust Protocol - What Farmers Need to Know

1/23/2020

Field to Market: The Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of commodity crop production in the United States.

Resource Use Efficiency for Cotton

<table>
<thead>
<tr>
<th>Category</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>Nitrogen</td>
<td>0.7</td>
<td>0.66</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.36</td>
<td>0.36</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Potassium</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
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</tr>
<tr>
<td>Water Use</td>
<td>5,223</td>
<td>5,223</td>
<td>5,223</td>
<td>5,223</td>
</tr>
<tr>
<td>Overall</td>
<td>0.7</td>
<td>0.66</td>
<td>0.64</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Ken Burton - 2020 TAWC Water College
U.S. Cotton’s Journey To Sustainability

1970's + 2006 2013

Cotton Producers
Increased Management and Environmental Practices

Field to Market
Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of commodity crop production in the U.S.

Cotton LEADS
Producers’ commitment to sustainability. Message conveyed to Manufacturers, Brands and Retailers with over 500 partners.

Cotton USA Sustainability Task Force
More information needed from Supply Chain. Emphasis on continuous improvement. Set national goal for key environmental metrics with a target date of 2025.

KEY POINTS ABOUT THE COTTON LEADS PROGRAM

CREATION
Created in 2013 as a means of promoting sustainability of US and AU cotton to retailers, brands and manufacturers

DESIGN
Founded on 5 principles Strategically designed to address sustainability concepts, benevolence, and bale identification (traceability)

FUNCTION
Joint promotion, with individual bragging rights Cotton LEADS website features U.S. growers, researcher profiles, and videos. We control content of US postings and almost all the direct outreach to and meetings with Cotton LEADS partners.
COTTON USA Sustainability Task Force

Producers
Aaron Barcellos
Matt Coley
Dahlen Hancock
John Hardwick
Mark Nichols
Ted Schneider
Gregory Waertz

Cottonseed
Fred Serven

Merchants
Steve Dyer
Tim North

Cooperatives
Kevin Brickley
Hank Rechle

Ginner
Curtis Stewart

Warehouse
Coalter Paxton III

Manufacturers
Garry Bell
Charles Little
Jim Marin

Advisors
Jesse Daystar
Bill Gilson
Andy Jordan
Marty Matlock
Berrye Worsham

U.S. Cotton’s Sustainability Goals for 2025

BY ACHIEVING GOALS, THE FOOTPRINT SHRINKS
U.S. Cotton Trust Protocol - What Farmers Need to Know

1/23/2020

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U.S. Cotton’s Journey To Sustainability

- 1970's +
- 2006
- 2013
- 2017
- 2018

Cotton Producers

Increased Management and Environmental Practices

Field to Market

Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of commodity crop production in the U.S. and beyond.

Cotton LEADS

Producers' commitment to sustainability. Message conveyed to Manufacturers, Brands and Retailers with over 500 partners.

Cotton USA Sustainability Task Force

More information needed from Supply Chain. Emphasis on continuous improvement. Set national goals for key environmental metrics with a target date of 2025.

U.S. Cotton Trust Protocol

Engage producers in continuous improvement. Will help the industry measure and track against its 2025 goals. Will provide aggregate data to the supply chain.

2006

Field to Market Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of commodity crop production in the U.S. and beyond.

2013

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2017

Cotton USA Sustainability Task Force

More information needed from Supply Chain. Emphasis on continuous improvement. Set national goals for key environmental metrics with a target date of 2025.

2018

U.S. Cotton Trust Protocol

Engage producers in continuous improvement. Will help the industry measure and track against its 2025 goals. Will provide aggregate data to the supply chain.

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U.S. COTTON TRUST PROTOCOL

- Two questions to answer

  ✓ What is the Trust Protocol?

  ✓ Why do we need it?

