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# Automated Irrigation Scheduling Application of the North Dakota Agricultural Weather Network

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**ABSTRACT**

During the last 30 years, the development of agricultural weather networks and other technologies have made scientific irrigation scheduling much easier to apply and use. However, at the present time the most frequent complaints by irrigators about scientific irrigation scheduling is that it has a steep learning curve, takes too much time to gather all the bits of information and they just don't have the time during the growing season. To address these concerns a site-specific irrigation scheduling program, accessible through the North Dakota Agricultural Weather Network (NDAWN) website, was developed. The irrigation scheduling application has become one of the most popular agricultural applications on the NDAWN website (http://ndawn.ndsu.nodak.edu). It is designed to increase proficiency in water usage of irrigators by calculating site-specific water deficiency in soil. The soil-water deficiency is calculated based on a selected field and the growth stage of a selected crop. The application interfaces with a Geographic Information System (GIS) to select a specific field and thus obtain the geographic coordinates for the soil types and soil water holding capacity in the field. It also interfaces with the nearest NDAWN automated weather station to obtain meteorological information to automatically calculate crop water requirements on a daily basis of the crop in the selected field. The output is the daily checks and balances of the soil-water deficiency for the selected field.

**Key words:** irrigation scheduling, weather data, site specific, NDAWN, soil properties

## INTRODUCTION

There are 15.9 million hectares (39.4 million acres) of farmlands in North Dakota, USA (USDA, 2002) . It makes up 87% of total land cover in the state (4th largest percentage in the United States). In 2007, North Dakota ranked number one in ten agricultural commodities in the nation including spring wheat, durum wheat, oats, barley, flaxseed, navy beans, pinto beans, lentils, sunflower and canola

NDAWN: North Dakota Agricultural Weather Network
GIS: Geographic Information System
USDA: United States Department of Agriculture

(USDA, 2007). It is apparent that agriculture makes up a big portion of North Dakota's economic power. Small increases in yield due to farming practice (such as adaptation of irrigation farming) can translate into a significant statewide economic gain. The emerging importance and impact of climate change has raised the concern by policymaker, researcher, producer or consumer. This issue is recognized as a fundamental component of the world's future food, feed and fuel security. The state's annual average temperature rose 0.16°C per decade during the last 114 years in North Dakota. Unfortunately, precipitation regime since 1895 did not yield any significant trend in North Dakota. In fact, since the advent of the National Drought Monitor in 2000, North Dakota was exposed to extreme droughts (category 3 of a 4-category drought depiction with 4 being the most severe drought) at least once every year (NDMC, 2008). This raises 2 questions of concern:

1. How might cropping practices change in a changing climate, and how it might impact farmers' decisions on the best crop choices to suit today's climate?
2. How might changing climate impact our water resources, and what are the best practices to mitigate our vulnerability to extreme droughts?

Based on the 2007 census, United States Department of Agriculture (USDA) reported by the Farm Service Agency (FSA) over 105,000 hectares of land were irrigated in North Dakota (0.66% of total agricultural land). Installation and maintenance cost of irrigation systems, poor access to water resources and generally good dryland crop yields are the main reasons for lack of adaptation of irrigation in North Dakota. Amongst the most frequent complaints by irrigators who adopted the irrigation systems are the steep learning curve and complexity of the former scheduling systems. Up until the advent of the North Dakota Agricultural Network Irrigation Scheduling Application, irrigation scheduling was time consuming and required a significant effort to acquire the correct information to make good irrigation decisions.

Web-based irrigation scheduling has the potential to overcome many of the objections raised by irrigators. Singels and Smith, 2006, demonstrated that a web-based irrigation advisory service that reduced irrigation amounts by 33 percent reduced deep drainage by 64 percent and reduced irrigation costs for small-scale sugarcane producers. Thysen and Detlefsen (2006) have adapted a computerized irrigation decision support system for use on the web so that much of the data gathering is transparent to the user. Hillyer, et al. (2007) described a web-based irrigation advisory system for optimum irrigation management.

