Developing Irrigation Management Strategies under Drought Conditions in Texas. Agreement Number: 69-3A75-13-82
Project Director: Juan Enciso, Ph.D. P.E.

(1) PROJECT SUMMARY:

To address the effect of periodic drought such as the historic drought of 2012, we developed some computational tools to optimize irrigation and conserve agricultural water. We also developed several educational workshops for farmers to transfer these tools and demonstrated the technologies among EQUIP farmers. We extended the weather network, and the stations are located in Mercedes (Annex), Weslaco (Center), Rio Grande City, Edinburgh, and Harlingen, Texas. The weather network is being used by an internet weather based program to provide daily crop ET for farmers of the Low Rio Grande Valley (LRGV) of Texas depending on Regional Planning Group M (Fig. 1). The internet program will be posted on the Texas A&M AgriLife Research and Texas A&M AgriLife Extension sites. The ET weather information was also used to develop irrigation guidelines using historical data collected from three weather stations.

These irrigation guidelines indicate the number of irrigations and amounts required by the crop for full irrigation. Additionally, an extension publication was published to guide farmers on how to apply different water allocations in case of limited water supplies. It is recommended to apply the reduced water amounts in critical phenological stages to avoid reductions in yield. These general guidelines are based on standard crop water requirements and depend on soil type. These guidelines were determined for operators that traditionally don't use the internet. Recommendations were provided to adjust them according to rainfall received and to different water allocation situations as result of adrought.

The main irrigation management objective is to increase water use efficiency (productivity per unit of water applied). The internet program also provides information about heat units, chilling units, accumulative rainfall for sugarcane, citrus, corn, cotton and corn, onions, watermelons and pastures ET. The internet-based program was used in selected demonstration trials to train more advance irrigators on using on real-time irrigation. Additionally, we demonstrated the use of flexible plastic pipes and remote soil water sensors to increase irrigation efficiency. The demonstrations were used for outreach and education. The sensors were used to monitor irrigation and to determine if crop ET is under or over-estimated and to adjust the irrigation schedules if needed. A protocol was handed to farmers to adapt irrigation using soil water sensors and crop ET data. The water use by the farmers and crop budgets obtained from the demonstrations sites were used to determine irrigation use efficiencies, productivities per unit of water and net return per unit of water applied. A partnership with the nearby researchers, extension specialists, and educators from Texas A&M University Kingsville, Texas A&M AgriLife Research and Extension Center in Weslaco, and local offices of the NRCS joined forces to provide guidance and leadership in adapting best agronomic practices in irrigation scheduling, increase water conservation, reduce erosion, and preserve water quality in a diverse group of farmers with different education levels.

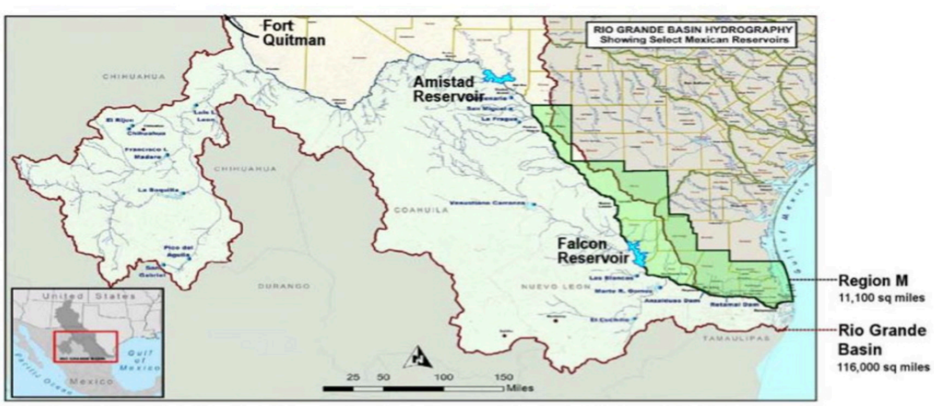


Figure 1: Lower Rio Grande Basin, Texas.

(2) METHODS

We developed **irrigation guidelines** for sugarcane, citrus, corn, cotton, onions, watermelons, and pastures in the LRGV. The ET patterns over more than 10-year period of historical data were used to generate irrigation guidelines considering that the coefficient of ET variability between months of different years has averaged less than 15%. The irrigation guidelines were developed for the main crops of the region. The yields, production costs, water use efficiencies were determined for the main crops of South Texas.

Three more weather stations were installed (Edinburgh, Harlingen and Rio Grande City). The old stations (Weslaco and Mercedes) were replaced by new weather stations. The internet program used the Penman-Monteith ASCE standardized reference equation to calculate sugarcane, citrus, corn, cotton, onions, watermelons, and pasture ET using the crop coefficients recommended by the Food and Agriculture Organization of the United Nations. The crop coefficients were adapted to local conditions from observations obtained from agricultural demonstrations.

We established more than eight demonstrations with EQIP eligible producers. In those demonstrations, we installed flexible plastic pipes or used drip or micro-irrigation. We obtained soil water data with dataloggers with manual and remote retrieval options. We compared the water estimated with our program with the water applied by the farmers. An example of the demonstrations is shown in Fig 2.

