

## FELLOWSHIP BRIEF

# Vegetative and Climatic Controls of Aboveground Net Primary Production and Radiation Use Efficiency Along a North to South Transect in the Western Great Plains

Isabella R. Goodman - Master of Environmental Science '26

## The Need.

Aboveground net primary production (ANPP) in drylands is often estimated using the Montieth Model, which relies on radiation use efficiency (RUE) – how efficiently plants convert sunlight into biomass. While ANPP trends are well studied, RUE remains less explored, particularly regarding the role of photosynthetic pathways (e.g., C3, C4, CAM) in RUE. The U.S. Great Plains, with its natural gradient of temperature and plant composition, provided an ideal setting to investigate patterns in RUE. The findings from this research advance our understanding of the influence of photosynthetic pathways and climatic variables on ecosystem RUE in drylands. These results have direct implications for improving our understanding of ANPP, the key process that determines both carbon inputs and forage availability for herbivores. Additionally, as climate change continues to alter precipitation and temperature, a deeper understanding of RUE variability and its drivers will inform land management and agricultural decision-making, deepen our knowledge of the ecosystem carbon balance, and improve our ability to anticipate future ecosystem responses to global change.

## The Project.

Isabella studied seven sites along a latitudinal gradient spanning nearly 1,800 miles from Kyle, Saskatchewan, Canada, to Marfa, Texas. These sites encompassed a range of mean annual temperature (2°C - 22°C) and grassland plant composition, while grazing levels and history remained relatively constant. At each site Isabella sampled herbaceous biomass and soil. The herbaceous biomass was separated by plant functional type and photosynthetic pathway, while the soil was used to estimate soil texture that was then used as a parameter in an ecosystem water balance model. In the lab, the biomass samples were dried and weighed to estimate ANPP and determine the proportion of C3 vs C4 plants. This estimate of ANPP was then used in the Montieth model to determine RUE. Isabella then used an ecosystem water balance model to estimate soil moisture to be used in linear models. These linear models were created using RUE as the response variable and predictors, such as, precipitation, plant composition and soil moisture to determine the climatic vs. vegetative controls of radiation use efficiency along the latitudinal gradient in the western Great Plains.

## The Findings.

These data indicate that there are substantial differences among sites along the latitudinal gradient for both RUE and ANPP. Average ANPP ranged from 60 g/m<sup>2</sup> in Montana to 130 g/m<sup>2</sup> in New Mexico. Similarly, the contribution of C3 and C4 plants also changed along the gradient. The site in Montana was 100% C3 plants while the site in Texas was 94% C4 plants.

Average site level radiation use efficiency ranged from 0.45 g/Mj in Wyoming to 0.86 g/Mj in Saskatchewan (Figure 1). When analyzing the drivers of RUE, we found a positive relationship between the percent contribution of C<sub>3</sub> plants and RUE. Additionally, we found a positive relationship between both 2025 mean precipitation and 2025 aridity index and RUE. We found strong relationships between ANPP and mean annual precipitation, 2025 mean temperature, and growing degree days.

## The Impact.

The results from this analysis suggest that both RUE and ANPP are highly variable along the gradient from Saskatchewan to Montana, highlighting strong spatial heterogeneity in productivity. While these results reiterated the well know relationship between ANPP and mean annual precipitation, the results also provided new insight into the relationship between photosynthetic composition and climatic factors and RUE. Specifically, the relationship between RUE and C<sub>3</sub>proportion suggests that C<sub>3</sub> dominated systems are more efficient at converting sunlight into biomass than C<sub>4</sub> dominated systems. Additionally, the positive relationship relationships between RUE and 2025 precipitation and aridity index suggests that RUE is driven primarily by water availability. Together, these results provide novel information about the drivers of RUE across large environmental gradients and have important implications for predicting ecosystem responses to climate change. As shifts in temperature and precipitation alter species composition and water availability, there may be substantial changes in RUE.

