Climate Visualization for Natural Resources

Solution Approach Revision

Center for Sustaining Agriculture and Natural Resources

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TABLE OF CONTENTS

I. Introduction

The Center for Sustaining Agriculture and Natural Resources (CSANR) [1] has requested a web-based tool for aiding sustainable practices of agriculture in the face of climate change. The primary user group is agricultural professionals of the United States who advise agricultural producers on crop and livestock selection, growing and rearing practices, and pest management.

In 2016, a design team delivered one feature toward development of the decision tool. During the 2017-18 academic year, a second design team is undertaking development of an additional feature.

This design project aims to build a feature that shows through data visualization how climate change impacts land used for cattle production. The feature comprises a map of the United States and a series of graphs. The map visualizes data on a large spatial scale and the graphs visualize data on a smaller, aggregated spatial scale.

The data contains values for a set of environmental factors over decades at locations across the United States. The values range over time from the past to the future, where future values have been forecast by computational models of climate. The data was curated by the US Department of Agriculture, Forest Service, and has been reported in a peer-reviewed publication [2].

The outcome of the design project is delivery of one feature for extension of a web-based decision tool. The feature, hereafter called Rangelands, visualizes climate change on lands in the United States and will be made available to the public at no cost.

This document outlines an approach to the design of Rangelands. The design team elucidates a strategy by which to achieve delivery of Rangelands in the following eight sections:

Section II describes the function and design of Rangelands
Section III proposes a system architecture with component breakout
Section IV presents data structures and databases
Section V shows the user interface by use case
Section VI lists achievements in progressing toward the project outcome
Section VII shows a work schedule in the form of a Gantt chart
Section VIII presents a glossary of specialized terms
Section IX presents references

II. System Overview

This design project aims to build the Rangelands feature as a component of a web-based tool that aids planning in agriculture. Rangelands informs and educates users on the effects of climate change on the environment. It draws on climate models to produce maps and graphs that visualize environmental variables in time and space.

Decouple data. Rangelands shall incorporate design choices that disassociate data and code. With minimal code modification, Rangelands shall evolve as data evolves. Rangelands shall accommodate data updates and changes to data parameters such as number of climate models, indicators, and time periods.

Decouple spatial boundaries. Rangelands aggregates data by boundary selection for graphical display of indicators. One boundary option is congressional district, which is subject to change every decade. Rangelands shall aggregate data by congressional district with the foresight that district boundaries change.

Performance. Rangelands operates on large data volume, which slows computations and display of visualizations. Where possible, computations or visualizations shall be preprocessed to enhance performance.

Browser compatibility. Rangelands is a web application displayed by a browser on a screen. As browsers update, Rangelands shall continue to provide a consistent user experience. As screen resolutions increase in density, Rangelands shall maintain the quality of its visualizations.

The design team shall make choices that enable Rangelands to visualize climate for years to come with minimal code modification.

III. Architecture Design

III.1. Overview

We adopt a three-tier architecture pattern with tiers for user interface, system functionality and system storage. The user interface is represented by our ui.R file which sets up components with which the user views and interacts. The application logic is represented by our server.R file. This file reacts to user interaction, such as drop-down menu selection. The storage tier is represented by a collection of flat data files, where each file contains data values mapped to coordinates in the United States over 10 decades for a single environmental factor.

This three-tier pattern matches the framework of the R language library, Shiny, which we use as required by our sponsor. In that framework, user interface and system functionality are contained in separate files. The user interface file builds objects on screen to which the system functionality file reacts. For example, when a user makes a selection from a menu object, an event is signaled to the system functionality layer, which takes some action.

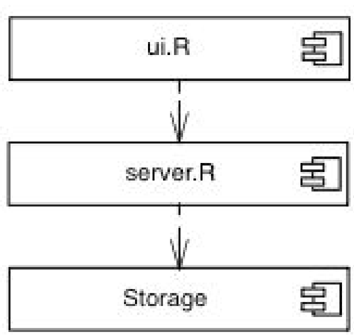

Figure 1. Block diagram representing the architectural design of our system.

III.2. Subsystem Decomposition

The system comprises the Client, Server, and Storage subsystems.

Client
The Client subsystem is responsible for displaying an interactive map, plots, and user input menu. The interface provides a drop-down menu for selection of climate model, map overlay, map boundary, time period, and climate indicator. The interactive map uses the Leaflet package in R. It has has different overlays (satellite, topographic, or basic) and boundaries (state, county, or congressional district) from which the user can select. As a cursor hovers over a bounded area, a pop-up displays the area's label. If the cursor selects a bounded area by clicking, a window appears containing a plot of data aggregated from the bounded area. The plot displays a mean value and standard deviation of one climate indicator forecast over 10 decades.

