Grassland dynamics shift with climate fluctuations

By Melanie Lenart

As the drought deepened, ranchers and others at a January workshop brainstormed ways to keep southwestern grasslands resilient despite rising temperatures and pendulum-like swings in rainfall.

"I make my living when it rains," rancher Dennis Moroney of the CrossU Cattle Company told the group of about 130 ranchers, range managers, and natural resources specialists gathered for the two-day Climate and Rangeland workshop and Society for Range Management (SRM) meeting held near San Carlos, Arizona. "Last spring I said, 'If this is global warming, I'll take it.' I'm not so sure today,"said Moroney.

Plentiful rainfall during the winter and usually bone-dry southwestern spring in 2004–2005 put a dent in the drought that has plagued Arizona and New Mexico since at least 1998, but a dearth of rainfall since October has plunged much of the Southwest back into drought over the last few months. On the first day of the January 25 workshop, Phoenix had not received a drop of rain in 98 days, and Tucson had only received about 0.1 inches during that same period. Meanwhile, northern Arizona was still without snowpack.

"As we left town, we were getting our first significant snowfall of the year," noted Northern Arizona University (NAU) Professor George Koch, who drove up from Flagstaff on the morning of January 26. "This is shaping up to be the driest winter since the driest winter a couple of years ago," he added. On February 7, Flagstaff's National Weather Service office announced that the 2.49 inches of precipitation received between September 1 and February 6 represented a new record low in 109 years.

Gregg Garfin, program manager for the University of Arizona's (UA) Climate Assessment for the Southwest (CLIMAS), noted that El Niño exerts a tremendous influence on regional winter precipitation tallies. When El Niño reigns, sea surface temperatures run higher than average in the eastern Pacific Ocean. Often this helps pull jet stream moisture down to this region for the winter and sometimes through the spring, as it did last year. But things have changed.

"This winter's temperatures in the eastern Pacific, although not officially a La Niña, are cooler than average. We think that's what initiating this dry episode," Garfin told the group. Conditions officially met National Oceanic and Atmospheric Administration standards for a La Niña event the following week, after eastern Pacific sea surface temperatures had remained cooler than average for the required three months. This suggests the drought is likely to continue through the winter at least, Garfin indicated.

Garfin had worse news to convey. He is among the climatologists who suspect that a related influence commonly known as the Pacific Decadal Oscillation (PDO) switched in the late 1990s into a phase that spells long-term drought for the Southwest. While El Niño works at the seasonal scale with phases that typically last only a year or two, the PDO can stay in one phase for 20 years or more.

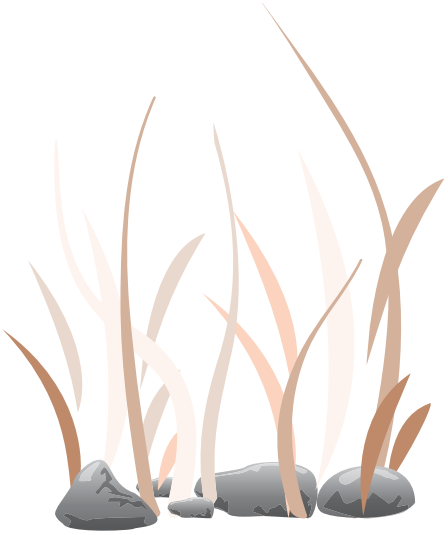
El Niño variations represent one of three processes influencing PDO phases, Garfin told the group, referring to research by Niklas Schneider and Bruce Cornuelle (*Journal of Climate*, November 2005). The other two influences are the Aleutian low, an atmospheric measure of sea level pressure that fluctuates much faster than El Niño; and the Kuroshio-Oyashio Extension, an ocean current that responds to El Niño phases but fluctuates much more slowly. At this point, skill in predicting the influences affecting the PDO is limited to a few years, the authors indicated in their paper.

Global warming's influence falls on top of fluctuations of El Niño, the PDO and other climate patterns. It launches a relatively predictable rise in temperatures accompanied by largely unpredictable changes in precipitation patterns. Following the ongoing trend for increasing temperatures, globally 2005 registered as the hottest or second-hottest year on record, depending on the analytical method used.

In time, the Southwest might experience more heat waves and record-breaking highs and fewer frost days, Garfin explained, citing a research paper by Noah Diffenbaugh and others (*Proceedings of the National Academy of Sciences*, November 2005).) Precipitation is also likely to become more extreme, in effect featuring more droughts and floods as the water cycle speeds up along with evaporation rates.

