Understanding plant production variability to assist management

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Introduction

Native rangelands are a unique and important natural resource that provide valuable ecosystem goods and services including forage for livestock, habitat for wildlife, and cycling of water and soil nutrients. The management of rangelands in much of Nebraska is accomplished on private ranches with the dominant land use as forage for livestock grazing. While these grazinglands are critical for Nebraska's beef cattle industry (ranked 4th in the US in 2019), they concurrently provide many other ecosystem goods and services that are of value to the larger community. For example, the Nebraska Sandhills region in the north central part of the state offer one of the largest intact rangeland areas in the Great Plains with inherent value as a minimally disturbed, working ecological landscape.

Plant production, or the vegetative biomass accrued on a landscape through photosynthesis, is an important driver in supporting many ecosystem services provided on rangelands (Robinson et al. 2019). Understanding how spatial and temporal variability influence rangeland plant production can improve adaptive management opportunities that increase the multifunctionality of provided ecosystem services. This proceedings paper will discuss research in the Nebraska Sandhills that explores relationships between precipitation and plant production and tools that range managers can use to increase their capacity to understand the environments they work in.

Relationship between precipitation and plant production in the Sandhills

Between and within year variability in precipitation drives plant production in the semi-arid grasslands of the Great Plains. Timing and frequency of precipitation events during the peak plant growth periods are important in explaining annual plant production variability. Long-term plant production (2001 – 2019) data collected at the University of Nebraska – Lincoln (UNL) Barta Brothers Ranch near Bassett, NE provide insight into the importance of frequent precipitation events on total plant production during the growing season (Fig. 1). With long-term plant production data, we evaluated relationships between total plant production collected in mid-August and the number of precipitation events or the total precipitation amounts during the peak growth window in the Sandhills (i.e., May, June, and July). More variability in total plant production (greater R^2 value) was explained using the number of precipitation events over 0.1" occurring during May, June, and July ($R^2 = 0.83$, $P < 0.01$) compared to using total precipitation amount*s* over the same period ($R^2 = 0.58$, $P < 0.01$). However, both variables could be used to explain peak standing crop of plant production in mid-August.

Frequent rainfall events, at even relatively small amounts, sustain continued plant growth and can be used as a relatively good predictor of total plant production as the growing season progresses in the Sandhills. The linear model equation for Figure 1A indicated that for every precipitation event greater than 0.1" occurring during May, June, and July nearly 80 lbs per acre was added to the total annual plant production collected in mid-August. Mean number of precipitation events greater than 0.1" from 2001 to 2019 was 18 events (low of 7 in 2002 and high of 26 in 2018). Tracking the number of precipitation events can help in making early adaptive management decisions during a drought. For example, if few events were recorded in May and June, precipitation events in July will likely not make up the difference and reduced plant production should be expected. In contrast, if precipitation events in May and June are closer to the average, than more precipitation events in July will likely increase forage production to above average levels.

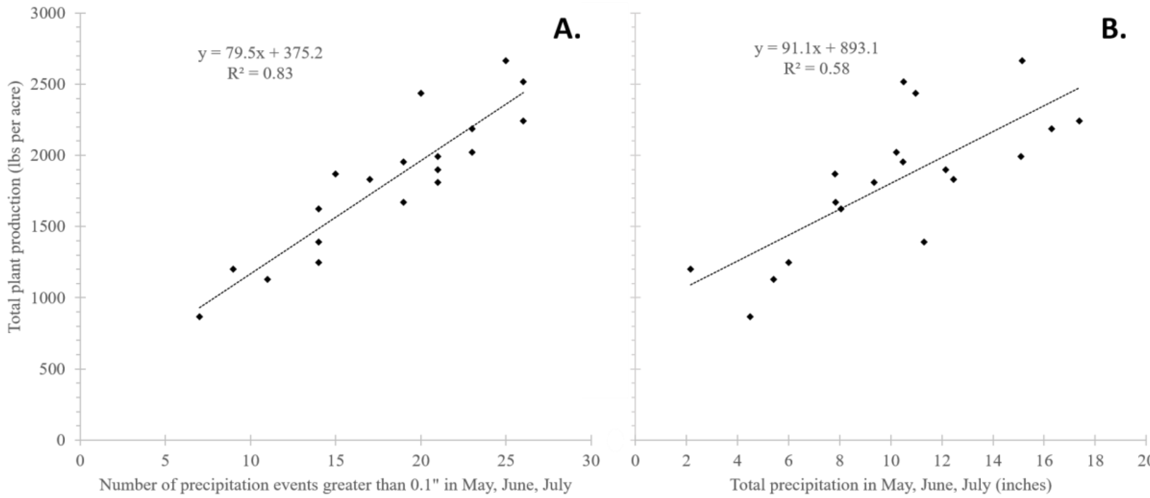

Figure 1. Linear relationships for total plant production and A.) the number of precipitation events ≥ 0.1" in May, June, and July and B.) the total precipitation amounts occuring in May, June, and July. Plant production data were collected annually at peak standing crop in mid-August at the University of Nebraska – Lincoln Barta Brothers Ranch from at least sixty, ¼ m quadrats from 2001 through 2019.

