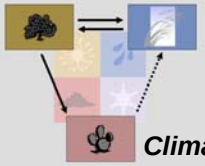
THE GAME

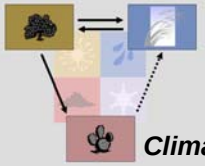
STATE & TRANSITION MODELS

- Conceptual vegetation models
- Different succession models
- Depict changes rangelands
- Response to climate and/or mismanagement



STATE & TRANSITION MODELS

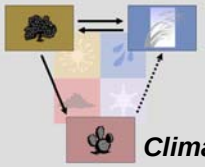
- **Aid land managers**
- **Anticipate consequences of management decisions**
- **Identify management decisions leading to desired outcomes**



What are the boxes & arrows?????

STATE

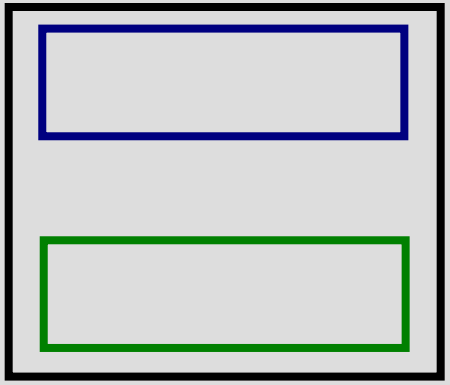
TRANSITION

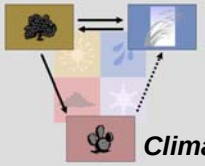


BOXES

- **VEGETATION STATES**
  - **Different distinctive plant communities that may exist on an ecological site. Not easily reversible**

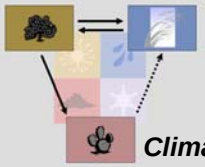
- **Communities**
  - **Changes in the dominant or significant species. Easily reversible**





ARROWS

- **TRANSITIONS**
  - **Events or actions that cause a shift from one state to another. Not easily reversible**
- **COMMUNITY PATHWAY**
  - **Changes in plant abundance. Easily reversible**



Sideoats grama, other grasses

False mesquite, shrub buckwh

Other shrubs 1-10%

Annual forbs & grasses fluctua
(drought/ El Nino)

Roads, Trails introduce lovegrass

Drought / Fire

Continuous heavy grazing

Fire/Drought/Grazing

Shrubs succulents dominate

Lesser perennial grasses

Annual grasses fluctuate with climate
(drought/ El Nino)