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FSA: Farm Service Agency

## MATERIALS and METHODS

The irrigation scheduling program can be activated from the NDAWN web site (http://ndawn.ndsu.nodak.edu/) by selecting the “Irrigation Scheduler” from the “Applications” menu on the left hand side of the web page (Figure 1). The irrigation-scheduling method uses a soil water balance algorithm to determine the soil water deficit in the effective root zone on a daily time step. Soil water deficit is zero when the moisture level in the effective root zone is at field capacity and is at 100 percent when all plant available water has been depleted (which should not occur under irrigated conditions). This method is explained in Lundstrom and Stegman (1988) where it is called the checkbook method. In the checkbook method water added to the soil (rain and irrigation) is treated as a deposit and water removed from the root zone (crop water use, runoff and deep drainage) is treated as a withdrawal, similar to a common bank checking system.

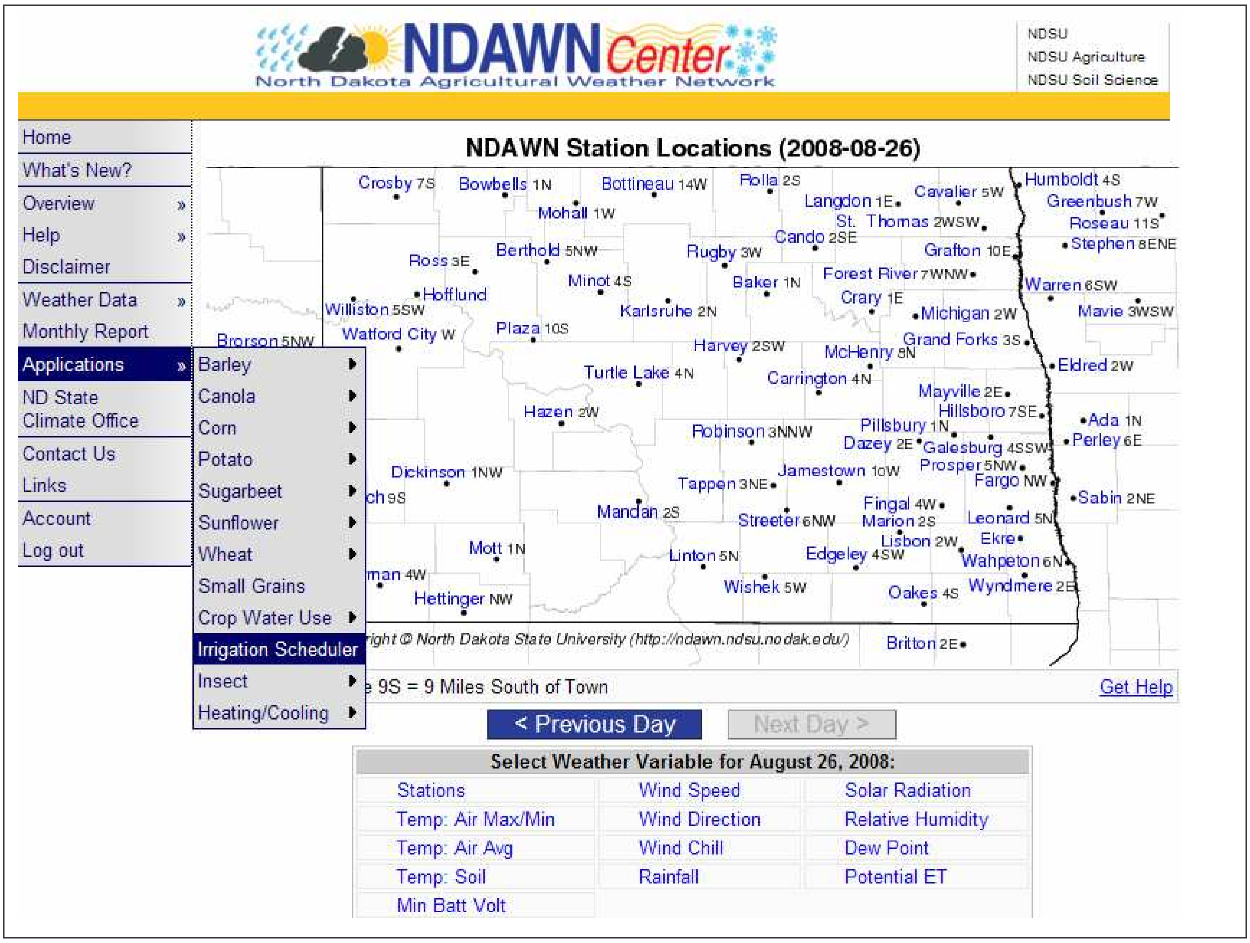
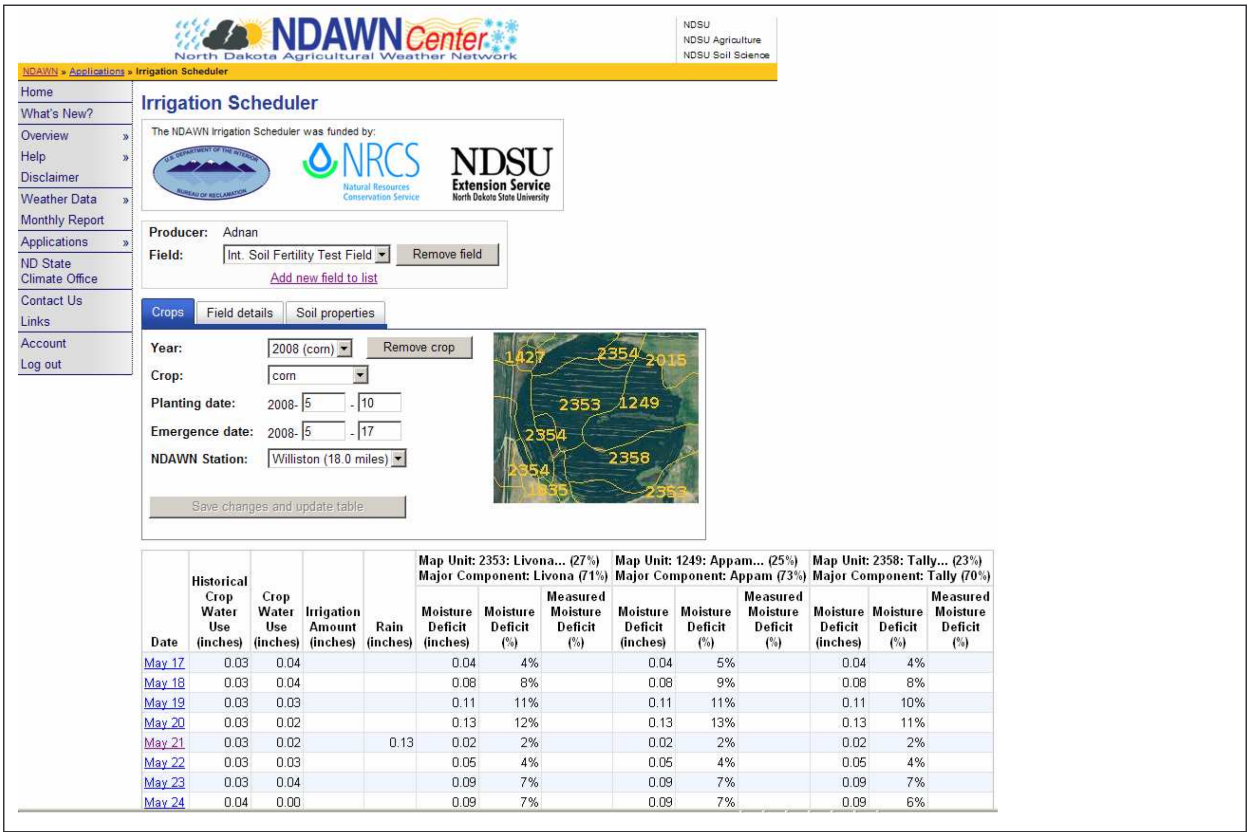



