Applied Economics Teaching Resources

Teaching and Educational Methods

Developing R Shiny Web Applications for Extension Education

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Abstract
The agriculture sector has entered a new era wherein every stage of the supply chain involves gathering an increasing amount of data. Most of these data are generated in real-time and require rapid analysis that can support optimal decision making for agribusinesses to remain competitive. Consequently, extension audiences are demanding more sophisticated, rapid analysis to aid their decision making using the data they have at their disposal. This paper discusses using R Shiny web applications to meet the new demand.

1 Introduction

> *All producers are realizing that agriculture is now a data-driven industry, said Daniel Schmoldt, a program leader at the National Institute of Food and Agriculture. They need to adopt as much technology as they can to both collect and analyze data.* (Pattani 2016, para. 5)

The agriculture sector is increasingly gathering and analyzing more data. Indeed, every stage along the supply chain is generating an increasing amount of new data in real time from the sensors on planting equipment and combines; to imagery from satellites; and scanners used by food retailers to name a few. The gathering of real-time data has also altered the demand for high-speed analysis that can support optimal decision making in agribusinesses (Pattani 2016). To help agribusinesses remain competitive, extension educators can harness the recent developments in web applications to meet the new demand.

Although some of the same techniques for educating students to develop their own data analytics can be applied to extension audiences, many want extension educators to provide the latest data analytic methods and only the results. Indeed, many do not have the time to learn to code, understand application programming interfaces (APIs), or how to build, estimate, and test the latest data analytic models using the data extension audiences have at their disposal. This article discusses using R shiny web applications to disseminate real-time data analytics to an extension audience. We outline some strategies and resources to begin developing and using web applications for extension education.

To meet the new demand for data analytics across a broad extension audience, we have focused our efforts on developing R shiny web-based applications (https://shiny.rstudio.com/) that incorporate contemporary, sophisticated methods and models. R is a common, open-source programming language used by many agricultural and applied economists. With the Shiny package in R, the data analytics that are done can be disseminated to a broad audience. Extension specialists can also use R markdown (https://rmarkdown.rstudio.com/) to disseminate analytics with limited interactivity in web pages and documents. As an example, we used Shiny web applications for agricultural producers to analyze policy and marketing decisions (e.g., Elliott et al. 2018; Elliott and Elliott 2020) and to understand the nuances of measuring tariff impacts (Elliott and Elliott 2019). By developing web applications, we can empower agricultural producers to use the latest data analytics methods and avoid having to teach complex topics and jargon.

2 Strategies and Resources for Developing Agricultural Data Analytics via Web Applications for Extension Audiences

2.1 Degree of User Interactivity

Web applications can range in complexity and interactivity for the user. The developer of a web application can choose to allow a limited amount of user input, or interactivity, and design the web application to focus on clear communication of results of a predetermined analysis. The results in a web application of this type do not have to be a static analysis, however. Rather, the web application can update in real-time to maintain relevancy to the user (e.g., flex dashboards in R Markdown). An extension product with limited user interactivity can be developed in R Shiny, but it may be easier to implement this type of product using R markdown. This type of web application is often designed so a broad extension audience can understand how to use and interpret the application without additional education or supplementary resources. However, HTML text, logos, figures, and data tables can accompany the analytics to communicate the analytics extensively.

Alternatively, web applications can also allow users to input their data and change modeling assumptions, conduct sensitivity analyses, or change the model itself. This type of web application can allow the user to understand the effect better, and the impact that modeling assumptions have on firm specific results. These types of web applications often require users to gain additional education to best use the web application. Additional training can be delivered through articles, workshops, webinars, or help videos that accompany the web applications.

2.2 Enable Contemporary Methods, Models, and Visualizations

Web applications and web computing can be a game-changer for extension educators. Specifically, web applications enable the sharing of applied research that allows for more flexibility in methods used and to communicate the complexity of analysis better. This same flexibility is not generally available when publishing extension articles or when developing Excel\macro workbooks. Web applications can also provide more transparency in research to stakeholders, fostering trust, and the use of applied research to make management and policy decisions. Moreover, user-friendly web applications can better reach a broader audience with limited attentiveness.