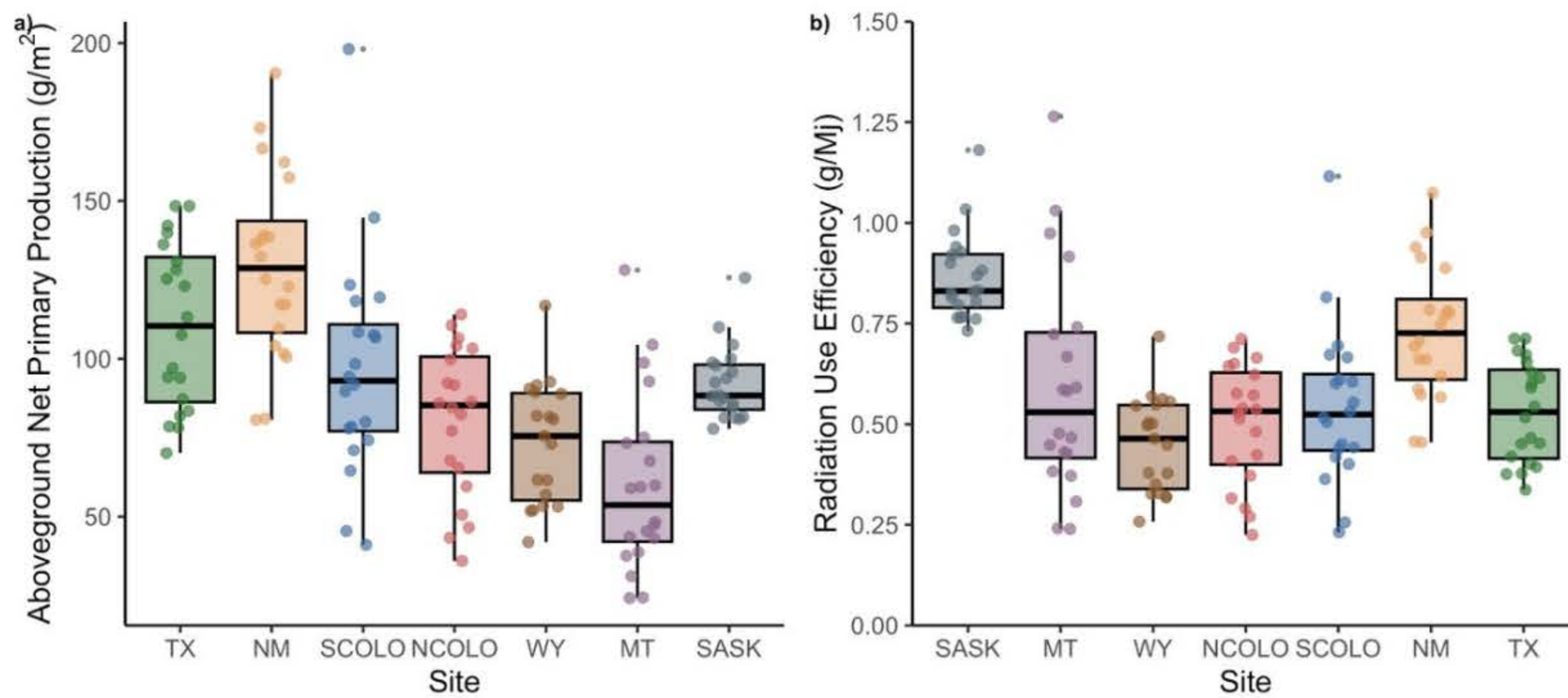


Figure 1: Site level a) ANPP (g/m<sup>2</sup>) and b) RUE (g/Mj). Each point represents a value from each quadrat.



## The Student.

Isabella Goodman – Western Resource Fellow | Isabella Goodman is a Master of Environmental Science Student at Yale School of the Environment studying dryland ecosystems in the American west. Her research focus on how climate change is driving changes in primary production in the western great plains. Originally from Alaska, Isabella has always been passionate about ecology, conservation, research, and the outdoors. She holds a B.S. in Conservation Biology from Montana State University, where she also worked as a research assistant. When not studying grasses and ID-ing plants she loves to trail run, ski, and knit.