RANGELANDS

USING SOIL MOISTURE TO ESTIMATE THE ECONOMIC VALUE OF RAINFALL EVENTS FOR RANGE FORAGE PRODUCTION

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THE STORY IN BRIEF: Using probe-recorded and simulated soil moisture, we estimated the relationship between annual end-of-season herbaceous production and weather conditions on the Corona Ranch. Daily levels of soil moisture (SM) depend on the history and magnitude of storm events. Based on the 1991 to 2006 storm history on the ranch we categorized daily soil moisture into low (< 20% SM by volume), moderate (20% < SM ≤ 30%), and high (>30%) levels and used the defined growing-season moisture conditions along with air temperature to estimate annual end-of-season herbaceous standing crop. We then estimated how grass yield and potential economic returns would change if additional storm events had occurred, and estimated the economic value of the additional 1 inch rainstorm. As compared to the driest soil moisture state, an intermediate SM level was found to add 2.45 kg/ha/day to herbage yields and a high SM level added 6.43 kg/ha/day. On a large ranch with blue grama grasslands in central New Mexico, like the Corona Ranch, a single 1 inch growing-season storm event adds enough forage to support 70 to 80 animal units yearlong (AUY), or about 3 AUY/section. The economic value of a 1 inch storm is nearly $10,000 ($0.61/acre). Soil moisture and grazing capacity in this region is mainly built from isolated large storms that happen about 20 times each year.

THE PROBLEM: Precipitation amounts, especially from storms occurring within the April – October growing season, greatly influences the amount of forage available to grazing animals. This variability was evident at Corona Ranch broom snakeweed study plots where herbaceous production was monitored over a 17-year period (1990 – 2006). Mean herbaceous production over the period was 581 lb/acre with a standard deviation of 178 lb/acre. Reduced forage yields from 2000 to 2003 clearly corresponded to the drought realized over this period (Figure 1). Had more rain fallen rangeland grazing capacity would have been increased. The expected forage response and economic value of additional precipitation is of interest.

OBJECTIVES:

13. Estimate how soil moisture is related to annual rangeland grazing capacity on blue-grama rangeland areas on the Corona Ranch.
14. Estimate the economic value of a large summer rainstorm.

OUTCOMES:

1. The relationship between annual soil moisture conditions and end-of-season herbaceous standing crop was quantified.
2. The economic value of a 1 inch summer rainstorm was estimated.

DURATION: 1990 through 2006

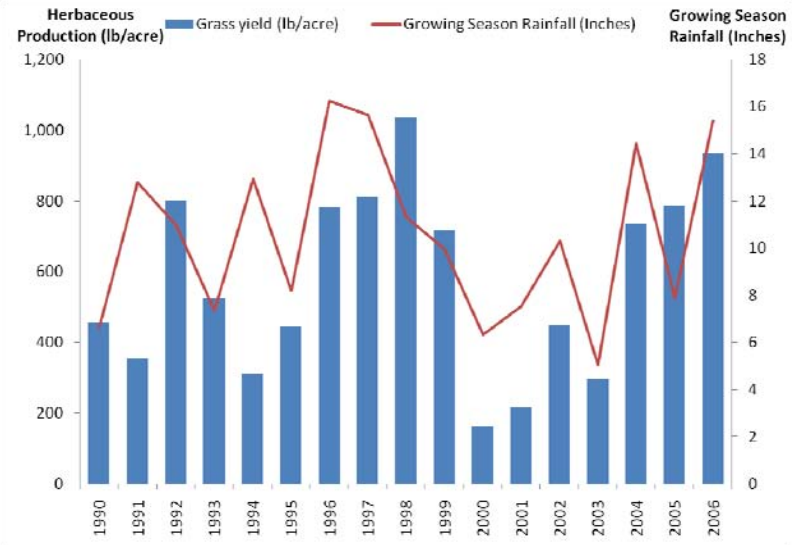

Figure 1. Annual average herbaceous production (lb/acre) on blue grama grasslands on the Corona Ranch as compared to annual growing season rainfall (inches).

APPROACH: Automated weather stations supported with data loggers and soil moisture probes recorded hourly weather data on the Corona Ranch from 2001 through 2006. To expand the period of soil moisture data, soil moisture was also simulated using a modified Sacramento Accounting Model that estimates soil moisture at two depths based on rainfall, evaporation rates, and air temperature. Soil moisture was simulated back to 1991. Using simulated soil moisture with verification from data recorded by the soil moisture probes during the later years the number of days over the growing season when soil moisture was at alternative levels was estimated for each year (1991 – 2006).