Web applications empower users to have access to the latest data and analytic methods and allow them to interact with a model in real-time to generate firm-specific results. For example, web applications can employ deep learning image recognition to identify plant species from smartphone photos (e.g., Lam n.d.), assess pasture potential using quantile regression (e.g., Woodward n.d.), or provide a learning application to teach the basics of machine learning and multivariate methods to analyze data (e.g., Nijs n.d.).

There are numerous new machine learning and visualization packages that are available through R and Python that can be incorporated into R shiny web applications for users to apply the latest data analytics to their particular problem. A summary of the latest machine learning methods available for R has been described by Lesmeister (2019). Also, R shiny can use the latest mapping and plotting javascript tools available through data analytics firms such as Plotly (https://plotly.com/r/), Leaflet (https://rstudio.github.io/leaflet/), and Mappbox (https://plotly.com/r/mapbox-layers/).

2.3 Reaching Mobile and Tablet Users

Web applications are beneficial in that they can be used on PCs, Macs, tablets, and smartphones. A recent study by the Pew Research Center found that 37 percent of Americans now go online, mostly using a smartphone (Anderson 2019). Indeed, 35 percent of the users visiting our web applications have used a mobile phone or a tablet. As extension audiences continue to view more of their content on mobile phones and tablets, it becomes increasingly necessary to optimize extension educational materials to be delivered through these devices. R shiny web applications automatically scale to various screen sizes. However, some web applications are more challenging to navigate and use on small mobile screens. A promising recent package, *shinyMobile* (https://rinterface.github.io/shinyMobile/), has been made available to provide shiny Apps with a more user-friendly mobile look and standalone capabilities. A shiny application using the shinyMobile framework can appear similar to native iOS and Android applications (e.g., Granjon, Coene, and Rudolf 2019).

2.4 Resources to Get Started Developing Web Applications

Developing web applications using R and Shiny is not difficult for extension professionals with a background in R already. However, for users with no background using R, the learning curve to develop a basic application applied to an extension problem may be steep.

There is an increasing amount of resources available to help extension educators begin developing web applications. Some resources reduce the need for extension educators to become proficient coders to develop interactive web applications or dashboards (e.g., Plotly Dash). Other open-source resources allow for extension educators access to web application codes to use as templates that can be adapted to their particular problem (e.g., github.com). There are several recent books on web application development using R Shiny. For example, *Web Application Development with R Using Shiny* by Chris Beeley and Shitalkumar Sukhdeve (2018), *Interactive Web-Based Data Visualization with R, Plotly, and Shiny* by Chris Sievert (2020), and *Hands-on Dashboard Development with Shiny: A Practical Guide to Building Effective Web Applications and Dashboards* by Chris Beeley (2018) . Updates and other information can be found on R pubs (rpubs.com) to gain ideas and view web application designs from other developers. There are also online training courses that developers can enroll in to learn R and web application development using Shiny (e.g., Udemy and Datacamp).

2.5 Publishing Web Applications

Once a developer has created a web application, it can be hosted on a server. Numerous cloud computing services allow web applications to be hosted with generally reasonable rates based on use. The default publishing site for R Shiny apps is shinyapps.io (https://www.shinyapps.io/). Developers can register and host five apps, with 25 active hours per month for free. Additional abilities, like faster servers, custom URLs, more active user time, and hosting more applications, requires a paid subscription. Developers can also purchase the Rstudio connect server software (https://rstudio.com/products/connect/) and host their applications on their server or a university server.

3 Examples of Shiny Web Applications We Have Developed

3.1 Ag Land Highest and Best-Use Web Application

We have developed several R Shiny applications in the past for extension education. For example, the Ag Land Highest and Best Use Web Application was developed to disseminate ag land assessment analyses to policy makers and stakeholders. Specifically, we quantified the probability of cropland or noncropland use of agricultural land for property tax assessment (see http://agland.sdstate.edu/HBU/; see Figure 1). The analysis explored what the impact would be on the state and county if there were a change in assessment policy for ag land. A specific policy impact we explored was the change to ag land assessments if the highest and best use was determined by how the property was used rather than basing the assessment using the USDA-NRCS land capability classification system. The layout of this application was a fluid page design with a navigation bar (i.e., Navbar Page) at the top to allow users to move between different web pages with different content. The maps used in this web application were soil raster maps with high resolution (10 square meters) and were displayed using R leaflet. The raster maps