NATIVE GRASS, FORB HALF SHRUB

Unknown

ss invades

herbs minor amounts

Native plants persists in rock outcrops and canyons

Lehmann lovegrass more dominant with repeated fire

LEHMANN LOVEGRASS

D. Robinett, NRCS

Drought, Climate Warming

Continuous heavy grazing

Unknown

Mimosas and mesquite 10-35%

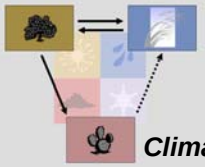
Mimosas and mesquite sprout after fires

Other shrubs/succulents 5-20%

Understory annuals and half-shrubs

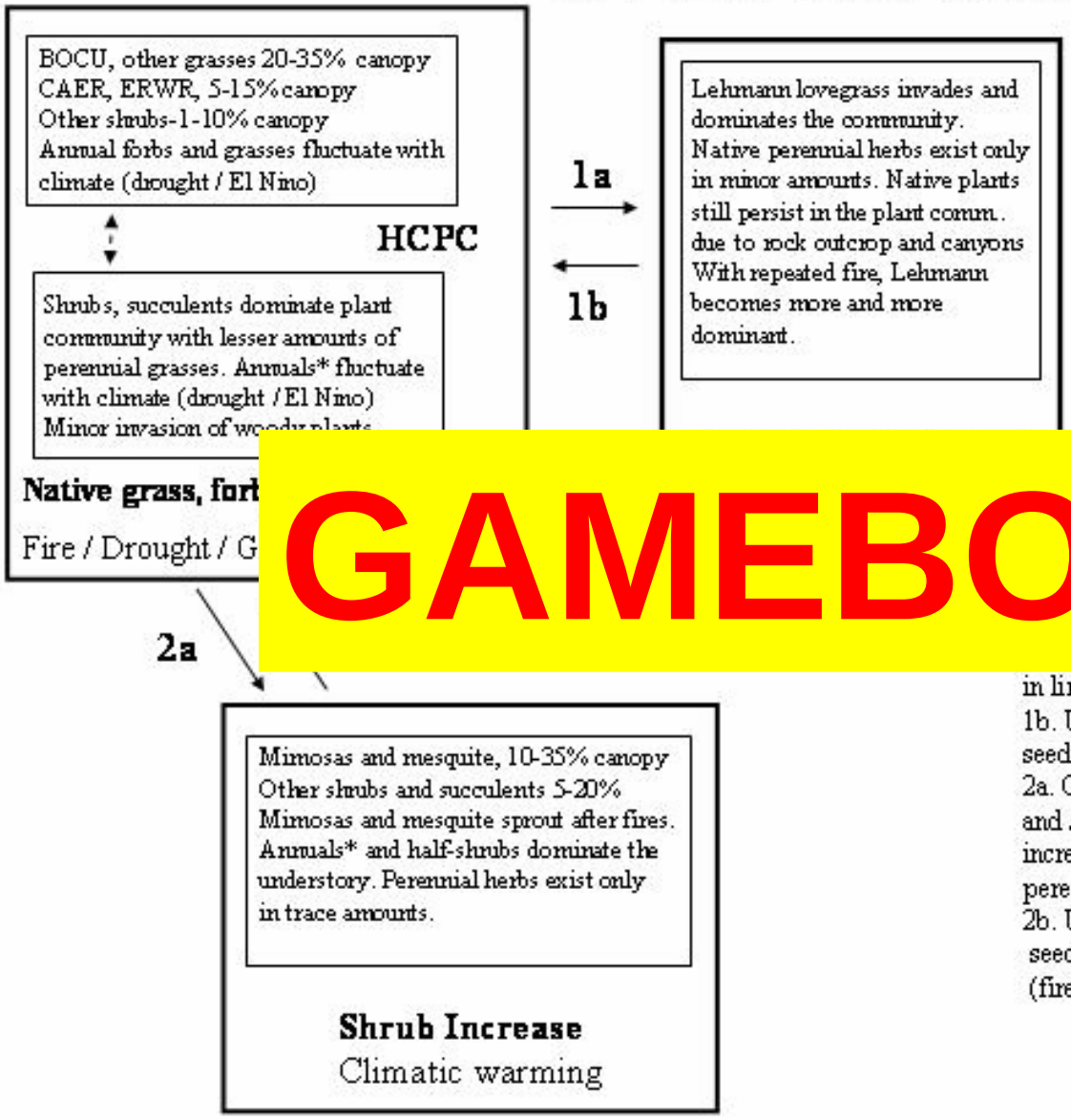
Trace perennial herbs

SHRUB INCREASE



Climate Change & Range Management: The Game of States and Transitions

MLRA 41-3 (12-16"), Granitic Hills



lovegrass
he site. Other
in grass occur
in limited areas.

1b. Unknown. Possible herbicide treatment of exotics species and seeding of native grasses.

2a. CHG with drought, climatic warming. Increase by mimosas and / or mesquite. Other shrubs and succulents can increase also. Shrubs quickly re-sprout after fire. Remnant perennial grasses cannot re-colonize areas with shrub competition.

2b. Unknown, PG/NG with herbicide shrub control. Possible seeding of native grasses, maintenance treatments for shrubs (fire, herbicide).

