Changes on the Range: Exploring Climate Change with Range Managers

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ABSTRACT In the southwestern United States, climate variability strongly influences range conditions and thus is an important factor in range managers' land management decisions. Access to cutting-edge climate and range science information is vital for managers to make better short and long-term decisions. To engage land management practitioners and scientists in communicating about climate change and range science concepts, an experiential learning exercise was implemented at a recent meeting of land managers and scientists. Within a state and transition model framework, participants explored potential trajectories for rangeland management units under a changing climate. Small groups collectively managed a 400-hectare (1000-acre) parcel of land given financial constraints and environmental disturbances determined by chance for six decision periods, representing 60 years. In each round, groups discussed potential changes to and transitions of their parcel based on the interaction between initial state, disturbances, and the decade-by-decade climate time series data provided. The groups enacted management strategies based on trying to keep the parcel in the current state or trying to move the parcel to a more favored state. Evaluation results indicate that the exercise was useful in facilitating small group discussions between scientists and managers on the complex interactions between short-term climate variability, longer-term changes, and management decisions at all time-scales. Additionally, participants' knowledge and comfort levels with state and transition models significantly increased following the exercise. With minor adaptations, the exercise could be implemented in any part of the country and for use by college courses studying land management issues.

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A working knowledge of climatic patterns and processes is an important tool for range managers in the southwestern United States. High variability in temperature and precipitation patterns require that climatic conditions be considered when implementing best management practices. It is widely accepted that the earth's climate is changing (Houghton et al., 2001). Climate model projections for the southwest United States predict a continuation of rising average temperatures and the potential for an increase in the frequency of extreme heat events (Diffenbaugh et al., 2005).

Rangelands and cattle operations have a high exposure to impacts from climate because of high interannual precipitation variability and a tendency for the Southwest to experience multiyear drought (Eakin and Conley, 2002; Sheppard et al., 2002; Vasquez-Leon et al., 2002). Severe sustained multiyear drought since the mid-1990s has increased range managers' awareness of their exposure to climate variations, and potentially enhanced exposure to long-term climate trends. Impacts have included successive failures of summer monsoon rainfall and exceedingly low winter precipitation and snowpack; these climate conditions have strong effects on the availability of forage and reliable water sources for cattle. As a result, range managers in Arizona and New Mexico are both sensitive to and attentive regarding climatic changes. Accordingly, the range management community in this region has a strong interest in integrating climate science research into management decision-making over short and long-term timescales. The prospect of continued trends and changes in climatic variability outside of historical ranges is of great concern to range managers.

Organizations at the University of Arizona (UA), Cooperative Extension (CE), and the Climate Assessment for the Southwest (CLIMAS), exist in part to extend climate science from university research into applications. In partnership, UACE and CLIMAS collaborated with the Arizona

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Abbreviations: AZ-SRM, Arizona Section of the Society for Range Management; CLIMAS, Climate Assessment for the Southwest; MLRA, major land resource area; PDSI, Palmer Drought Severity Index; UACE, University of Arizona Cooperative Extension; USDA, United States Department of Agriculture.

section of the Society for Range Management (AZ-SRM) to host a workshop in January of 2006 to facilitate a two-way dialogue between range managers and university scientists. The two-way information exchange benefited both presenting scientists and attending managers. This dialogue allowed land managers to convey their needs for new research and application development. Such a connection between science producers and users is part of a growing movement to make science usable and relevant to operational decision-makers (Jagtap et al., 2002; Jacobs et al., 2005), and is only possible when these groups are brought together in an organized way (Gamble et al., 2003).

A key component of the workshop was an experiential learning exercise. Within the framework of state and transition models, participants explored potential trajectories for rangeland management units under a changing climate. The main objective of the exercise was to challenge range managers to explore how long-term changes in temperature and precipitation regimes may impact their management strategies and how different planning windows may be needed to adjust to changing climatic conditions. The exercise also served to identify strengths and weaknesses of the state and transition approach, highlighting information gaps for everyday decision-making.

Materials and Methods

Workshop Exercise

This exercise was developed for a program titled 'Beyond Boxes and Arrows: Assessing Climate Change/Variability and Ecosystem Impacts in Southwestern Rangelands' organized by UACE and CLIMAS and held in conjunction with the Arizona Section of the Society for Range Management's winter meeting in January of 2006. Further use of the exercise is being planned through future AZ-SRM and Cooperative Extension In-service training sessions.