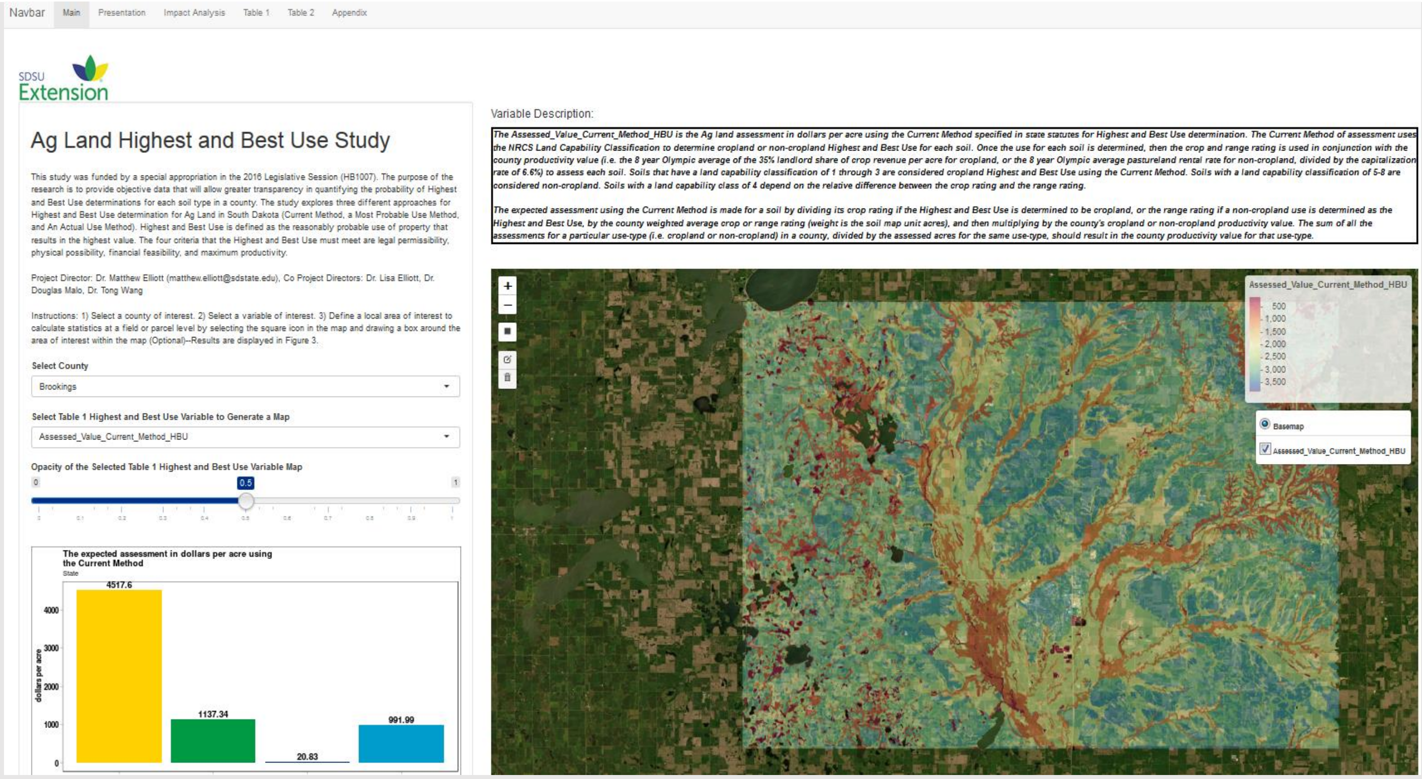

Figure 1. South Dakota State University Ag Land Highest and Best Use Study Web Application

were large files, and loading times took longer for this application to begin. One of the policies explored in the study and reported in the web application used a random forest regression (a machine learning technique) to determine the probability of cropland use based on soil, climate, topography, and location.

