

Rocky Mountain Research Station Science You Can Use Bulletin



September / October 2017 | Issue 27

Where's the Beef? Predicting the Effects of Climate Change on Cattle Production in Western U.S. Rangelands

Despite the iconic status of the hamburger in the United States, beef was not a significant part of the American diet until after the Civil War, when large numbers of cattle were moved westward to take advantage of grazing lands. In western rangelands, these livestock fed on native grasses and were moved, in cattle drives, to feedlots to be finished. The westward expansion of the railroads allowed cattle to be transported by train from the West to the Midwest,

where they were slaughtered and shipped via refrigerator cars to the population centers of the East.

Today, the beef industry still widely uses western rangelands to feed young cattle. The economic success of the industry depends on the availability of natural forage on both private and public lands in the western United States. Grazing is managed through a permit system on over 95 million acres of National Forest System (USFS) lands spread



Cattle in the arid west (photo by Keith Weller, USDA Agricultural Research Service, Bugwood.org.)

SUMMARY

Cattle production capacity on western rangelands is potentially vulnerable to climate change through impacts on the amount of forage, changes in vegetation type, heat stress, and year-to-year forage variability. The researchers in this study projected climate change effects to rangelands through 2100 and compared them to a present-day baseline to estimate vulnerability of cattle operations. The analysis predicted:

1. an increase in forage quantity in northern regions;
2. a move from woody dominance toward grassier vegetation types overall but with considerable variability between areas;
3. a substantial increase in the number of heat-stress days across all regions beginning as early as 2020–2030; and
4. higher year-to-year variability of forage quantity for most regions.

All four factors combined to predict declining grazing capacity in southwestern regions. In northern and interior regions of the West, the benefits of increased forage are mostly offset by increases in heat stress and forage variability. The predicted increased vulnerability of cattle production in the Southwest provides strong impetus for adaptation by livestock producers and public land managers in anticipation of these changes. This study can be used by range managers to begin to think about long-term planning and communication with stakeholders (such as grazing permit holders) about what kinds of conditions to expect in the future.

KEY FINDINGS

- *Potential climate change scenarios can be used to model the future vulnerability of cattle production in the western United States to warmer, drier conditions, and more variable conditions.*
- *Under future climate change scenarios, the southwestern United States rangelands are projected to have a diminished capacity to support cattle due to greater moisture deficits and high temperatures that affect forage and stress livestock.*
- *Projections for the northern rangelands are less clear cut, but the modeled effects of climate change indicate mostly neutral to positive changes for rangeland's ability to support livestock due to warmer and possibly wetter conditions.*

across 29 States. The Bureau of Land Management also manages significant areas of grazing land by permit. On western Forest Service lands (Regions 1–6) in 2015 there were approximately 5,500 permits issued for the grazing of about one million head of cattle.

Forage availability for grazing animals has always been vulnerable to the effects of variations of weather and climate from year-to-year, with some years and decades markedly drier than others. For example, [the Northern Great Plains recently experienced the worst drought in 30 years](#) by some measures, causing ranchers to run out of grass and water for their animals and forcing adjustments to herd sizes, which can have longer-term economic consequences. It

is unclear how climate change will impact the western cattle industry—are grazing conditions likely to get worse, better, or stay the same? Matt Reeves, a research economist with the USFS Rocky Mountain Research Station, along with collaborators Karen Bagne (Kenyon College) and John Tanaka (University of Wyoming Extension), have been trying to understand the impacts of climate change and what they might mean for cattle numbers and operations. Reeves explains, “We want to identify specific regions throughout the western United States that are most vulnerable to climate change. The USFS and other public land managers can use this information to communicate with stakeholders, such as livestock producers that rely on public land grazing permits, and let them know what could be possible in the future and what we are preparing for.”

How is vulnerability measured?