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U.S. COTTON TRUST PROTOCOL

- Single-Member LLC within the National Cotton Council
- Governed by a Board comprised of growers, ginners, merchants, coops, spinning mills, civil societies, and Brands/Retailers. This includes people from the following organizations:
  - World Wildlife Fund
  - Environmental Defense Fund
  - Tesco
  - Levi Strauss & Co.
  - Louis Dreyfus Company

- Emphasis on continuous improvement.
- Set national goals for key environmental metrics with a target date of 2025.
- Engage producers in continuous improvement.
- Will help the industry measure and track against its 2025 goals.
- Will provide aggregate data to the supply chain.
U.S. Cotton Trust Protocol - What Farmers Need to Know

1/23/2020

Ken Burton - 2020 TAWC Water College

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U.S. COTTON TRUST PROTOCOL

• A voluntary farm-level program designed to engage growers in continuous improvement

• A program that can help the industry reach its 2025 goals

• A system that will provide aggregate data that can be passed through the textile supply chain which includes: producers, merchandisers, manufacturers, brands and retailers and others

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KEY REQUIREMENTS FOR THE PRODUCER

• Self-assessment against standards

• Use of a data tool for environmental metrics

• Verification by an independent party

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SELF-ASSESSMENT QUESTIONNAIRE

• 9 categories with approx. 100 questions

• Choices for answers
  A. I do this now on my operation
  B. I am implementing on 1 or more of my fields
  C. I will consider in next 3 years
  D. Not appropriate for my farming operation
Sample Questions for Water Management

Water Management
1. On installation of new wells or existing wells (where applicable), comply with local and state requirements including licensing if appropriate.

Management Planning
2. Conserve and utilize natural rainfall and/or tail water through use of cover crops, terraces, farmside ditches, buffer strips, reservoirs or conservation tillage.

Sample
4. Utilize variable rate irrigation (VRI) or fields with known spatial variability in soil types, topography, and/or crop zones.
5. Utilize flow meters to measure water use.
6. Use soil, climate, or plant-based measurements such as infrared guns or potential evapotranspiration (PET) data to monitor soil and crop water status.
7. Keep records of application dates, materials and rates to track efficiency and identify opportunities for improvement.

Sample Questions for Soil Health

Soil Health
1. A management plan for soil health can include measures to increase soil organic matter, improve water infiltration, and reduce soil erosion.
2. Practices such as cover crops, reduced tillage, no-till, or strip-till can help improve soil health.
3. Utilize conservation tillage practices such as minimum, strip, mulch or no-till.
4. Prevent or alleviate soil compaction through prescribed tillage operations, controlled traffic patterns and avoidance of traffic where soil moisture is above field capacity.
5. Use permanent and/or annual windbreaks to reduce wind erosion.

Sample Questions for Crop Protection

Crop Protection
14. Use licensed qualified consultants or certified crop consultants to monitor crop and pest status and make recommendations for management.
15. Use plant-based measurements to help determine economic thresholds.
16. Use science-based action thresholds to initiate insecticide treatments.
17. Monitor for pest resistance and follow resistance management guidelines.
18. Insecticide resistance can be monitored through the use of field monitors, laboratory tests, and/or other methods.
19. Improve and document field testing and laboratory investigations and develop or update appropriate pest strategies.
20. Manage crop rotations and intercrops to reduce pest pressure and enhance crop health.

Sample Questions for Soil Health

Soil Health
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SELF-ASSESSMENT QUESTIONNAIRE

<table>
<thead>
<tr>
<th>Categories</th>
<th>Required Practices</th>
<th>Recommended Practices</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Health</td>
<td>1</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Nutrient Management</td>
<td>1</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Water Management</td>
<td>1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Crop Protection</td>
<td>13</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Harvest Preparation</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Wildlife Habitat</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fiber Quality and Traceability</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Farm Management</td>
<td>9</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Worker Relations</td>
<td>11</td>
<td>5</td>
<td>16</td>
</tr>
</tbody>
</table>

• 33% Required Management Practices
• 67% Recommended Management Practices with 4 Choices
• Provides Cumulative Data as Producers Answer Questionnaire

THE USE OF COVER CROPS

Plant cover crops with a goal to have living roots on as many months of the year as possible to protect soil and improve soil organic matter.
**U.S. Cotton Trust Protocol - What Farmers Need to Know**

**SELF-ASSESSMENT DATA RESULTS**

**WATER MANAGEMENT PLANNING**

Conserve and utilize natural rainfall and/or tail water through use of cover crops, terraces, furrow diking, holding ponds, reservoirs or conservation tillage.

- Do now on most of my fields.
- Implementing this on one or more fields.
- Will implement in the next 3 years.
- Not appropriate for my farming operation.

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**SELF-ASSESSMENT DATA RESULTS**

**UTILIZE FLOW METERS**

Utilize flow meters to measure water use.

- Implementing on 1 or more fields.
- Do Now on Most of the Fields.
- Consider in the Next 3 Years.
- Not Appropriate for Farming Operation.

