

# Using Soil Moisture to Estimate the Economic Value of Rainfall Events for Range Forage Production



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## Summary



On a large ranch with blue grama grasslands in central New Mexico a single growing-season storm event adds enough forage to support 70 to 80 animal units yearlong (AUY). The economic value of this storm is nearly \$10,000 (\$1.50/ha). Soil moisture in this region is mainly built from isolated large storms that occur about 20 times each year.

Using probe-recorded and simulated soil moisture, we estimated the relationship between annual end-of-season herbage production and weather conditions on the New Mexico State University (NMSU) Corona Ranch located in central New Mexico. Daily levels of soil moisture depend on the history of storm events. Based on the 1991 to 2006 storm history 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 herbage standing crop. We then estimated how grass yield and potential economic returns would change if additional storm events occurred.

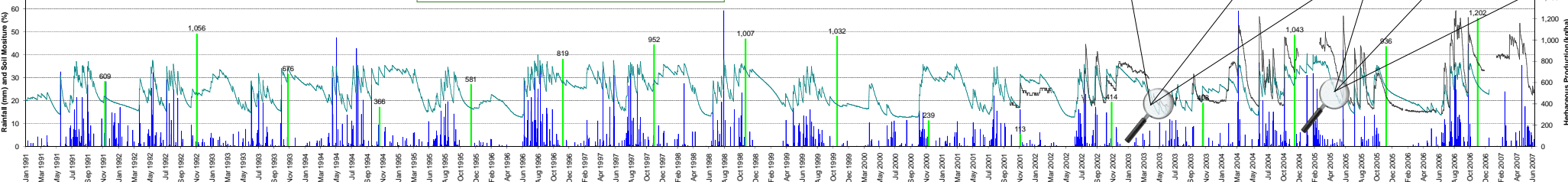
As compared to the driest moisture state, grass yield was found to increase by 2.45 kg/ha/day if daily soil moisture was intermediate and by 6.43 kg/ha/day if it was high. An added 1 inch (25.4 mm) rain storm on 1 April 2003, a relatively dry year, and 2005 (a normal year) would add between 50 and 57 kg/ha (0.14 to 0.16 AUMs/ha) to forage production. If the added forage were valued at \$10/AUM, the single large storm event would add between \$1.40 and \$1.60/ha in economic value. The added forage would have a total value of nearly \$10,000 and support between 70 and 80 animal units yearlong (AUY) on the 6,175 ha of blue grama (*Bouteloua gracilis*) rangeland found on the Corona Ranch.

## Acknowledgements

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**Figure 1. Rainfall, Soil Moisture, and Forage Production History on the Corona Ranch, 1991 – 2007.**

- Measurements at study Site 2 with soil moisture probe measurements taken at 10 – 30 cm depth
- Blue Bars - mm of daily rainfall
- Green Line - simulated SM at 10 - 30 cm
- Black Line (after 2001) - probe-recorded SM at 10- 30 cm
- Green Bars - average end of season standing herbage crop (kg/ha)



## Study Area and Methods



- Corona Ranch and Livestock Research Center in central New Mexico
  - 44 section (11,381 ha) NMSU research ranch
  - 13 inches (331 mm) annual average rainfall
  - Average rangeland carrying capacity (15 AUY/section)
  - Two study plots about 10 km apart
  - Major forage species
    - Blue grama (*Bouteloua gracilis*)
- Weather Stations
  - Automated weather stations supported with data loggers and time domain reflectivity (TDR) soil moisture probes recorded hourly weather data
    - Rainfall (1990 – 2006)
    - Air and Soil Temperature (1990 – 2006)
    - Volumetric Soil Moisture (2001 – 2006)
      - Measured at 10 cm and 10 – 30 cm
- Simulated Soil Moisture
  - A modified Sacramento Soil Moisture Accounting Model that estimates hourly soil moisture levels at two depths based on rainfall, evaporation rates, and air temperature (Burnash 1995).
    - Simulated hourly (1991 – 2006)
- Year-end Standing Crop
  - Long-term studies measured the herbage response to broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) control using chemicals and fire (McDaniel et al. In Press).
    - Standing crop was measured at the end of the growing season (1991 – 2006)

- Regression Analysis
  - Regression analysis related end-of-season grass yield to the number of accumulated degree days above 10° C, the amount of snakeweed present, and the number of days over the April - October growing season when soil moisture was at low (< 20% SM by volume), moderate (20% < SM ≤ 30%), and high (>30%) levels.
    - n = 372 observations on replicated plots over 16 years
    - R<sup>2</sup> = 0.39, RMSE = 284 kg/ha

- Economic Value of a Storm
  - 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).