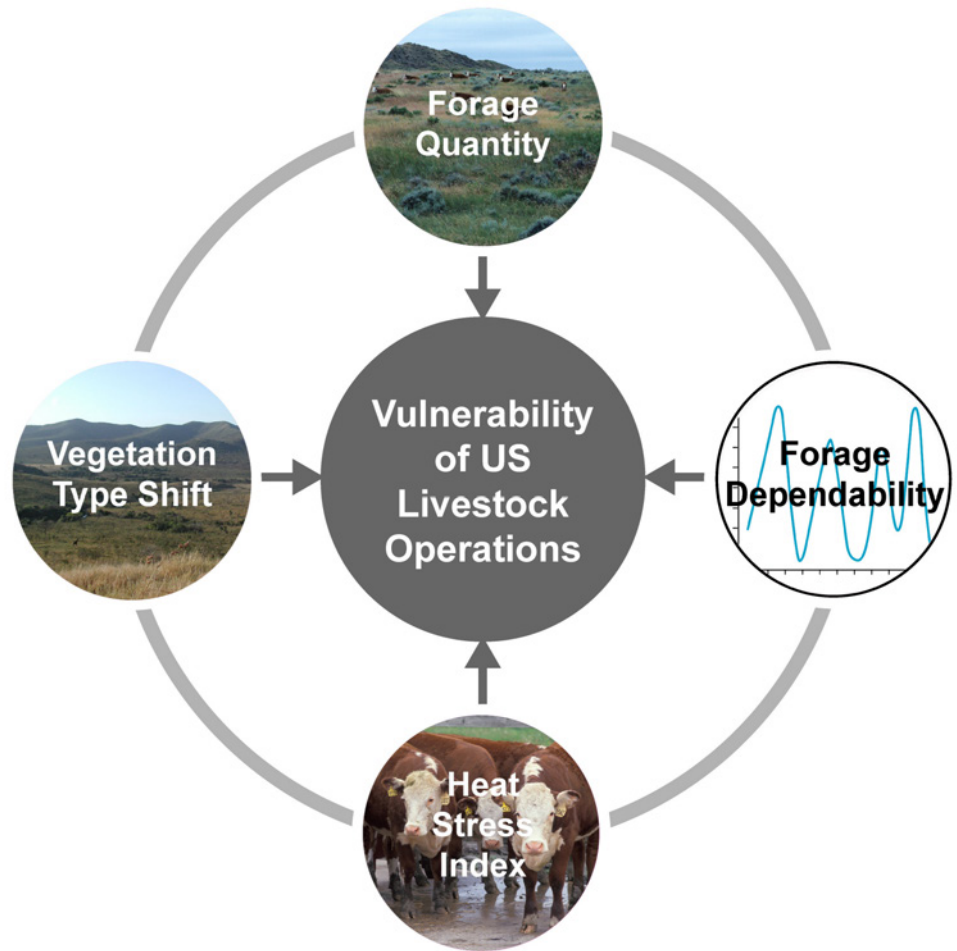
Reeves used modeling tools to compare regions across the United States to identify which places would be most affected in their ability to support cattle under future climate change scenarios. In this study, an area that is vulnerable to climate change would have a diminished capacity to support cattle in the future compared to present day. Climate change effects were projected to both 2060 and 2100. A comparison between current conditions (data from 2001–2010) and the projected

future conditions was used to estimate vulnerability of present-day cattle operations. This analysis employed four key indicators that would be most likely to be affected by changes in temperature and precipitation: forage quantity, shift in vegetation type, heat stress index (how the heat affects the cattle), and forage dependability (or, how much the amount of forage varies from year-to-year). The model results were distilled into a vulnerability measure for each of the four indicators: most vulnerable, vulnerable, no change, less vulnerable, and least vulnerable.

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Because no one knows with certainty how the future will play out, researchers studying the effects of climate change usually incorporate a range of possible future climate scenarios. These scenarios are based on projections developed by the well-known Intergovernmental Panel on Climate Change (IPCC). The IPCC developed a set of alternative climate scenarios, the [Special Report on Emission Scenarios](#), based on various future emission levels. Reeves used three of these scenarios in the model known as A1B, A2, B2—these scenarios are associated with different CO₂ emission levels in the future and represent “storylines” about how the world could change in the next century.

Reeves’ vulnerability model uses projections of temperatures and precipitation conditions across western rangelands based on these three climate scenarios. Temperature is projected to increase to some extent, but the impacts will vary by region. In relatively cooler areas, these temperature increases can have the effect of improving conditions for livestock, whereas in the southern rangelands, higher temperatures could make some areas unsuitable for cattle production. Regarding predicted precipitation changes in the future, Reeves explains, “It’s one of the trickiest things to estimate with respect to climate change, and a known source of uncertainty in all the models.”



