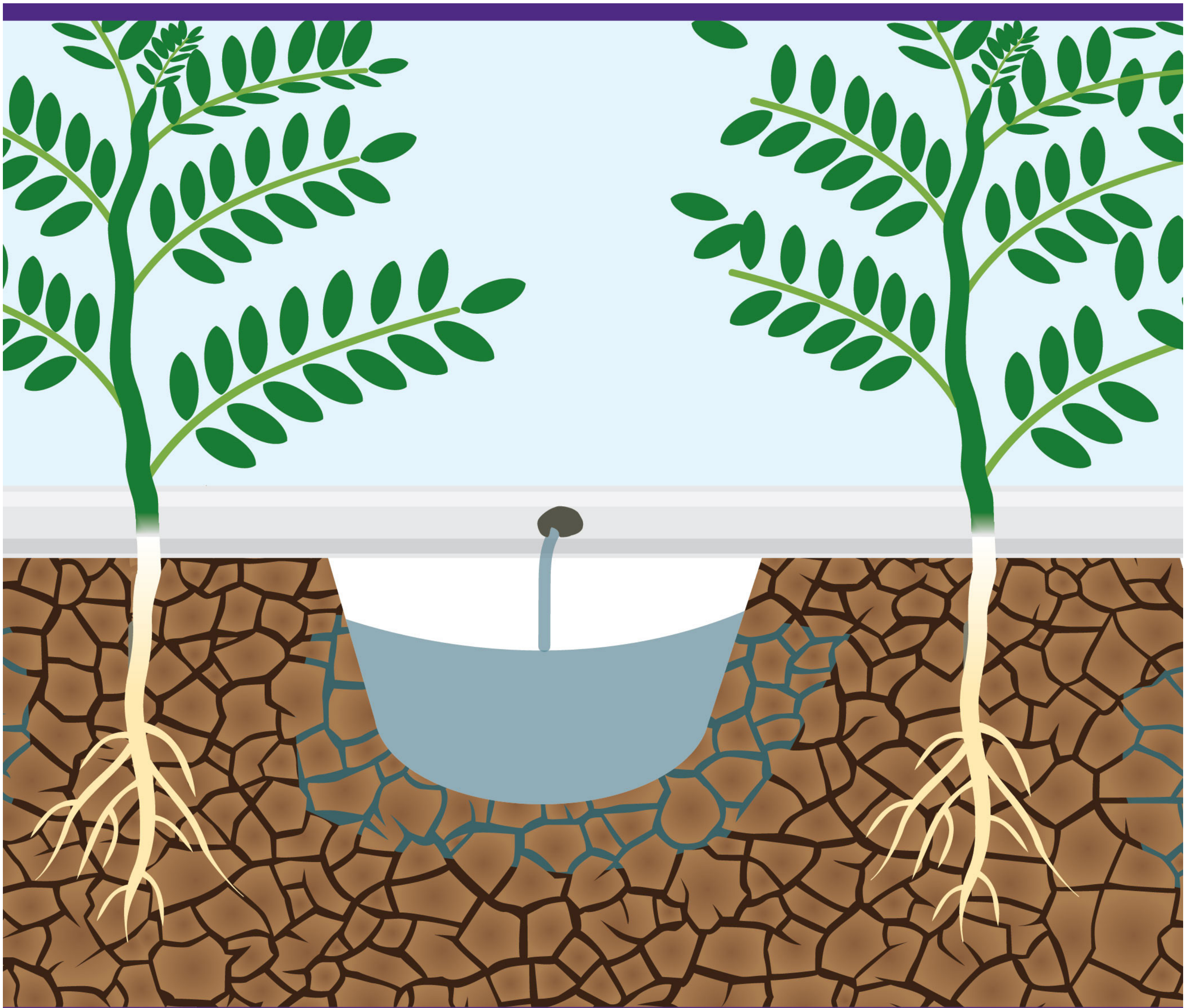


DROUGHT IRRIGATION RESPONSE TOOL (DIRT): A MANUAL

LSU AgCenter
Research · Extension · Teaching

CONTENTS

Introduction

Drought continues to increasingly impact agriculture in the normally humid Midsouth and Gulf South regions of the United States. Current scientific predictions suggest storm systems will slow down resulting in increasing precipitation intensity and associated severe weather events. This slowdown phenomenon will exacerbate drought intensity and duration. Thus, wet times will likely become wetter and dry times will likely become drier. Irrigation will become critical for crop production during drier times.

In addition to changing climate conditions increasing demand for irrigation, competition between water use sectors (i.e., urban consumption, recreation, industrial, power generation, etc.) will also increase. As a result, water intensive irrigated agriculture that relies heavily on limited groundwater resources will become a target for regulatory action to restore aquifer health. According to the U.S. Geological Survey, about 37% of the freshwater usage in the U.S. is for irrigation, and the demand for irrigation is accelerating. However, irrigating inefficiently will lead to unsustainable withdrawals that will eventually render water resources as environmentally or economically unavailable. With these concerns in mind, it is important to set goals that inspire behavioral change in overall water consumption across increasing drought risk scenarios to enhance regional environmental sustainability.

The Drought Irrigation Response Tool (DIRT) was designed to address this overarching goal by providing guidance on irrigation scheduling that is responsive to highly variable rainfall patterns, drought conditions and hydrological status. DIRT was originally developed and validated as a spreadsheet but was never publicly released due to the overall awkwardness of using a spreadsheet in relation to modern farming practices and available technologies. This version of DIRT is available as a webtool hosted on the LSU AgCenter website and can be easily accessible through any web browser, including on a smart phone.

Due to the technical nature of irrigation engineering principles, it is recommended that you also review LSU AgCenter Publication 3552 titled Speaking the Language of Irrigation Scheduling: Glossary of Terms to get the most out of the webtool.

Accessing the Site, Account Creation and Log In

The DIRT webtool can be accessed by navigating to www.lsuagcenter.com/DIRT using your preferred web browser. You should see some introductory information on this page, including some basic information about the project and project team.

From here, tap the purple button that says Click here to access the Drought Irrigation Response Tool. On the following page, click the Sign In button on the top right of the page. This will take you to a new page with login options (Figure 1). You can access the webtool using LSU AgCenter, Google or Facebook credentials. Access to your fields requires the use of the same selected account option each time even if you maintain multiple accounts from the list. Please note that your credentials are verified by the selected third party; the LSU AgCenter will never know your login information and cannot help with recovering passwords.

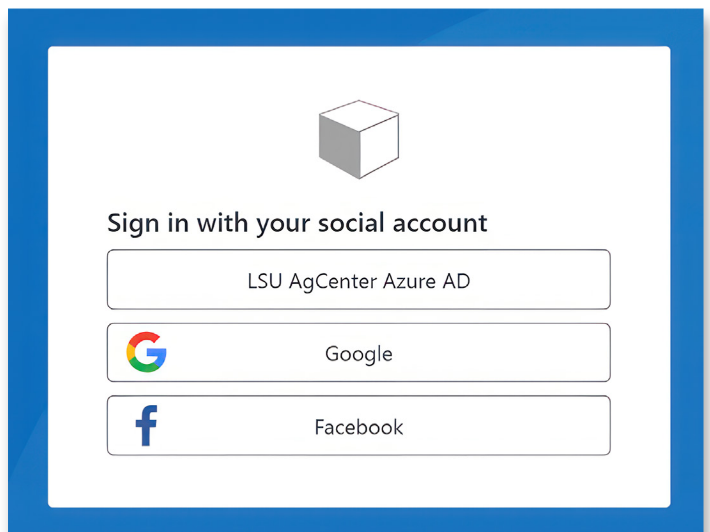


Figure 1. You can sign in to the webtool using LSU AgCenter, Google or Facebook credentials.

Creating a Field

After successfully logging into the webtool, the webpage opens to the My Fields page. If this is your first time logging in, then you will see an empty page with a prominent Add New Field button (Figure 2). Each field represents a single irrigation set. If you have multiple irrigation sets on the same field, then each set will need to be added separately.

The page changes to a fillable form so that you may add the unique characteristics associated with your field. Each fillable entry box requires input to create an accurate irrigation schedule (Table 1). While suggested values are listed to help, it's important to be as specific to the site as possible. The auto-populated values were selected from long-term average values obtained from various sources and should only be used if accurate and specific information is unavailable.