While relationship models for precipitation and plant production may not be available for all areas of Nebraska, rainfall records can help in developing site-specific indicators of what to expect during the growing season. May, June, and July precipitation are the most important months for explaining plant production over much of the state. A tool developed by researchers at the University of Arizona (https://uaclimateextension.shinyapps.io/SPItool/) allows range managers opportunities to visualize long-term precipitation records to make management decision based on how current precipitation matches up with previous years and probabilities of dry and wet periods. Figure 2 shows precipitation during the months of May, June, and July at the UNL Gudmundsen Sandhills lab near Whitman, Nebraska. Management considerations for stocking rates and drought management triggers can be assessed based on site specific precipitation information and the departure from average during. Having a clear understanding of expected precipitation is a vital part of a ranch drought management plan.

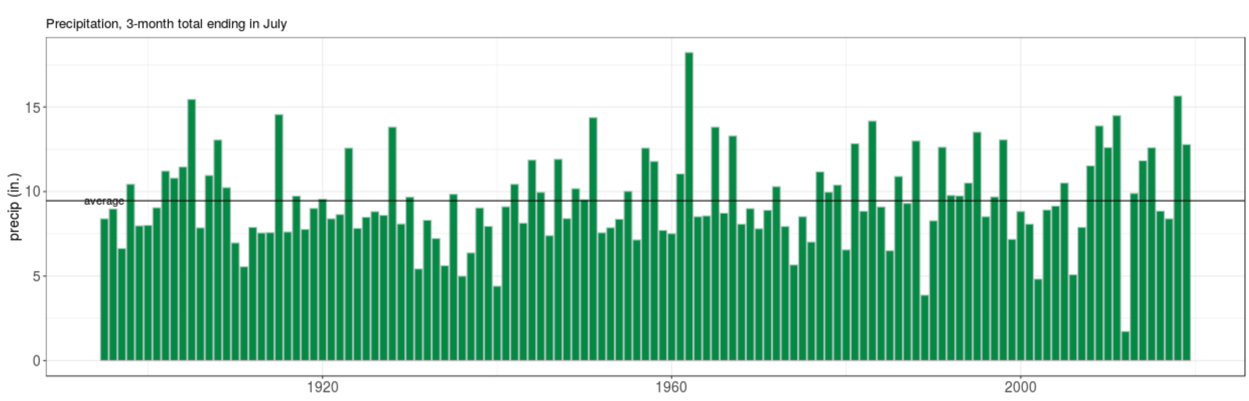

Figure 2. Long-term estimated precipitation for May, June, and July at the UNL Gudmundsen Sandhills Lab near Whitman Nebraska. Data downloaded from the Standardized Precipitation Index Explorer Tool (https://uaclimateextension.shinyapps.io/SPItool/) on June 9, 2020.

Spatial variability of plant production in the Sandhills.

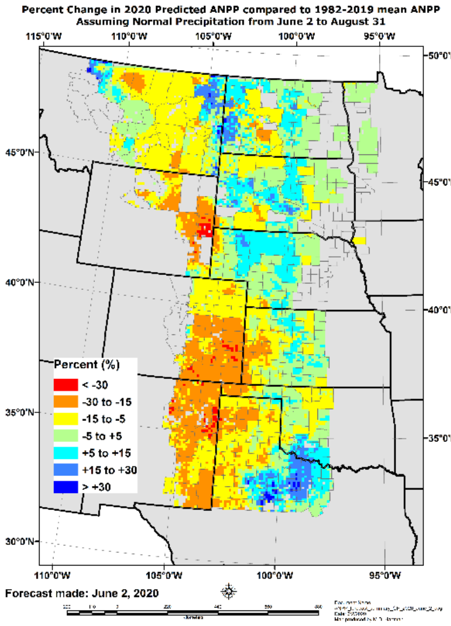

Figure 3. Map downloaded from GrassCast (https://grasscast.unl.edu/) on June 9, 2020 showing predictions for total annual plant production later in the growing season if average precipitation is achieved moving forward.