State and Transition Models

The exercise used a state and transition model in conjunction with climate data to develop a potential scenario that could be used to explore the connections between range management decisions and climate change. State and transition models are being developed for the entire United States by the USDA Natural Resources Conservation Service as potential management tools. A *state* represents a unique vegetation community whereas a *transition* is the movement from one state to another. These models define the range of possible vegetation states for a parcel and further restrict which transitions are possible and when. State and transition models can better accommodate the wide spectrum of vegetation dynamics on a managerial basis (Westoby et al., 1989), because these models account for the multi-dimensionality of vegetation transitions and allow vegetation transitions to happen along many trajectories or axes (Briske et al., 2005). This is a departure from the previously accepted succession single-axis model, which assumes linear transitions in vegetation community composition. The single axis model has been heavily criticized because it was not able to cover the entire spectrum of vegetation changes occurring on rangelands (Laycock, 1991). In the state and transition model different fire regimes, management prescriptions, soil erosion, and

State and Transition-Climate Worksheet Group Number: ***1*** Management Objective: ***production*** Desired State: ***sacaton***

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	Sacaton grassland	Climate and Wildfire	Good	Rest rotation grazing	*No change; adequate summer precipitation through period, climatic conditions favor quick recovery after fire.*	Sacaton Grassland
2	Sacaton Grassland					
3						
4						
5						
6						

Fig. 1. Sample worksheet used in experiential learning exercise engaging range managers in climate change discussions with example results provided for the first decision period. Note that ending state from first period is carried over to the initial state of the second as beginning point of discussion for that period.

climate change can lead to vegetation changes along different trajectories or axes (Briske et al., 2005). Because of the explicit identification of climatic drivers in state changes, these models offer the ideal platform from which to discuss climate-range management interactions.

Exercise Structure: Provided Materials

During the exercise, each group collectively managed a 400-hectare (1000-acre) parcel of Sacaton/Loamy Bottom rangeland (MLRA 41-3; young soils on loamy to clayey alluvium of mixed origin), typical of southeastern Arizona. The exercise featured sacaton/loamy bottom rangeland due to the availability of a state and transition model for this type of site and sacaton/loamy bottom rangeland's known sensitivity to climate variability. To provide context on past and current rangeland conditions, participants also received the land use history for the parcel, which reported the site to have been grazed historically and presently stocked at rates based on site potential.

The following exercise materials were distributed to each small group:

1. Instruction sheet. Detailed set of instructions provided for reference on overall objectives, steps to complete the exercise, and information on how to interpret different exercise components.

2. Worksheet (Fig. 1). Sheet where all group discussions, observations, and decisions were logged. The sheet is divided into six rows to represent each of the six decision periods that were used in conjunction with climate scenario data.

3. Look-up table (Fig. 2). This sheet is structured as a reference sheet with two different tables.

- The top look-up table provides six possibilities for three different elements of the exercise: management goals, financial standing, and disturbances. Each element is determined randomly via the roll of a die.
- The bottom table provides a listing of management options and their relative cost that can be used during each decision period.

4. State and transition Model Sheet (Fig. 3). The model used in this version of the exercise was the Sacaton/Loamy Bottom model (MLRA 41-3) developed by the Natural Resources Conservation Service (D. Robinette, personal communication, 2006). Each model shows potential vegetation states and transitions, conceptually, using boxes and arrows. The states are labeled in the boxes and the transitions are labeled arrows described in a list next to the conceptual diagram. The model constrains and guides the possible changes in vegetation states by only allowing for the movement of one state to another through a limited number of connections between boxes.

5. Temperature Data Sheets (Fig. 4). This exercise used synthetic climate data, consistent with climate change projections for the Southwest and taking into account the high level of uncertainty in precipitation projections. The intention was to provide a realistic scenario of warming temperatures and continuation of high temporal variability in precipitation; others have demonstrated the effect of warming temperatures in the western United States on watershed hydrology (Stewart et al., 2004, 2005; Mote et al., 2005). Arizona statewide averages of precipitation and temperature during the past 60 years served as the dataset for this exercise (1932–1991; National Climatic Data Center, 2006). A trend of 0.56°C (1°F)/decade was applied to the temperature time series to create a warming scenario, which allowed the temperature trend to be consistent with projections for the southwestern United States provided by global circulation models (Sprigg and Hinkley, 2000).

6. Precipitation Data Sheets (Fig. 5). Major uncertainties in precipitation projections provided by global circulation models informed the decision to leave the precipitation time series unchanged (Sprigg and Hinkley, 2000). Maintaining the same time series structure for precipitation preserved short-term and decadal variability in annual precipitation amounts related to the El Niño-Southern Oscillation and other climate patterns important to Southwest precipitation variability. Both the temperature and precipitation time series were relabeled to represent a scenario of future climatic conditions from 2010 to 2069. Data were presented as raw seasonal temperature and precipitation

Lookup Table

	Mgt Goals towards	Financial Standing	Disturbance
Number Rolled	Once at beginning	Every decade	Every decade
1	continued production	Good	Climate & Wildfire
2	continued production	Poor	Climate Only
3	preservation	Poor	Climate & Invasive Species Introduction
4	preservation	Good	Climate & Insect/Small Mammal Herbivory
5	continued production	Poor	Climate Only
6	preservation	Good	Climate & Erosion from Roads/Recreation

Management Options	Relative Cost
Prescribed burning	Low
Herbicide control of mesquite	High
Herbicide control of non-native grasses	High
Rock and wire gabions	High
Earthen retention dams	Medium
Seeding of sacaton	High
Seeding of non-natives	Medium
Grubbing	High
Wood harvesting	Low
Deferred rotation grazing (infrastructure in place)	Low
Deferred rotation grazing (infrastructure not in place)	High
Rest rotation grazing (infrastructure in place)	Low
Rest rotation grazing (infrastructure not in place)	High

Fig. 2. Look-up tables for various components of an experiential learning exercise engaging range managers in climate change discussions. Top table contains elements of the exercise that are determined randomly with the roll of a die. The bottom table lists management options with a qualitative ranking of relative expense.