Once the field is defined satisfactorily, click the Save button. The page will update to the Results page and display "Results calculation is in progress" while the weather data is converted to evapotranspiration and rainfall values for your location (Figure 4). If field setup occurs more than a few weeks after planting, please expect several minutes of calculations before observing results.

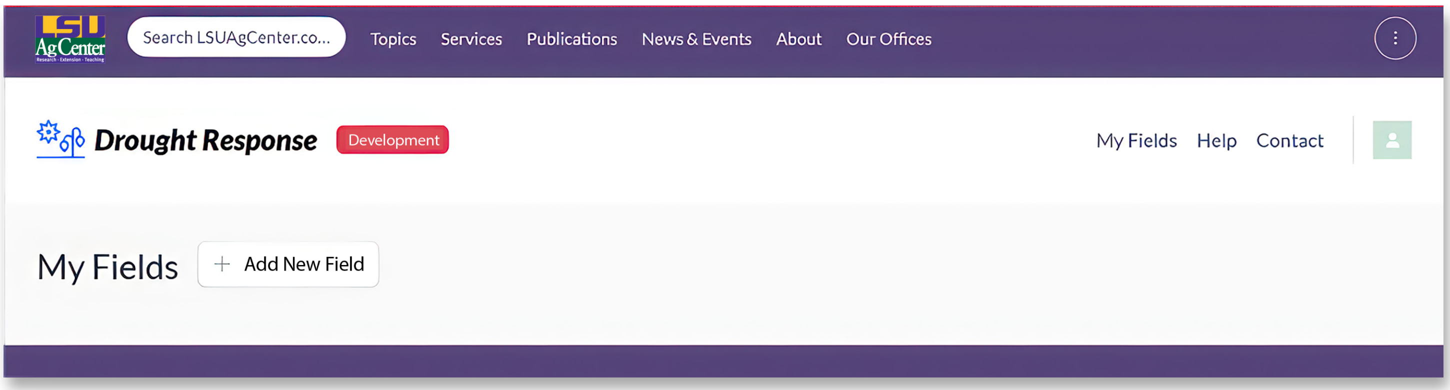


Figure 2. Click the Add New Field button after initial login to start creating a schedule for an irrigation set.

TABLE 1. ANSWERS TO THE ENTRY BOXES ARE REQUIRED TO SET UP THE MODEL.

ENTRY BOX	DESCRIPTION OR GUIDANCE
Field Name	You will provide a name to describe the field or irrigation set (e.g., Corn Set Hwy 71).
Location (Open Map)	This process includes the selection of a point location that does not calculate acreage or any other land features currently. You can select the field location by following these steps (Figure 3): 1. Click the Open Map button. 2. Zoom into the field's location using a double click of a mouse, the +/- buttons or by moving two fingers apart on a touchable screen like a smartphone. a. You can move around on the map by holding the left mouse button or by holding one finger on the screen while moving around. 3. Once zoomed, tap once to place a pin somewhere within the boundaries of the field. a. If you need to move the pin, zoom into the new location and re-click once. b. Once a location is selected, the elevation, latitude and longitude information populate at the bottom of the map. 4. If you are confident about the selected location, press the X button on the top right of the box to continue editing the field.
Irrigated Acreage	While water volumes are typically measured, depths are used in the webtool calculations. This value is used to convert between irrigation volumes and irrigation depths. Units are in acres.

ENTRY BOX	DESCRIPTION OR GUIDANCE
Planting Date	This value serves as the beginning of the soil moisture calculations. Root depth begins at 1 inch on this date and increases into the developmental growth stages until reaching maximum root depth. Although listed as planting date, it should reflect the date of emergence under dry conditions. Planting date and date of emergence are interchangeable under normal/wet weather conditions. The date can be selected using the calendar widget located on the right side of the input box or by directly typing in the form of MM/DD/YYYY. **Note for sugarcane:** Please see the crop type description for more information on planting date.
Crop Type	Crop type selection will affect the season length and the suggested days after planting (DAP) for each change in crop stage for early season, mid-season and late season. These values represent the starting day of the crop growth stage. It will also change the crop coefficient values used to convert reference evapotranspiration to crop evapotranspiration. Crop type can be selected by using the dropdown menu. The crops listed in the menu are the only crops supported currently. **Note for sugarcane:** The webtool is designed for annual crops planted from seed due to the utilization of a specific root growth model. While sugarcane is available in this tool, it may not be as accurate due to its multi-seasonal growth. If attempting to manage sugarcane, it is recommended that you set the planting date for at least 45 days before an irrigation schedule is expected. For example, if interested in irrigating sugarcane planted two years ago, across the summer months of June-August, then set the planting date to be prior to April 15 of the current year.
Drainage Type	This value will help to determine the portions of each rainfall or irrigation event that will infiltrate the soil or become surface runoff. There are four possible options for selection by drop-down box. Good drainage will increase the amount of infiltration compared with poor drainage. Residue options should match cultivation practices.
Soil Moisture on Planting Day	The selection of a starting soil moisture value will provide a general starting point on the first day of calculations. The four options are: really wet (100% of field capacity), somewhat wet (75% of field capacity), somewhat dry (50% of field capacity) and really dry (25% of field capacity). Given the root growth model being used, this parameter will not greatly affect the irrigation schedule.
Soil Type	Selection of the soil type will provide suggested values for field capacity, permanent wilting point, maximum allowable depletion and maximum root depth. Field capacity and permanent wilting point are both difficult to estimate as they are affected by soil structure in addition to texture. The listed values are national averages for texture and may need to be adjusted for site-specific conditions.
Growing Period Days	This value represents the number of days from planting to harvest. It is auto-filled once a crop type is selected but can be edited to better match the variety.
Field Capacity	Selecting this value sets a maximum volumetric water content for irrigation scheduling purposes. In practice, soil moisture can exceed field capacity temporarily, reaching saturation, but drains within a few days depending on soil type. For this purpose, it is considered a target for irrigation applications. Units are in % or m^3/m^3.
Permanent Wilting Point	Selecting this value (%) sets a minimum volumetric water content for irrigation scheduling purposes. In practice, the soil still holds some water, but it cannot be removed by the plant due to surface tension. Allowing soil moisture to reach this point is not advisable. This value is used to determine the maximum allowable depletion, which is the threshold for initiating irrigation events. Units are in % or m^3/m^3.
Plant Available Water	This value is calculated as the difference between field capacity and permanent wilting point. It represents the amount of water storage within the root zone. Units are in % or m^3/m^3.

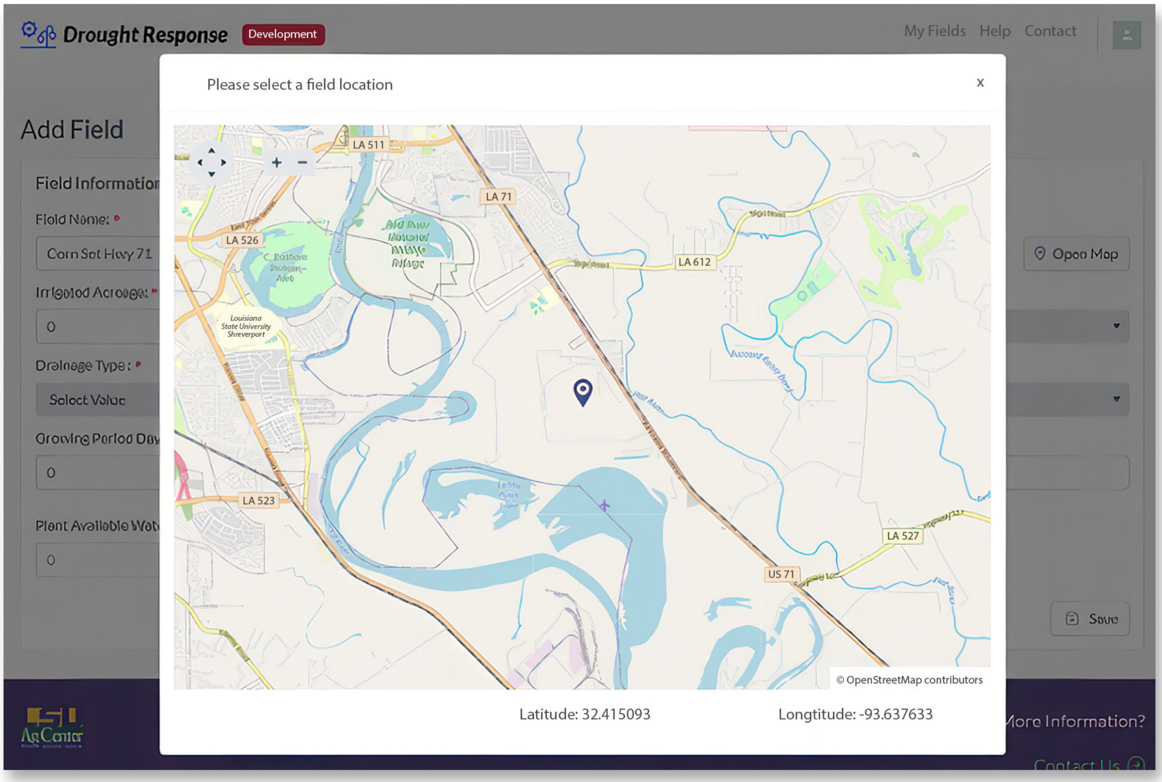


Figure 3. After clicking the Open Map button, you may select the location of the field by clicking once in the general area. Once a location is selected, the elevation, latitude and longitude information populate at the bottom of the map.