A recent web application we developed following the Ag Land Highest and Best Use was targeted to county assessors and stakeholders who use the soil data to make ag land assessments. This application allows users to view baseline ag land assessment data. Users are also provided with additional data and automated notes on soil attributes to study areas where adjustments to baseline assessments may be necessary (see https://agland.sdstate.edu/Soil_Tables/). In this application, spatial points were used instead of raster maps to decrease the loading time for users. Further, we have made this application more mobile- and tablet-friendly by using the *shinyMobile* package (see Figure 2). The ag land assessment data associated with each point is displayed when the user hovers their finger or mouse pointer over the map points. This web application also has an embedded interactive document made using R markdown explaining the data and methods in more detail (see Figure 3).

Both applications allows users to select a county and variable of interest such as the assessed value; the percent soil that has been cropped; representative yields; the percent of sand, silt, and clay in the topsoil; and the expected animal units monthly the ag land can support. Spatial maps are displayed with color-coded results for each county. The web application allows the users to pan in and out and to select different base maps such as a satellite map, a road map, or a topography map.

3.2 "Nowcast" Tariff Impact Estimates Web Application

Another web application we have developed examines real-time Chinese tariff impact estimates on the prices of U.S. agricultural commodities that can be monitored with changes in market events (see http://agland.sdstate.edu/Tariff/). Market data are collected using an API license with Thomson Reuters Eikon. The data are periodically updated for users to generate new "nowcasts" of tariff impacts using commodity prices in alternative markets; latest supply and demand estimates from USDA; and relevant currency and transportation rates. The application allows users to examine a certain commodity and

Figure 2. South Dakota State University Ag Land Soil Tables App Map Tab on an iPad Mini

market (e.g., futures or cash markets), and user specified date range, as well as the ability to change model variables to analyze the tariff impact using a Bayesian Structural Time Series model. The layout of this application uses *shinyDashboard* (https://rstudio.github.io/shinydashboard/). Results are shown in a graph, and quantified loss values are provided in information boxes above the chart (see Figure 4). Below these results is a description of the method used, an explanation of what is being reported, a detailed analysis, and model reports that are provided by the R packages used to do the analysis. Users can make changes to the model and perform sensitivity analyses of variables used in the model. For