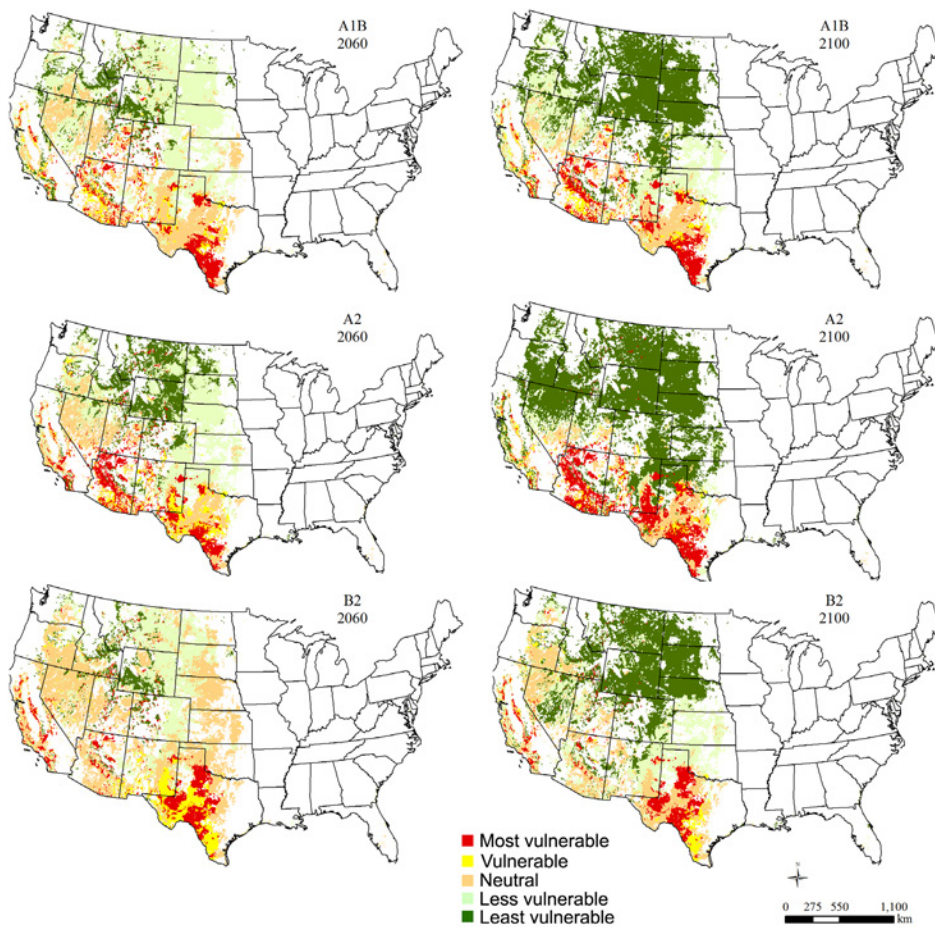
To assess vulnerability of cattle operations to climate change, this analysis uses four key indicators that would be most likely to be affected by changes in temperature and precipitation: forage quantity, forage dependability (or how much the amount of forage varies from year-to-year), heat stress index (how heat affects cattle), and shift in vegetation type (graphic by Matt Reeves).

How could the amount of forage be affected by climate change?

To predict how forage quantity is affected by climate change, Reeves’ model used the future climate scenarios to estimate future distribution and abundance of warm-season v. cool-season grasses, in tandem with wetter/drier, warmer/cooler scenarios.

The model can account for a lot of complicated interactions between carbon and nitrogen nutrient interactions, disturbance patterns, and can link these nutrient availabilities with the backdrop of the climate and the CO₂ to determine what it means for annual production. Reeves explains, “For example, if an area with warm-season grasses, like blue grama, buffalo grass, and little

Projected Forage Quantity in 3 Climate Scenarios



Comparing present-day with three future climate scenarios, the model predicts a general trend of “greening” in the northern rangelands and “browning” (indicated by the warmer colors) in the Southwest, meaning that growing seasons and forage quantity are enhanced in areas like Montana, Idaho and Wyoming whereas forage quantities decrease across the Southwest (graphic by M. Reeves).

bluestem, doesn’t get any warm season precipitation for the next 10 years because it all comes in the spring, that will begin to favor the cool-season grasses.” Comparing present-day conditions with future climate scenarios, Reeves’ model projects a general trend of “greening” in the northern rangelands and “browning” in the

southwestern rangelands, meaning that growing seasons and forage quantity are enhanced in the north whereas higher temperatures and moisture deficits reduce forage quantity in the Southwest. “The southwestern rangelands come out scoring pretty poorly in forage quantity in all future climate scenarios,” points out Reeves.

Will forage amounts become more variable from year-to-year?

While the overall amount of forage available to cattle is important, it is also critical that livestock producers can count on a dependable supply from year-to-year. Reeves explains, “If variability is low—for example, if I know I’ll have 500 lbs of forage per acre every year forever—I can dial in my stocking rates. But if it’s highly variable, I’ve got to be on the drawing board and on the telephone, I’ve got to be watching the weather, flexing my herd size, and buying and selling cattle.”

Even now, however, some rangelands can vary as much as 40 percent in forage quantity from year-to-year based on climate and land condition. The southwestern rangelands in particular are