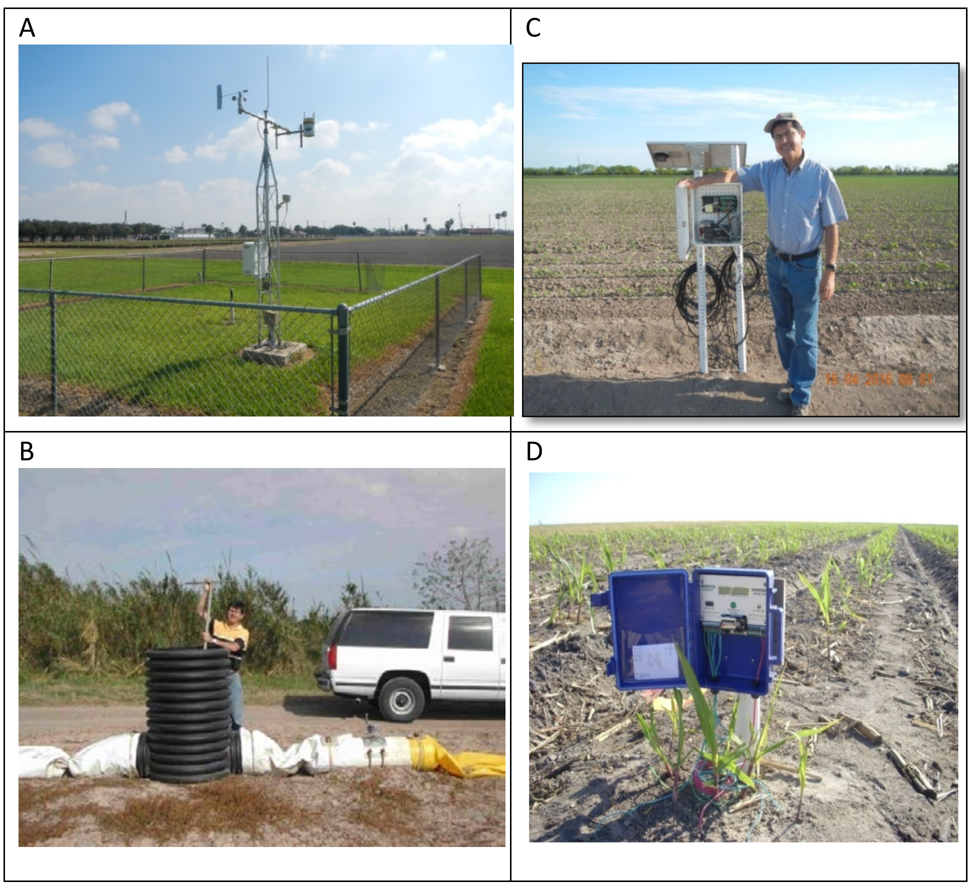
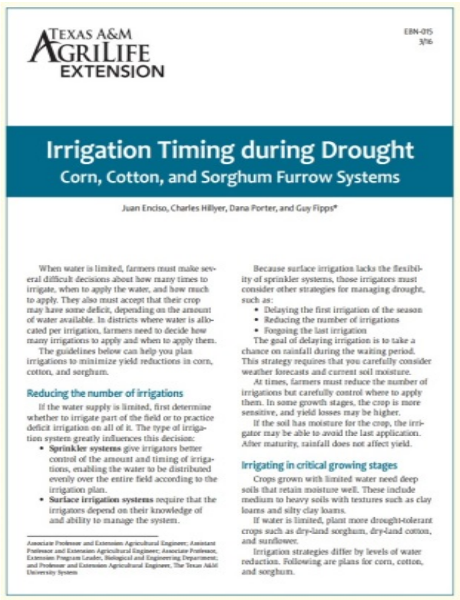


Fig. 2. Irrigation Result Demonstrations. **A.** Weather Station located in Weslaco. **B.** Demonstrations setup that includes the flow-meter and the flexible plastic pipe. **C.** Time Domain reflectometers and soil water data obtained remotely. **D.** Soil Water data measured with watermark sensors and stored in a datalogger.

(3) THE PRODUCTS

3.1. Extension Publications


TEXAS A&M AGRILIFE EXTENSION

EBN-015
3/16

Irrigation Timing during Drought
Corn, Cotton, and Sorghum Furrow Systems

Juan Enciso, Charles Hillyer, Dana Porter, and Guy Fipps*

When water is limited, farmers must make several difficult decisions about how many times to irrigate, when to apply the water, and how much to apply. They also must accept that their crop may have some deficit, depending on the amount of water available. In districts where water is allocated per irrigation, farmers need to decide how many irrigations to apply and when to apply them.

The guidelines below can help you plan irrigations to minimize yield reductions in corn, cotton, and sorghum.

Reducing the number of irrigations

If the water supply is limited, first determine whether to irrigate part of the field or to practice deficit irrigation on all of it. The type of irrigation system greatly influences this decision:

- **Sprinkler systems** give irrigators better control of the amount and timing of irrigations, enabling the water to be distributed evenly over the entire field according to the irrigation plan.
- **Surface irrigation systems** require that the irrigators depend on their knowledge of and ability to manage the system.