Server
The Server subsystem is the logic layer. It receives input from the user in the Client subsystem and requests data from from the Storage subsystem. The Server processes data and outputs maps and plots to the Client for display to the user. The Client handles selection of parameters to which the Server responds by selecting data from Storage and generating an image for display by the Client.

Storage
The Storage subsystem is responsible for providing data to the Server subsystem. It is a collection of files that encode data values for climate indicators mapped to coordinates in the United States over 10 decades.

I.1.1. Client

a) Description: The Client subsystem is a front end for users to initiate use cases.

<u>Services Provided:</u>

1. Service name: setIndicator, setBoundary, setTimePeriod, setClimateModel
   Service provided to:
   Description: The service sets a menu value selected by the user.
2. Service name: setZoom
   Service provided to:
   Description: The service sets a zoom level selected by the user.
3. Service name: setCoordinate
   Service provided to:
   Description: The service sets a map coordinate selected by the user.
4. Service name: getIndicator, getBoundary, getTimePeriod, getClimateModel
   Service provided to: Server
   Description: The service gets a menu value.
5. Service name: getZoom
   Service provided to: Server
   Description: The service gets a zoom level.

6. Service name: getCoordinate
Service provided to: Server
Description: The service gets a map coordinate.
7. Service name: displayToScreen
Service provided to: Server
Description: The service outputs images to screen.

Services Required:
The Server subsystem renders images for display by Client.

I.2.1 Server

a) Description: The Server subsystem reacts to user interaction. It applies logic to map or plot data.

Services Provided:
1. Service name: identifyArea
Service provided to: Client
Description: The service outputs a code corresponding to a bounded area from a map coordinate. The service takes in boundary and coordinate.
2. Service name: aggregateData
Service provided to: Client
Description: The service outputs the average value of data for a bounded area. The service takes in indicator, boundary, time period, climate model, and bounded area code.
3. Service name: renderMap
Service provided to: Client
Description: The service outputs a map of the United States that is populated with color-coded data. The service takes in indicator, boundary, time period, climate model and zoom level.
4. Service name: renderPlot
Service provided to: Client
Description: The service outputs a plot of time-series data for a bounded area. The service takes in indicator, boundary, time period, climate model, and bounded area code.

Services Required:
The Storage subsystem provides data on which Server applies logic.

I.3.1 Storage

a) Description: The Storage subsystem is a back end responsible for access to data. There will be use of flat files instead of a database management system. This obviates the need to configure or manage a database.

Services Provided:
1. Service name: selectData

Service provided to: Server
Description: The service outputs data for a bounded area. The service takes in indicator, boundary, time period, climate model, and bounded area code.

<u>Services Required:</u> None

IV. Data design

Data from file is interpreted by the R language in data frames, a data structure that binds vectors of equal length. Each file represents 10 decades of values mapped to coordinates across the United States for one climate indicator. A given file contains a data frame for each decade.

Data is selected from file spatially and temporally. For generating images to overlay on a map, values from file corresponding to a selected indicator and decade are coded to a color scheme and mapped to locations specified by file. For generating plots for a bounded area, values are subset by taking the intersection of all values in file with a spatial file that defines the polygonal boundary of the selected area.

V. User Interface Design

The user opens a web browser and navigates to the web address,

http://agclimatetools.cahnrs.wsu.edu/cbcct/

The user clicks on a “Rangelands” tab to view the application. The user interface is intuitive with similarity to other prevalent map web applications, such as google maps. The user can click and drag on the map to navigate to different areas and use the scroll function to zoom in and out. To visualize data overlain on a map of the United States, the user interacts with a drop-down menu, setting parameters of time period, indicator, and boundary, prompting display of mapped and color-coded data. To visualize data specific to a region, the user selects a bounded area, prompting display of a plot that forecasts mean values of an indicator.