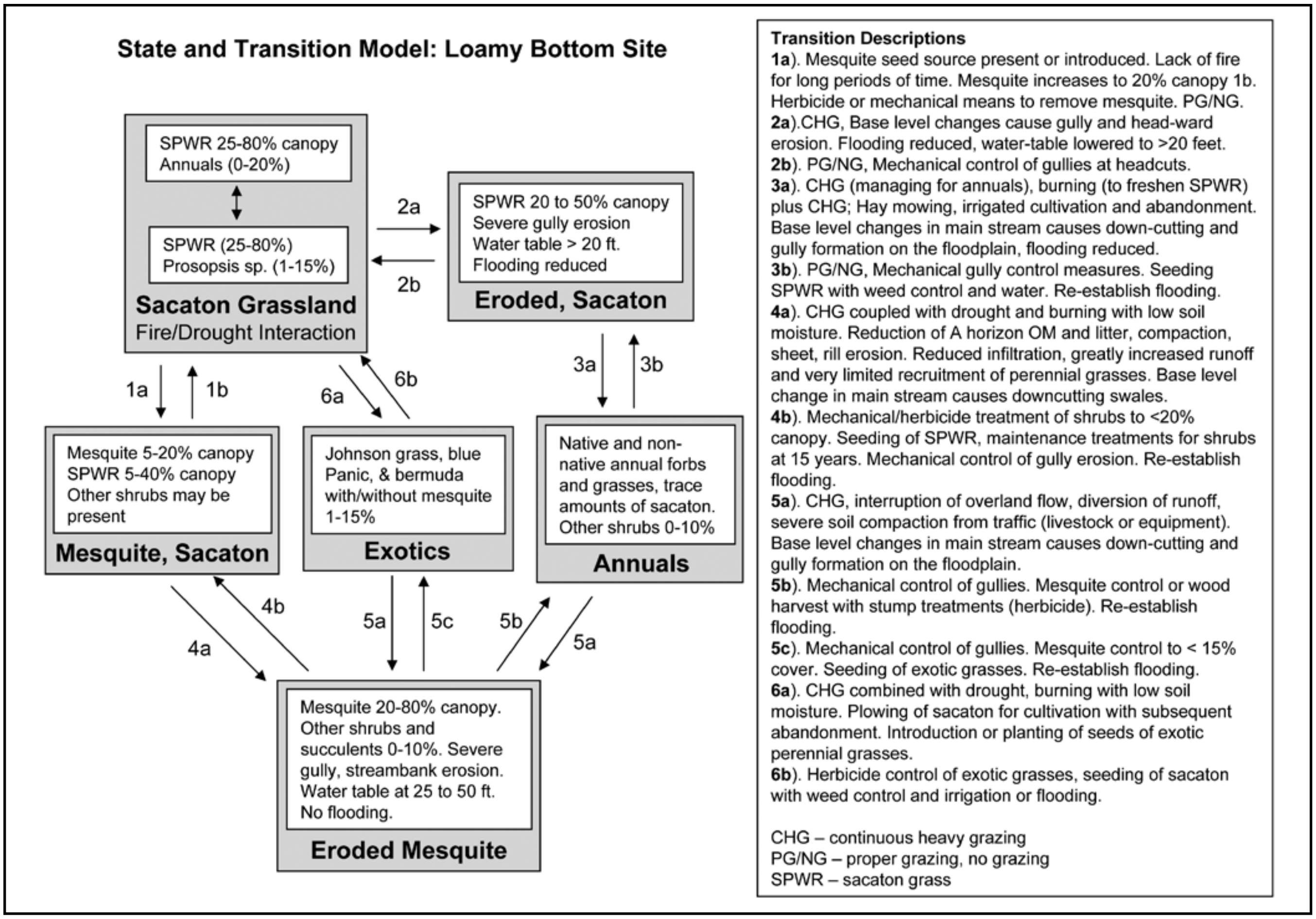


Fig. 3. Example of state and transition model developed by Natural Resources Conservation Service. This model was developed in southeastern Arizona for the "41-3 loamy bottom" ecological site description.

amounts, departure from averages (to highlight the difference between future and recent temperatures, the average period was the first 10 years of the time series), and qualitative rankings based on quintiles of the raw data (Fig. 6).

