Multi-disciplinary development of state and transition models
An Example from Northwestern Colorado

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Outline

• Introduction
• Integrating Local Knowledge and Field Data to Create STMs in northwestern Colorado
• Lessons Learned
Models help us learn about the way the world works.
State and Transition Models: A Road Map to Ecological Change
STMs also help us learn

- Tacit $\rightarrow$ explicit knowledge
- Store our current understanding of vegetation dynamics
- Allow it to be updated as we learn more

Adaptive Management Cycle

Grantham et al. 2010 Front. Ecol. Environment
Study Area: Elkhead Watershed, northwestern Colorado
A Patchwork of Ecological Sites

Example Ecological Site Map with Aerial Photo
State and Transition Model Project
Learning from the Land in Northwest Colorado
How did we Learn from the Land in Northwest Colorado?

Local Knowledge
Semi-structured interviews
2006-7

Ecological Data
Observational Study
2007-9

Integrated Participatory Workshops
2009

Simplified Team and literature review
2010-11
Sagebrush Steppe State-and-Transition Model Based on Local Knowledge

Corrie Knapp, MS in Rangeland Ecology Colorado State University
Local Knowledge Documentation

Participant Identification
- County Ownership Records
- Community Referrals Interviews (43)
  - Semi-structured interviews (32)
  - Field Interviews (11)
Community Meetings
- Validation
Building Data-Driven State-and-Transition Models

Emily Kachergis
PhD in Ecology, Colorado State University
Where did we collect data?

Claypan and Mountain Loam Ecological Sites based on NRCS soil maps + Different Combinations of Management Practices

Sprayed

Mechanically Treated
Mountain Loam STM

Mountain Loam Data-Driven State-and-Transition Model

- Mountain Big Sage/Western Wheatgrass Shrubland
- Eroding Mountain Big Sage Shrubland
- Cultivated Lands
- Mountain Big Sage Shrubland with Diverse Understory
- Planted Grassland
- Dense Mountain Big Sage Shrubland
- Snowberry Shrubland

Transition labels: T1, T2, T3, T4, T4R, T5, T5R, T6, T6R, T7, T7R
Model Evaluation & Integration Workshops
2009 Model Integration Workshops -- Process

1. Brief introduction to STMs and concepts
2. Brief introduction to each model
3. Small-group breakout sessions with a large paper copy of each model
4. Group modeling process
5. Assessing agreement
6. Survey
Integrated Mt. Loam Model
Model Simplification

Maximum of four states, in order to quantify

Review by interdisciplinary team: 3 human ecologists, 4 rangeland ecologists, 2 ag economists

Literature review

Transition probability elicitation
1.3 Imagine a situation like that described by the conditions in row A—land that has been aerially sprayed in the last 3 years. How many pastures out of 10 that had been aerially sprayed but not burned in the last 3 years have Moderate-High Shrub Cover? Circle that number.

<table>
<thead>
<tr>
<th>Fire</th>
<th>Aerial Spraying</th>
<th>Probability Moderate-High Shrub Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>No</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
**Mt. Big Sagebrush-Diverse Understory**

- **T1** Reduction of the herbaceous understory, caused by heavy grazing and/or drought, combined with lack of disturbance that reduces shrub cover.
- **T1R** Disturbance that reduces shrub cover (fire, herbicide) combined with recovery of the herbaceous understory under lower grazing pressure and/or more precipitation.

**Mt. Big Sagebrush-Wheatgrass Shrubland**

- **T2** Moderate grazing in wetter years allows western wheatgrass to become dominant.

**Dense or Eroding Mt. Big Sagebrush-Shrubland**

- **T3** Heavy grazing causes continued reduction in wheatgrass cover and an increase in shrub cover.
Mt. Big Sagebrush-Diverse Understory
1934 lbs/acre
Species richness: 41.4
Invasives: 0%
Erosiveness: 5.2
Sage Grouse habitat: .67
Mule Deer habitat: .61

Mt. Big Sagebrush-Wheatgrass
1215 lbs/acre
Species richness: 43.4
Invasives: 0.6%
Erosiveness: 7.1
Sage Grouse habitat: .75
Mule Deer habitat: .64

Dense or Eroding Mt. Big Sagebrush Shrubland
807 lbs/acre
Species richness: 38.2
Invasives: 2.2%
Erosiveness: 6.6
Sage Grouse habitat: .53
Mule Deer habitat: .51
Claypan STM-Simplified for Simulation Model