*Native annuals dominant, may be patches of some non-natives

CHG – continuous heavy grazing
PG/NG – proper grazing, no grazing
CAER – false mesquite, ERWR– shrub buckwheat
BOER – black grama, BOCU – sideoats grama

Objectives

1. **Use state & transition models**
   - **illustrate interactions between climate variability/change and range management activities**

Objectives

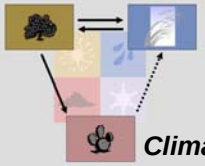
2. **Explore how state and transition models are constructed**
   - **highlight strengths/weaknesses**
   - **assumptions**
   - **new information needs**

Objectives

3. Assess needs
   - research
   - applications
   - tools
   - data

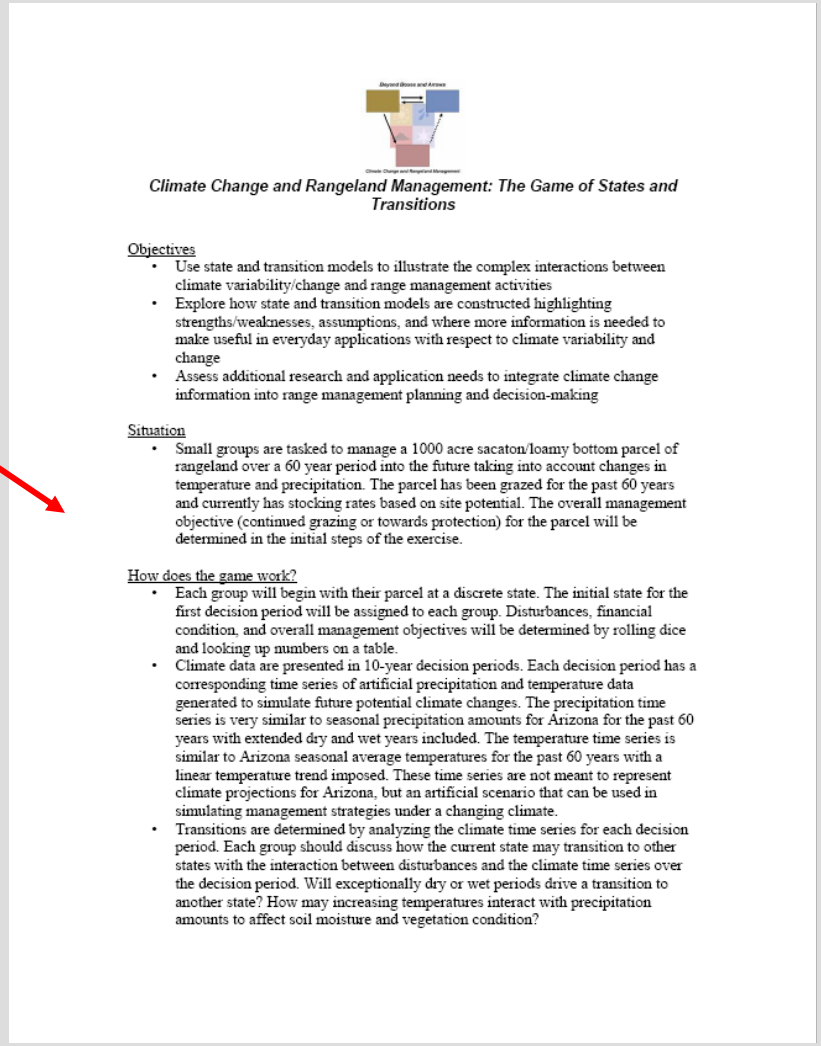
Situation

- Small groups are management teams
- 1000 acre sacaton/loamy bottom parcel
- ‘birdseye view’ of 60-year management period with 10-year decision windows
- parcel has been historically grazed (60 years)
- currently has stocking rates based on site potential
- management objective (continued grazing or towards protection) will be determined



What you need to play

- **Instruction Sheet**



Climate Change and Rangeland Management: The Game of States and Transitions

Objectives

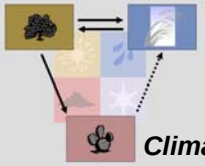
- Use state and transition models to illustrate the complex interactions between climate variability/change and range management activities
- Explore how state and transition models are constructed highlighting strengths/weaknesses, assumptions, and where more information is needed to make useful in everyday applications with respect to climate variability and change
- Assess additional research and application needs to integrate climate change information into range management planning and decision-making

Situation

- Small groups are tasked to manage a 1000 acre sacaton/loamy bottom parcel of rangeland over a 60 year period into the future taking into account changes in temperature and precipitation. The parcel has been grazed for the past 60 years and currently has stocking rates based on site potential. The overall management objective (continued grazing or towards protection) for the parcel will be determined in the initial steps of the exercise.