Temporal variability in both the amount and timing of precipitation is complicated by spatial variability in topography, soils, and vegetation species composition across a landscape. This spatial variability is present at regional, ranch, and even within pasture scales. At larger, regional scales (e.g., regional), long-term plant production data sets provide valuable information for modeling and predicting total plant production early in the growing season. Predictive tools that rely on satellite imagery, weather predictions, and established long-term relationships with plant production and precipitation are now available freely online. Tools such as the Drought Monitor (https://droughtmonitor.unl.edu/) and GrassCast (https://grasscast.unl.edu/, see Fig. 3) provide timely estimates on current and expected weather and plant production conditions throughout the growing season. Utilizing these decision support tools can assist managers by providing large scale views across regions.

At ranch and pasture scales in the Nebraska Sandhills, topographic position (e.g., slopes or interdune swales) influences species composition, soil-moisture accumulation, and total plant production. Interdune swales, at even relatively small scales, can increase plant production and the response of plant production to increasing precipitation. A 17-year study at the UNL Barta Brothers Ranch found that mean total plant production was 46% greater on interdune swales than the surrounding dunes (Stephenson et al. 2019, Fig. 4). As a gravity fed site, interdunes typically have greater soil moisture content early in the growing season compared to surrounding dunes. Because of differences in soil-moisture retention, plant production on interdune swales was more responsive to increases in growing season precipitation. Figure 4 highlights this relationship with interdunes expressing a “steeper” linear response in increased plant production with increasing precipitation during the growing season compared to locations on the dunes. Understanding this spatial variability is important to avoid over- or under-estimating forage production based on the common topographic positions found in the Nebraska Sandhills.

Adaptively managing with spatially and temporally variability

Adaptive management is a process of decision making that includes identifying objectives, evaluating tradeoffs, and monitoring of outcomes to increase learning and information gained and improve future management decisions. Adaptive management is best suited for situations where there is a high degree of uncertainty in future outcomes or conditions (Birge et al. 2016). Understanding climate and weather variables and the subsequent relationship between precipitation and plant production on rangelands is important for managing landscapes with a high amount of variability. Flexibility in management is key to maintaining and improving resilient working landscapes that provide forage for livestock and opportunities for a diverse suite of ecosystem services.

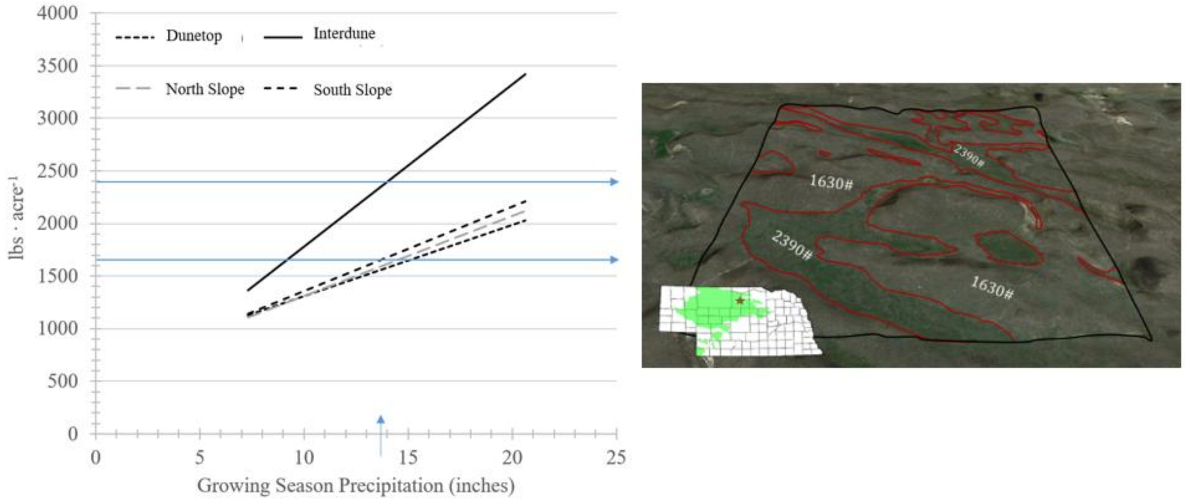

Figure 4. Relationship between total plant production (lbs · acre^{-1}) and growing season precipitation (April 1 to August 15) at different topographic positions at the UNL Barta Brothers Ranch in the eastern Nebraska Sandhills. Plant production data collected from 2001 to 2017. Arrows on the y-axis indicate the mean plant production averaged over all years for the dune positions (1,630 lbs acre) and interdune positions (2,390 lbs acre). The arrow on the x-axis indicates the mean growing season precipitation (13.8 inches). The image on the right shows a pasture at the Barta Brother Ranch and average plant production on dune and interdune (red outline) positions. Interdunes at this site make up 15 to 20% of the total land area.

Literature cited

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