Figure 1. Accessing the North Dakota Agricultural Weather Network’s Irrigation Scheduling Application.

Figure 2 is an example output for a test field that contains the picture of the irrigated field, soil information and the checkbook table with daily moisture deficit values for each soil type. In order to achieve the output seen in Figure 2, the user must select the field from aerial photos using a GIS interface and then field specific soil parameters are accessed from the USDA-Natural Resource Conservation Services (NRCS) digitized soil survey database. The user then selects the crop, planting date, emergence date and year. The user can then select one of the three nearest weather stations to be used to calculate crop water use estimates. The program automatically creates a soil water accounting sheet for each of the three major soils in the field (based on area). The user also has the choice to select the NDAWN weather station from the nearest station drop-down menu for the meteorological parameter calculations.




| Date | Historical Crop Water Use (inches) | Crop Water Use (inches) | Irrigation Amount (inches) | Rain (inches) | Map Unit: 2353: Livona... (27%) Major Component: Livona (71%) | | | Map Unit: 1249: Appam... (25%) Major Component: Appam (73%) | | | Map Unit: 2358: Tally... (23%) Major Component: Tally (70%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture Deficit (inches) | Moisture Deficit (%) | Measured Moisture Deficit (%) | Moisture Deficit (inches) | Moisture Deficit (%) | Measured Moisture Deficit (%) | Moisture Deficit (inches) | Moisture Deficit (%) | Measured Moisture Deficit (%) |
| May 17 | 0.03 | 0.04 | | | 0.04 | 4% | | 0.04 | 5% | | 0.04 | 4% | |
| May 18 | 0.03 | 0.04 | | | 0.08 | 8% | | 0.08 | 9% | | 0.08 | 8% | |
| May 19 | 0.03 | 0.03 | | | 0.11 | 11% | | 0.11 | 11% | | 0.11 | 10% | |
| May 20 | 0.03 | 0.02 | | | 0.13 | 12% | | 0.13 | 13% | | 0.13 | 11% | |
| May 21 | 0.03 | 0.02 | | 0.13 | 0.02 | 2% | | 0.02 | 2% | | 0.02 | 2% | |
| May 22 | 0.03 | 0.03 | | | 0.05 | 4% | | 0.05 | 4% | | 0.05 | 4% | |
| May 23 | 0.03 | 0.04 | | | 0.09 | 7% | | 0.09 | 7% | | 0.09 | 7% | |
| May 24 | 0.04 | 0.00 | | | 0.09 | 7% | | 0.09 | 7% | | 0.09 | 6% | |

Figure 2. A Sample NDAWN Irrigation Scheduling Checkbook Output for a Test Field.

There are 3 main tabs under the field created by the user: “Crops”, “Field details” and “Soil properties”.

**Crops:** This is the default page that program returns upon saving the field, crop and date information. This is where crop moisture deficits are calculated for each soil type in the selected field. The calculations under the “Moisture Deficit” for each soil type utilizes the following equation (Scherer et al., 2008)

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NRCS: Natural Resource Conservation Services

$$\mathbf{SWD_i = SWD_{i-1} + ET_c - (I + R)} \qquad (1)$$

where:

$SWD_i$ – soil water deficit at the end of day i (cm)

$SWD_{i-1}$ – soil water deficit at the end of previous day [i-1] (cm)

$ET_c$ – crop evapotranspiration on day i (cm)

I – irrigation amount on day i (cm)

R – rain amount on day i (cm)

i – day after crop emergence

The percent soil water deficit is calculated using the following equation:

$$SWD_i = \frac{100 * (PAWC_{rz} - AW_{rz})}{PAWC_{rz}} \qquad (2)$$

where:

$AW_{rz}$ – available water in the root zone on day i

$PAWC_{rz}$ – total soil-water holding capacity in the root zone on day i

Crop evapotranspiration values are obtained using daily weather data from the nearest NDAWN weather station. The farthest distance from any point in North Dakota to an NDAWN weather station is approximately 80km. In order to calculate the water deficits more accurately, precise precipitation data is necessary. Rainfall distribution in North Dakota can sometime be very variable in short distances especially during a summer thunderstorm event. Therefore, irrigators are encouraged to make on-site rainfall measurements. These observations are entered manually.

**Field details:** The field details contain the following information: total area, latitude, longitude and county. The field details also show the aerial photo of the field with soil types labeled. Figure 3 is a sample output for this test field showing the field details. The technology behind how this information is populated can be found in the following section.