It is important to note that the climate data were presented in six discrete 10-year decision periods. This was done for the first 10-year decision period representing the years from 2010 to 2019. This presentation of climate information is an unrealistic "birds-eye" view of all 10 years at once, but creates emphasis on the importance of temporal patterns in precipitation and temperature. The 10-year window allows the group to see patterns in climate (multi-year droughts and wet spells, temperature trends) that are important to consider in both short and long-term management decisions. The exercise forced participants to consider and analyze this longer-term climate variability in the context of both short and long-term management decisions.

Conducting the Exercise

Step One: Determine the Initial State

Each group was either assigned or selected an initial state from which to begin managing their parcel. This was predetermined by the workshop organizers, but could also be determined randomly by the group through rolling dice and using the look-up table with possible states listed (Fig. 2).

Step Two: Determine Management Objectives

The groups decided on conservation or production as the management objective for their parcel. The exercise constrained the options to managing for continued livestock grazing or moving toward removing livestock and managing for restoration. Each group was required to come to a consensus on their management strategy before moving forward in the exercise, forcing the participants to work together from this initial step.

Step Three: Determine Financial State and Environmental Disturbances

The group determined their financial condition (low, medium, or high) and potential disturbances (e.g. wildfire, invasive species introduction) by (1) rolling a die, (2) using the look-up table, and (3) logging the results on the exercise worksheet (Fig. 2). Financial conditions and environmental disturbances limited the potential management activities.

Step Four: Managing the Land

With the information regarding the initial state, management objectives, the financial state, and the environmental disturbances already determined, the group proceeded to discuss potential changes to and transitions of their parcel based on the interaction between initial state, disturbances, and the decade-by-decade climate time series data provided on the climate information sheets (Fig. 4, 5, and 6). The groups were permitted to actively manage the parcel by enacting management strategies based on trying to keep the parcel in the current state or trying to move the parcel to a more favored state.

The following example illustrates how financial conditions and vegetation state combine in actively managing a parcel: The initial vegetation state is characterized by encroaching mesquite, but the desired state is a rangeland populated more by native grasses. If the group had been fortunate enough to receive a "good" determination of financial standing (determined by rolling die and using look-up table) during the 10-year decision period they may decide that they want to use an herbicide treatment listed as an option on the Management Options table. This option is listed as a "high cost" option and would only be possible under a "good" financial standing. The financial component of the exercise was left in qualitative terms as an opportunity to gain feedback on which management options were really possible and how much they cost based on actual experiences from land managers.

The group then discussed when and if this treatment would work in conjunction with the climate time series during the current decision period. Prolonged wet or dry periods may support or hinder certain management activities. As an example, prescribed burning activities may not be possible during extended wet periods, so other management options need to be considered. All of the complexities inherent in considering range management decisions within the context of climate change and variability are not known. The exercise was structured as an opportunity to explore this area in discussions at the small group level. This discussion of the effectiveness of the management option put forth led to a final determination of the ending vegetation state within the decision period.

The exercise was introduced via a presentation lasting approximately 25 minutes. The groups then worked through the exercise. Groups were given 1.5 hours to complete the exercise; some groups finished more quickly. Finally, participants were reconvened and groups reported their outcomes. A large group discussion ensued for approximately 30 minutes.

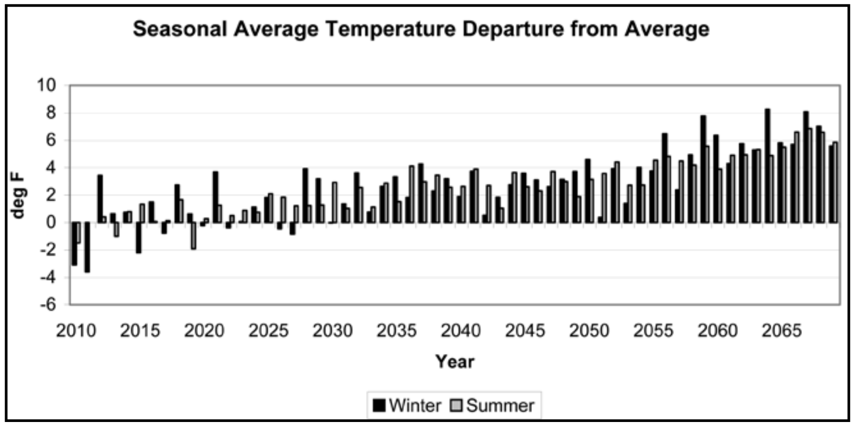


Fig. 4. Synthetic time series of hypothetical seasonal temperature anomalies for Arizona 60 years into the future. Seasonal temperatures contain a 0.56°C (1°F)/decade trend in temperatures. The anomaly values represent departures from the 10-year average calculated on the period from 2010 to 2019.