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**SELF-ASSESSMENT DATA RESULTS**

**MONITORING SOIL AND CROP WATER STATUS**

Use soil, climate, or plant-based measurements such as infrared guns or potential evapotranspiration (PET) data to monitor soil and crop water status.

- Do now on most of my fields.
- Implementing this on one or more fields.
- Will consider in the next 3 years.
- Not appropriate for my farming operation.

27
SELF-ASSESSMENT DATA RESULTS

Test drinking water used by family and farm workers periodically to assure bacteria, nitrate and other pollutants do not exceed safe levels.

<table>
<thead>
<tr>
<th>Test Drinking Water</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not appropriate to farming operation</td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider in the next 3 years</td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do now on most of the fields</td>
<td>46%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing on 1 or more fields</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

28

SELF-ASSESSMENT DATA RESULTS

Utilize conservation tillage practices such as minimum, strip, mulch or no-till.

<table>
<thead>
<tr>
<th>Conservation Tillage Practices</th>
<th>0%</th>
<th>20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do now on most of my fields</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am implementing this on one or more fields</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I will consider in the next 3 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not appropriate for my farming operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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DATA TOOLS

- Field to Market tool named the FieldPrint Platform
  - Record inputs into a system that measures the environmental impacts of crop production and identify opportunities for improvement

- Additional qualified data management Field to Market partners who can make these recordings for the producer

30
Sensitivity Analysis Field 27

Before:
- Conventional tillage
- Includes erodible area
  - 150 acres cultivated
  - 50 acres poor productivity
- Average slope 1.5%
- Cultivated crop to bayou

After:
- No-till
- Excludes erodible area
  - 100 acres cultivated
  - 50 acres in native vegetation
- Cultivated slope 0.5%
- Riparian buffer

Impacts
Yield and Inputs-Constant (1000 lb/a)

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss t/ac</td>
<td>9.4</td>
<td>1.1 T/ac</td>
</tr>
<tr>
<td>Soil Carbon Index</td>
<td>-4.0</td>
<td>+0.42</td>
</tr>
<tr>
<td>Green House Gas CO2e</td>
<td>23 lb</td>
<td>19</td>
</tr>
<tr>
<td>Energy Btu</td>
<td>12,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Water Quality Index</td>
<td>5.0</td>
<td>9.4</td>
</tr>
</tbody>
</table>
**VERIFICATION**

- Validate accurate use of the on-line enrollment tool such as the self-assessment questionnaire and the data tool.
- A statistically valid random sample of the producers will be selected each year for an independent third-party verification of their questionnaire and data.

---

**U.S. COTTON TRUST PROTOCOL**

- Two questions to answer
  - ✔ What is the Trust Protocol?
  - ✔ Why do we need it?

---

**Why? To Drive Continuous Improvement**

- Annual quantitative measurements
- Feedback for the producer
- How do you compare?
Why? To Achieve Industry Goals

Industry's 10-Year Goals For Environmental Metrics

- Reduce Land Use by 13%
- Increase Irrigation Efficiency by 18%
- Reduce GHG by 39%
- Reduce Energy Use by 15%
- Reduce Soil Loss by 55%
- Increase Soil Carbon by 20%

<table>
<thead>
<tr>
<th>Environmental Category</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Health</td>
<td>✔</td>
</tr>
<tr>
<td>Nutrient Management</td>
<td>✔</td>
</tr>
<tr>
<td>Water Management</td>
<td>✔</td>
</tr>
<tr>
<td>Crop Protection</td>
<td>✔</td>
</tr>
<tr>
<td>Harvest Preparation</td>
<td>✔</td>
</tr>
<tr>
<td>Wildlife/Biodiversity</td>
<td>✔</td>
</tr>
<tr>
<td>Worker Relations</td>
<td>✔</td>
</tr>
<tr>
<td>Farm Management</td>
<td>✔</td>
</tr>
<tr>
<td>Fiber Quality/Traceability</td>
<td>✔</td>
</tr>
</tbody>
</table>

Best Management Practices

- Environmental: Soil Health, Nutrient Management, Water Management, Crop Protection, Harvest Preparation, Wildlife/Biodiversity
- Social: Worker Relations, Farm Management, Fiber Quality/Traceability

Why? To Meet the Needs of Our Customers

"It's the Wild West out there right now," says Paul Magel, president of the business applications and technology outsourcing division at CGS, a software company that works with retail clients.