Because surface irrigation lacks the flexibility of sprinkler systems, those irrigators must consider other strategies for managing drought, such as:

- Delaying the first irrigation of the season
- Reducing the number of irrigations
- Forgoing the last irrigation

The goal of delaying irrigation is to take a chance on rainfall during the waiting period. This strategy requires that you carefully consider weather forecasts and current soil moisture.

At times, farmers must reduce the number of irrigations but carefully control where to apply them. In some growth stages, the crop is more sensitive, and yield losses may be higher.

If the soil has moisture for the crop, the irrigator may be able to avoid the last application. After maturity, rainfall does not affect yield.

Irrigating in critical growing stages

Crops grown with limited water need deep soils that retain moisture well. These include medium to heavy soils with textures such as clay loams and silty clay loams.

If water is limited, plant more drought-tolerant crops such as dry-land sorghum, dry-land cotton, and sunflower.

Irrigation strategies differ by levels of water reduction. Following are plans for corn, cotton, and sorghum.

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Fig. 3. Extension Publication

Juan Enciso, Charles Hillyer, Dana Porter, and Guy Fipps. Irrigation Timing during Drought Corn, Cotton, and Sorghum Furrow Systems. Texas A&M AgriLife Research. EBN-015. 3/16

When water is limited, farmers must make several difficult decisions about how many times to irrigate, when to apply the water, and how much to apply. They also must accept that their crop may have some deficit, depending on the amount of water available. In districts where water is allocated per irrigation, farmers need to decide how many irrigations to apply and when to apply them. This extension factsheet (fig. 3) can help farmers plan irrigations to minimize yield reductions in corn, cotton, and sorghum.

3.2. Peer Review Publications

1. Juan Enciso, J. Jifon, L. Ribera, S.D. Zapata, G.K. Ganjegunte. 2015. Yield, water use efficiency and economic analysis of energy sorghum in South Texas. Biomass and Bioenergy. 81:339–344.
2. Enciso Juan, John Jifon, Juan Anciso, and Luis Ribera. 2015. Productivity of Onions Using Subsurface Drip Irrigation versus Furrow Irrigation Systems with an Internet Based Irrigation Scheduling Program. International Journal of Agronomy, Volume 2015 (2015), Article ID 178180, 6 pages.

3.3. Posters

1. **J. Enciso**, S. Elsayed-Farag, S. Zapata, L Ribera. Validation and Evaluation of an Internet ET Weather Program. Poster presented at the 2017 Annual Conference of the Soil and Water Conservation Society. Madison, Wisconsin. July 30- Aug 2, 2017.
2. **Juan Enciso.** Developing Irrigation Management Strategies under Drought Conditions in Texas. 2016. Poster 69-3A75-13-082. 71st SWCS International annual conference. June 24-27, 2016. Louisville, KY

3.4. Conferences Proceedings

1. **Juan Enciso**, Juan Landivar. Irrigation Management Strategies Under Drought Conditions. 2016., Texas A&M AgriLife Research. ASA/SSSA/CSSA. Phoenix, AZ. Nov 8.
2. **Juan Enciso**, Anthony Garza, Shad Nelson, Luis Ribera, Juan Landivar, Carlos Fernandez, Juan Enciso-Siller. An Internet Program for Managing Irrigation. 2014. Paper Number: 1904283, 9 pages. Presented at the 2014 ASABE and CSBE/SCGAB Annual International Meeting. The papers will be posted online on the ASABE website.
3. Corina Fuentes, **Juan Enciso**, Shad Nelson, Rafael Lopez, Luis Ribera, Juan Anciso. 2014. Comparing Water Use Efficiency in South Texas Furrow and Drip Irrigated Cabbage. American Society of Horticultural Sciences Annual Conference. Orlando Florida.

4. Fuentes C., **J. Enciso**, S. Nelson, J. Anciso, and M. Setamou. 2015. Comparing Water Use Efficiency in South Texas Furrow and Drip Irrigated Watermelon. Subtropical Agriculture and Environment Society (February 6, 2015 – Weslaco, TX).
5. Fuentes C., **J. Enciso**, S. Nelson, J. Anciso, and M. Setamou. 2015. Irrigation Scheduling: A Water Balance Approach to Improve Water Efficiency for South Texas Horticultural Crops. 2015 ASHS Annual Conference (August 3-7, 2014 – New Orleans, Louisiana)
6. **Juan Enciso**, Murilo Maeda, Juan Landivar, Carlos Avila, Jinha Jung, Anjin Chang. Unmanned aerial system (UAS) for Precision Agriculture and Management Decisions. 2016 ASABE Annual International Meeting 162428013. (doi:10.13031/aim.20162428013)