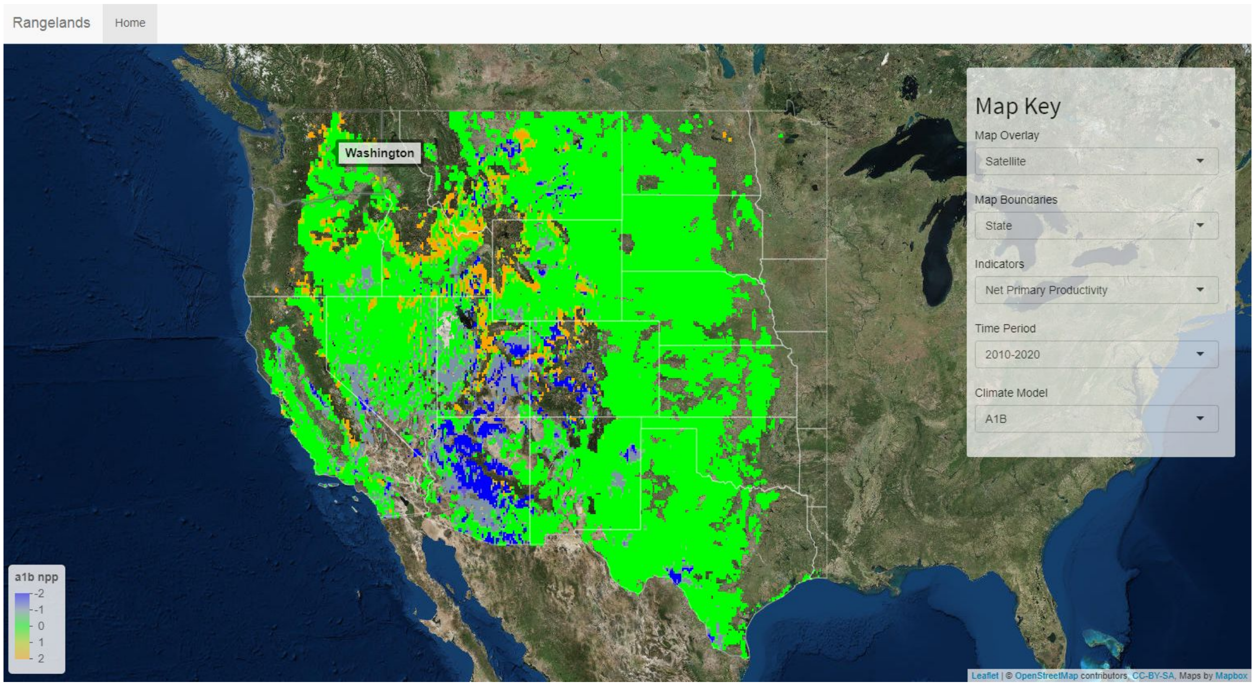

Figure 2. Display of mapped and color-coded data.

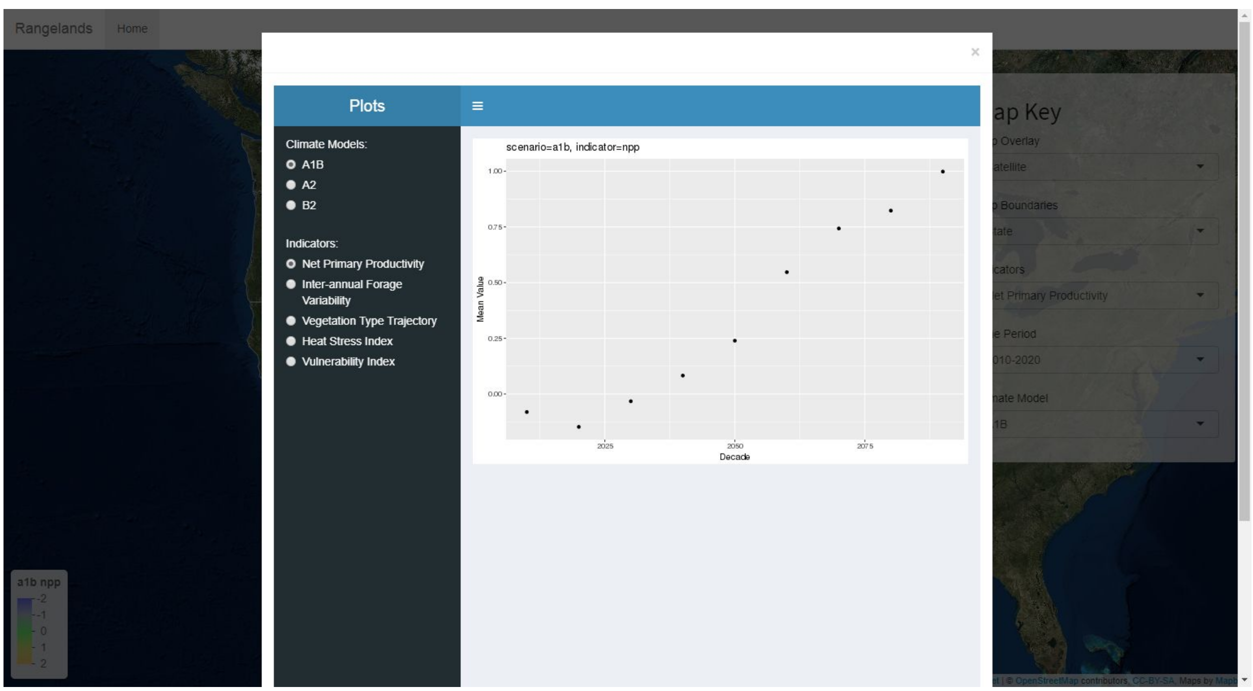

Figure 3. Display of plot that forecasts mean values of an indicator.