Native Alkali Sagebrush Steppe

T1

Eroding Alkali Sagebrush Shrubland

T2

Native Grassland

T3

Alkali Sagebrush-Western Wheatgrass Shrubland

T4
Claypan STM-Ecosystem Services

Native Alkali Sagebrush Steppe
- 1192 lbs/acre
- Species richness: 36.6
- Invasives: 0.7%
- Erosiveness: 8.5
- Sage Grouse habitat: .47
- Mule Deer habitat: .26

Native Grassland
- 960 lbs/acre
- Species richness: 28.3
- Invasives: 0.5%
- Erosiveness: 8.0
- Sage Grouse habitat: .24
- Mule Deer habitat: .11

Alkali Sagebrush-Western Wheatgrass Shrubland
- 1039 lbs/acre
- Species richness: 29.3
- Invasives: 0.8%
- Erosiveness: 4.6
- Sage Grouse habitat: .41
- Mule Deer habitat: .27

Eroding Alkali Sagebrush Shrubland
- 268 lbs/acre
- Species richness: 34.7
- Invasives: 2.8%
- Erosiveness: 15.2
- Sage Grouse habitat: .32
- Mule Deer habitat: .1
What did we learn?

Local Knowledge
Semi-structured interviews
2006-7

Ecological Data
Observational Study
2007-9

Integrated Workshops
2009

Simplified Team and literature review
2010-11
Model development is a process...
A. Soil descriptions and plant species composition differ from other ecological sites, justifying the separation into the Claypan ecological site (ED)

B. “Diverse” and “Bluegrass” are perceived to shift easily between each other/not make a big difference for management, so are grouped within a “Native Sagebrush Steppe” state (LK, ED, IN)

C. Alkali Sagebrush/Western Wheatgrass is perceived to be different from the Native SBS because of soil dynamic property differences (ED); LK, IN, SI varied from seeing this as part of the range of variability of Native SBS (weather or soil texture-related) to seeing it as a degraded state to seeing it as a desirable state for grazing

D. Eroding Alkali sagebrush shrubland is a separate state because the process of erosion is accelerated here (LK, ED, IN)

E. High grazing pressure, drought, and/or fire reduce herbaceous plant cover, causing erosion; reverse transition caused by the opposite (LK, ED, IN, SI)
Different knowledge types have different strengths and limitations…

<table>
<thead>
<tr>
<th>Type</th>
<th>Strength</th>
<th>Limitation</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Knowledge</td>
<td>- Long time frame &lt;br&gt;- Variety of management practices/disturbances &lt;br&gt;- Identifies social drivers &lt;br&gt;- Improves communication</td>
<td>- No quantitative evidence &lt;br&gt;- Not as specific about biophysical dynamics</td>
<td>STM for a vegetation type in a region (or, with field trips, ecological site)</td>
</tr>
<tr>
<td>Ecological Data (Observational)</td>
<td>- Quantitative evidence &lt;br&gt;- Records a variety of biophysical indicators</td>
<td>- Misses temporal variability &lt;br&gt;- May miss value-defined states</td>
<td>STM for an ecological site in a region</td>
</tr>
<tr>
<td>Model Integration</td>
<td>- Reconciles different knowledge sources &lt;br&gt;- Complex &lt;br&gt;- More accurate</td>
<td>- Representing areas of disagreement &lt;br&gt;- Complex</td>
<td>Complex STM for an ecological site, incorporating more drivers</td>
</tr>
<tr>
<td>Simplified</td>
<td>- Easier to use and quantify</td>
<td>- Lacks complexity and nuance of real world</td>
<td>Simple STM for an ecological site, focused on the most frequent/important dynamics</td>
</tr>
<tr>
<td>Local Knowledge</td>
<td>Ecological Data</td>
<td>Integrated</td>
<td>Simplified</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------</td>
<td>------------------------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>Natural sagebrush steppe</td>
<td>Mountain big sagebrush/diverse understory</td>
<td>Mountain big sagebrush/diverse understory</td>
<td>Mountain big sagebrush/diverse understory</td>
</tr>
<tr>
<td>Native sagebrush steppe</td>
<td>Native sagebrush steppe</td>
<td>Early seral</td>
<td></td>
</tr>
<tr>
<td>Degraded sagebrush steppe</td>
<td>Mountain big sagebrush/western wheatgrass</td>
<td>Mountain big sagebrush/western wheatgrass</td>
<td>Mountain big sagebrush/western wheatgrass</td>
</tr>
<tr>
<td>Improved sagebrush steppe</td>
<td></td>
<td>Invaded sagebrush steppe</td>
<td></td>
</tr>
<tr>
<td>Chemically managed grassland</td>
<td></td>
<td>Intensively managed grassland</td>
<td></td>
</tr>
<tr>
<td>Weedy sagebrush steppe</td>
<td></td>
<td>Weedy sagebrush steppe</td>
<td></td>
</tr>
<tr>
<td>Thick sagebrush steppe</td>
<td>Dense mountain big sagebrush shrubland</td>
<td>Dense/eroding mountain big sagebrush shrubland</td>
<td>Dense/eroding mountain big sagebrush shrubland</td>
</tr>
<tr>
<td>Cultivated lands</td>
<td>Cultivated lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation Reserve Program</td>
<td>Planted grasslands</td>
<td></td>
<td>Planted</td>
</tr>
</tbody>
</table>