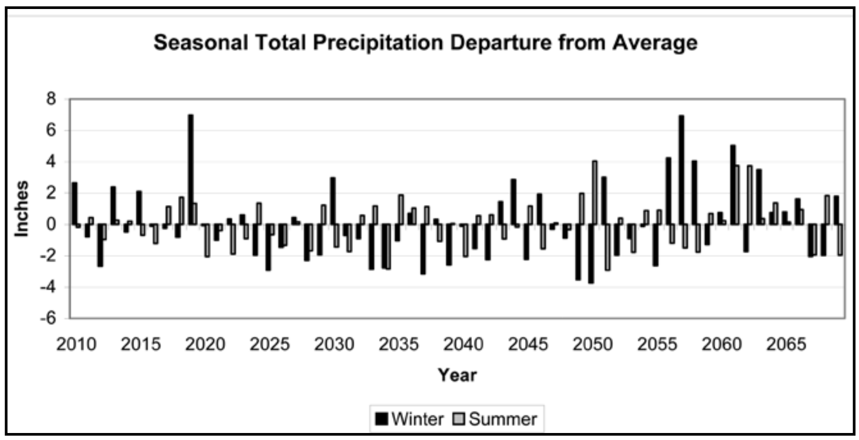


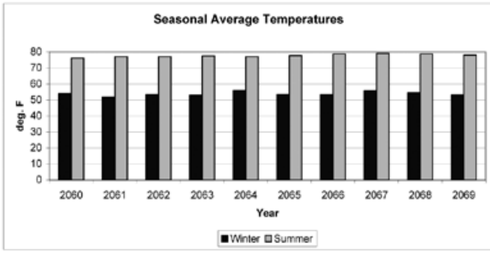
Fig. 5. Synthetic time series of hypothetical seasonal precipitation anomalies for Arizona 60 years into the future. Seasonal precipitation amounts match the period from 1932 to 1991, maintaining seasonal precipitation variability into the future. The anomaly values represent departures from the 60-year average calculated on the period from 2010 to 2069.

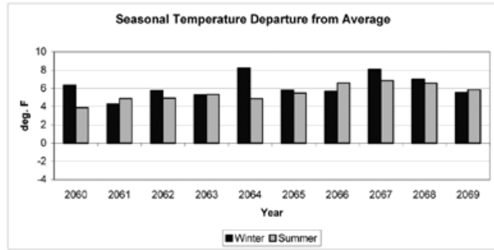
Exercise Evaluation

The impact of the workshop exercise on participants' knowledge and comfort levels pertaining to the material presented was evaluated via written pre- and post-exercise surveys. Pre-exercise surveys consisted of eight questions; post-exercise surveys included 11 questions (Table 1). Six of the questions were included in both pre- and post-activity surveys to assess the impact of the activity on the learners' knowledge and comfort levels with the subject matter. Answers to pre- and post-exercise survey questions were tested for differences using the Wilcoxon signed-rank test and McNemar's tests where appropriate.

Decision Window 6: 2060-2069

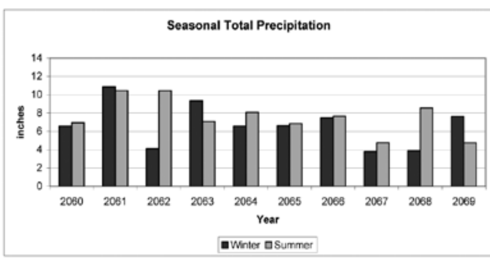
Temperature

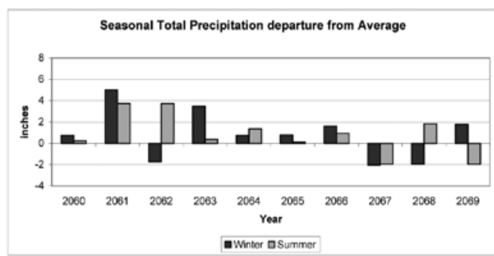




Year	Winter Avg Temp (°F)	Winter Temp Departure from Avg (°F)	Winter Temp Rank	Summer Avg Temps (°F)	Summer Temp Departure from Avg (°F)	Summer Temp Rank
2060	54.0	6.3	exceptionally warm	76.1	3.9	extremely warm
2061	51.9	4.3	extremely warm	77.1	4.9	exceptionally warm
2062	53.4	5.8	exceptionally warm	77.2	4.9	exceptionally warm
2063	52.9	5.3	exceptionally warm	77.6	5.3	exceptionally warm
2064	55.9	8.3	exceptionally warm	77.1	4.9	exceptionally warm
2065	53.5	5.8	exceptionally warm	77.7	5.5	exceptionally warm
2066	53.3	5.7	exceptionally warm	78.8	6.6	exceptionally warm
2067	55.7	8.1	exceptionally warm	79.1	6.9	exceptionally warm
2068	54.6	7.0	exceptionally warm	78.8	6.6	exceptionally warm
2069	53.2	5.6	exceptionally warm	78.1	5.9	exceptionally warm