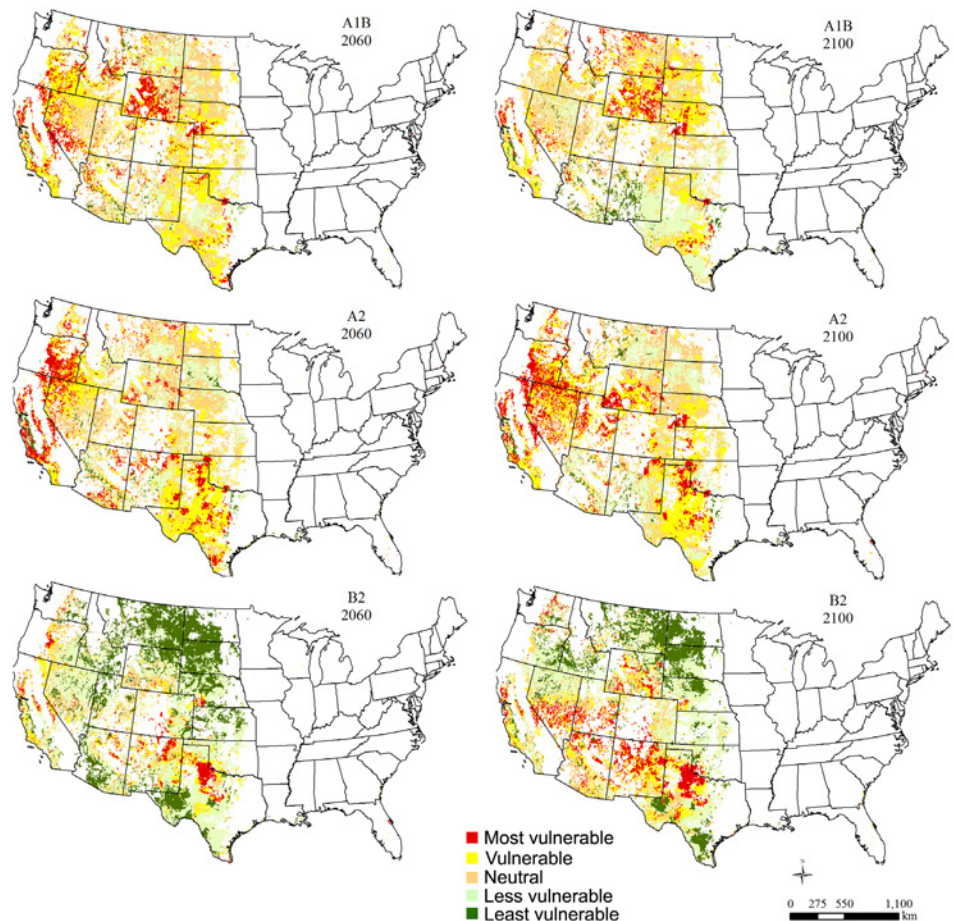
“For example, if an area with warm-season grasses, like blue grama, buffalo grass, and little bluestem, doesn’t get any warm season precipitation for the next 10 years because it all comes in the spring, that will begin to favor the cool-season grasses.”

already in a precarious position with the largest interannual fluctuations in forage abundance compared to other areas, as indicated by the cool colors on the map. “It is feast or famine on a year-to-year basis in the blue zones of the map right now,” says Reeves.

Compared to present day, this situation with interannual variability in forage is worse under future climate change scenarios, particularly in the Southwest. Under the A2 and A1B scenarios—thought to be the most likely future scenarios—the Great Basin and the Southwest have a lot of red zones on the map, meaning that the forage quantity gets more variable over time. Overall the model predicts a higher year-to-year variability of forage quantity for most regions.

“If variability is low—for example, if I know I’ll have 500 lbs of forage per acre every year forever—I can dial in my stocking rates. But if it’s highly variable, I’ve got to be on the drawing board and on the telephone, I’ve got to be watching the weather, flexing my herd size, and buying and selling cattle.”

Projected Forage Dependability in 3 Climate Scenarios



The model shows that the Great Basin and the Southwest have a lot of red zones (especially under the A1B and A2 scenarios), meaning that the forage quantity will be less dependable on a year-to-year basis in these areas. The greener tones indicate areas that are less vulnerable to greater fluctuations (graphic by Matt Reeves).

How might vegetation types shift in the future?

The type of vegetation in rangelands is also likely to shift in the future in ways that are complex and hard to predict. The analysis used a “dynamic global vegetation model” (DGVM) called MC2 to ask how weather, climate, and nutrient pathways predict which vegetation types will be favored under future climate scenarios.

For example, will climate change favors encroachment of woody species into grasslands? Currently, eastern redcedar is making inroads in wetter regions of the Central Great Plains, such as in the tallgrass prairie (presumably from a lack of fire), which is not good for cattle producers. Cows will eat brush, but they need to be trained to do so or have natural inclination because of breed (unlike goats, that naturally



This photo shows conifer encroachment into a montane grassland. Because most cattle breeds are not inclined to eat brush, cattle production is negatively impacted by woody encroachment. According to results of this study, wood encroachment to continue in some areas of the West due to climate change (photo by M. Manning).

browse). Along with woody encroachment, the model can be used to ask, will there be a shift from cool-season to warm-season grasses? This can affect the time of year forage is available to the cattle. Overall, the model predicts a move from woody dominance toward grassier vegetation types but with considerable differences across the map, meaning that vegetation shifts will be favorable in some areas and less so in others. Along the eastern edge of the plains, the green shift reflects increases in more grassy, less woody vegetation types. In part this is due to an expectation of more frequent wildfires due to lower humidity and warmer temperatures.