VI. Summary of the State of This Project

The front-end and back-end have been implemented. The aesthetics of the application are in place. However, following testing, there will likely be some need to make revisions for enhanced usability and performance. Nonetheless, much has been accomplished, including,

- Implementation of an interactive map
  - Display of map overlays
  - Display of area boundaries
  - Display of color-coded data points
- Implementation of plots
  - Display of time series data

The application is near completion and ready for testing.

VII. Future Work for This Semester

The remaining work for the project consists of testing, revising, and finalizing the application:

- Testing: Usability; Compatibility; Performance
  - Usability testing: We will seek to find out how easy our product is is use by testing it with real users. Users will be asked to complete tasks with our supervision so we can see where they encounter problems.
  - Compatibility testing: We will test our system with commonly used web browsers to ensure compatibility across platforms.
  - Performance testing: We will test the system response time of various functions of our system using a timer to ensure sufficient performance.
- Revisions: User feedback; Client acceptance
  - User feedback: We will analyze the user feedback given in usability testing and make revisions accordingly.
  - Client Acceptance: We will meet with our client, Kirti Rajagopalan, and elicit feedback on our product. We will make revisions to the product based on this feedback.
- Integration: Fold Rangelands into web app
  - We will upload our final product to the CSANR server to make it publicly available. It will be the “Rangelands” tab on the climate visualization tool.

Table 1. Tabular work schedule.

Students	Task Name	Start Date	End Date	Duration
MB,RT	Test usability	20-Mar	3-Apr	14
HM,RY	Produce user help video	20-Mar	3-Apr	14
MB,RY	Test browser compatibility	20-Mar	3-Apr	14
RT,HM	Test performance	20-Mar	3-Apr	14
MB,RT	Set aesthetics of map	3-Apr	10-Apr	7
HM,RY	Set aesthetics of plots	3-Apr	10-Apr	7
MB,RT,HM,RY	Integrate with prior work	10-Apr	24-Apr	14

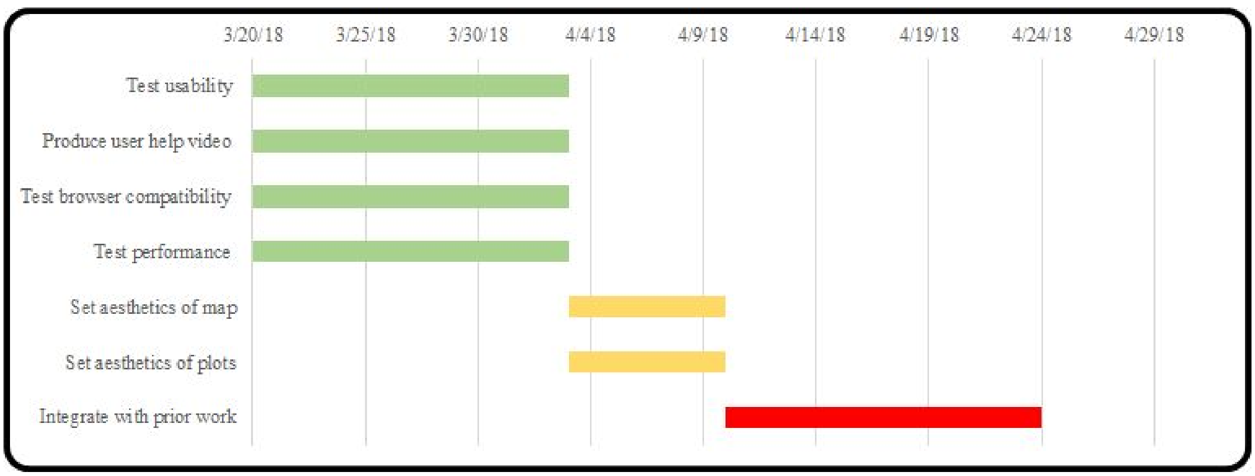

Figure 4. Gantt chart illustrating schedule to project completion.

The client required that the application contain a map view with options to change the overlays and boundaries, a legend, visually appealing colors, and a data view page based on user input information. We are almost done with all of these requirements. So, heading into the next few weeks of the semester, the AgViz team will focus on testing and finalizing the application for client acceptance as well as creating a user help video.

VIII.Glossary

Agriculture Professional - Crop consultant who advises on crop choices or university extension staff member that advises on best practices

Data Frame - R language data structure containing a collection of equal-length vectors

Leaflet - Open-source JavaScript library for interactive maps

Rangeland - Open country used for grazing or hunting animals

Shiny - An open-source R package that provides an elegant and powerful web framework for building web applications using R

IX. References

[1] CSANR. (2017). *Center for Sustaining Agriculture and Natural Resources* [Online]. Available: http://csanr.wsu.edu

[2] M. C. Reeves, K. E. Bagne, J. Tanaka, "Potential Climate Change Impacts on Four Biophysical Indicators of Cattle Production from Western US Rangelands," *Rangeland Ecology & Management*, vol. 70, pp.529-539.