## Results

- Soil Moisture Levels (1991 – 2006)
  - Average number of days in the 214 day growing season (April – October) with soil moisture
    - <20% 89 days
    - 20% < SM ≤ 30% 93 days
    - >30% 32 days
  - It only rains or snows on the Corona Ranch about 18% of the days (66 days per year)
    - < 5 mm (0.2 in) 70% of the time
    - > 10 mm (0.4 in) 15% of the time
  - SM is largely built with storms > 5 mm which occur on about 20 days per year
  - Rate of SM decline is faster when plants are actively growing
    - High soil moisture levels dissipated in as little as 2 weeks from June to September
- Regression Results
  - As compared to the driest state, an intermediate SM level added 2.45 kg/ha/day to herbage yield
  - High SM levels added 6.43 kg/ha/day to herbage yield
- Marginal Grass Yield Increase of a 1 inch (25.4 mm) Rainfall Event
  - Effect over the April – October growing season

### 2003 Dry Year (Figure 2)

- Increased high SM classification by +10 days
- Decreased intermediate classification by -3 days
- Decreased low classification by -7 days

$$\Delta \text{ Grass yield} = +10 \text{ days} \times 6.43 \text{ kg/ha/day} - 3 \text{ days} \times 2.45 \text{ kg/ha/day} = 57 \text{ kg/ha or } 0.16 \text{ AUMs/ha.}$$

\*Blue grama rangeland on the Corona Ranch is about 6,175 ha.  
 $\Delta \text{ total capacity} = 0.16 \text{ AUMs/ha} \times 6,175 \text{ ha} = 988 \text{ AUMs or } 82 \text{ AUY}$

### 2005 Normal Year (Figure 3)

- Increased high SM classification by +10 days
- Decreased intermediate classification by -6 days
- Decreased low classification by -4 days

$$\Delta \text{ Grass yield} = +10 \text{ days} \times 6.43 \text{ kg/ha/day} - 6 \text{ days} \times 2.45 \text{ kg/ha/day} = 50 \text{ kg/ha or } 0.14 \text{ AUMs/ha.}$$

$$\Delta \text{ total capacity} = 0.14 \text{ AUMs/ha} \times 6,175 \text{ ha} = 865 \text{ AUMs or } 72 \text{ AUY}$$

## Economic Importance

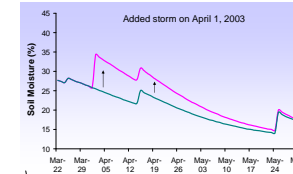
- A 1 inch (25.4 mm) storm adds about 0.15 AUMs/ha (averaged across both simulated years) or about 3 AUY/section, assuming minimum residual forage requirements have already been met.
  - With an average carrying capacity on the Corona Ranch of 15 AUY/section, this one storm produced about 1/5<sup>th</sup> of the average grazing capacity of the ranch.
- Current private land lease rates suggest a value for forage in New Mexico of about \$10/AUM. This value would likely be higher during dry years.
  - 0.15 AUMs/ha × \$10/AUM = \$1.50/ha or with over 925 AUMs added on blue grama rangeland areas this would be nearly a \$10,000 economic value. Forage production would also increase on the less productive piñon-juniper rangeland areas on the ranch (5,207 ha) such that this reflects a minimum estimate of economic value.

## Literature Cited

- Burnash, R. J. C. 1995. The NWS river forecast system – catchment modeling. In Singh, V. P. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, Littleton, Colorado, p. 311-366.
- McDaniel, K.C., C.A. Ebel, L.A. Torell, and D.M. VanLeeuwen. In Press. Fire and herbicide treatments affects on blue grama grassland in New Mexico. Rangeland Ecology and Management.

**Figure 2. Change in number of days with different levels of SM, 2003 (dry year).**

In 2003, the 25.4 mm added storm means 10 more days with SM >30% and 3 fewer days with SM between 20% and 30%. This adds 0.16 AUMs/ha with an economic value of \$1.60/ha.



**Figure 3. Change in number of days with different levels of SM, 2005 (normal year).**

In 2005, the 25.4 mm added storm means 10 more days with SM >30% and 6 fewer days with SM between 20% and 30%. This adds 0.14 AUMs/ha with an economic value of \$1.40/ha.