Precipitation





Year	Winter Total Precip (in)	Winter Precip Departure from Avg. (in)	Winter Precip Rank	Summer Total Precip (in)	Summer Precip Departure from Avg (in)	Summer Precip Rank
2060	6.6	0.74	wet	7.0	0.23	average
2061	10.9	5.02	very wet	10.5	3.74	very wet
2062	4.1	-1.74	dry	10.5	3.73	very wet
2063	9.3	3.49	very wet	7.1	0.37	average
2064	6.6	0.74	wet	8.1	1.36	very wet
2065	6.6	0.79	wet	6.9	0.13	average
2066	7.5	1.62	wet	7.7	0.94	wet
2067	3.8	-2.04	dry	4.8	-1.96	very dry
2068	3.9	-1.97	dry	8.6	1.84	very wet
2069	7.6	1.79	wet	4.8	-1.97	very dry

Fig. 6. Example climate data sheet for the decision period 6 (Periods 1–5 not shown) used in an experiential learning exercise engaging range managers in climate change discussions. Note temperature anomalies (upper right graph on each sheet) for this last period. Temperature anomalies in this last decision period are positive for each season in each year, reflecting the trend in temperature imposed on the temperature time series.

Table 1. Pre- and post-activity questions used during an experiential learning exercise using state and transition models for managing rangeland under a changing climate.

Survey	Question no.	Question	Choices provided (check all that apply)
Pre	1a	Have you heard of state and transition models?	
Pre	2a	Do you use state and transition models?	
Pre, Post	3a, 1b	Would you use state and transition models? Please explain why or why not.	
Pre, Post	4a, 2b	On a scale of 0–5, how much do you know about state and transition models?	
Pre, Post	5a, 3b	On a scale of 0–5, what is your comfort level with state and transition models?	
Pre, Post	6a, 4b	What would increase your comfort level with state and transition models?	
Pre, Post	7a, 5b	Which of the following types of climate information do you use now?	seasonal temperature forecasts; historical temperature information; seasonal precipitation forecasts; historical precipitation information; departure from average (precipitation); departure from average (temperature)
Pre, Post	8a, 6b	Which of the following climate information would you consider using in the future?	seasonal temperature forecasts; historical temperature information; seasonal precipitation forecasts; historical precipitation information; departure from average (precipitation); departure from average (temperature)
Post	7b	The handouts from this exercise contained precipitation data; this information was…	consulted during the course of the break-out group; helpful when making management decisions; too complicated; not specific enough
Post	8b	The handouts from this exercise contained temperature data; this information was…	consulted during the course of the break-out group; helpful when making management decisions; too complicated; not specific enough
Post	9b	The information about departures from average contained in the handouts from this exercise was…	consulted during the course of the break-out group; helpful when making management decisions; too complicated; not specific enough
Post	10b	Did you encounter any problems when using the climate information provided in the handouts? If so, what problems occurred?	
Post	11b	What changes would you suggest to make this exercise easier to participate in and/or understand?	

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Results and Discussion

More than 80 workshop attendees, split into 10 small groups, took part in this first execution of the workshop exercise. Though all participants were encouraged to complete pre- and post-exercise surveys, we received both surveys from 42 participants. The surveys from these 42 participants comprise our survey population.

Value of Exercise

This study is an example of experiential education, a process in which actively engaged participants make discoveries to increase their knowledge rather than hearing about the experiences of others (Kraft and Sakofs, 1988). Many studies have suggested that guided discovery instruction is a more effective teaching technique than traditional lectures (McLennan and Heath, 2000; Mayer, 2004; Dolmans et al., 2005).

The value of the exercise was threefold. First, engaged learners became more comfortable with the concepts of climate change and increased their awareness of the potential impacts of long-term changes in temperature and precipitation regimes on their management strategies. Second, the exercise significantly increased participants' knowledge of and comfort working with state and transition models. Finally, involving land managers in a dialogue with scientists increased both groups' comfort levels by working together.

Exercise Impacts

Surveys results from 42 respondents indicate that the exercise was useful in exploring climate change concepts with respect to range management. Post-activity comments from participants included, "good exercise," "I really liked it," and "wasn't complicated; wouldn't change it." However, the exercise and ensuing discussion did not impact the types of climate information used or under consideration for future use by participants (Questions 7a, 8a, 5b, and 6b; Table 2). No statistically significant changes in the types of climate information used by or under consideration for future use by participants were observed between pre- and post-activity surveys based on McNemar's test. Participants mainly rely on seasonal precipitation forecasts (69%) and historical precipitation information (73%) to make management decisions.

The exercise was also useful in increasing knowledge of and comfort with using state and transition models for management decision-making, as indicated by the survey results. At the commencement of the exercise, only 29 of 42 survey respondents (69%) stated they had heard of state and transition models (Question 1a). Of the 42 respondents, only 16 (38%) claimed to use them (Question 2a). On both the pre- and post-exercise surveys, respondents were asked to rate their knowledge level pertaining to state and transition models on a scale from 0 to 5. Over the course of the exercise, participants' knowledge level significantly increased from mean of 2.52 to 2.88 (two-sided *p* value = 0.011, Wilcoxon signed-rank test; Table 2). Similarly, participants were asked to rate their comfort level with using state and transition models on a scale from 0 to 5 on both the pre- and post-exercise surveys. Participants' comfort levels with state and transition models also increased significantly during the exercise from mean of 2.26 to 2.67 (two-sided *p* value = 0.007, Wilcoxon signed-rank test; Table 2).