3.5. Workshops

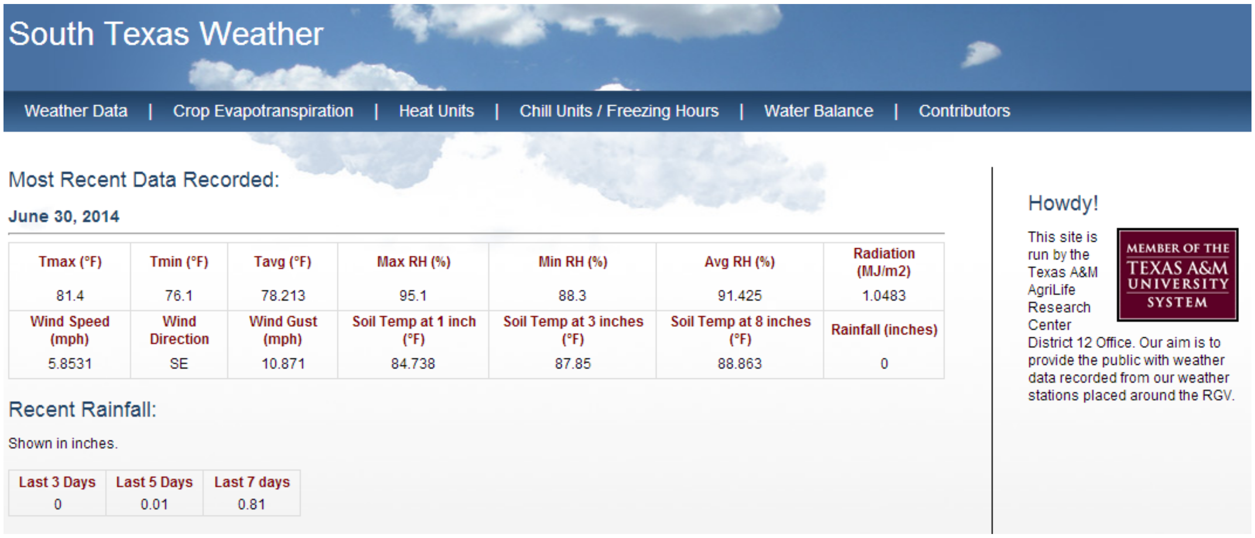
The workshops were part of Objective 3: Establish five field demonstrations in EQIP eligible producer' farms to demonstrate water scheduling strategies using remote soil water sensors and internet based data and quantify water use, water application efficiency, and net return per unit of water applied. The workshops that were organized were:

- Annual Sugarcane Field Day. Weslaco, TX. Presented strategies for irrigation and fertilization management. Attendants: 45 (20 white, 20 hispanic). About 60 persons attended the workshop. September 19, 2013.
- Surge Irrigation field day. 3 hour workshop. September 12, 2013.
- Surge Irrigation Field day. 3 hour workshop. November 14 2013.
- Water Programs in the Lower Rio Grande. Texas Farmers Bureau. October 15, 2013
- Onion and Water Melon Irrigation field day. The field was organized to present the program and explain farmers about the capability of the internet weather based program. I gave a 50-minute presentation about the use of our irrigation scheduling program and presented results of the demonstrations. May 8, 2014.
- Soil Health and Irrigation Management Workshop. We organized a 6.5-hour workshop in to train farmer about the use of the internet based weather program to schedule irrigation. About 50 persons attended the workshop. August 24, 2016.
- Maverick County Agricultural Irrigation Field Day. 4-hour workshop in irrigation management. About 15 persons attended the workshop. September 13 ,2017.
- Irrigation Training Program for the Lower Rio Grande Valley. 4 hours workshop. About 40 persons attended the workshop. September 12, 2017.

3.6. Internet ET weather program

3.6.1. Program description:

An internet ET weather based program developed by Texas A&M AgriLife Research was used to schedule irrigation for citrus, cotton, sugarcane, watermelons, and onions. Irrigation was managed using a water balance method and monitored with soil water sensors (Watermark sensors) and other soil water sensors. The program uses input parameters such as crop type and soil type. The user can select the crops, weather station and soil types with a scroll down bar, which automatically selects the root depth and recommended allowable depletion. The user can change the values of root depth and maximum allowable depletion as desired as well as the planting date and the date to end calculations. It is also possible to select the initial water content and date to start the calculation. The program calculates the available water, when irrigation is needed, and what amount is needed. The water amount needed is calculated when the water level is below the allowable depletion. The weather station uses the Penman-Monteith equation to estimate evapotranspiration for weather variables such as solar radiation, wind speed, maximum and minimum temperature, and relative humidity. To validate the program plant characteristics such as canopy cover and growth stage were determined using remote sensing technologies and soil water was monitored. The number of irrigations and irrigation depths were used to validate the program. The program was used to determine irrigation guidelines oriented to farmers and based on average of historical weather data. The irrigation guidelines provide general recommendations such as the number irrigations required per crop for three main soil textures considering an average year.



South Texas Weather

Weather Data | Crop Evapotranspiration | Heat Units | Chill Units / Freezing Hours | Water Balance | Contributors

Most Recent Data Recorded:

June 30, 2014

Tmax (°F)	Tmin (°F)	Tavg (°F)	Max RH (%)	Min RH (%)	Avg RH (%)	Radiation (MJ/m2)
81.4	76.1	78.213	95.1	88.3	91.425	1.0483
Wind Speed (mph)	**Wind Direction**	**Wind Gust (mph)**	**Soil Temp at 1 inch (°F)**	**Soil Temp at 3 inches (°F)**	**Soil Temp at 8 inches (°F)**	**Rainfall (inches)**
5.8531	SE	10.871	84.738	87.85	88.863	0

Recent Rainfall:

Shown in inches.

Last 3 Days	Last 5 Days	Last 7 days
0	0.01	0.81

Howdy!