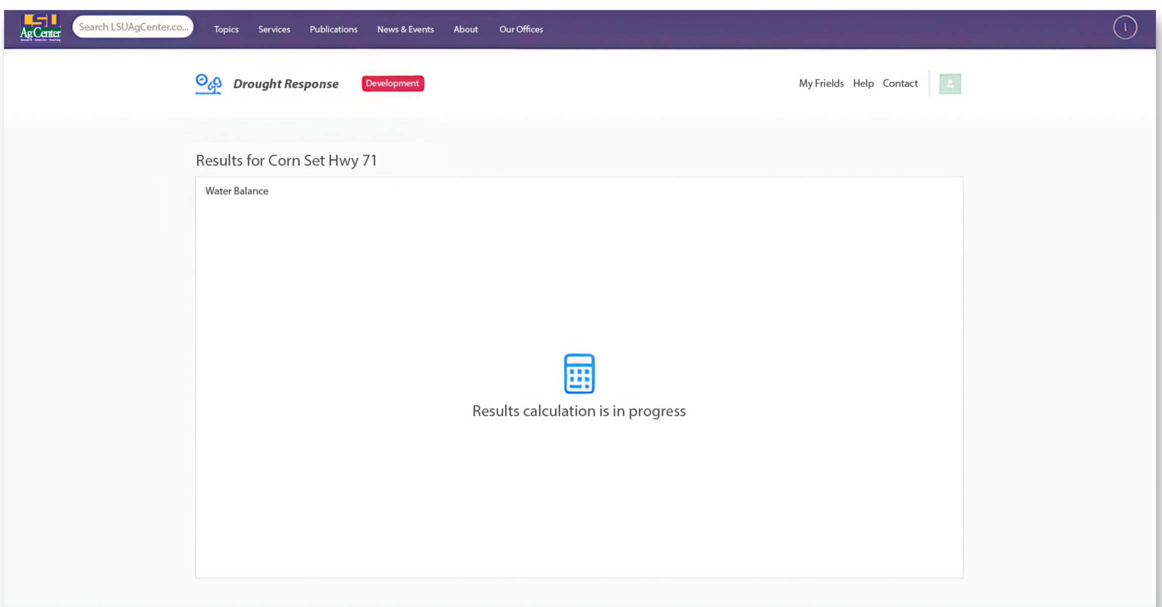


Figure 4. Once a field is created and saved, the program accesses weather data to calculate evapotranspiration and estimate rainfall for the location selected on the map.

Viewing All Fields

On the My Fields page, each field added to the account will be listed in individual boxes called cards. Each card lists the name of the field as well as the basic field setup information stored for that field. These values can be edited by using the Edit Field button. Results can be viewed using the See Results button. For making quick decisions, a visual indicator of current soil water status is available on each card. There are four possible indicators that can appear in the top right corner of the box (Table 2).

Please note that these indicators will be valid from the last time the results were viewed for that field. Thus, you must click on the See Results button and then exit back to the My Fields page for these indicators to be the most accurate. While updating upon login is the ultimate goal, this feature has not been implemented at this time.

TABLE 2. LIST OF INDICATOR IMAGES AND DESCRIPTIONS THAT PROVIDE A QUICK UNDERSTANDING OF THE SOIL WATER STATUS FOR EACH FIELD.

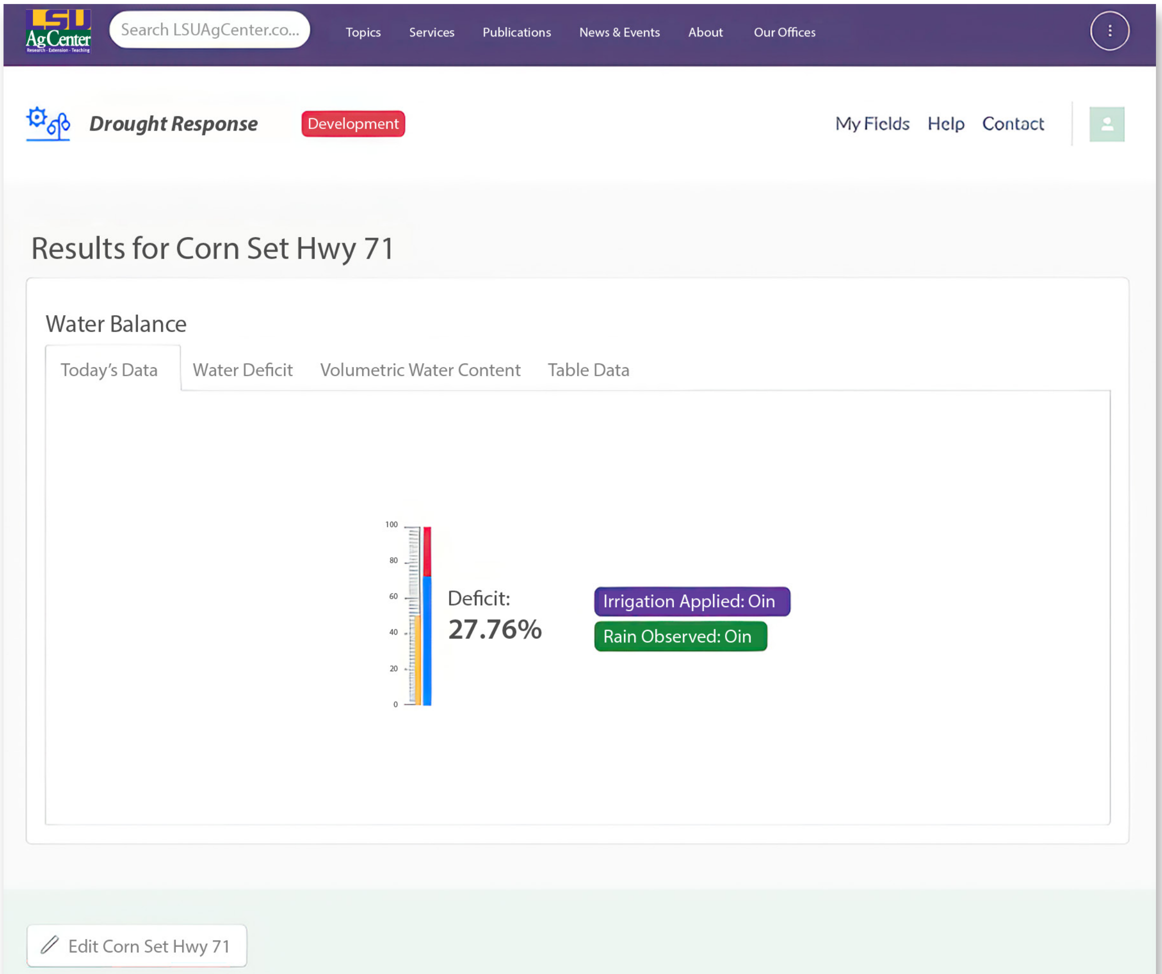
IMAGE	COLOR	DESCRIPTION	MEANING
	Green	Checkmark	Deficit is less than 34.9%
	Yellow	Exclamation Point	Deficit falls between 35% and 50%
	Red	Siren	Deficit is more than 50%
	Gray	Question Mark	No results to display

