ARTICLE IN PRESS

Rangeland Ecology & Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Satellite Assessment of Early-Season Forecasts for Vegetation Conditions of Grazing Allotments in Nevada, United States☆

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ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form 20 April 2017
Accepted 12 June 2017
Available online xxxx

Key Words:
drought
grazing
livestock
MODIS
PDSI
precipitation

ABSTRACT

The extent and heterogeneity of rangelands in the state of Nevada (United States) pose a challenging situation for land managers when determining stocking levels for livestock grazing. Overutilization can cause lasting environmental damage, while underutilization can create unnecessary economic hardship for livestock operators. An improved ability to forecast vegetation stress later in the growing season would allow resource managers to better manage the tradeoffs between ecological and economic concerns. This research maps how well growing season conditions for vegetation within grazing allotments of Nevada can be predicted at different times of the year by analyzing 15 yr of enhanced vegetation index (EVI) data from the Moderate Resolution Imaging Spectroradiometer sensor, cumulative monthly precipitation, and the Palmer drought severity index. Land cover classes within the grazing allotments that are not relevant to grazing were removed from the analysis, as well as areas that showed > 50% change in EVI since these likely represented transitions or disturbances that were not related to interannual climate variability. The datasets were gridded at spatial resolutions from 4 to 72 km, and the correspondence between image and meteorological datasets was found to improve as measurements were averaged over larger areas. A 16-km sampling grid was judged to provide the best balance between predictive ability and spatial precision. The average R^2 of regressions between the vegetation index and meteorological variables within each of the 16-km grid cells was 0.69. For most of Nevada, the ability to predict vegetation conditions for the entire growing season (February–September) generally peaks by the end of May. However, results vary by region, with the northeast particularly benefiting from late-season data. Regressions were performed with and without very wet years, and the ability to make early predictions is better when including wet years than in dry to typical conditions.

Introduction

Publicly owned rangelands that are managed by the US Bureau of Land Management (BLM) cover approximately 18 million ha, and livestock grazing is one of the most commonly permitted activities on public lands in Nevada. Rangelands managed by the BLM-Nevada office cover over 2 million hectares and are divided into 745 grazing allotments of widely varying sizes and characteristics. Permits issued by the BLM define stocking levels and the timing of grazing activities within these allotments for approximately 550 operators, with the goal of maintaining soil and site stability, hydrologic function, and biotic integrity. One point of contention between ranchers and range management agencies arises from the assignment of stocking levels well before the end of the rainy season. In some cases, anomalous late-season precipitation leads to underutilization of grazing resources and unnecessary economic losses for ranchers. Disputes regarding stocking levels or management responses to drought and wildfire can lead to a lack of trust in the land management agency (van Kooten et al., 2006).

Although the BLM's mission is to sustain the health, diversity, and productivity of America's public lands for the use and enjoyment of present and future generations, variations in weather and climate can make this task difficult. Adjustments to existing public land use authorizations can occur during drought conditions in order to reduce stress on rangeland ecosystems and maintain the long-term productivity of public lands. Such adjustments to grazing activities include reducing

☆ This work was supported through the Great Basin Cooperative Ecosystems Study Unit and Nevada office of the Bureau of Land Management (grant L13AC00169); a Cooperative Agreement with the USDA-ARS (agreement 59-5370-3-001); and the National Oceanic and Atmospheric Administration's National Integrated Drought Information System—Nevada Drought Early Warning System (grant AB-133E-16-CQ-0022).

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http://dx.doi.org/10.1016/j.rama.2017.06.005
1550-7424/

Please cite this article as: McGwire, K.C., et al., Satellite Assessment of Early-Season Forecasts for Vegetation Conditions of Grazing Allotments in Nevada, United States, Rangeland Ecology & Management (2017), http://dx.doi.org/10.1016/j.rama.2017.06.005

livestock numbers, shortening the season of use, altering pasture move dates, changing pasture rotations, authorizing water hauling, closing allotments to grazing, or allowing grazing in vacant allotments. From 2014 through 2016 the Farm Service Agency (FSA) declared much of Nevada a drought disaster area, making livestock producers who own or lease grazing or pasture lands eligible for federal compensation via the Livestock Forage Disaster Program (LFP). Drought disaster declarations are based on U.S. Drought Monitor map (USDM) (Svoboda et al., 2002), and lengths of LFP payments are based on drought categories of severe to exception drought, equating to one to five monthly payments, respectively (FSA, 2016). Improved early season forecasts for vegetation conditions on rangelands could help to improve the timeliness of such drought response and mitigation actions.

