

## Motivation

Valued at over \$60 billion per year, cattle production is the largest segment of the United States (US) food and fiber industry, and livestock grazing in rangeland agroecosystems is a critical component of the cattle industry.

Climate change alters the rangeland production environment through changes in forage availability and grazing suitability, creating risks for profitability and sustainability of the industry, rural communities, and rangeland management.

A decision support tool that helps planning agencies (e.g. US Forest Service, Department of Natural Resources) visualize changing vulnerabilities of rangeland ecosystems will help them better plan adaptation strategies for a changing climate. Our senior design was tasked with developing a web based decision support tool for these stakeholders.

## Client Requirements

Our clients were the Center of Sustaining Agriculture and Natural Resources at WSU, and the United States Forest Service. Client requirements included:

- Gather metrics of rangeland vulnerability to climate change through changes in net primary productivity (forage availability), year to year variability in forage availability, forage quality, and heat stress (Reeves et al., 2016)
- Create a Rshiny/Leaflet Map of the United States
- Develop a way to efficiently plot gathered vulnerability metrics
- Implement a homepage to describe our work

## Usability Testing

The client recruited a group of researchers and agricultural professionals to participate in testing a series of use cases. A protocol was developed that standardizes three tasks. Participants were evaluated for task success. All testing was conducted remotely without direct observation. The results of usability testing was reviewed with the client.