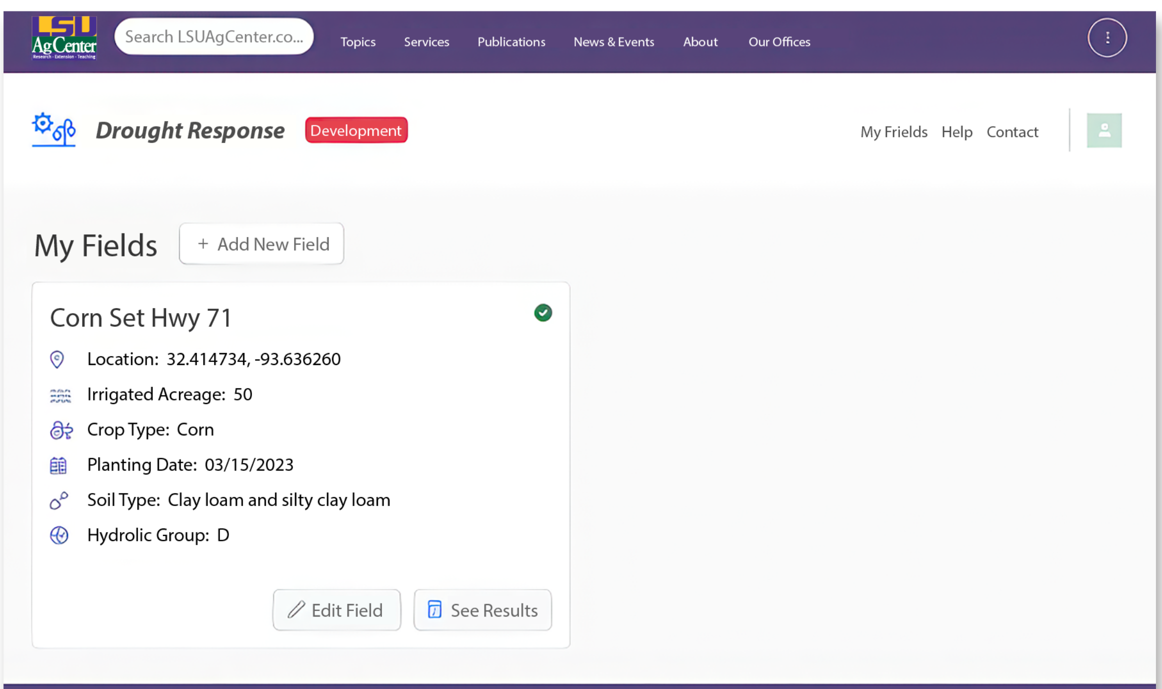
Editing a Field

The primary reason to edit or update a field is to add irrigation events that were applied, but it is possible that some of the values selected during the Add New Field process will need to be adjusted later once more information is known. Examples of updating values include changes to field capacity, permanent wilting point, or growing period days.

If changes are needed, you can access the Edit (Field Name) button directly from the results page (Figure 5a) or select the Edit Field button located on the card for that field from the My Fields page (Figure 5b). You must select the Save button to save all changes made. This action may require some time for recalculation.

If you encounter an error or suspect that the webtool has not updated correctly, there is an option to delete and recalculate the daily calculations from the planting date. This option can be found within the gear image of the Edit Fields section (Figure 6). Also, there may be times when it's preferable to delete a field. In these cases, you can use the "Delete" button found within the gear image of the Edit Field section. There are currently no options for mass-deletion of fields; they must be deleted individually. Please note that a fully deleted field using the "Delete" button cannot be recovered.





Figures 5a and 5b. After field creation, you can edit the field characteristics or add irrigation events through the Edit (Field Name) button located below the results (top screenshot) or at the bottom of the card for that field (bottom screenshot).

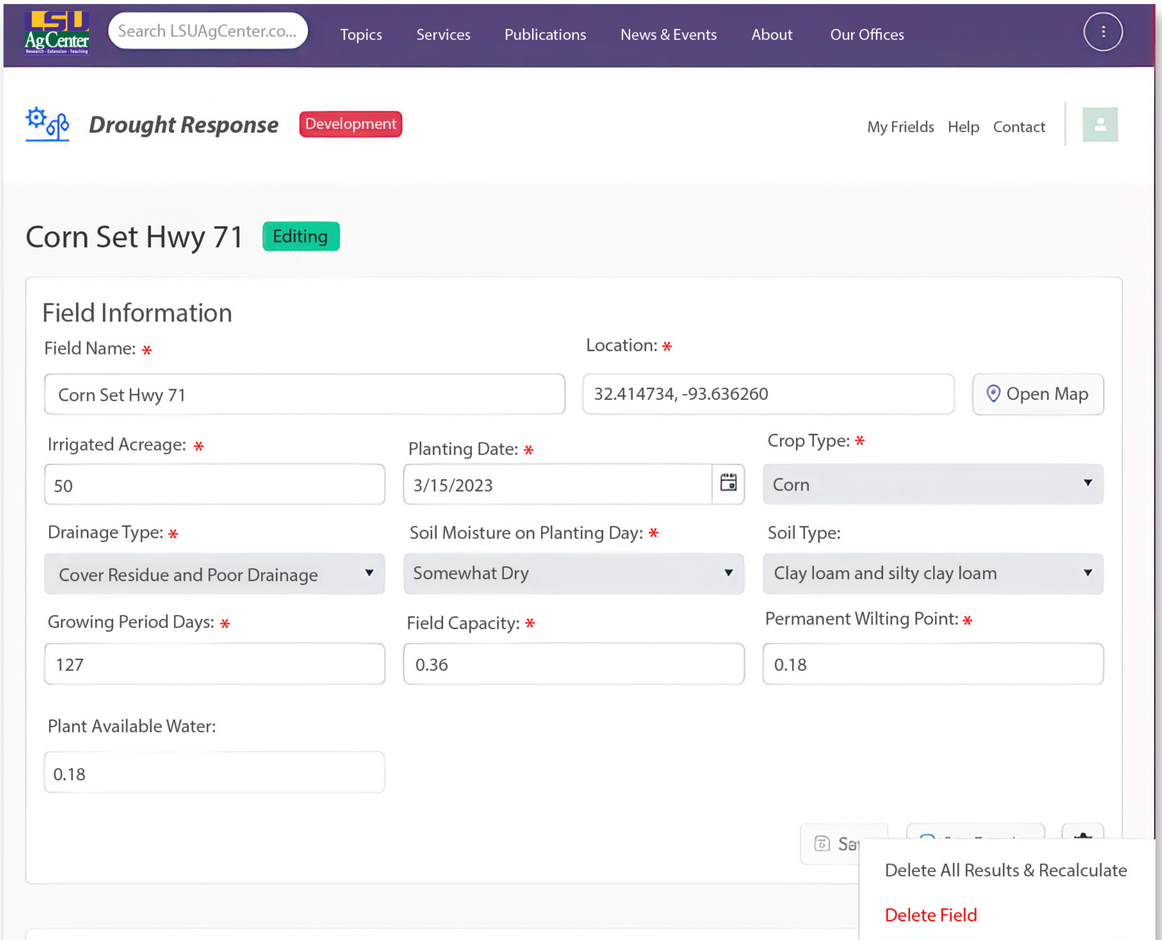


Figure 6. You can delete an entire field using the Delete button or delete and recalculate the daily values called into the soil water balance using the Delete All Results and Recalculate" button, both found by clicking the gear icon at the bottom right.

Adding Irrigation Events

Irrigation events can be added using the Edit Field section after the field was created the first time. The Irrigation Activities section is located at the bottom of the page under the Field Information section (Figure 7). Please note that even if you wait to create the field after you have initiated irrigation, you will still have to create the field first, wait for results to load, and then go back into field editing to add irrigation events for an accurate irrigation schedule.

Each irrigation can be added by the date of completion (i.e., turned the water off) in units of inches (in), acre-inches (ac-in), gallons (gal) or kilogallons (kgal) selected using a drop-down menu. These units were selected to match common flow meter measurement devices. If you do not have a flow meter, please assume somewhere between 2 to 3 inches for furrow irrigation methods. A more efficient irrigation will apply closer to 2 inches whereas a less efficient irrigation will apply closer to 3 inches. While initiation date can also be used, the results may show an earlier increase in soil moisture than expected when comparing to soil moisture sensor data. Once entered, select the check mark to complete the entry and recalculate results to include this information.