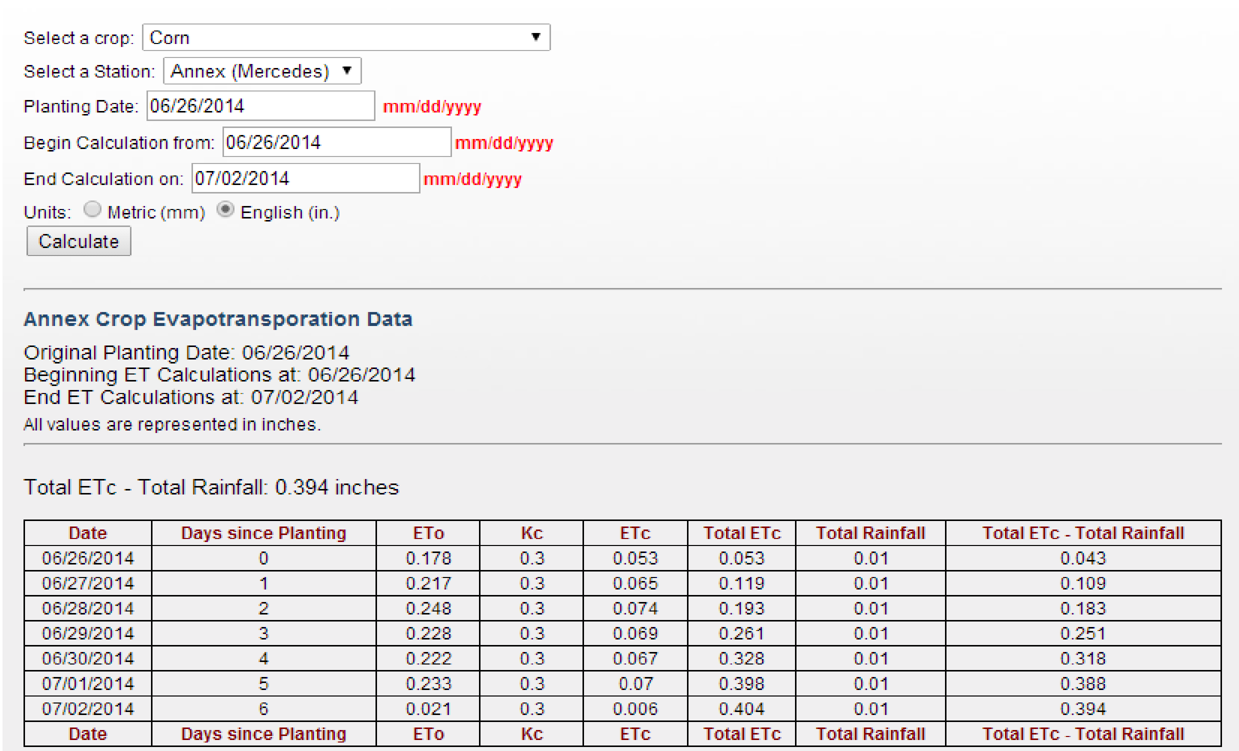
This site is run by the Texas A&M AgriLife Research Center District 12 Office. Our aim is to provide the public with weather data recorded from our weather stations placed around the RGV.

MEMBER OF THE TEXAS A&M UNIVERSITY SYSTEM

Fig. 4. First page of the internet weather based program

3.6.2. Crop Evapotranspiration calculation:

Crop Evapotranspiration (ETc) is calculated using the single crop coefficient method and standard crop coefficients and lengths of the growing season adapted to local conditions. The program calculates the ETc for sugarcane, cotton, corn, sorghum, watermelon, onion, cantaloupe, cabbage, sudangrass, tomatoes, and citrus.



Select a crop: Corn

Select a Station: Annex (Mercedes)

Planting Date: 06/26/2014 mm/dd/yyyy

Begin Calculation from: 06/26/2014 mm/dd/yyyy

End Calculation on: 07/02/2014 mm/dd/yyyy

Units: Metric (mm) English (in.)

Calculate

Annex Crop Evapotransporation Data

Original Planting Date: 06/26/2014
Beginning ET Calculations at: 06/26/2014
End ET Calculations at: 07/02/2014

All values are represented in inches.

Total ETc - Total Rainfall: 0.394 inches

Date	Days since Planting	ETo	Kc	ETc	Total ETc	Total Rainfall	Total ETc - Total Rainfall
06/26/2014	0	0.178	0.3	0.053	0.053	0.01	0.043
06/27/2014	1	0.217	0.3	0.065	0.119	0.01	0.109
06/28/2014	2	0.248	0.3	0.074	0.193	0.01	0.183
06/29/2014	3	0.228	0.3	0.069	0.261	0.01	0.251
06/30/2014	4	0.222	0.3	0.067	0.328	0.01	0.318
07/01/2014	5	0.233	0.3	0.07	0.398	0.01	0.388
07/02/2014	6	0.021	0.3	0.006	0.404	0.01	0.394
Date	Days since Planting	ETo	Kc	ETc	Total ETc	Total Rainfall	Total ETc - Total Rainfall

Fig. 5. Crop Evapotranspiration calculation.