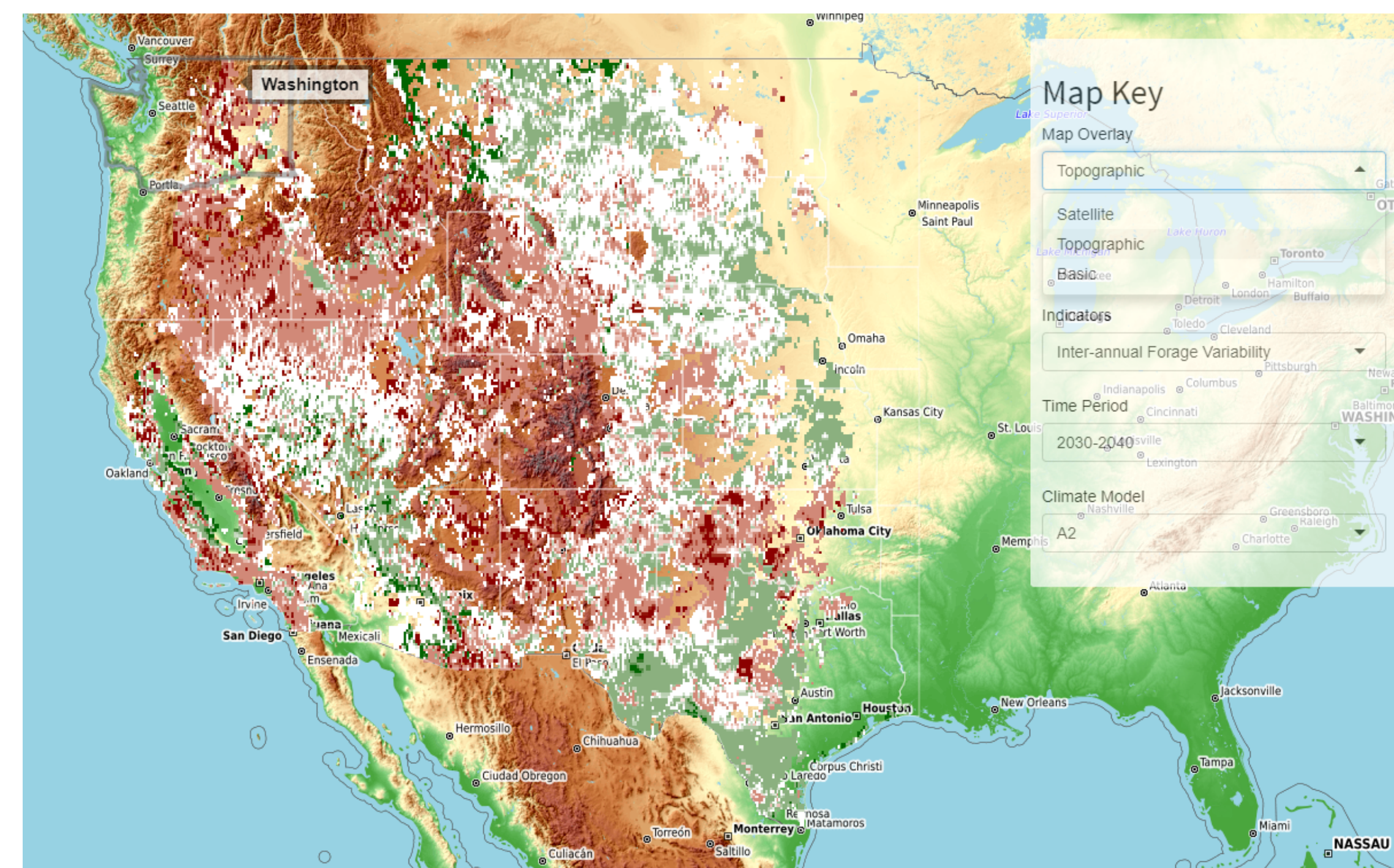
## Glossary

**Heat Stress** - Negative physiological effects on cattle due to temperature  
**Interannual Variability** - Standard deviation in annual average forage quantity  
**Leaflet** - Open-source JavaScript library for interactive maps  
**Net Primary Productivity** - Amount of carbon ...  
**RShiny** - An open-source R package for building web applications using R  
**Vegetation-Type Trajectory** - Edible to inedible vegetation

## AgViz Tool Design

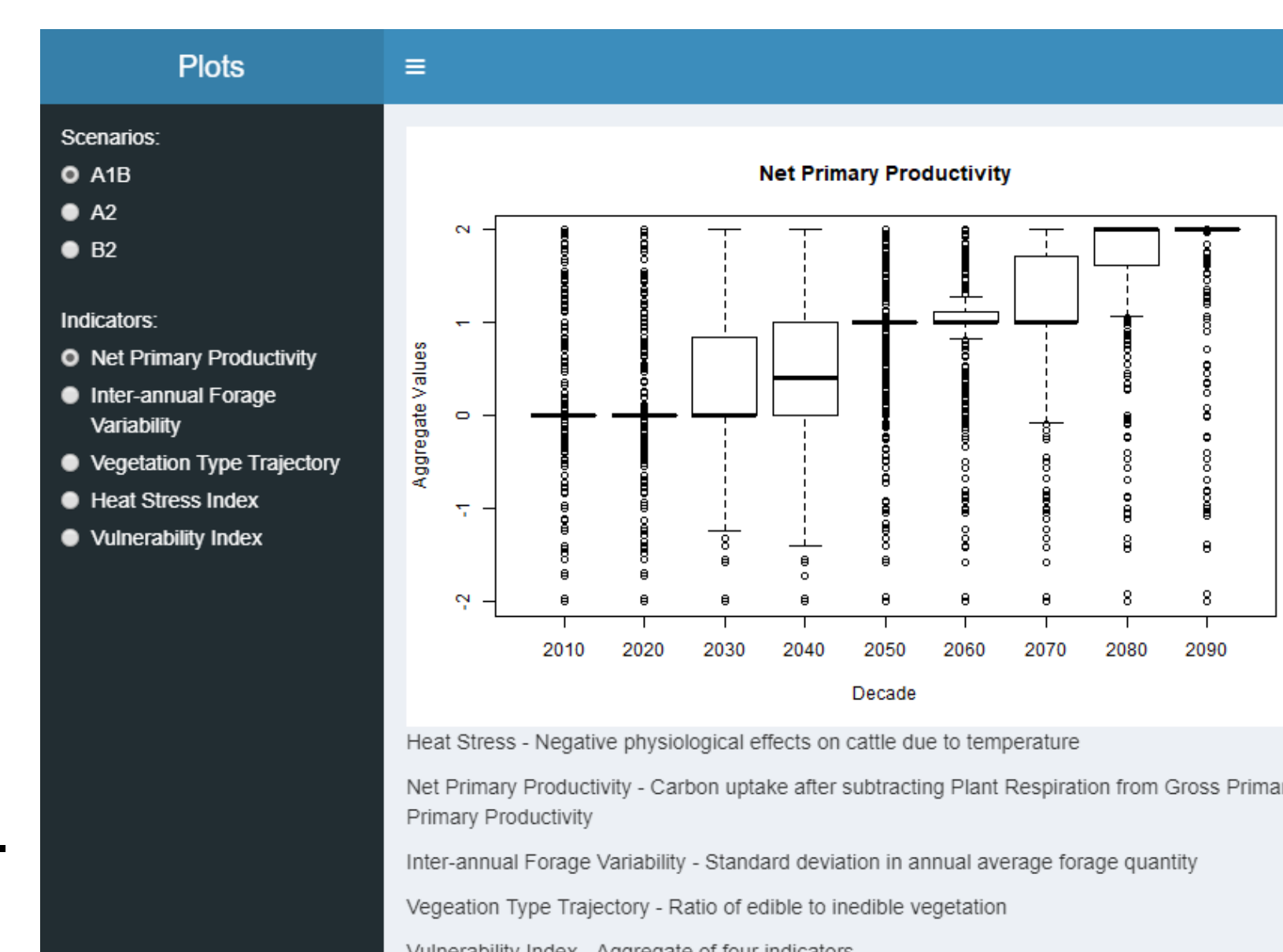
The main view is a geographic map that displays color coded data points for change in vulnerability metric compared to a baseline at different time scales into the future. Once a user selects a region of interest, the tool also generates plots of that variable over time for multiple climate scenarios.