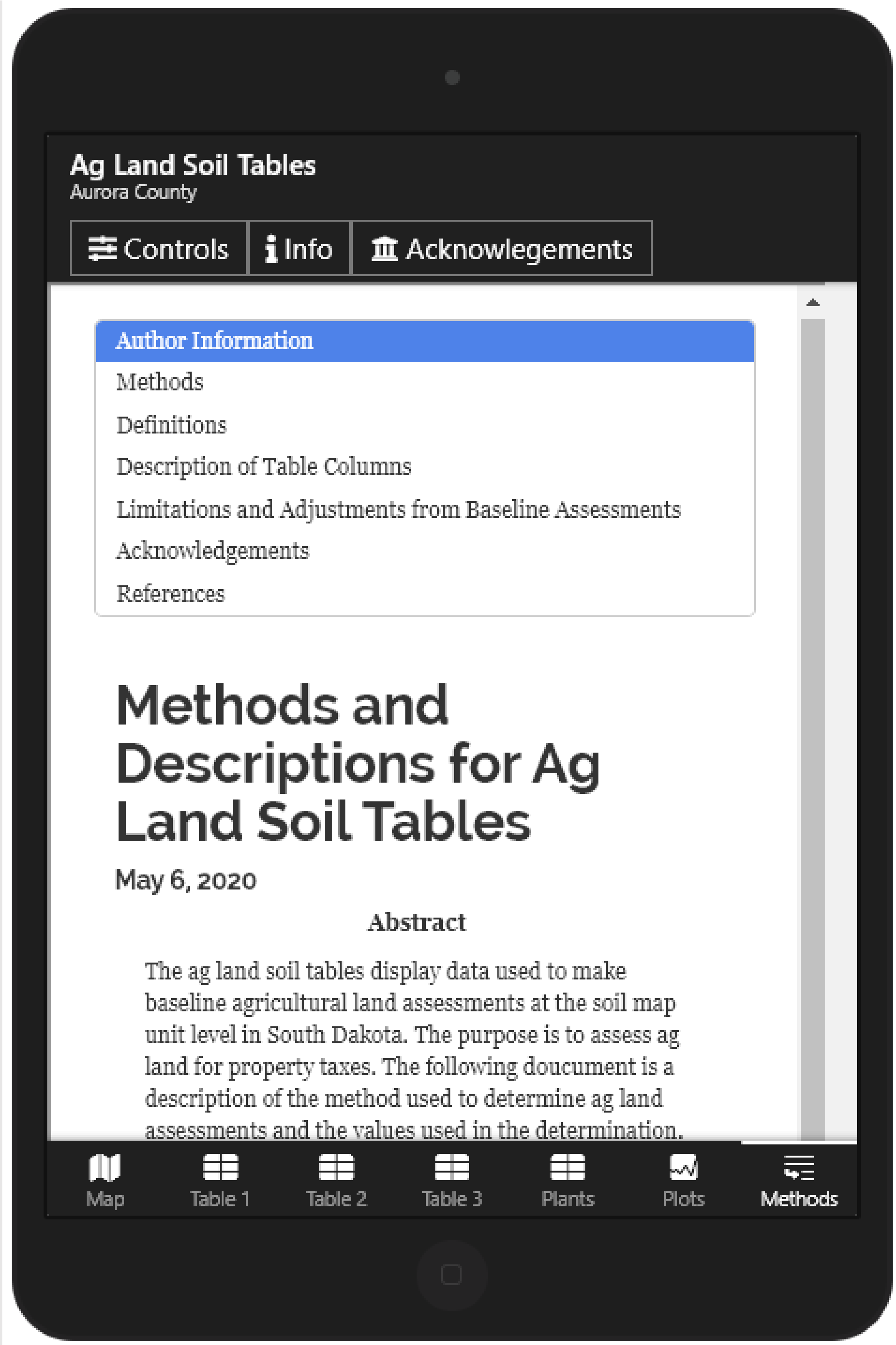

Figure 3. South Dakota State University Ag Land Soil Tables App Methods Tab on an iPad Mini

example, users can include different world grain prices in the model to understand the impact on U.S. prices from tariffs. We advise that discretion must be applied when determining which components to make interactive for users. This particular application is more flexible than most and allows the user to engage in model building and testing. This web application can easily be redesigned to limit user flexibility, but we were using the application to understand the sensitivity of different models on tariff impact estimates. We found the application useful for explaining the complicated nature of understanding tariff impacts to multiple users, including students, and to allow sensitivity testing of models.