How might a changing climate affect cattle?

Heat stress on cattle is one of the easier indicators to work with, according to the researchers,

because it is a simple temperature and humidity equation based on published stress tests on cows. In effect, it's just like the calculation for human heat stress, except that respiration and panting are factored in. According to Reeves, "If you reach a certain threshold—and most, but not all breeds are susceptible to these thresholds—bad things start happening." Above 25 degrees C, cows begin to pant and respiration, in breaths per minute, increases. The more heat stress, the less weight cows gain because for every bite of forage they take, they are producing less body mass and this is a bad situation for livestock producers.

While growing condition for plants may improve in some areas, climate change models predict that it's going to get hotter or more humid everywhere, hence the red and yellow tones all over the map for cattle heat stress. Compared to present-day conditions, in the future there will be many more days where heat stress threshold for cattle is exceeded in a lot of

MANAGEMENT APPLICATIONS

- Long-term planning by USFS and other range managers and cattle producers should incorporate the possibility for changing conditions and more variability across the West.
- Range managers and cattle producers should be prepared for lower grazing capacity in southwestern rangelands and the need for greater flexibility overall.
- In the Southwest, where conditions are projected to get worse for cattle operations, adaptation strategies might include adjusting stocking rates, planning for supplemental feed and water, and changing animal type.
- In northern regions or where higher elevations are projected to exhibit improved conditions more diverse and flexible cattle operations may improve financial sustainability.

areas—this is projected to begin as early as 2020. This is particularly acute in the more northern reaches of the country. Reeves explains it this way, “If you are in a hot area already, adding a few more days doesn’t make as much of a difference. The systems in the South are presumably more prepared for this change based on their breed choices and production systems, such as providing shade and water.” This is not necessarily the case in northern areas, since they do not regularly experience the types of heat stress seen in more southern latitudes, leading to their higher vulnerability scores.

How do these factors combine into an overall vulnerability index?

To get an overall measure of vulnerability, each of the four variables – forage quantity, forage availability, vegetation type, and heat stress—were simply combined by the researchers. According to Karen Bagne, a collaborator on the project, “We tried to be transparent so that things were easy to see and so the four variables have equal influence on the overall number. Some thought that we should have weighted some indicators more heavily than other; but we don’t know which, if any, are more important.”

The cooler tones on the map represent areas of lower overall vulnerability after all the indicators were combined. “In the upper right side of the map, which is the Northern Great Plains, you have

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE SCENARIOS

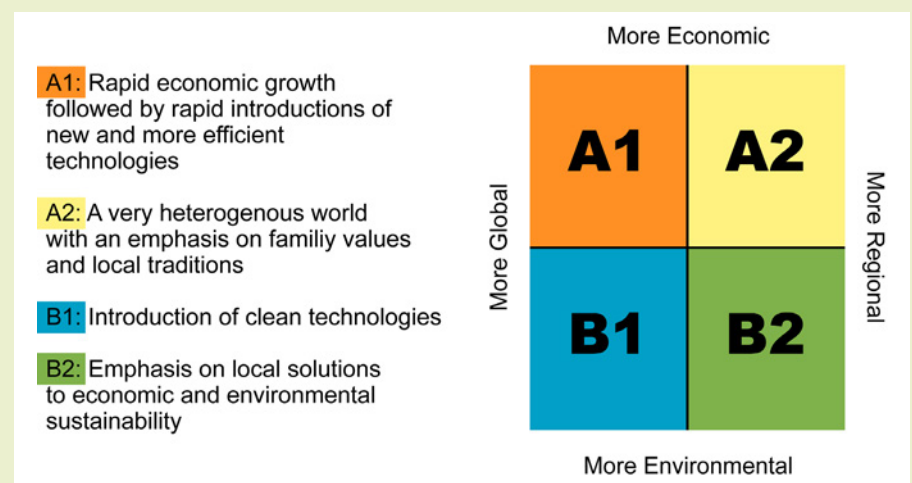
*The Intergovernmental Panel on Climate Change (IPCC) scenarios are four different storylines (with some subgroups) that were developed to describe consistently the possible relationships between the forces driving greenhouse gas (CO₂, CH₄, N₂O and sulphur dioxide) emissions and the actual estimates of those future emissions (the **bolded scenarios are the ones used for the analysis in this article**).*

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where **balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies).**

