# Climate Change and North American Rangelands: Trends, Projections, and Implications

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*Invited Synthesis*

# Climate Change and North American Rangelands: Trends, Projections, and Implications

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**Abstract**

The amplified "greenhouse effect" associated with increasing concentrations of greenhouse gases has increased atmospheric temperature by 1°C since industrialization (around 1750), and it is anticipated to cause an additional 2°C increase by mid-century. Increased biospheric warming is also projected to modify the amount and distribution of annual precipitation and increase the occurrence of both drought and heat waves. The ecological consequences of climate change will vary substantially among ecoregions because of regional differences in antecedent environmental conditions; the rate and magnitude of change in the primary climate change drivers, including elevated carbon dioxide ($CO_2$), warming and precipitation modification; and nonadditive effects among climate drivers. Elevated atmospheric $CO_2$ will directly stimulate plant growth and reduce negative effects of drying in a warmer climate by increasing plant water use efficiency; however, the $CO_2$ effect is mediated by environmental conditions, especially soil water availability. Warming and drying are anticipated to reduce soil water availability, net primary productivity, and other ecosystem processes in the southern Great Plains, the Southwest, and northern Mexico, but warmer and generally wetter conditions will likely enhance these processes in the northern Plains and southern Canada. The Northwest will warm considerably, but annual precipitation is projected to change little despite a large decrease in summer precipitation. Reduced winter snowpack and earlier snowmelt will affect hydrology and riparian systems in the Northwest. Specific consequences of climate change will be numerous and varied and include modifications to forage quantity and quality and livestock production systems, soil C content, fire regimes, livestock metabolism, and plant community composition and species distributions, including range contraction and expansion of invasive species. Recent trends and model projections indicate continued directional change and increasing variability in climate that will substantially affect the provision of ecosystem services on North American rangelands.

**Key Words:** atmospheric $CO_2$, atmospheric warming, climate variability, greenhouse gases, livestock production, precipitation patterns

## INTRODUCTION

Climate change science predicts warming and greater climatic variability for the foreseeable future, including more frequent and severe droughts and storms, as a consequence of increasing atmospheric concentrations of greenhouse gases (GHGs). A climate change footprint has become evident in the form of atmospheric warming, rapid glacial retreat, accelerated plant phenology, modified precipitation patterns, and increasing wildfires (Parmesan and Yohe 2003; IPCC 2007). These changes to the Earth system are consistent with those of a warmer and more variable climate and have important consequences for the provisioning of ecosystem services to an increasing and more affluent human population (Walther 2003, 2010). Greater warming and climatic variability, expressed against the backdrop of large-scale and accelerating shifts in land use, pose a major challenge to society and more directly to natural resource managers, producers, and policymakers (Parmesan and Yohe 2003; Rockstrom et al. 2009).

The science of climate change inevitably contains uncertainties partly because climatic and ecological systems are complex and the consequences of this unprecedented phenomenon will be expressed over long time frames. Despite these uncertainties, it would be irresponsible to ignore the cumulative evidence for climate change—both the current footprint and model projections—on the basis that the rates and magnitude of change are not fully known. Unfounded optimism regarding climatic consistency currently constrains our ability to anticipate and develop effective contingency plans for nominal weather variation, and this perspective will pose a challenge to the development of strategies for confronting climate change (Joyce et al. 2013 [this issue]).

This synthesis was developed to provide an objective, concise assessment of climate trends and projections and potential

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