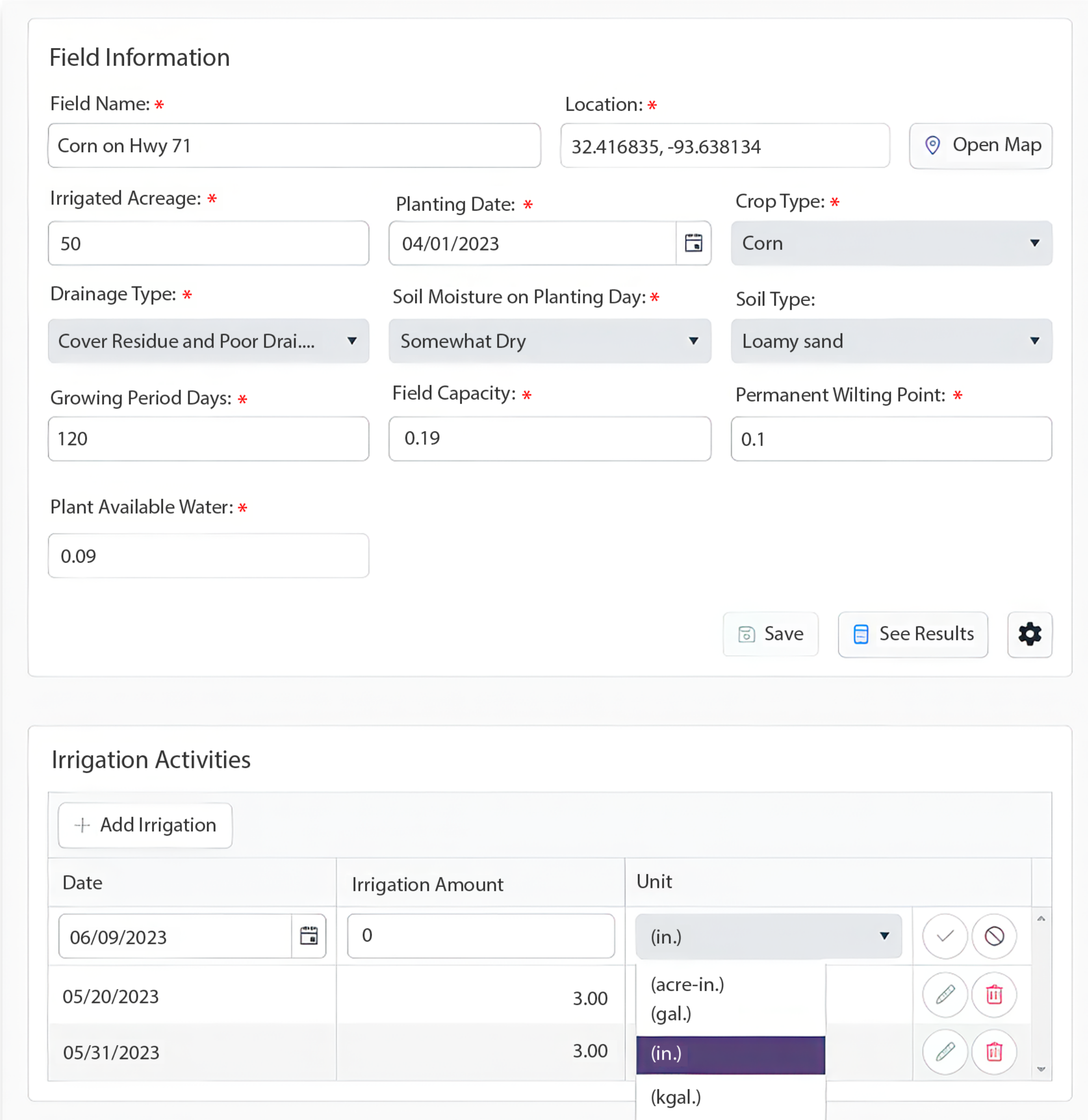


Figure 7. Irrigation events are added as activities on the bottom of the My Fields page.

Viewing Results

There are several accessible ways to view the results for each field. They include:

1. Automatically displayed when a field is added or edited once the Save button is activated.
2. Clicking the See Results button on the card listed on the My Fields page.
3. Clicking the See Results button while editing the field.

Today's Data Tab

Once results are loaded successfully, the page will land on the Today's Data tab. This tab shows a scale expressed on a percentage basis with two independent bars indicating the threshold for scheduling an irrigation event (yellow bar) and current soil moisture status as a deficit (red/blue bar) (Figure 8). The red portion of the bar is equivalent to the deficit percentage displayed next to the scale. The blue portion of the bar represents the remaining moisture available within the soil. Once deficit reaches maximum allowable depletion represented by the yellow bar, an irrigation event should be applied. If rainfall occurred or irrigation was applied on the current date, those totals will be displayed on this tab for quick reference. For accuracy, the date of the last recalculation is listed on the top right of the tab and should match today's date to be considered valid.

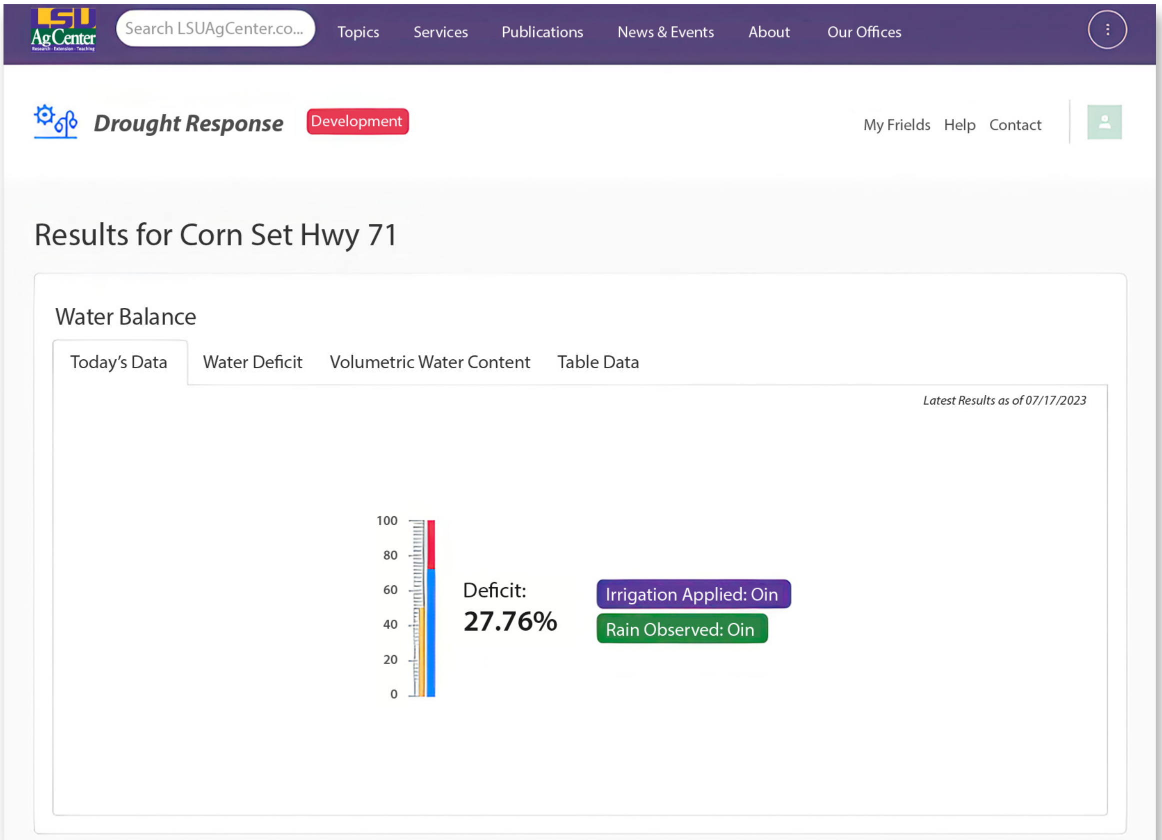


Figure 8. The Today's Data tab of the results page gives a quick look at the current soil moisture status with deficit (red), plant available water (blue), and maximum allowable depletion (yellow). Irrigation should be applied once deficit approaches maximum allowable depletion.