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

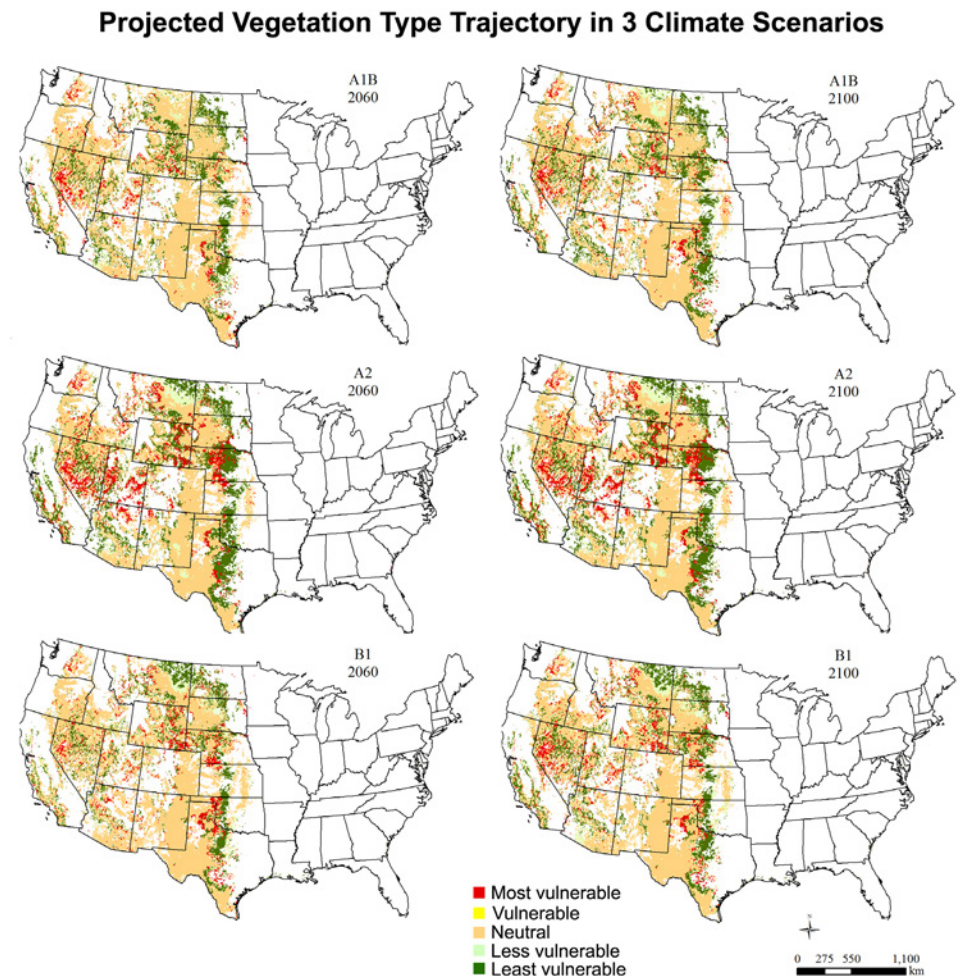


mostly neutral to maybe slightly positive effects,” says Reeves. Here, the benefits of increased forage availability or increasing abundance of herbaceous vegetation are mostly tempered by increases in heat stress and forage variability, producing these neutral scores along with the positives.

The warmer tones indicate conditions will become worse. The southwestern rangelands, as shown in the red box, show a preponderance of yellow-to-red tones and are projected to become more vulnerable with climate change, with diminished grazing capacity. There is a fair amount of uncertainty (as in when vulnerability indicators disagree in the same area), but overall a picture of greater vulnerability has emerged, according to Reeves. “A lot of these systems already require 55 acres or more per cow, it only takes a small change to make that 120 acres. You’re already perilously close to the edge in these very low production areas.”

What does this all mean for cattle management on western rangelands?

According to John Tanaka, another project collaborator and University of Wyoming extension agent, the basic structure of grazing on USFS land is that range-management specialists determine how much forage is available for livestock that year, considering soil protection, wildlife use, and any other use that puts a demand on that forage. Then they issue a permit that allows