…but are ultimately complementary
Disagreements happen...
...but they are fruitful for future research and learning

Hypotheses that can be tested using Adaptive Management:

**Claypan Eroding**
- Transition to Eroding caused by heavy grazing, drought, and/or fire
- Transition back to Diverse is caused by reduction in grazing and favorable precipitation, although it is very unlikely

**Mountain Loam Dense**
- Transition to Dense caused by heavy grazing and/or drought that reduces shrub cover
- Transition back requires shrub disturbance in addition to favorable precipitation and reduced grazing, and is fairly likely given these conditions
Implications for STM development

• Integrating multiple knowledge sources makes better models
• Increases buy-in, willingness to use models on the ground
• Increases potential for learning
• Next step: apply STMs on the ground in an adaptive management context
Thanks!

**Project team:** Maria Fernandez-Gimenez, Emily Kachergis, Windy Kelley, Corrie Knapp, Kira Puntenney, Willow Hibbs, Jay Parsons, James Pritchett, John Ritten, Roy Roath, Monique Rocca, Ryan Wattles

**Community Advisory Group:** Ranchers of the Elkhead watershed and Moffatt County, Routt County Extension, Routt National Forest, BLM Little Snake Field Office, CO Division of Wildlife, TNC Carpenter Ranch, NRCS, Community Agricultural Alliance, Tread of Pioneers Museum.

Funding provided by: USDA NIFA AFRI, CO Agricultural Experiment Station, USDA NRCS
Summing it all up…
Ways of incorporating local knowledge

<table>
<thead>
<tr>
<th>Method</th>
<th>Number needed per ecological site</th>
<th>Opportunity for ranchers to learn about state-and-transition models</th>
<th>Time commitment for ranchers</th>
<th>Time required for analysis</th>
<th>Interaction among participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development team</td>
<td>Single ongoing process (4–8 meetings)</td>
<td>High</td>
<td>Weeks–months</td>
<td>None</td>
<td>High</td>
</tr>
<tr>
<td>Workshops</td>
<td>1–2</td>
<td>Medium</td>
<td>3–8 hours</td>
<td>4–8 hours</td>
<td>Medium–High</td>
</tr>
<tr>
<td>Interviews</td>
<td>5–10</td>
<td>Medium</td>
<td>1–3 hours</td>
<td>1–2 days</td>
<td>None</td>
</tr>
<tr>
<td>Focus groups</td>
<td>1–2</td>
<td>Low</td>
<td>2 hours</td>
<td>2–6 hours</td>
<td>Medium–High</td>
</tr>
<tr>
<td>Surveys</td>
<td>30–50</td>
<td>Low</td>
<td>30 minutes–1 hour</td>
<td>1–2 days</td>
<td>None</td>
</tr>
<tr>
<td>Feedback meeting</td>
<td>1–2</td>
<td>Low</td>
<td>1–2 hours</td>
<td>2–4 hours</td>
<td>Low–Medium</td>
</tr>
</tbody>
</table>

1The time estimations provided in this table serve as a general reference and will vary based on the individual and prior experience with methods.

2Number of events will vary based on the heterogeneity and spatial scale of the ecological site.

Knapp et al. 2010 Rangelands
Where to Find ESDs?

Reviewed and completed ESDs: [http://esis.sc.egov.usda.gov](http://esis.sc.egov.usda.gov)
Where to Find Soil Maps?

http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
Identifying Ecological Sites on Your Ranch

1. Gather Information
   - Key to Ecological Sites
   - Topographical Map
   - Soil Map
   - Soil Survey Descriptions
   - Ecological site descriptions (ESD)

2. Go to the field
   - Go to a site.
   - Find out where you are on the maps.
   - According to the soil and topographic maps, what ecological site should you be on?

3. Compare physical characteristics
   - Do you have the same topography as the ESD?
   - Are you at the same elevation as the ESD?
   - Is the site in the same aspect as the ESD?
   - Are the soil properties the same as described in the ESD?

4. Compare vegetation
   - What plants are on the site?
   - Which state or community are you in?