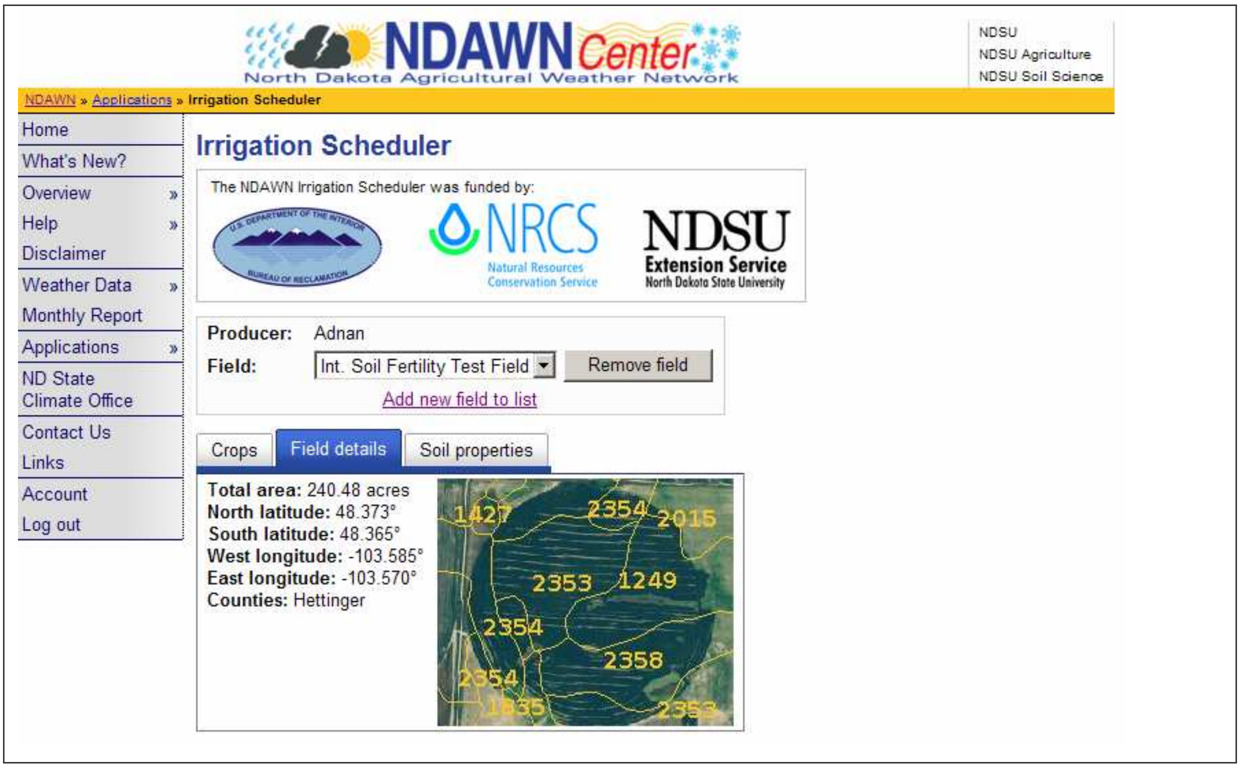


Figure 3.  A Sample output of the NDAWN Irrigation Scheduling Field Details.

**Soil Properties:** The soil properties field contains information related to type of soils that occupies the field. Percent coverage, slope, soil-water holding capacity by depth are the information given in this section. Figure 4 is a sample output for this test field showing the soil properties. The technology behind how this information is populated can be found in the following section.

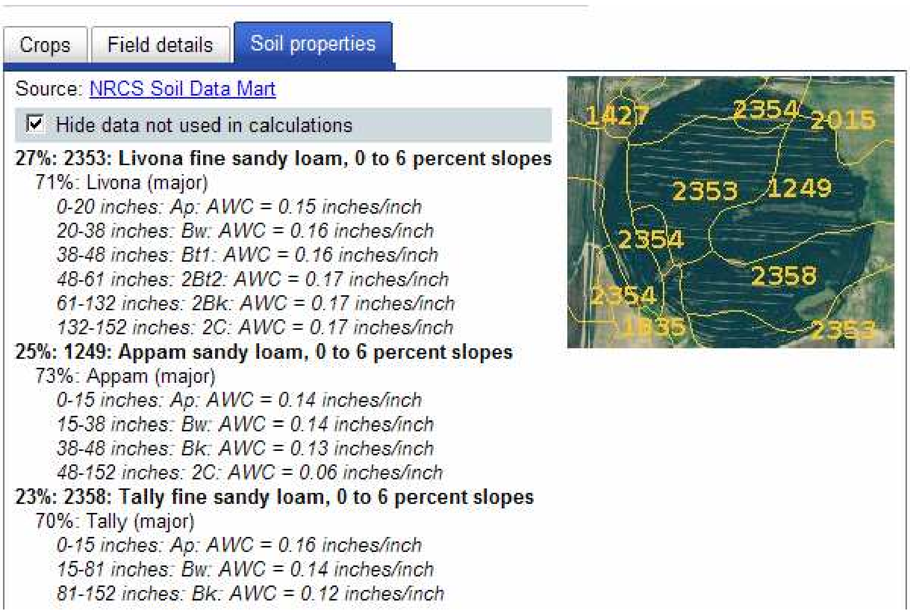


Figure 4.  A Sample output of the NDAWN Irrigation Scheduling Soil Properties.