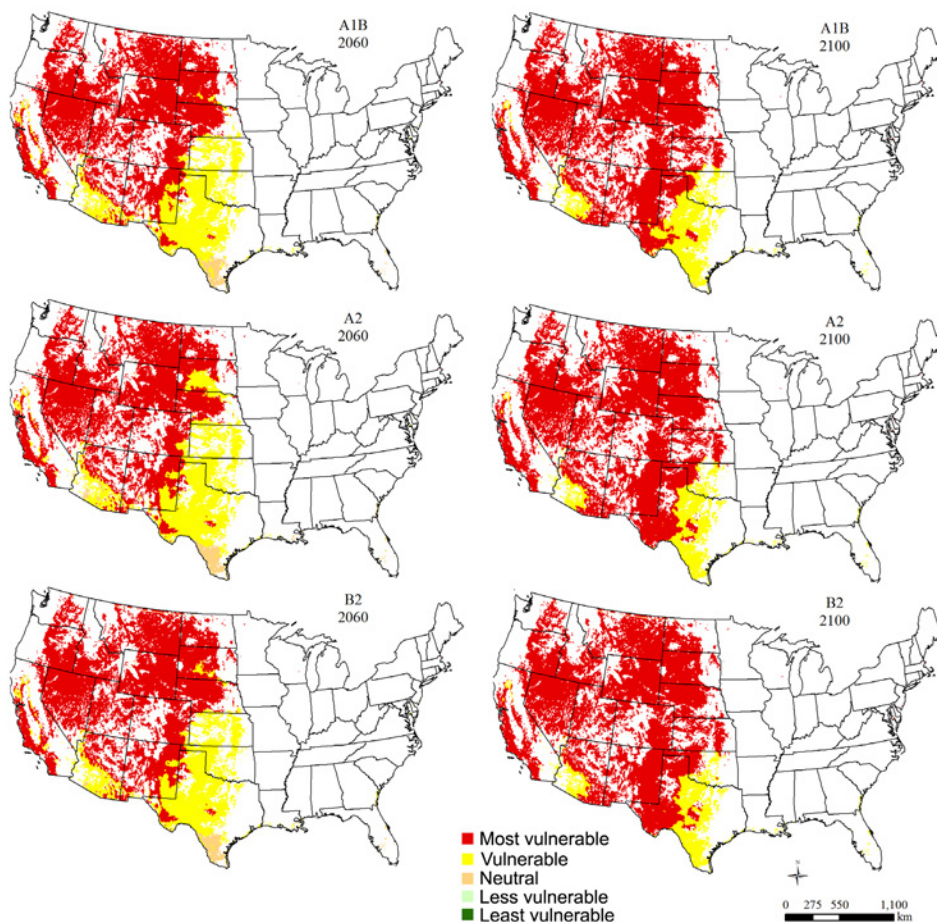
Overall, the model predicts a move from woody dominance toward grasses but with considerable differences across the map, meaning that vegetation shifts will be favorable in some areas and less so in others. Red areas depicted above are expected to increase in woody dominance while green areas represent shifts towards increased grasses and forbs (graphic by M. Reeves).

ranchers to graze cows or other animals for a certain amount of time on the USFS land. Usually there is a “turn-on” date—the earliest the producers can put their animals out—and a “take-off” date that may be adjusted if there is a drought and forage runs out. An overarching question is how whatever is currently working in western rangelands now may have to be modified for future changes, especially as growing seasons

and production levels respond to changes in climate.

Long-term planning by USFS and other public land range managers working with permittees may need to incorporate the possibility of lower grazing capacity in vulnerable regions, particularly the Southwest and Desert Southwest, to aid in sustaining goods and services from USFS rangelands. Opposing indicators in northern

Heat Stress Index in 3 Climate Scenarios



There are no future climate change scenarios where heat index conditions improve for cattle operations, according to Reeves' model. Red zones indicate areas most vulnerable to increases in heat stress; yellow areas are also vulnerable (areas that are already hotter climates may be better equipped to deal with increased heat). Compared to present-day conditions, in the future there will be many more days where the heat stress threshold for cattle is exceeded in a lot of areas (graphic by Matt Reeves).

"The livestock have to be somewhere every day of the year, so if the USFS makes a change in the season of use or type of animal that can have a pretty significant impact on ranch viability or sustainability. In the Desert Southwest, where the potential is likely to be hotter and drier, and there might be conversion to more woody species, ranchers may have to look at reducing traditional livestock use (which is generally cattle) and convert that to other species such as goats or even sheep."