3.6.3. Water Balance Program

The water balance program was part of objective 2 which was to **Develop an internet-based computer program to adapt irrigation management according to drought conditions using weather station network.**
The program is on the website page: http://southtexasweather.tamu.edu/waterBalance/

This page shows a water balance program and irrigation scheduler. The program uses input parameters such as crop type and soil type. The user can select the crops, weather station and soil types with a scroll down bar, which automatically selects the root depth and recommended allowable depletion. The user can change the values of root depth and maximum allowable depletion as desired as well as the planting date and the date to end calculations. It is also possible to select the initial water content and date to start the calculation. The program calculates the available water, when irrigation is needed, and what amount is needed. The water amount needed is calculated when the water level is below the allowable depletion.

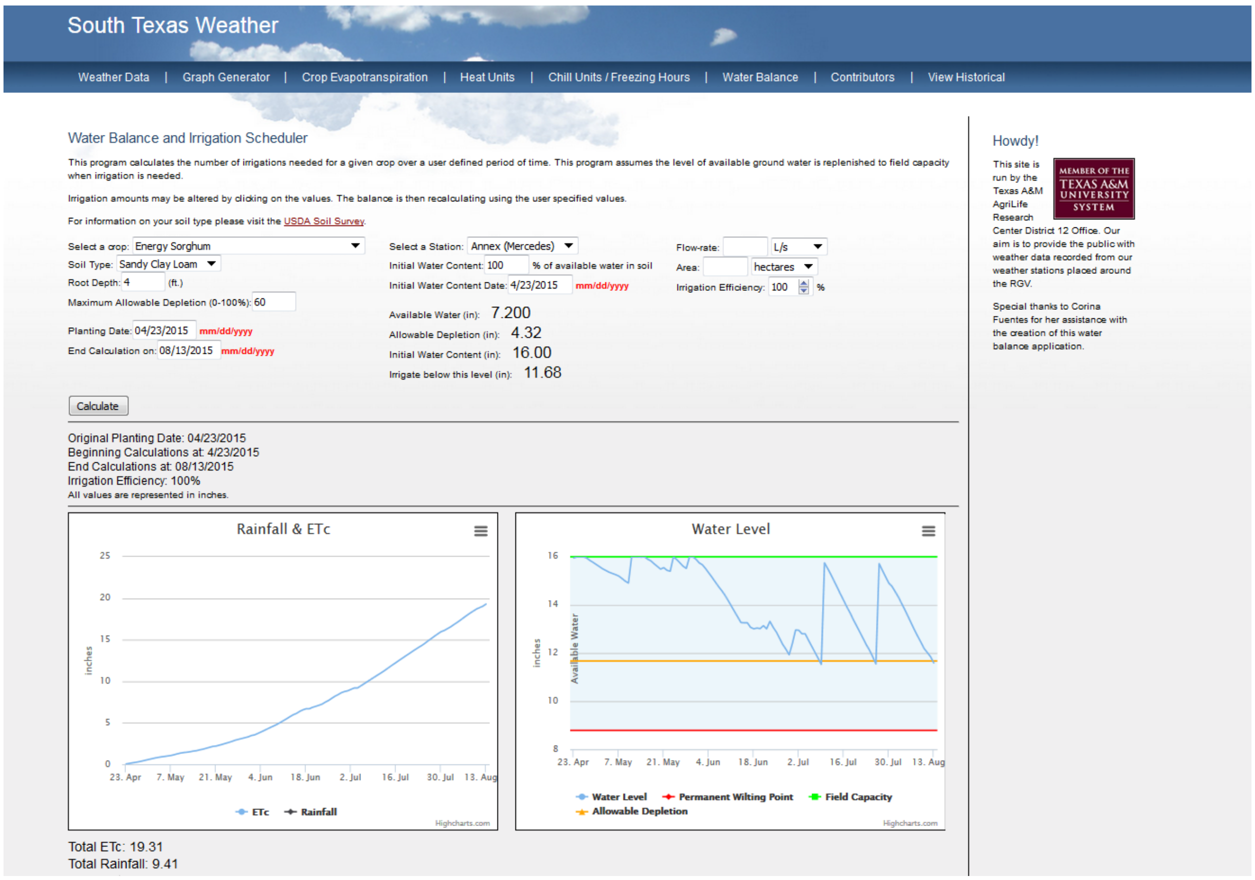


Fig. 6. Water Balance subprogram.

3.6.4. Download current and historical data:

The weather station presents more than 15 years of data in some weather stations. The data can be used for planning purposes. We developed the option to download historical data from our weather stations. Recently, we added a password to download information. We added the password to interact with the persons to use the data. We wanted to know who and for what purpose the data was being downloaded. The subprogram template is shown in the following figure:

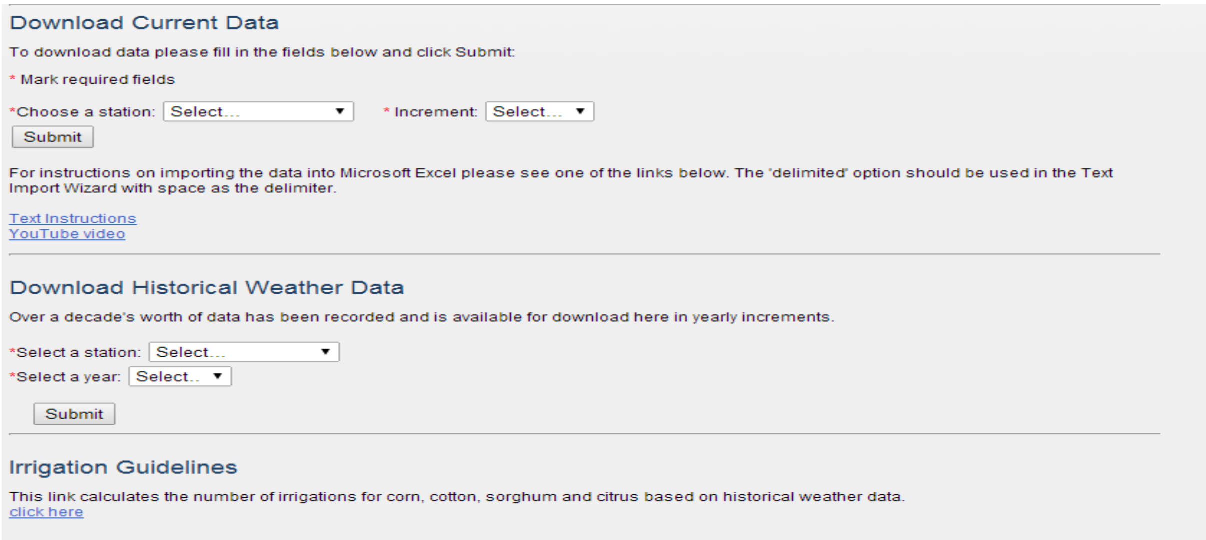


Fig. 7. Downloading historical data.

3.6.5. Contributors

(i) Graduate Students:
Askarali Karimov. Ph.D. Student (Main advisor: Ralph Wurbs)
Jose Carlos Chavez. Ph.D. Student (Main advisor: Dr. Vijay Singh)
Beatriz Contreras. Master student (Main advisor: Juan Melgar, TAMUK). Graduated
Corina Fuentes. Master student (Main advisor: Shad Nelson, TAMUK).

(ii) Undergraduate student internships
Anthony Garza. Student from University of Texas- Austin
Emmanuel Zapata. Student from University of the Rio Grande Valley.
Jason Carmona. Student from Texas A&M University-Kingsville
Jose Rodriguez. Student from University of Texas-Pan American
Luis del Rio. Student from University of Texas-Pan American
Sergio Davila. Student from UAAAN. Saltillo, Coahuila, Mexico

3.7. Result Demonstrations

We demonstrated the use of poly-pipe, irrigation scheduling using the internet weather based program and correcting it with soil water sensor data. We established demonstrations in citrus, sugarcane, onions, watermelons, corn, and cotton with EQUIP farmers. The impacts of demonstrations and outreach program are that with the implementation of these Best Management Practices farmer can reduce at least 20% of the water, and increase their productivities per unit of water. A demonstration in citrus is shown in Fig. 8 and one in sugarcane in Fig.9. It is estimated that at least 30 farmers switched from open earth ditches to flexible plastic pipes.

Fig. 8. Surface Irrigation in Citrus demonstrating the use of poly-pipe.

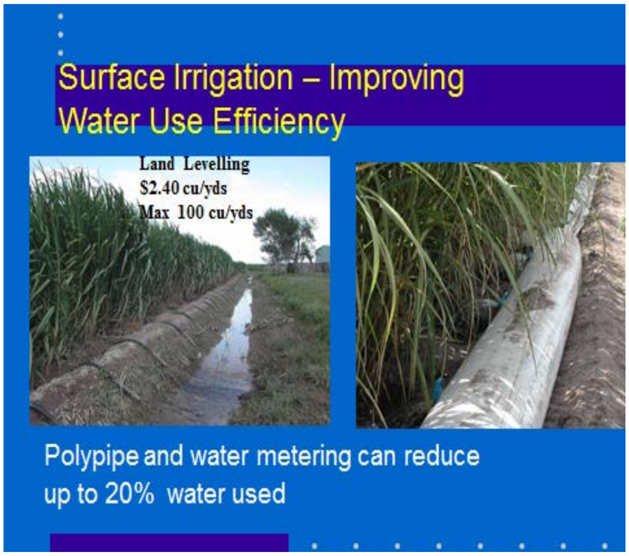


Fig. 9 Demonstration in sugarcane demonstrating the use of poly-pipe.

3.8. Water Productivity, Net Return and Number of Irrigations for the main crops of the LRGV.

The water use efficiency and net return per unit of water for the main crops of the Lower Rio Grande Valley is shown in Table 1. This table demonstrates that during drought, priority should be given to crops such as vegetables and fruits. This Tables also presents the main crops, planting and harvesting dates, crop evapotranspiration, and effective rainfall received during the growing season. This table was used for farming purposes and it was derived from evapotranspiration calculated with the ET website using historical weather data.