Water Deficit Tab

Sometimes trends over time are more informative to irrigation scheduling than a snapshot. The Water Deficit tab illustrates the changes in daily deficit for every completed day starting from planting date using the same definitions for red/blue as the Today's Data tab (Figure 9). Deficit fluctuates daily based on the water inputs and outputs as described in the Scientific Background Information section.

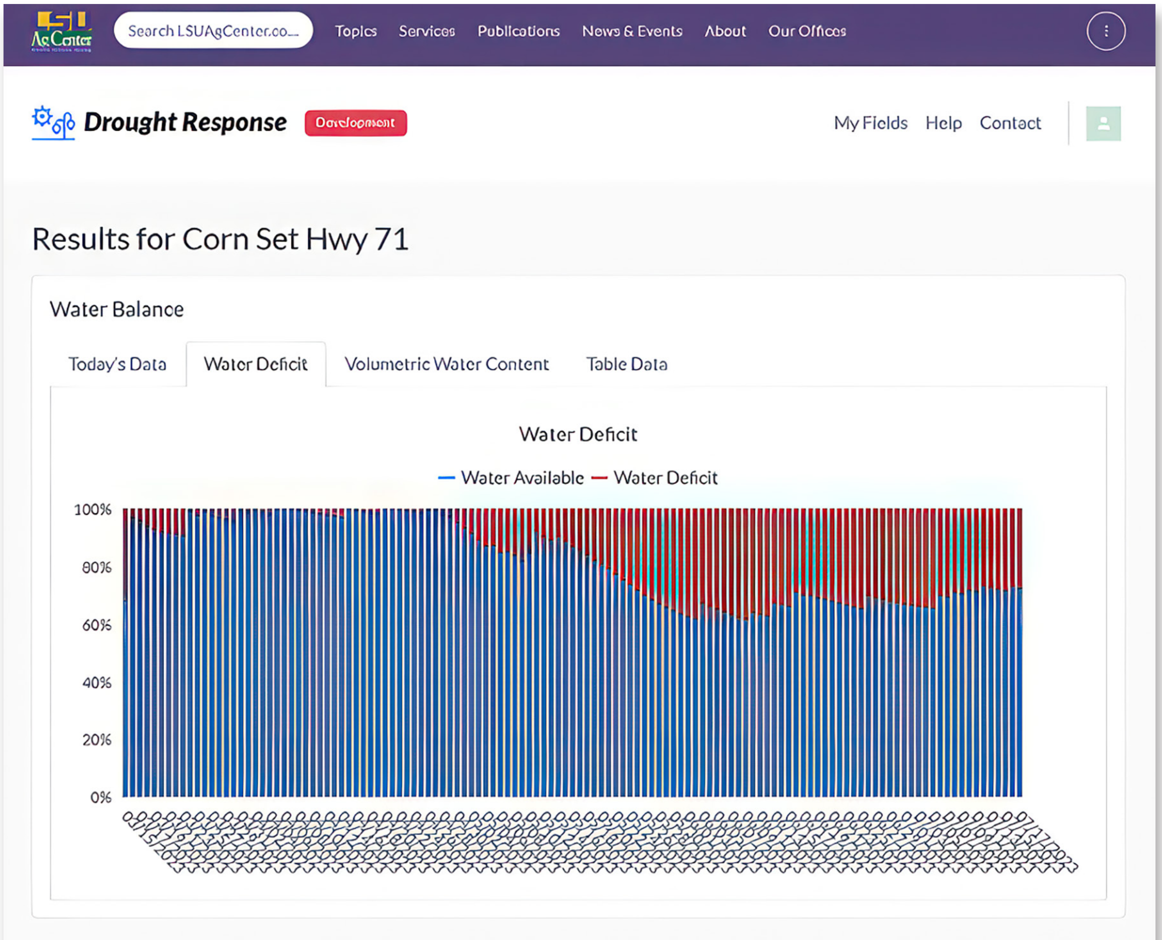


Figure 9. The Water Deficit tab of the results page provides the daily deficit bars for every day starting from planting date so that trends in soil moisture status can be viewed.

Volumetric Water Content Tab

Similar to the Water Deficit tab, this graph also shows the changes in soil moisture over time (Figure 10). However, this tab provides perspective for what the current water content means. Instead of presenting the status as declining from full (i.e., 100%), this graph presents the volumetric water content calculated as the ratio of the available unit volume of water to the total unit volume determined from the root depth. This graph better relates visually to time series graphs commonly provided by commercial products (e.g., soil moisture sensors).

From the left-side y-axis, each graph includes lines that represent field capacity (green), maximum allowable depletion (yellow) and permanent wilting point (red) for the specific soil loaded into field creation. Blue dots indicate the estimated soil moisture for each day from planting date until today. For a well-watered crop, the blue dots should remain above the yellow line for the entire season. However, the most efficient irrigation schedule maintains soil moisture above the yellow line during critical growth stages that typically occur during the reproductive cycles.

Daily rainfall and irrigation totals are also provided on this graph as bars using the right-side y-axis. Rainfall values are obtained automatically through the weather data source and will be displayed on the date it occurred. Irrigation events are added as an irrigation activity followed by recalculation of results before being visualized here. Once an irrigation event is added, the event is displayed on the graph as a bar and soil moisture increases to reflect the input (Figure 11).

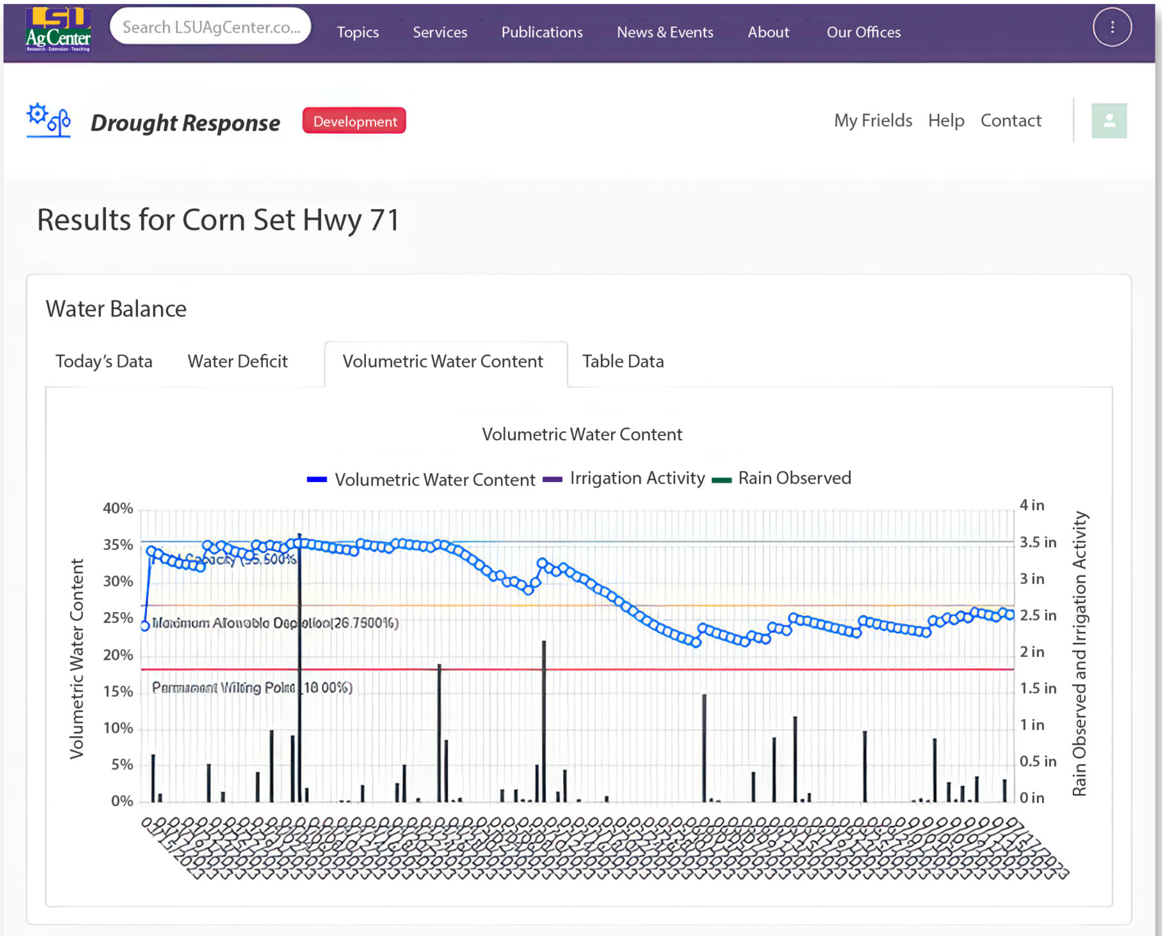


Figure 10. The Volumetric Water Content tab provides the trends in soil moisture over time as they relate to the soil physical properties. This graph also visualizes irrigation and rainfall events over time.