Annual standing crop of herbaceous production was measured in the late fall at long-term study sites established to evaluate broom snakeweed control technologies. Regression analysis was used to relate end-of-season grass yield to the number of accumulated degree days above 50° F, the amount of broom snakeweed present, and the number of days over the April – October period when soil moisture was at low (< 20% SM by volume), moderate (20% < SM ≤ 30%), and high (>30%) levels.

The economic value of a 25.4 mm (1 inch) rain storm was estimated by simulating soil moisture levels with the realized rainfall history (Figure 1) and then redoing the simulations assuming an additional storm occurred on 1 April 2003 (dry year) and 1 April 2005 (normal year). Combined with the regression analysis this provided an estimate of how much added forage and grazing capacity would have occurred had the additional storm occurred.

RESULTS:

- Over an estimated 214 day growing season (April – October) for the 1991 to 2006 production years, on average, soil moisture was < 20% for 89 days, between 20% and 30% for 93 days, and > 30% for 32 days. By comparison, during the drought year of 2000, 176 days in the growing season had < 20% SM.
- It only rains on the Corona Ranch on about 18% of the days (66 days per year)
  - < 5 mm (0.2 inches) 70% of the time
  - > 10 mm (0.4 inches) 15% of the time
- Soil moisture is largely built from storms > 5 mm which occur on about 20 days per year.
- The rate of SM decline is much faster during the summer when temperatures are hot and plants are growing and transpiring. High soil moisture levels dissipated in as little as 2 weeks from June to September.
- Temperature was a significant variable in the regression model for predicting grass yield and fit best as a cubic function. The desired daily temperature for maximum grass production would be near the daily averages reported in NMSU research report 761. Temperatures hotter than average significantly reduce grass yields.
- Grass yield, as expected, was found to depend largely on the number of days when soil moisture conditions were relatively wet. Each day during the growing season with midnight soil moisture reading between 20% and 30% increased grass yield by 2.45 kg/ha (2.75 lb/acre) relative to the yield obtained if the day were categorized in the dry state (< 20% SM). Days with soil moisture exceeding 30% added 6.43 kg/ha (7.2 lb/acre) relative to the dry state and over 2.5 times the daily production as compared to the intermediate state. Peak production given ideal rainfall and temperatures was estimated to be about 1,800 kg/ha (2,016 lb/acre).
- Goodness-of-fit measures for regression equations relating annual grass yields to accumulated seasonal rainfall amounts, versus measured soil moisture levels, gave nearly identical statistical results. We were surprised by this result. Soil moisture is conceptually a better measure of moisture availability for predicting grass yields because it considers the accumulated, recent and past history of rainfall events. We anticipated that using accumulated days when soil moisture levels were at low, intermediate, and high levels would substantially improve grass yield estimates relative to using rainfall amounts, but this was not the case. In humid, wet climates there may be many days with saturated soils where additional rainfall does not build soil moisture. But, in the dry environment of the Corona Ranch, and for many other arid western rangelands, soil moisture levels are strongly tied to the amount of rainfall received, so much so that either measure provides a satisfactory indication of moisture conditions for grass grow.
- Had an additional 1 inch spring rainstorm occurred, herbaceous production was estimated to increase by 50 to 60 kg/ha (56 to 67 lb/acre) because soil moisture conditions would shift to wetter, more desirable levels.
- If the added forage were valued at $10/AUM, the single large added storm would

add between $1.40 and $1.60/ha ($0.57/acre to $0.65/acre) in economic value. For blue grama areas on the Corona Ranch (15,250 acres) the total economic value would be about $10,000 and would support 70 to 80 additional animal units yearlong. Forage production would also increase on the less productive pinyon-juniper rangeland areas of the ranch (12,861 acres) and this forage response is not included in the $10,000 estimate.

- With an average carrying capacity on the Corona ranch of 15 AUY/section, a 1 inch storm produces about 1/5th the average grazing capacity of the ranch.

POTENTIAL APPLICATION: Understanding how climate influences forage production is important for stocking rate decisions and ranch planning. Tracking weather conditions on the Corona Ranch and relating climatic and environmental conditions to annual changes in grazing capacity can help area livestock producers develop least cost strategies for adjusting to drought.

EDUCATIONAL PLANS:

1. Results from this study will be made available as a journal article.

REFERENCES:

Torell, L.A., K.C. McDaniel, B.H. Hurd, and S. Cox. 2008. Using Soil Moisture to Estimate the Economic Value of Rainfall Events for Range Forage Production. 2008 Society for Range Management Meetings, Louisville, KY, January 30. Abstr. No. 1790.