Grassland thresholds

The one-two combination of rising temperatures and more drought can really impact grasslands and other ecosystems. Grasslands rank among the most sensitive ecosystems to climate fluctuations,



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whether from natural variability or climate change.

"We're working with an ecosystem that has very quick responses to climate variability," noted Michael Crimmins, a UA Cooperative Extension climatologist who helped organize the workshop along with others from cooperative extension, CLIMAS, and SRM. Climate influences act along with past management actions, soil type, competition between species, and environmental disturbances, he added. "These increasing temperatures, even if precipitation remains the same, are going to change things."

Changes in climate can push a grassland system over a "threshold" into a new state, NAU Professor Thomas Sisk said. He showed an image of an idealized conceptualization of thresholds (Figure 1). A ball resting in the bottom of a pit represents one ecosystem state. Drought, global warming, or related disturbances can metaphorically lift the ball out of this "steady state" and shift it up and over the edge of a threshold into an entirely different steady state.

"Where are those thresholds? That's sort of the $64,000 question," Sisk told the group. "It's chaotic, unpredictable. That's why we're here today."

Protecting grasslands

Sisk is working with the Diablo Trust, a collaborative rangeland management group in northern Arizona, to monitor how selected plots respond to different grazing approaches. Monitoring involves keeping track of rangeland conditions by systematically measuring variables such as soil moisture and the percentage of desirable vs. undesirable plants within a specific area. This can help ranchers understand when they are risking a threshold change.

Ranchers may need to remove some grazing animals from shriveling grasslands during times of drought, Sisk noted, with or without a dictate from the government agencies that issue grazing permits. Often, people have a tendency to "wait, hope, and pray" rather than reduce livestock numbers, he observed.

"If it's really late, or we pray for a really long time, then we may cross that threshold," he added. The field of decision theory weighs the costs of changing management against the risks of inaction or of making a bad decision. In an acknowledgement of the difficulty in making decisions based on an uncertain future, Sisk noted that the best decision sometimes can be to wait out a dry spell—if it does rain in time to save the ranch.

"The response when it rains is phenomenal," said Moroney, whose ranch in McNeal reacts rapidly to rain, like most southwestern grasslands. "You see change take place in three or four days."

Summer rains can make or break a rancher's fiscal year. Yet the success of climate predictions for southwestern summer rainfall—largely dependent on the monsoon circulation that drives in the rain—lags far behind the skill in forecasting winter precipitation, mainly because of El Niño's influence on the latter. Arizona state climatologist Andrew Ellis, though, has found that late monsoons often equate to weak monsoons (*International Journal of Climatology*, February 2004). The 2005 monsoon fit the bill on both counts.

The larger spatial coverage of winter storms eases predictability, Crimmins explained. Winter storms often extend across the state for several days, he indicated, while summer thunderstorms pop up almost randomly over small areas.

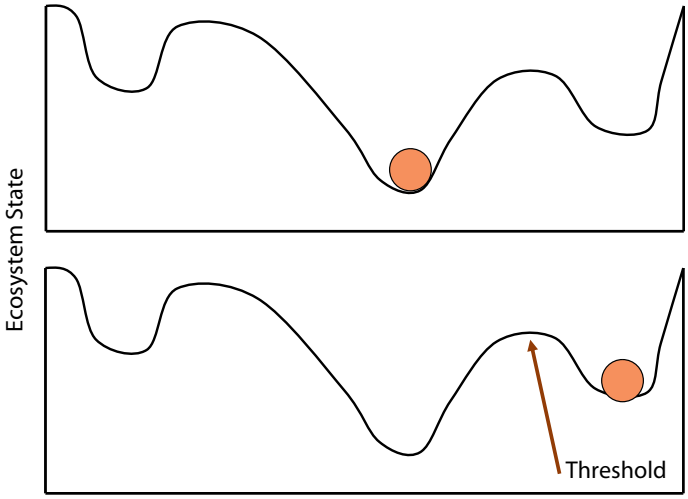

Figure 1. Grasslands and other ecosystems have "thresholds" relevant to specific states, such as forage production. Changes in climate can theoretically shift the grassland from one stable state (top) into a different stable state (bottom). Once the system has passed the threshold, it is difficult for it to return to its pre-existing state. Source: Thomas Sisk, NAU.

During years when the monsoon falters and sputters, like last summer, ranchers face a tough decision about whether to buy feed while hoping for rain, seek out greener pastures for a few months, or prematurely sell some of their carefully bred herd. If large-scale drought leads ranchers to flood the market with cattle, prices will drop for everybody.

A greener pasture

"Grass banking" can help ease the risk of running out of forage before the calves are fatted. For instance, a group of ranchers might set aside a common field for times of trouble, or individual ranchers can use their own land in ways that lessen the impact of grazing in any one spot, Moroney suggested.