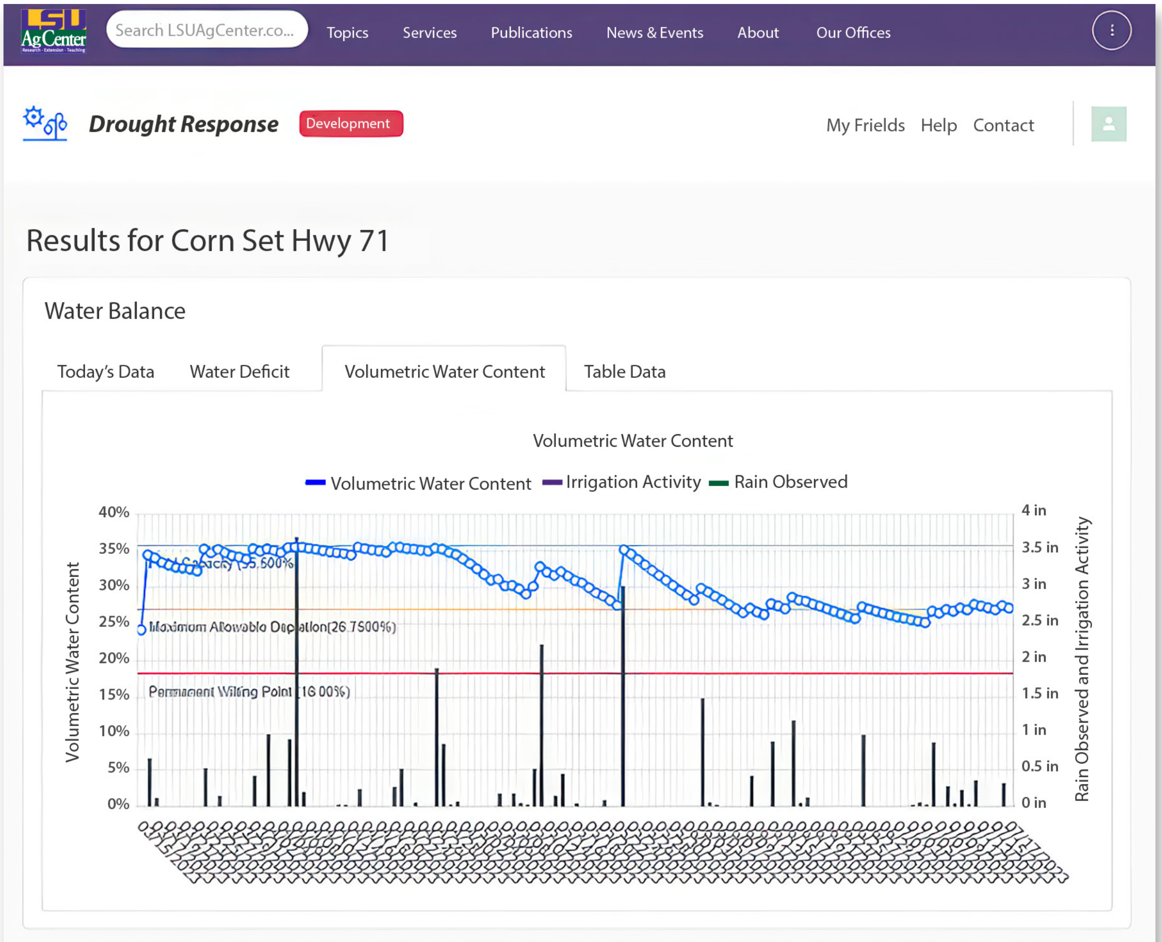


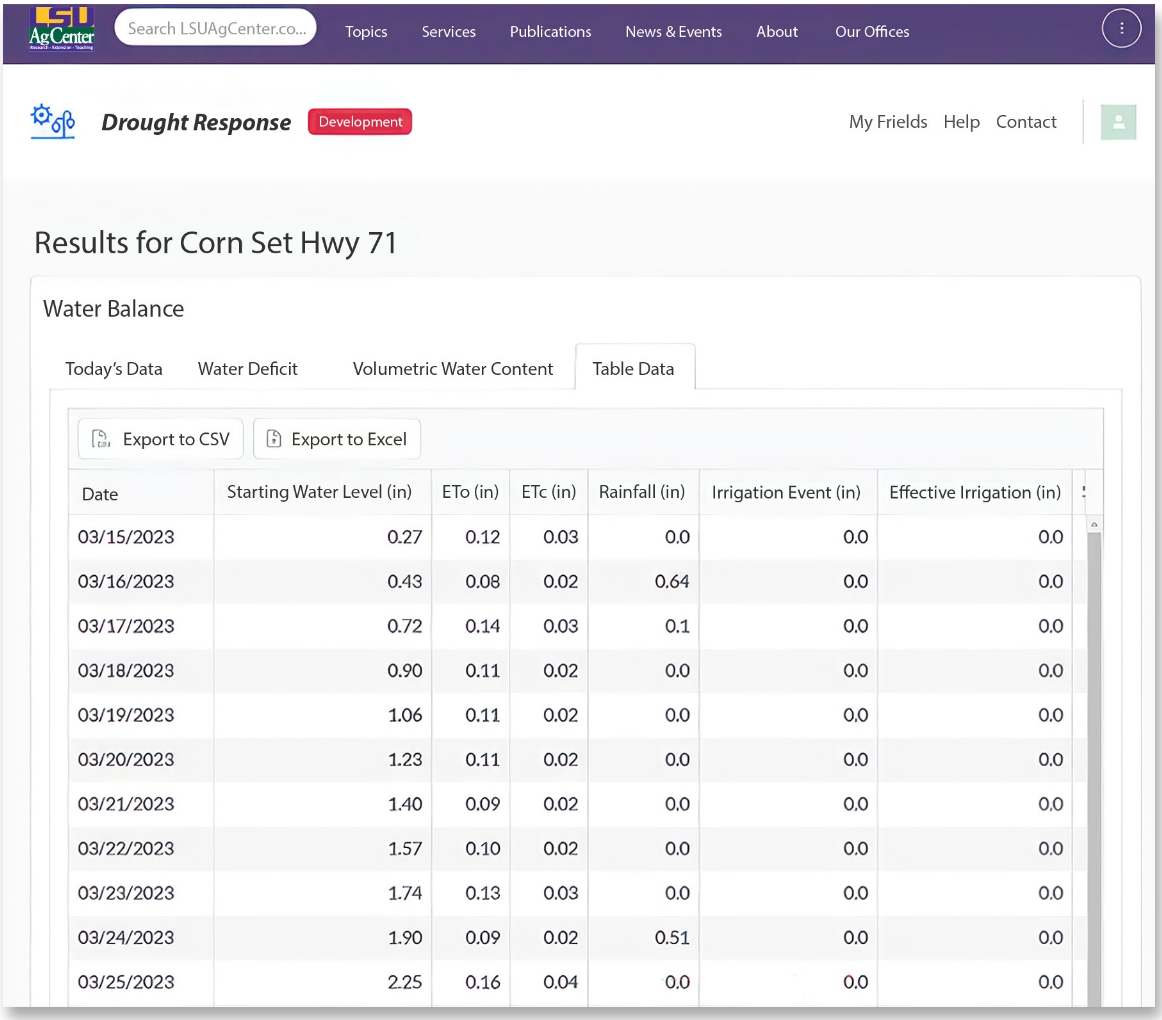
Figure 11. As in Figure 10, except there is a 3-inch irrigation event added on May 23, 2023, as the soil moisture approached maximum allowable depletion, resulting in a bar that reaches the 3-inch mark on the right-side y-axis and a sharp increase in soil moisture (blue line).