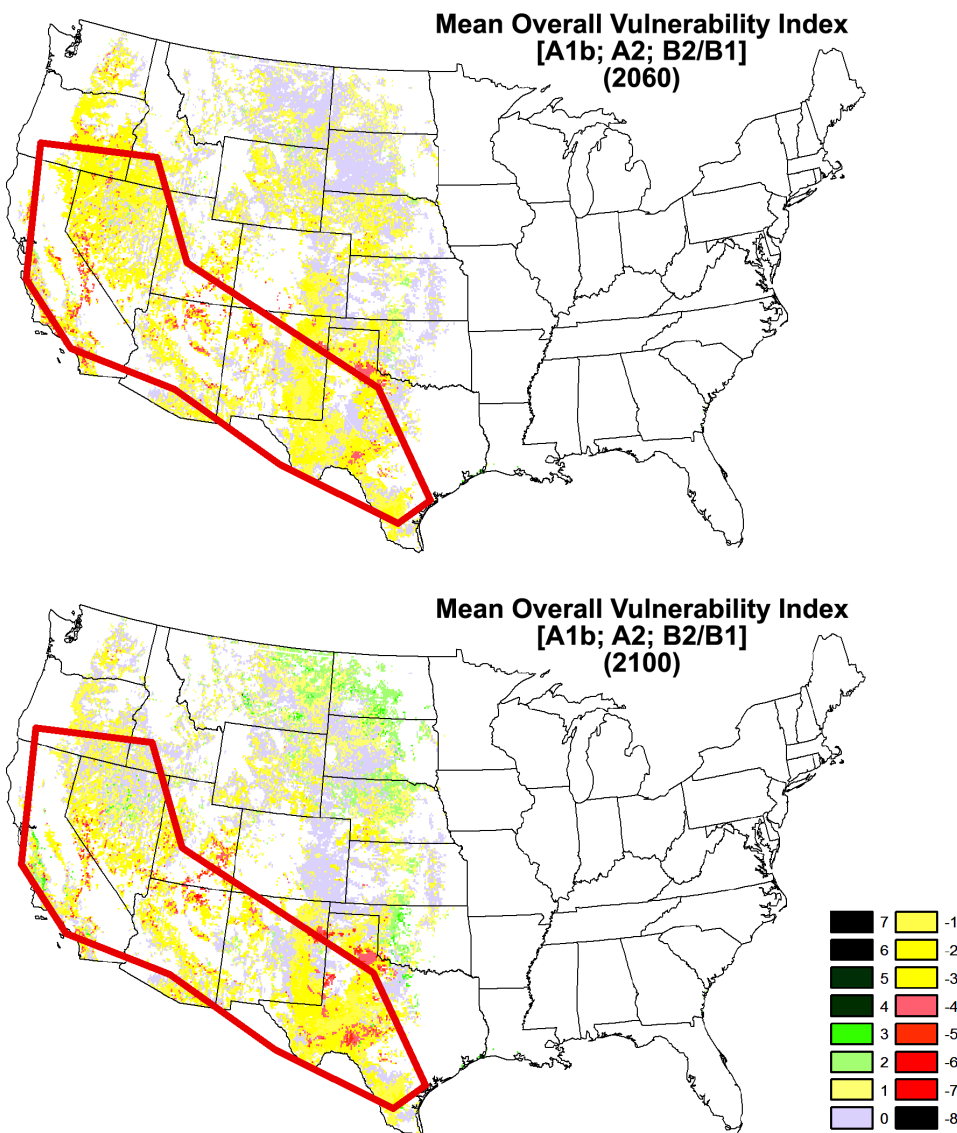
regions (e.g., more forage vs. higher heat stress) point toward the need for cattle operations to increase flexibility to take advantage of periods of favorable production while preparing for uncertainty, variability, and increasing stress from individual factors.

In the Southwest, "We don't know with exact precision what will happen, but it seems clear that

we'll probably need to deal with some cattle operation issues here," explains Bagne. "It is important to be prepared for more variability in this area. You can look at these places where everything is expected to be worse and then do a cost analysis by asking what is the easiest thing for me to do? Possibilities include more water, or other range improvements to help cattle through the heat problems,

or supplemental feed. Another is aiming for a very flexible-level stocking rate, instead of trying to maximize but having it fluctuate more."

Tanaka points out the importance of considering how changes in range management by the USFS may affect both the cattle producers and the agency from an economic standpoint. He says, "The livestock



have to be somewhere every day of the year, so if the USFS makes a change in the season of use or type of animal, that can have a pretty significant impact on ranch viability or sustainability. In the Desert Southwest, where the potential is likely to be hotter and drier, and there might be conversion to more woody species, ranchers may have to look at reducing traditional livestock use (which is generally cattle) and convert that to other species such as goats or even sheep. He adds, “There are management complications that come with doing that; for example, the fences all need to be changed, and waters have to be developed differently.”

Although the study paints a relatively bleak outlook for the southwestern United States, Reeves points out, “Our models don’t account for the full range of adaptive options by the U.S. cattle industry to these conditions.” The industry has some ability to flex its herd sizes and make some infrastructure adaptations. Perhaps even more importantly though, Reeves says, “One potential for adaptation to climate change is in cattle breeding, specifically crossing our European breeds (like the Herefords and Angus) with some of Asian origin (like Brahman cattle), and using this as a genetic tool to improve the adaptability of cattle to the future warmer conditions they are likely to encounter.”

The four indicators used in this model (forage quantity, forage dependability, changes in vegetation type, and heat stress index) were combined into one overall measure of vulnerability to climate change. The southwestern rangelands, as shown in the red box, show a preponderance of yellow-to-red tones and are projected to become relatively more vulnerable with climate change, with diminished grazing capacity (graphic by M. Reeves).

FURTHER READING

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SCIENCE YOU CAN USE BULLETIN

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Forest Service
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240 W. Prospect Rd.
Fort Collins, CO 80526

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The US Forest Service RMRS Science You Can Use Bulletin is published regularly by: Rocky Mountain Research Station (RMRS)

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