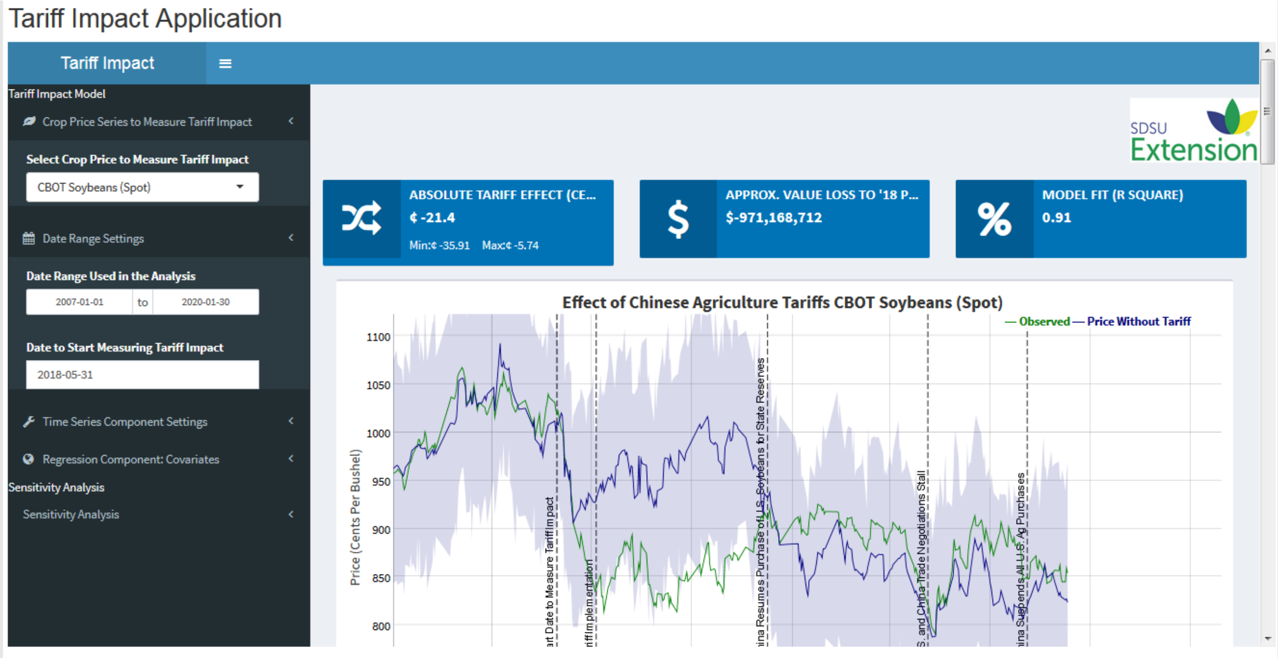

Figure 4. South Dakota State University Tariff Impact Web Application

Web applications can also be embedded in a web page to allow developers to write an accompanying article using common web formatting languages. For example, we created a separate webpage using R markdown where we described the context of the tariff web application we described above. The article was written using HTML and the web application was embedded into the report to allow users to interact with the web application without having to leave the article (see http://agland.sdstate.edu/Tariff_web/).

3.3 Interactive Charts—Web Documents and PowerPoint Presentations

In addition to interactive web applications, interactive charts are becoming more widely available to include in extension products so users can further interact with the chart as they are listening to an extension presentation or while reading a web article. Numerous firms are offering interactive chart hosting where the charts can easily be embedded. Some examples of these types of charting services are Plotly, Tableau, and Google Charts. For instance, we have created interactive grain basis charts and maps for South Dakota that can be found at http://agland.sdstate.edu/Basis/ and http://agland.sdstate.edu/Basis2/ using R Shiny and Plotly. These charts are standalone applications viewable on a smartphone (see Figures 5 and 6), and are embedded in HTML presentations we have given, and in extension articles on the web (e.g., see https://extension.sdstate.edu/south-dakota-grain-basis-tools).

3.4 Challenges with Excel

We initially tried to accomplish real-time data analytics products for extension audiences using Excel workbooks coupled with macros to feed in real-time data. However, we quickly realized the many issues associated with Excel when hosting producer workshops. Some problems emerged because producers experienced trouble utilizing the tool on their home computers (e.g., because of limited memory space, compatibility issues across different Excel versions, and an inability to use the decision tool on Macs). Also, as the Excel-based decision tools became more complex, increasing issues emerged because of the number of complicated steps that were conditional on the user entering accurate input in the previous