Table Data Tab

The Table Data tab provides the data values used to create the graphical information in the other three tabs. This table can be exported as a comma-separated value (.csv) or Excel (.xlsx) file using the buttons found above the column headings (Figure 12). This feature enables the end user to create historical records of their evapotranspiration rates, rainfall totals and irrigation applications for each field.

The table populates daily values of the soil water balance parameters from the planting date until the most recent recalculation. The first page lists the first 50 days; values occurring later in the season can be viewed using the page navigation at the bottom of the table by selecting the preferred page number or using the arrows to flip through each page. Scrolling is enabled for both vertical and horizontal directions to view all data on the page.

Each page includes 12 columns of information based on the calculations listed in the Scientific Background Information section. While Irrigation Events (in) lists the user-added events from the irrigation activities section, the Effective Irrigation (in) column can be used to predict when an irrigation event is necessary. If a non-zero value appears within this column, an irrigation event was needed to maintain soil moisture above maximum allowable depletion (Figure 13). Please note that this column is a predictive output used to suggest when irrigation events should have occurred and is not reflected in the actual soil moisture status.



Date	Starting Water Level (in)	ETo (in)	ETc (in)	Rainfall (in)	Irrigation Event (in)	Effective Irrigation (in)
03/15/2023	0.27	0.12	0.03	0.0	0.0	0.0
03/16/2023	0.43	0.08	0.02	0.64	0.0	0.0
03/17/2023	0.72	0.14	0.03	0.1	0.0	0.0
03/18/2023	0.90	0.11	0.02	0.0	0.0	0.0
03/19/2023	1.06	0.11	0.02	0.0	0.0	0.0
03/20/2023	1.23	0.11	0.02	0.0	0.0	0.0
03/21/2023	1.40	0.09	0.02	0.0	0.0	0.0
03/22/2023	1.57	0.10	0.02	0.0	0.0	0.0
03/23/2023	1.74	0.13	0.03	0.0	0.0	0.0
03/24/2023	1.90	0.09	0.02	0.51	0.0	0.0
03/25/2023	2.25	0.16	0.04	0.0	0.0	0.0

Figure 12. Tabular data can be viewed to look at individual values affecting the irrigation schedule or exported to maintain a historical record of irrigation management for the field.

Date	Starting Water Level (in)	ETo (in)	ETc (in)	Rainfall (in)	Irrigation Event (in)	Effective Irrigation (in)	Surface Runoff (in)
05/04/2023	8.87	0.18	0.23	0.0	0.0	0.0	0.00
05/05/2023	8.83	0.12	0.15	0.16	0.0	0.0	0.00
05/06/2023	9.02	0.23	0.29	0.0	0.0	0.0	0.00
05/07/2023	8.92	0.14	0.17	0.16	0.0	0.0	0.00
05/08/2023	9.10	0.13	0.17	0.03	0.0	0.0	0.03
05/09/2023	9.12	0.19	0.24	0.01	0.0	0.0	0.01
05/10/2023	9.07	0.12	0.15	0.5	0.0	0.0	0.06
05/11/2023	9.56	0.09	0.12	2.2	0.0	0.0	1.27
05/12/2023	10.56	0.20	0.25	0.0	0.0	0.0	0.00
05/13/2023	10.50	0.22	0.28	0.13	0.0	0.0	0.01
05/14/2023	10.54	0.20	0.25	0.43	0.0	0.0	0.03
05/15/2023	10.87	0.17	0.22	0.0	0.0	0.0	0.00
05/16/2023	10.84	0.18	0.23	0.03	0.0	0.0	0.03
05/17/2023	10.80	0.11	0.13	0.0	0.0	0.0	0.00
05/18/2023	10.85	0.21	0.27	0.0	0.0	0.0	0.00
05/19/2023	10.78	0.22	0.28	0.0	0.0	0.0	0.00
05/20/2023	10.49	0.12	0.15	0.07	0.0	0.0	0.07
05/21/2023	10.35	0.17	0.22	0.0	0.0	0.0	0.00
05/22/2023	10.13	0.19	0.25	0.0	0.0	0.0	0.00
05/23/2023	9.88	0.20	0.26	0.0	3.0	2.89688937005707...	0.00
05/24/2023	12.63	0.17	0.21	0.0	0.0	0.0	0.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 13. The table data associated with Figure 11 reflects the 3-inch irrigation event added on May 23, 2023. The Effective Irrigation (in) column reflects the need for irrigation on the same date, observed as a non-zero value (2.896889…), and converts back to zero on May 24, 2023, in accordance with the user-added event.

Scientific Background Information

DIRT was created as a daily soil water balance that can be used to predict, record and visualize irrigation events for each irrigated field. The soil water balance relies on the physics-based law of conservation of mass; water cannot be created or destroyed thus it may be always accounted for. This results in the ability to track daily water movement within the root zone over time (Equation. 1; Table 3). Many refer to the soil water balance as the "checkbook method" as it is like keeping a checkbook balance.

Equation 1. Calculation for estimating the soil water level based on the water level at the previous time step and multiple factors affecting movement of water in the soil.

$$SWL_i = SWL_{i-1} - ET_C + R + I - P_d - RO$$

TABLE 3. THE VARIABLES LISTED IN EQUATION 1 WERE USED TO ESTIMATE CHANGES IN SOIL MOISTURE STATUS ON A DAILY BASIS. THE INFORMATION LISTED BELOW IS SPECIFIC TO DIRT.

VARIABLE	DESCRIPTION	ESTIMATION/CALCULATION/NOTES
SWL_i	Soil water level on day i	This value is being calculated daily and used to estimate the volumetric water content by dividing it by the root zone depth.
SWL_{i-1}	Soil water level on day i-1	The previous day's water level is used to begin calculations for the current day.
ET_C	Crop evapotranspiration $ET_C = K_S K_C ET_O$	Weather data obtained through an online service was used to calculate a reference value (ET_O) based on the GPS coordinates selected from the map. The reference value is converted to a crop value using crop coefficients (K_C) identified through the crop type selection. Stress coefficients (K_S) are introduced when soil moisture falls below maximum allowable depletion as a linear response from 1 (not limited) to 0 (permanent wilt).
R	Rainfall	Weather data obtained through an online service was used to estimate rainfall based on the GPS coordinates selected from the map.
I	Irrigation	Irrigation is added manually by the user by navigating to the irrigation activities section of the webtool.
P_d	Deep percolation	For calculation purposes, deep percolation is estimated as any applied irrigation or rainfall that exceeds field capacity.
RO	Surface runoff	For calculation purposes, surface runoff is estimated from rainfall only using the Curve Number method. The parameterization of the Curve Number method uses the hydrologic group determined from the GPS coordinates selected from the map and the drainage type selected during field creation.

As with any model, it is important to start with accurate input data to receive informative and usable output. The assumption inherent in the soil water balance is that there are no restrictive interactions across the various elements of the production system that would prevent free water movement throughout the root zone. However, certain soil textures and structures may limit infiltration rates, restrict evapotranspiration rates or be conducive to compaction issues. This is just one example; there are numerous physical or environmental factors that may cause DIRT's prediction to stray from actual soil moisture status. The following occurrences should include field verification before following the irrigation schedule provided by DIRT:

- High intensity rainfall events (high volume, short duration).
- Volumetric water content falls below maximum allowable depletion for a long time.
- Crop experiences significant delays in growth due to other possible stress factors.

Conclusion

Proper irrigation scheduling is extremely important to sustainable agricultural practices due to highly variable rainfall patterns and limited water resources available for irrigation. Over-irrigating will negatively impact crop production due to leaching of highly valuable nutrients, increasing erosion potential, generating excessive surface runoff or any combination of these possible outcomes. Under-irrigation during critical growth stages can lead to significant declines in yield quantity as well as yield quality. Managing surface irrigation efficiently in Louisiana has become critical due to both under- and over-irrigation frequently occurring in the same crop season. Irrigation management is best accomplished by utilizing a scheduling technique or combination of techniques that is most comfortable for the irrigator. While there are multiple methods or tools available to irrigators today, DIRT can be a highly valuable option, especially when considering it is free for everyone and has a relatively low learning curve. Thus, DIRT can provide guidance on irrigating various crops so that yield can be maximized while wasteful and costly applications are minimized.

Acknowledgments

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