On both the pre- and post-exercise surveys, participants were asked whether they would use state and transition models (Question 3a, 1b). Fifteen participants clearly responded "yes" to this question in both the pre- and post-exercise surveys. Similarly, two participants clearly responded "no" in both surveys. However, three individuals who provided no answer to this question in the pre-exercise survey responded "yes" in the post-exercise survey. Additionally several respondents' comments took on a decidedly more positive tone in the post-exercise survey. Post-exercise comments included, "yes, [I] will try to incorporate [state and transition models] with research results," "[state and transition models are] good for general trends," and "yes [state and transition models are useful] as explanation for observed changes."

Table 2. Statistical test results for questions repeated on pre- and post-activity surveys during an experiential learning exercise using state and transition models for managing rangeland under a changing climate.

Survey questions	Test type	*p* value
On a scale of 0–5, how much do you know about state and transition models? (4a, 2b)	Wilcoxon signed-rank	0.011
On a scale of 0–5, what is your comfort level with state and transition models? (5a, 3b)	Wilcoxon signed-rank	0.007
Which of the following types of climate information do you use now? (7a, 5b–Seasonal temperature forecasts)	McNemar's test	0.617
Which of the following types of climate information do you use now? (7a, 5b–Historical temperature information)	McNemar's test	0.683
Which of the following types of climate information do you use now? (7a, 5b–Seasonal precipitation information)	McNemar's test	0.480
Which of the following types of climate information do you use now? (7a, 5b–Historical precipitation information)	McNemar's test	0.617
Which of the following types of climate information do you use now? (7a, 5b–Departure from average, precipitation)	McNemar's test	0.617
Which of the following types of climate information do you use now? (7a, 5b–Departure from average, temperature)	McNemar's test	1.000
Which of the following climate information would you consider using in the future? (8a, 6b–Seasonal temperature forecasts)	McNemar's test	0.450
Which of the following climate information would you consider using in the future? (8a, 6b–Historical temperature information)	McNemar's test	0.752
Which of the following climate information would you consider using in the future? (8a, 6b–Seasonal precipitation information)	McNemar's test	1.000
Which of the following climate information would you consider using in the future? (8a, 6b–Historical precipitation information)	McNemar's test	1.000
Which of the following climate information would you consider using in the future? (8a, 6b–Departure from average, precipitation)	McNemar's test	0.248
Which of the following climate information would you consider using in the future? (8a, 6b–Departure from average, temperature)	McNemar's test	0.371

When asked what would increase the participants' knowledge and comfort levels (Question 6a, 4b), 60% of the participants cited increased hands-on exposure and practice with state and transition models. Responses to this question included, "more exercises like this one," "practice and observation," and "more work with them."

Lessons Learned

Key findings from this exercise fell into several categories:

- While a substantial majority of participants found the climate data and information straightforward, some participants found the climate information too complicated to understand.
- Many participants required more detailed data to give them a sense of the extreme events that drive many of their decisions and ecosystem processes.
- Simultaneously interpreting precipitation variations and temperature trends posed a major challenge to participants, who, in this very arid region, gave greater weight to precipitation variations.
- Despite intentional efforts to keep the exercise simple, the participants found that the exercise would have had greater value if it were more realistic, particularly with respect to the connection between management options and financial condition.

Overall, the participants indicated that the exercise was worthwhile. Comments heard following the exercise and survey responses indicated that the data provided as part of the exercise were realistic, useful, and were presented at an appropriate level of difficulty. Many participants felt no changes were necessary to the exercise; however, several offered useful insights for ways to improve the activity and to make it more realistic.

During the break-out group, 37 participants (88%) consulted the precipitation information provided for the exercise (Question 7b), and 35 participants (83%) indicated that the information was helpful in making management decisions. Three respondents (7%) indicated that the information was too complicated; one participant (2%) indicated that the information was not specific enough.

The results were similar for the temperature data and the departures from average information provided as part of the exercise (Questions 8b and 9b). Thirty-one participants (74%) used the temperature data and 35 participants (83%) used departures from average data provided. Both datasets were reported to be helpful in making management decisions (69% for temperature data; 76% for departures from average). Three respondents indicated that the two datasets were too complicated; the same participants had indicated that the precipitation data was too complicated. Finally, two respondents felt the two datasets were not specific enough.