How does the game work?

- Each group will begin with their parcel at a discrete state. The initial state for the first decision period will be assigned to each group. Disturbances, financial condition, and overall management objectives will be determined by rolling dice and looking up numbers on a table.
- Climate data are presented in 10-year decision periods. Each decision period has a corresponding time series of artificial precipitation and temperature data generated to simulate future potential climate changes. The precipitation time series is very similar to seasonal precipitation amounts for Arizona for the past 60 years with extended dry and wet years included. The temperature time series is similar to Arizona seasonal average temperatures for the past 60 years with a linear temperature trend imposed. These time series are not meant to represent climate projections for Arizona, but an artificial scenario that can be used in simulating management strategies under a changing climate.
- Transitions are determined by analyzing the climate time series for each decision period. Each group should discuss how the current state may transition to other states with the interaction between disturbances and the climate time series over the decision period. Will exceptionally dry or wet periods drive a transition to another state? How may increasing temperatures interact with precipitation amounts to affect soil moisture and vegetation condition?

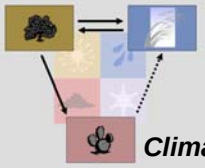


What you need to play

- **Worksheet**

State and Transition-Climate Worksheet Group Number _____ Management Objective _____ Desired State _____

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1						
2						
3						
4						
5						
6						



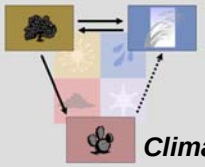
What you need to play

- Lookup Table

Lookup Table

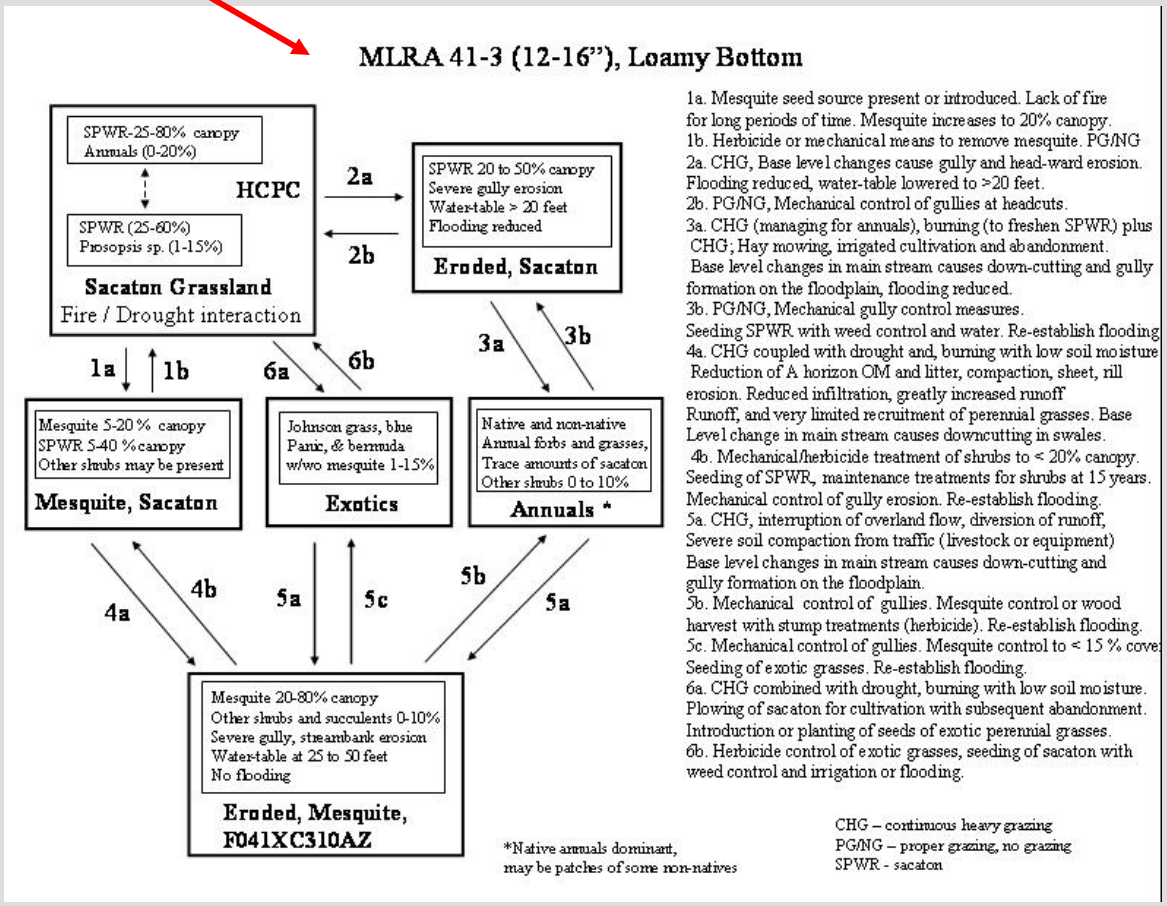
	Mgt Goals towards	*Financial Standing*	*Disturbance*
Number Rolled	Once at beginning	Every decade	Every decade
1	continued production	Good	Climate & Wildfire
2	continued production	Poor	Climate Only
3	preservation	Poor	Climate & Invasive Species Introduction
4	preservation	Good	Climate & Insect/Small 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