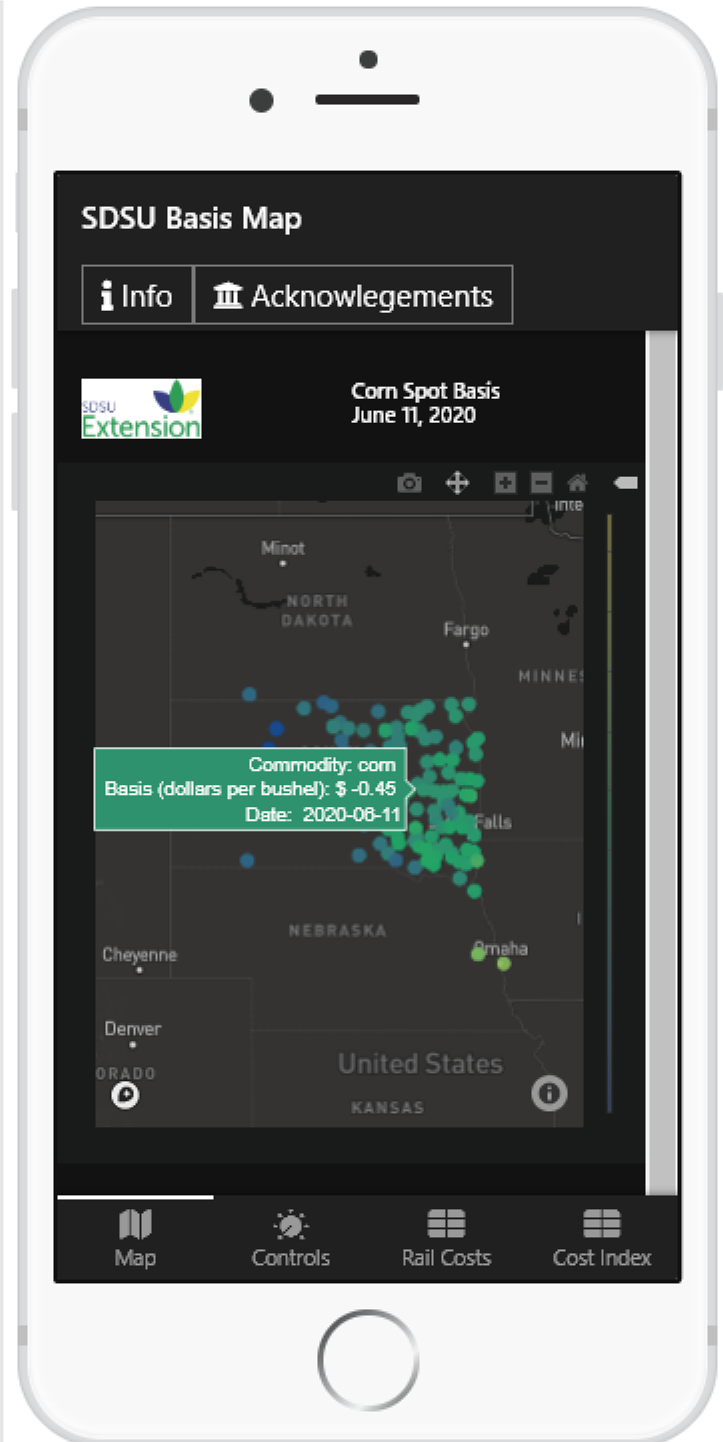

Figure 5. South Dakota State University Basis Map on an iPhone 8+

step. Given web applications functionality, user-friendliness, and compatibility with smartphones and tablets, we determined web applications were a more viable vehicle for disseminating applied research to extension clients that use more sophisticated, real-time data analytics.