### The Technology behind the NDAWN Irrigation Scheduler

The NDAWN irrigation scheduler is a web browser application with three separate pages. There are two pages for viewing and editing the schedule and a third page for setting up new irrigated areas (fields). The irrigation scheduler, like all NDAWN applications, is built on free and open source software. The web pages were created with a mixture of the jQuery [1], Yahoo User Interface (YUI) Library [2], and OpenLayers [3] software packages. jQuery is used for handling user interaction and manipulating the pages. YUI is used for its user interface components.

OpenLayers provides the Geographic Information System (GIS) functionality on the "field creation" page. Designing this page was a challenge because not only did the interface have to provide the tools necessary for users to find their irrigated plots on a map, but it also had to be easy to use for users who aren't familiar with GIS concepts. OpenLayers is a JavaScript library that runs in the web browser. It provides the functionality one would expect in a browser-based GIS application, such as zooming, panning, and manipulating maps, yet its interface is easy to use. On the server, NDAWN uses the University of Minnesota's MapServer [4] software to provide a single point of access for all of the map layers shown by OpenLayers. The aerial photograph, political boundary, and road layers are retrieved directly from the North Dakota GIS Hub (NDGIS) [5] via standard Web Mapping Service (WMS) queries. NDGIS provides North Dakota geospatial information in a centralized location and is a valuable resource for the irrigation scheduler. The soil map layers (the contours and their labels) are created from Soil Survey Geographic (SSURGO) [6] data stored in NDAWN's database. TileCache [7] runs between MapServer and an Apache Tomcat [8] HTTP server to cache map images to improve performance. MapServer's flexibility provides a powerful means of unifying map layers from different sources. The SSURGO soil data used by the irrigation scheduler is from the Natural Resource Conservation Service's Soil Data Mart [9]. The original shapefiles were imported into NDAWN's PostgreSQL [10] database using a technique similar to that the California Soil Resource Laboratory [11]. PostGIS [12] is used by MapServer for generating the soil data map layers. It's also used for storing the geographic coordinates of fields and for calculating the statistics shown in the irrigation scheduler, such as the total area of a field and the counties in which it exists. Table 1 (Scherer et al., 2007) shows the software development tools used to develop the irrigation scheduling application on the NDAWN website in the same order as mentioned in the text above.

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YUI: Yahoo User Interface
WMS: Web Mapping Service
SSURGO: Soil Survey Geographic

Table 1. (Scherer et al., 2008) Software development tools used to develop the irrigation scheduling application on the NDAWN website (row numbers indicate the order in which they were cited in the text above)

| | | |
|---|---|---|
| 1. | jQuery JavaScript Library: | http://www.jquery.com |
| 2. | Yahoo! User Interface Library: | http://developer.yahoo.com/yui |
| 3. | OpenLayers JavaScript GIS Library: | http://www.openlayers.org |
| 4. | University of Minnesota MapServer: | http://mapserver.gis.umn.edu |
| 5. | North Dakota GIS Hub: | http://www.nd.gov/gis |
| 6. | Soil Survey Geographic: | http://www.soils.usda.gov/survey/geography/ssurgo |
| 7. | TileCache: | http://www.tilecache.org |
| 8. | Apache Tomcat HTTP server: | http://tomcat.apache.org |
| 9. | NRCS Soil Data Mart: | http://soildatamart.nrcs.usda.gov |
| 10. | PostgreSQL database: | http://www.postgresql.org |
| 11. | Importing SSURGO data into PostgreSQL: | http://casoilresource.lawr.ucdavis.edu/drupal/node/369 |
| 12. | PostGIS, a GIS extension for the PostgreSQL database: | http://postgis.refractions.net |

## CONCLUSION

With changing climate, increasing demand in food, feed and fuel and increasing prices in commodities, irrigation will become more cost-effective by increasing efficiency in water use and reducing vulnerability to severe and extreme droughts. Farmers are going to adopt irrigation systems where benefits surpass costs. Irrigation would enable farmers to improve and maintain crop and pasture, develop healthier soils, and reduce wind erosion and the transfer of nutrients. The NDAWN irrigation scheduling application can make irrigation a science rather than guesswork, conserve water, reduce spending and increase earning through higher yield in North Dakota.

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