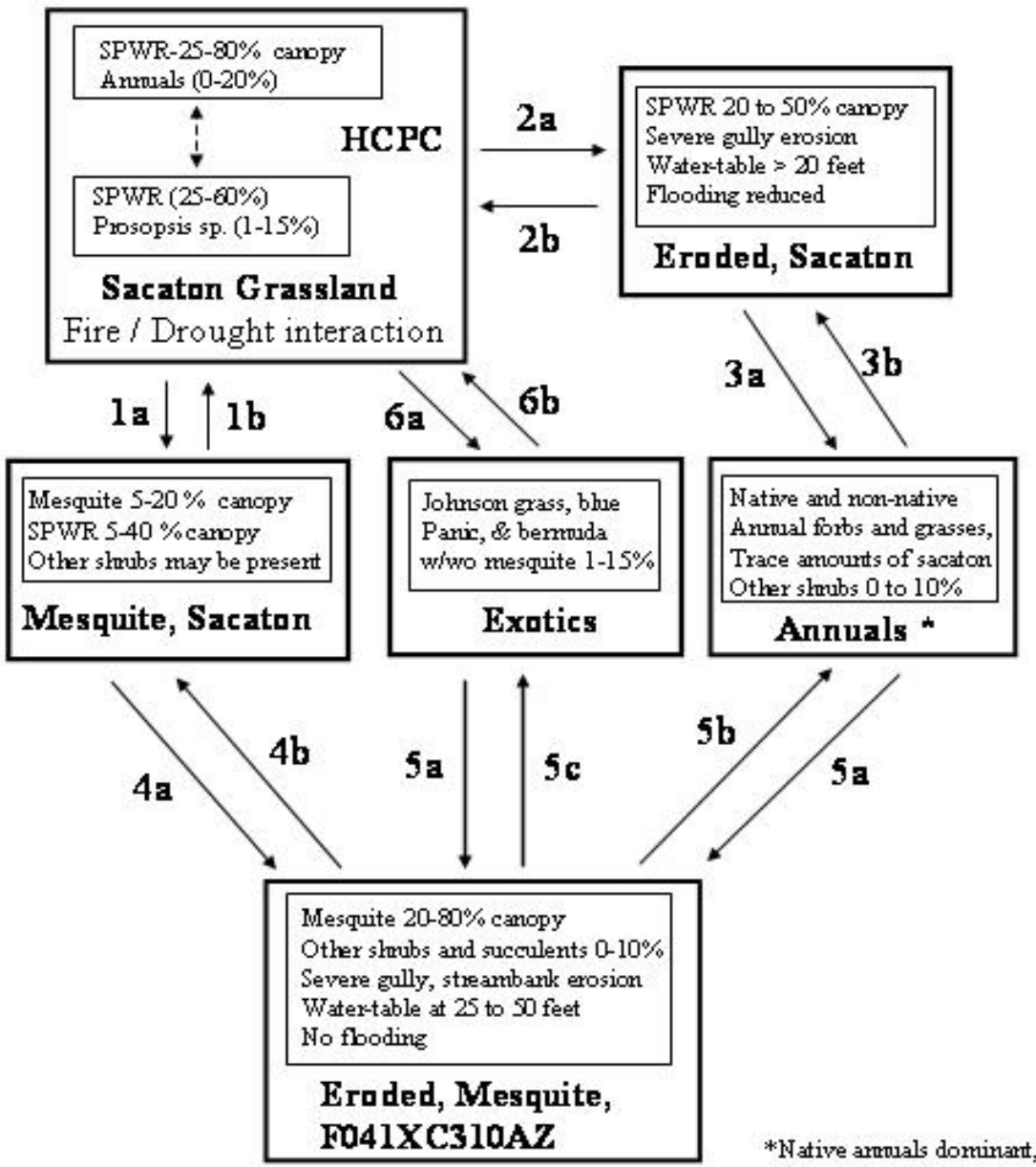


What you need to play

- State & Transition Model (**Game board**)



MLRA 41-3 (12-16"), Loamy Bottom



1a. Mesquite seed source present or introduced. Lack of fire for long periods of time. Mesquite increases to 20% canopy.
1b. Herbicide or mechanical means to remove mesquite. PG/NG
2a. CHG, Base level changes cause gully and head-ward erosion. Flooding reduced, water-table lowered to >20 feet.
2b. PG/NG, Mechanical control of gullies at headcuts.
3a. CHG (managing for annuals), burning (to freshen SPWR) plus CHG; Hay mowing, irrigated cultivation and abandonment. Base level changes in main stream causes down-cutting and gully formation on the floodplain, flooding reduced.
3b. PG/NG, Mechanical gully control measures. Seeding SPWR with weed control and water. Re-establish flooding
4a. CHG coupled with drought and, burning with low soil moisture Reduction of A horizon OM and litter, compaction, sheet, rill erosion. Reduced infiltration, greatly increased runoff Runoff, and very limited recruitment of perennial grasses. Base Level change in main stream causes downcutting in swales.