"I moved my cows 11 times last year. We do that to shorten up the amount of time they spend in a pasture," he said. "Then we're always feeling pretty good that we have feed ahead of us and

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behind us in case rain doesn't come through."

He noted that he favors pastures with mesquite trees—generally considered undesirable by ranchers—during the season when dangling bean pods serve as a protein supplement for cows.

Moroney also suggested that adaptive management ideas could include putting cattle out in the desert when grasses encroach, as they did in 2005. The spread of grasses into the desert during last year's plentiful spring rains caused trouble. The grasses quickly cured into fuel for summer fires that sparked a record number of acres burned in Arizona. A quarter of a million of these acres burned outside Phoenix in the Cave Creek Complex fire, killing many of the Sonoran Desert's signature cactus, the saguaro.

Fire in grasslands

While fire spells disaster for saguaros, it can help grasslands win the competition against other woody plants like juniper, mesquite, and creosote.

Grasses "expressed themselves dramatically" after Moroney worked with the Natural Resource Conservation Service to fight off mesquite trees by spraying several hundred acres with herbicides. In recent decades, mesquite trees have been invading his ranch, along with grasslands throughout the Southwest. But the chemical treatments cost too much and are fairly ineffective without a follow-up by fire, he said, so the plan is to conduct some prescribed burns to further control the mesquite invasion.

The proper fire regime can maintain grasslands facing invasions from woody plants such as juniper as well, UA Professor Steven Archer told the group.

Based on research about how long it takes juniper to establish and grow in similar Texas and Oklahoma grasslands, ranchers need to have a fire at least every 10 years to keep juniper off highly productive, non-grazed landscapes, Archer reported. On grazed sites, the window of opportunity to prevent juniper encroachment can shorten to five years, he explained. His research has shown that cattle grazing can help woody plants invade by removing the grasses, known as fine fuels, needed to carry fires capable of suppressing trees and shrubs. Less productive sites or more heavily grazed sites may need to be burned even more often because the sparser ground cover translates to reduced fuel loads and hence patchier fires with lower intensities, he indicated.

Other factors

Drought, global warming, fire, and woody plant encroachment all can change grassland dynamics. So can invasive grasses and weeds, insects, and carbon dioxide. Grassland insect invasions often track the ups and downs of rainfall. Invasive plants, too, can respond to plentiful rainfall, as Sahara mustard and red brome did when colonizing desert lands last spring.

The greenhouse gas carbon dioxide, responsible for about 60 percent of the ongoing warming, also affects invasive plants, insects, and other factors influencing rangelands dynamics. For instance, woody plants such as trees and shrubs tend to grow more quickly than grasses in experiments exposing them to the carbon dioxide levels expected by about mid-century. Desert landscapes have undergone "reverse desertification" when exposed to these elevated levels of carbon dioxide, with 40 to 50 percent increases in productivity, Sisk pointed out. (For more information, see the 2004 review paper by Robert Nowak and colleague in *New Phytologist*.)

Even among grasses, the extra carbon dioxide in the air will favor some species more than others. It provides a bigger boost to plants that use the "C3" pathway to photosynthesize, such as trees and many cool-season grasses including bromes and cheatgrass. So-called C4 plants, which include most warm-season grasses and invasive species like lovegrass and buffelgrass, are not as affected.

The rising levels of carbon dioxide offer a high note that may interest farmers as well as ranchers: Most crops are C3 species, while most "nasty weeds" are C4 species, Sisk noted. However, there's also some evidence that insects need to eat more when dining on plants grown under higher carbon dioxide levels.

Increasing resiliency

A growing list of disturbances join drought in impacting grasslands. Grassland dynamics are likely to become more complex with the changing climate and related factors, increasing the risk of crossing a vegetation threshold, with major shifts in the species composition and productivity of rangelands.

Although rancher Richard Collins mentioned he was having a difficult time maintaining his natural optimism when faced with the workshop news, Garfin compared the growing understanding of the climate risks facing grassland managers to the awareness that had grown in Louisiana over the past couple of decades that a major hurricane could devastate New Orleans.

"We did not reduce vulnerability and increase resilience," Garfin noted. "And I think that's the task. We've got the information. The challenge is to take climate change information … and try to translate that into something that converts into a real and practical management plan."

Melanie Lenart is a postdoctoral research associate with the Climate Assessment for the Southwest (CLIMAS). The SWCO feature article archive can be accessed at: http://www.ispe.arizona.edu/ climas/ forecasts/swarticles.html