- The needs of customers will vary
- Many brands/retailers accept U.S. cotton as sustainable or responsibly produced
- However, not all have done so. They point to the lack of a standard or independent verification
- We must be flexible in the ability to pass data to the textile supply chain

Why? To Reclaim Market Share

![Graph showing market share growth](image)

Ken Burton - 2020 TAWC Water College
Why? To Be the Supplier of Choice

- The Protocol is NOT about
  - One grower or one bale being more sustainable than another, or
  - Guaranteeing a premium
- The Protocol IS about U.S. cotton
  - Competing in every market and every supply chain
- The United States cannot afford to lose market access because of a perceived lack of sustainability

U.S. Cotton is Poised to Compete

With 14 million acres and increasing yields, there is excellent potential for 20-25 million bales of production

But, we must have the demand base!

Compete in Every Market & Every Supply Chain

- To be the Supplier of Choice, We Must Meet the Customer’s Needs for
  - Quality
  - Cleanliness
  - Timeliness
  - Sustainability
- The Protocol allows U.S. cotton to tell an even stronger story to our customers and provide support for their various reports.
OUR PLEDGE:
We will enable brands to meet their sustainability goals

trustUScotton.org
Institute of Genomics for Crop Abiotic Stress Tolerance (IGCAST)

Vision
In the next 10 years IGCAST will be one of the top 10 institutes in plant genomics worldwide, with a large production of high impact publications and patents.

Mission
Develop relevant research and technology to contribute to a more sustainable agriculture.

Optimize the use of natural resources and decrease the use of agrochemicals to diminish the impact of agriculture on the environment and create a significant social and economical benefit to the farmer.

Current IGCAST Faculty Members

Damar López-Arredondo: Cotton and microalgae
Nutrient stress, lipid metabolism, novel herbicides

Jinping Jiao: Maize and sorghum
Comparative genomics, drought and salinity tolerance

Gunvant Patil: Soybean and cotton
Genome editing, plant transformation, drought and heat tolerance

Mylea Lovell: Greenhouse Manager
The Future of Cotton Genetics and Weed Control

Potential Associated Faculty Members:

- Dr. Eric Hequet, PSS, CASNR
- Dr. Benildo de los Reyes, PSS, CASNR
- Dr. Noureddine Abidi, PSS, CASNR
- Dr. Werner Guo, PSS, CASNR
- Dr. Venugopal Mendu, PSS, CASNR
- Dr. Lindsey Slaughter, PSS, CASNR
- Dr. Jyotina Sharma, PSS, CASNR
- Dr. Rosalyn Shim, PSS, CASNR
- Dr. Jaime Malaga, AAE, CASNR
- Dr. Eduardo Segarra, AAE, CASNR
- Dr. Hong Zhang, DBS, CASNR
- Dr. Chris Rock, DBS, CASNR
- Dr. Amanda Brown, DBS, CASNR
- Dr. Natasha van Gestel, DBS, CASNR
- Dr. John D'Auria, DCB, CASNR
- Dr. Huachong Shi, DBS, CASNR
- Dr. Naime Moustard-Moussa, CHS

Many factors affect crop productivity

- Maximum Yield
- Pests and Diseases
- Crop variety
- Drought
- Low Soil Fertility
- Poor Soil Structure
- Fertilizer
- Water
- Disponibilidad de fósforo en el suelo
- Producción posible sin limitaciones
- Enfermedades
- Malezas
- Variedad inapropiada
- Estructura pobre del suelo
- Baja ferlidad del suelo
- Falta de agua

Dr. Luis Herrera-Estrella - 2020 TAWC Water College
The Future of Cotton Genetics and Weed Control

1/23/2020

Dr. Luis Herrera-Estrella - 2020 TAWC Water College

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**Water Use concerns**

- In 2014, the USDA designated 240 Texas counties as primary natural disaster areas due to drought.
- Texas’ agricultural industry suffered losses attributable to drought of $7.6 billion in losses in 2011 alone.
- If water supply needs are not met by 2060, the Texas WDB projects that the state will lose over 1 million jobs and as much as $115.7 billion per year.
- If extreme droughts persist by 2060, Texas businesses and income might suffer $12.8 billion in losses, leading to lost jobs and income that can result in a reduced population by 1.4 million people.

**2017 Surface & Groundwater Use Estimates**

Approximately 54% of the 2017 estimated water use in Texas was from groundwater sources, 43% from surface water sources and only 3% from reuse.