Responses to survey Question 10b, regarding problems encountered while using the provided climate information, indicated that this information was well-received by activity participants. Twenty-seven participants (64%) indicated no problems using the datasets provided, and another nine participants (21%) provided no answer to this question. Of participants reporting problems, the issues encountered were mainly with the level of detail of the datasets rather than problems with using the data. One participant reporting problems indicated that the climate information was not enough to merit land management decisions, as specific climatic conditions interact with other disturbances. Another respondent felt that temperature averages did not provide sufficient detail and desired the high and low values. Similarly, another participant felt that average precipitation values were not specific enough and desired specific event size and duration information. These comments about specificity and the need for precipitation event or temperature minimum–maximum information point to a larger issue about the complexity of range management decisions and the level of detail needed to portray climate variations that have meaningful effects on their operations. The mean is but one "statistical moment" and it may not be the most important one. This challenges climatologists to give more information on extremes, or it challenges the range mangers to make use of averages in more creative ways.

Many participants commented on the difficulty of simultaneously interpreting both temperature and precipitation. Comments from the small group discussions suggested that participants placed their emphasis on precipitation data when determining whether rangeland ecology would change or if specific management actions would be effective. Most commented that they noticed the trend in temperature, but did not know how to explicitly integrate it with the precipitation information. Discussions during the exercise debriefing session suggested that this issue could be addressed by the inclusion of a drought index, which combines the influences of temperature and precipitation, such as the Palmer drought severity index (PDSI). Similarly, a measure of soil moisture conditions, which is an important determinant of rangeland ecosystem function, could be incorporated into future exercises.

Other suggestions included improving the overall realism of the exercise, as well as increasing the variety of management options allowed and making explicit the financial component of the exercise. The initial list of management options was not intended to be complete, but rather a starting point to initiate discussion of additional options not listed. The financial component in the initial version of the exercise was kept simple to focus attention on the interactions between climate and management decisions. Participants commented that it was too simple and drastically reduced their vulnerability to climatic variability and changes. They were able to institute unrealistic management options to counteract climatic stressors because of the lack of explicit handling of finances. The relative ranking of the cost of management options (low to high) was too ambiguous for many participants and lacked the ability to carry finances gained in one period over to the next. Participants suggested incorporating a simple balance sheet with realistic monetary values attached to each management option and each randomly determined financial condition. This would allow users to "save" money for long-term planning or use all of their finances to take advantage of short-term climatic conditions that may favor a particular management action (seeding during a wet period or prescribed fire during a dry period). The chance component in rolling a die to determine financial condition for each period could also include additional bonuses or penalties like winning a grant for restoration effort, or needing to pay for infrastructure repairs.

The evaluation elicited suggestions for ways to improve the activity. Of the 24 participants that provided comments, six stated that the activity did not require any changes; that the activity "was not complicated," that it was a "good exercise," and they "really liked it." Some participants noted that the exercise could be improved by the inclusion of additional information as follows: more specific information relating to each state in the state and transition model, more background text information relating to state and transition models, and more general information about the assigned ecological site.

Broader Application

The climate change and range management experiential learning exercise proved to be quite valuable to both land managers and scientists. Though designed for use in semi-desert grasslands in the southwestern United States, this exercise could be adapted relatively easily for use in any part of the country. Required adaptations would include selecting a local major land resource area (MLRA); modifying the initial state of the parcel, the management objectives, and the potential environmental disturbances to be appropriate for the MLRA; and developing locally relevant temperature and precipitation datasets based on climate change projections for the region. Based on the time required to develop these datasets for the workshop, it is estimated that it would take a user 8 hours or less to make these modifications to the exercise.

The adapted exercise is equally appropriate for use by land managers, as presented in this article, or by undergraduate college classes studying land management issues. Experiential learning has been shown to be a more effective teaching method than expository instruction, as it fosters critical thinking, improves communication skills among participants, and actively engages learners (Dolmans et al., 2005). Experiential learning has effectively been incorporated into a variety of undergraduate and graduate-level natural resource courses (e.g., Stout and Lee, 2004; Barbarick et al., 2005; Teplitski and McMahon, 2006).

Conclusions and Next Steps

The exercise served as a useful mechanism to engage range managers and livestock producers on the issue of climate change and its potential impacts to their management decisions. It also served as a framework under which stakeholders and scientists could work together to explore research and information needs. The exercise helped reveal and highlight land managers' needs for climate information beyond traditional statistical averages. Needs appear to include information on potential changes to the likelihood, frequency, and duration of climate and weather extremes, important in long-term planning to reduce vulnerability to climate change. Finally, this exercise significantly increased participants' familiarity and comfort with state and transition models. The success of this exercise underscores the value of science extension and outreach in communicating information key for management decisions.

A working group consisting of private ranchers, agency range managers, and university scientists is presently being formed to continue the discussions initiated at the workshop. This group will work to refine the exercise using feedback from the workshop and develop a strategy to engage additional range managers through county-level extension programming and livestock grower associations. A software-driven version of the exercise is also being discussed for web deployment or for distribution on compact discs. Through these additional efforts, new groups of range managers will be able to explore potential interactions between climate change and range management across the southwestern United States.

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