- The Client subsystem is responsible for displaying an interactive map, plots, and user input menu.
- The Server subsystem processes data and outputs maps and plots to the Client for display to the user.
- The Storage subsystem is a collection of files that encode data values for climate indicators mapped to coordinates in the United States over 10 decades.

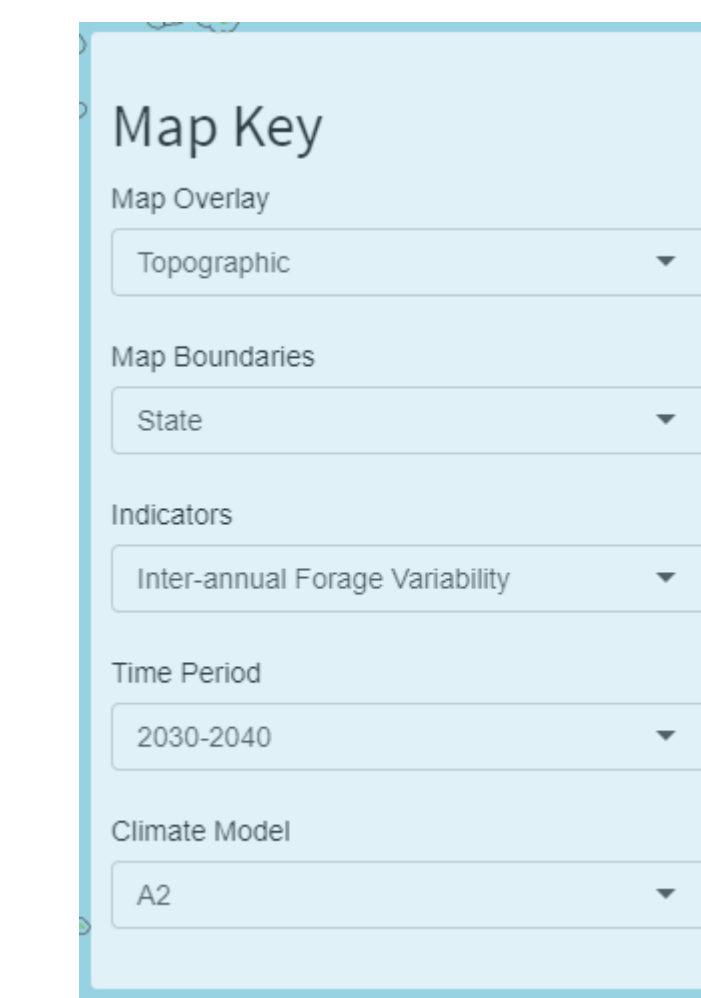


## Graphical Analysis

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.



## Spatiotemporal Map



The interface provides a drop-down menu for selection of climate model, map overlay, map boundary, time period, and climate indicator.

## Conclusion and Future Work

In conclusion our team was able to collect information from our client, plan solutions for the requirements requested by our client, then implement the features our client requested.

The end product allows users to visualize changing vulnerabilities of rangeland ecosystems in the context of climate change. The tool provides an easy way for users to visualize how competitive advantages for cattle grazing in rangelands is potentially shifting away from south central U.S. (increased vulnerability) to northern U.S. regions (reduced vulnerability), at least in terms of forage availability.

Future Work Includes:

- Incorporate feedback from usability testing.
- Enhance performance of plotting.

## References

- [1] CSANR. (2018). 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.  
[3] AgViz Tool. (2018). Something Something [Online]. Available: <http://agclimatetools.cahnrs.wsu.edu>

## Acknowledgements

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