Table 1. Planting and harvest dates, crop evapotranspiration and affective rainfall for the area main crops

Crop		Planting date	Harvest date	Growing days	Crop Evapotranspiration (mm)	Effective Average Rainfall (mm)	Water Deficit (mm)
Field Crops							
	Sorghum	Feb-20	Jun-29	125	557	167	389
	Cotton	Mar-5	Aug-31	179	902	271	631
	Corn (W)	Aug-15	Dec-17	124	402	296	106
	Corn (S)	Feb-20	Jul-9	139	628	184	444
	Soy-bean	Aug-1	Dec-27	148	535	204	331
Vegetables							
	Water Melon	Feb-1	May-21	120	398	102	296
	Cantaloupe	Feb-1	May-31	110	394	113	281
	Onions	Oct-15	Apr-13	120	559	156	403
	Carrots	Sep-19	Feb-16	110	444	199	245
	Cabbage	Aug-15	Jan-27	90	539	306	234
	Potatoes	Jan-6	Apr-30	100	404	84	321
Citrus							
	Without grass cover						
	70 Canopy	Jan-1	Dec-31	365	1105	560	545
	50 Canopy	Jan-1	Dec-31	365	1024	560	464
	20 Canopy	Jan-1	Dec-31	365	781	560	221
	With grass cover						
	70 Canopy	Jan-1	Dec-31	365	1188	560	628
	50 Canopy	Jan-1	Dec-31	365	1328	560	768
	20 Canopy	Jan-1	Dec-31	365	1411	560	851
	Sugarcane	Jan-1	Feb-28	365	1969	575	1394

The Water Productivity values for the main crops of the Lower Rio Grande Valley is shown in Table 2. We also developed irrigation guidelines for farmers and determine the number of irrigation based on historical weather data. We determined the number of irrigations needed for an average year. (Table 3).

Table 2. Water Productivity values for the studied crops.

Crop	Total yield (kg/ha)	Revenus ($)	Costs ($)	Crop Evapotranspiration ET_c (m^3)	Water productivity (kg/m3)	Net Return ($/$m^3$)
Cabbage	42032	5250	182	539	77.95	9.40
Cantaloupes	22417	3200	231	172	130.27	17.25
Corn	6277	380	168	499	12.58	0.42
Cotton	1401	788	231	561	2.50	0.99
Onions	50438	6300	185	372	135.64	16.44
Sorghum	2242	320	67	385	5.83	0.66
Soybeans	1681	270	156	739	2.28	0.15
Watermelon	50438	8100	232	197	256.33	39.99
Honeydews	44834	6400	231	172	260.53	35.85
Oranges	40351	2880	379	587	68.77	4.26
Grapefruit	51559	2760	379	587	87.87	4.06
Sugarcane (First planting)	11769	1313	145	1293	9.10	0.90
Sugarcane (Ratoon)	8944	998	135	1194	7.49	0.72

Table 3. Number of irrigations needed for the main crops based in different soil classes.

Crops	Sandy Loam	Loam	Silt Loam	Silt	Silty Clay Loam	Silty Clay	Clay	Find Sandy Loam	Clay Loam	Peat Mucks	Sandy Clay Loam
Cantaloupes	3	2	1	2	1	2	2	2	1	1	2
Corn	6	4	4	4	4	4	5	5	4	4	5
Cotton	5	3	3	3	3	3	4	4	3	3	4
Onions	15	10	8	10	8	11	11	12	8	8	11
Sorghum	4	3	2	3	2	3	3	3	2	2	3
Watermelons	4	2	2	2	2	3	3	3	2	2	3
Honeydews	3	2	1	2	1	2	2	2	1	1	2
Oranges	9	5	4	5	4	6	6	7	4	4	6
Grapefruit	9	5	4	5	4	6	6	7	4	4	6
Sugarcane (First Planting)	9	6	5	6	5	6	7	7	5	5	7
Sugarcane (Ratoon)	8	6	5	6	5	6	6	7	5	5	6

(4) LOOKING AHEAD

4.1 Remaining Challenges:

The water conservation should be an ongoing effort. There are always new farmers starting new operations and adapting to changing cropping patterns. Farmers are inclined to adopt irrigation guidelines. However, there is still the necessity to increase the accuracy of the ET estimations. The crop coefficients depend on the phenology of the crop, and this was not well determined in several crops. We feel that there is an opportunity to use emerging technologies in describing more accurately the phenology of the crop. For example, unmanned aerial vehicles (UAV) could be used to determine variations in crop canopy as the crop grows. In citrus orchards, the UAV could be used to determine the crop coefficients by estimating weed coverage between row trees and the canopy. Even detect diseases that could affect crop water use.

Some of the remote sensors to estimate soil water sensors were sensitive to salinity (TDR) and could not be used in some demonstrations. They were replaced with water mark sensors that were more reliable. There is the necessity to calibrate emerging sensors that are coming to the market. The weather station networks are very useful for agricultural production and environmental protection. However, they are expensive to maintain, and the stations require the capable personnel to maintain them in operation. Although farmers are interested in using them, they don't have the economic resources to share the costs. The support of these networks is still dependent on federal and state support.

4.2.Recommendations

The implementation of irrigation strategies is critical for the long-term sustainability of agriculture. Dryland irrigation is unprofitable in this region, and the water inventories for agriculture use are going to be reduced in the future. Expanded research and outreach programs should focus on strategies to increase net return per unit of water and consider the fragmentation of the land. There is an opportunity for vegetable production using more efficient irrigation methods and new farming technologies such as the use of greenhouses and wind tunnels. Additionally, new technologies such as the use of drones can be used for extensive crops to increase water and fertilizer use efficiencies.