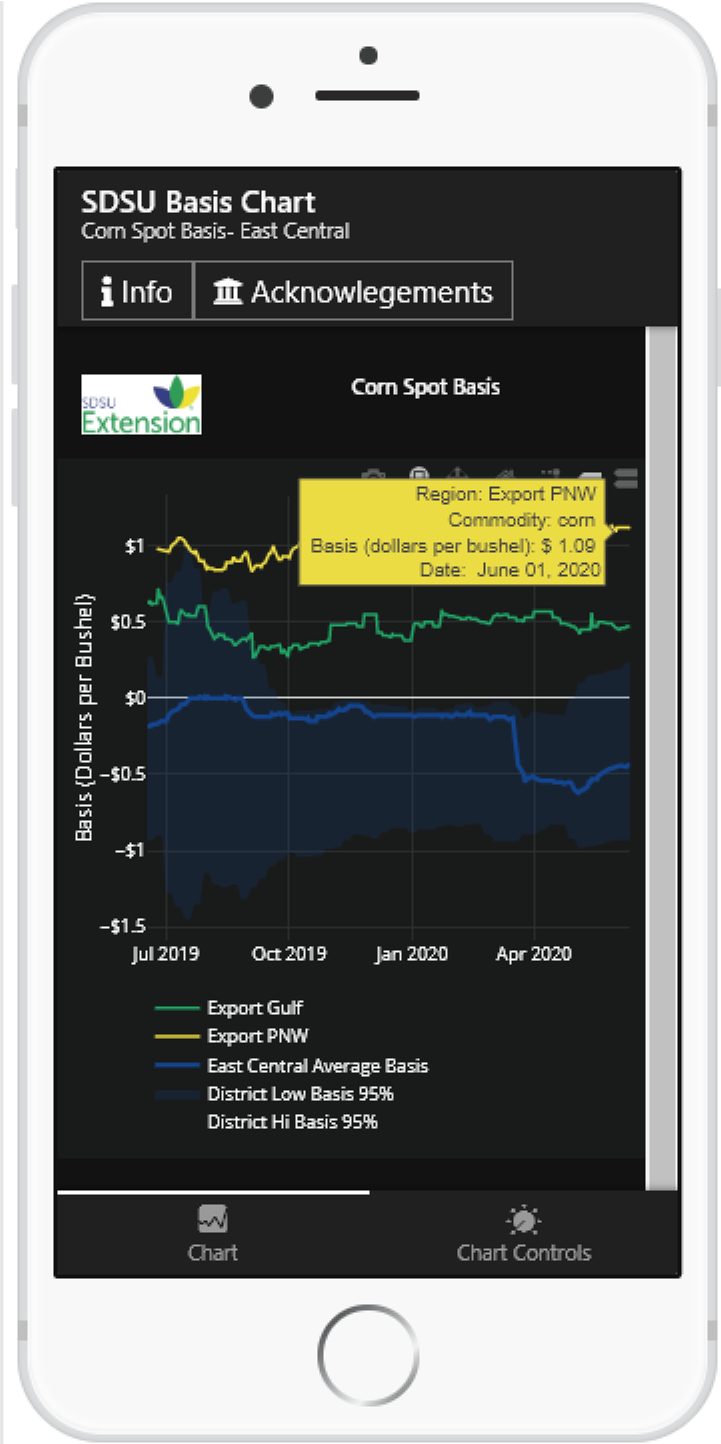

Figure 6. South Dakota State University Interactive Corn Basis Chart on an iPhone 8+

4 Takeaways from Agricultural Data Analytics via Web Applications for Extension Audiences

1. Spend adequate time designing the web application based on different requirements: educational learning, accessibility; whether the tool will be accessed mostly on a desktop, mobile, or tablet; and the degree of user-friendliness that is needed. Designing the application is often the most cumbersome, time-consuming process that requires a lot of trial and error.

2. Take plenty of time to beta test the web applications. As applications become more complex, bugs and glitches are common. Also, be aware if the application does not have the same performance and display across all types of devices.
3. It takes resources to design and develop a real-time web application, as most real-time data requires expensive APIs from vendors. Finding sources of funding is often imperative to provide real-time data analytics to extension audiences.
4. When considering developing web applications, strategize on how it can fit into a broader extension program with supplemental resources.
5. It is important to note that when sharing these web applications, one must secure supporting educational material that explains concepts and use of web applications. We provided supplemental support in using the web application through different mediums, including embedded articles and popups, concept-based short videos, webinars, presentations, and workshops offering hands-on training. Providing various forms of support allows users to decide on the level of support that they need and which mechanisms best suit their needs.
6. As documentation of impacts has become more critical in both extension and research settings, web applications can help in reaching broader audiences who would not regularly attend an extension workshop or read an applied research article. Moreover, web applications allow multiple methods to track progress in learning and measure the adoption and use of information for decision making. These features become invaluable in documenting impact, and in improving future web applications. Specifically, R shiny applications allow the user to embed Google Analytics (https://shiny.rstudio.com/articles/google-analytics.html), as well as create custom programs to save and store user information.

4.1 Synergies Between University Teaching, Research, and Extension with Extension-Based Web Applications

Web applications can empower stakeholders to engage in data analytics while avoiding having to teach them coding or teach them how to build and test models. Further, web applications can be incorporated into classroom settings to allow students to learn methods to develop the analysis used or to improve the design of the web application for more exceptional user-friendliness. Students can provide a productive beta testing environment for newly developed web applications. Ultimately, we aim to teach students in the future how to build web applications on their own. We believe it would be beneficial to foster competition between student web applications similar to poster competitions that can provide a forum for developing web applications that best communicate results. Through the use of web applications, agribusiness extension audiences can be kept abreast of the latest data analytic methods and analysis that give them a competitive advantage.

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