---

**Desiccation tolerance is a marvelous trait that has evolved in many organisms (Cryptobiosis)**

- *Artemia salina*
- Tardigrades (Water bears)

A. salina eggs are viable for over 10 years in the desiccated state

Water bears survive 50 years in the desiccated state

---

**Desiccation tolerance in plants**

- *Resurrection Plants*
Desiccated seeds maintain viable embryos for centuries

Germination of 1,300 year-old Lotus seeds

Germination, Genetics, and Growth of an Ancient Date Seed

2,000 year old date seed

1,100 year old Lotus seed

Biological processes are controlled by genetic networks that function similar to brain circuits

Plants have between 30,000 and 50,000 genes that can produce up to 500,000 different proteins, which functions are interconnected.

Acquisition of seed desiccation tolerance in plant seeds

Baud et al., 2002.
The Future of Cotton Genetics and Weed Control

1/23/2020

Dr. Luis Herrera-Estrella - 2020 TAWC Water College
The growing menace from superweeds, pigweed, ragweed and other monsters, have begun to outsmart the advanced technologies that protect the biggest U.S. cash crops.

Weeds are a major problem for crop production.

To control weedy plants the farmer needs to apply herbicides.

Herbicide resistant weeds are making herbicides obsolete.
Dynamic dispersion of increasingly herbicide resistant weeds

All organisms require phosphorus for their growth and reproduction

An alternative system: crop selective nutrition

Phosphorus can only be assimilated by the vast majority of organisms in the form of phosphate (PO₄).
Phosphites (Phi): a more efficient source of Phosphorus

Phosphite was proposed after Second World War as a superior alternative source of phosphorus-fertilizers over phosphate because of its physicochemical properties:

- Phosphite solubility is less dependent on pH than phosphate.
- Phosphite is less reactive than phosphate with soil components.
- Phosphite is already widely used in agriculture as an effective treatment against Oomycetes (i.e. Phytophthora, etc.).
- No toxicity reported for humans and animals (FDA).

Plants capable of using phosphite as a nutrient source

Transgenics are able to use phosphite as sole phosphorus source with a phenotype and yield comparable to non transformed control plants grown in phosphate.


Phosphite is not a herbicide, however, it cannot be used as a source of Phosphorus by conventional plants and inhibits their growth because it competes with phosphate for the entry into the plant via a common set of transporters.

Can phosphite be used to selectively fertilize crops and reduce weed growth?

Can we replace phosphate fertilizer and herbicides with phosphite?
Transgenic cotton easily outcompetes weeds in an agricultural soil rich in weeds.

Phosphite treated plots showed significant weed suppression in the field. Pandeya et al., PNAS, 115:E6946–E6955.

Control of one of the most important weeds for maize production in Mexico

- *Ipomoea purpurea*

---

*Chlamydomonas reinhardtii* expressing *ptxD* are able to grow using Phi as a sole P source

- Kinetics of growth in Pi and Phi are quite similar.

---

Engineered *C. reinhardtii* outcompetes the faster growing *Scenedesmus obliquus* in media containing Phi as a sole P source

---

Dr. Luis Herrera-Estrera - 2020 TAWC Water College
Transgenic *C. reinhardtii* grown in media containing Phi can outcompetes a natural mix of bacteria-microlagae-cyanobacteria.

The Phi systems allows a robust control of biological contaminants in open air reactors.

Development of industrial applications: hydrolytic enzymes for the degradation of lignocellulosic residues.
Technology to optimize light harvesting

The system is based on mutants that have altered light harvesting complexes to prevent an excess of harvested light that is eliminated as heat by the microalgae.

Applications and benefits

Applications
Biomass production
Production of enzymes
Production of vaccines
Production of pigments

Benefits
Facilitates the use of open air raceway systems
Reduces production costs
Eliminates use of antibiotics and herbicides
Increases biomass production
General Notes
General Notes
Thank You to our Sponsors:

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Hurst Farm Supply*
Lindsay Zimmatic*
Miller Chemical*
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Texas Sorghum Producers

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AgTexas (provided water)
Indigo Ag, Inc. (Provided lunch)
CASNR (Live Radio Coverage Sponsor)
Texas Water Development Board (Project Sponsor)

*Please see Display Booth in Exhibit Hall.
The TAWC project was made possible through a grant from the Texas Water Development Board.