It is a challenge to respond in an adaptive manner to changing conditions on these rangelands due to their large spatial extent, rough terrain, and highly variable biological and physical attributes (Weltz et al., 1994; Tueller, 2001; Marsett et al., 2006; Bradley and O'Sullivan, 2011). Long-term observations from satellite remote sensing systems can support adaptive management strategies by ameliorating many of the challenges of field monitoring, such as deployment logistics, cost, training, limited sample sizes, observer bias, and undefined reference conditions (Beever et al., 2005; Miller, 2008; Herrick et al., 2010). Satellite-based remote sensing systems can quantify plant cover, leaf area, and forage availability (Qi et al., 2000; Hunt et al., 2003; Marsett et al., 2006; Röder et al., 2008). Many satellite-based vegetation studies use spectral indices that respond to the amount and vigor of green vegetation. A prominent example is the normalized difference vegetation index (NDVI, Rouse et al., 1974), a ratio of reflected light from the red and near infrared (NIR) wavelengths in the form: (NIR − red)/(NIR + red). Sellers (1987) demonstrated a meaningful linear relationship between NDVI and photosynthetic capacity, though the index may be negatively affected by soil background color (Huete and Tucker, 1991) and requires proper atmospheric correction (Crippen, 1988). Since the development of NDVI, a number of other spectral vegetation indices have been developed with the goal of minimizing the confounding effects of soil background and atmosphere. These indices include the soil-adjusted vegetation index (SAVI, Huete, 1988), modified soil-adjusted vegetation index (MSAVI, Qi et al., 1994), transformed soil-adjusted vegetation index (TSAVI, Baret et al., 1989), and enhanced vegetation index (EVI, Huete et al., 2002). In rangelands, senesced plant material is also important for grazing, so Marsett et al. (2006) developed the soil-adjusted total vegetation index (SATVI) that responds to green and nonphotosynthetic biomass. Such satellite-based vegetation indices have been effective in monitoring shrub-steppe environments like the Great Basin (Ramsey et al., 2004) and are responsive to interannual changes in production of rangeland vegetation that is associated with precipitation (Browning et al., 2010).

Here we quantify the effectiveness of early-season forecasts of vegetation conditions within grazing allotments based on statistical relationships between cumulative precipitation, soil moisture status, and satellite-derived measures of vegetation vigor.

Methods

Study Area

The state of Nevada is located predominantly within the Great Basin region, the largest contiguous area of endorheic basins in North America. The southernmost portion of the state is in the Mojave Desert. Nevada's terrain is largely associated with the Basin and Range physiographic region, a vast area of horst and graben faulting that created parallel ranges of north-south — oriented mountain ranges separated by arid valleys (Fig. 1A). Prevailing winds are intercepted by the Sierra Nevada mountains to the west, creating a rain shadow that makes Nevada the driest state in the country. Annual precipitation ranges from 106 mm at Las Vegas in the south to 249 mm at Elko in the northeast (Fig. 1B). Greater precipitation occurs at higher altitudes in the many mountain ranges. The majority of lowland precipitation in the western and south-central portions of the state falls in the winter, the central and northeastern portions receive more in the spring, and some areas of the east receive the most from thunderstorms in late summer.

Across most of the Great Basin, the majority of precipitation occurs during colder months, November through April. Evaporative demands are minimal during this time period, allowing for a significant portion of the precipitation to be stored as soil moisture. Moisture that is stored during the winter months provides the majority of water for plant growth in the spring and summer. Tang et al. (2015) show that winter and spring precipitation plays a much larger role than air temperature in driving the interannual variability of vegetation greenness in the Great Basin, as measured by satellite-based NDVI. Summer precipitation is erratic and spatially discontinuous as thunderstorms skip across large areas of the state, saturating some grazing allotments while missing other allotments. Plant communities across the Great Basin have developed ecohydrologic survival mechanisms to take advantage of the seasonal nature of available precipitation and soil moisture.

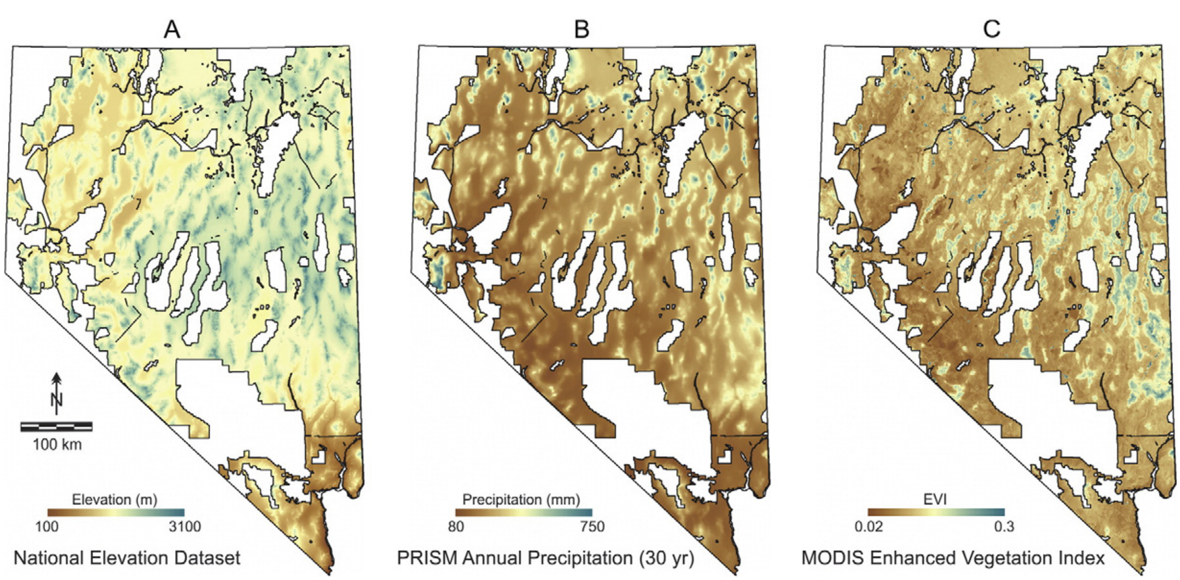

Figure 1. Elevation (**A**), precipitation (**B**), and enhanced vegetation index (**C**) within grazing allotments of Nevada.

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