4b. Mechanical/herbicide treatment of shrubs to < 20% canopy. Seeding of SPWR, maintenance treatments for shrubs at 15 years. Mechanical control of gully erosion. Re-establish flooding.
5a. CHG, interruption of overland flow, diversion of runoff, Severe soil compaction from traffic (livestock or equipment) Base level changes in main stream causes down-cutting and gully formation on the floodplain.
5b. Mechanical control of gullies. Mesquite control or wood harvest with stump treatments (herbicide). Re-establish flooding.
5c. Mechanical control of gullies. Mesquite control to < 15 % cove Seeding of exotic grasses. Re-establish flooding.
6a. CHG combined with drought, burning with low soil moisture. Plowing of sacaton for cultivation with subsequent abandonment. Introduction or planting of seeds of exotic perennial grasses.
6b. Herbicide control of exotic grasses, seeding of sacaton with weed control and irrigation or flooding.

*Native annuals dominant, may be patches of some non-natives

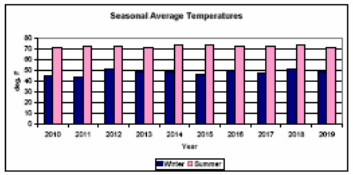
CHG – continuous heavy grazing
PG/NG – proper grazing, no grazing
SPWR - sacaton

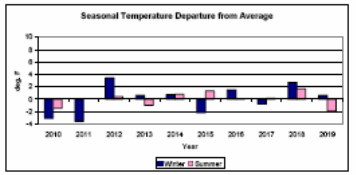
What you need to play

- Climate Data

Decision Window 1: 2010-2019

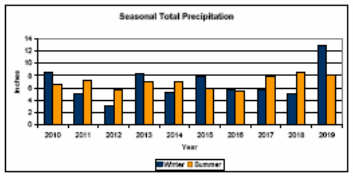
Temperature

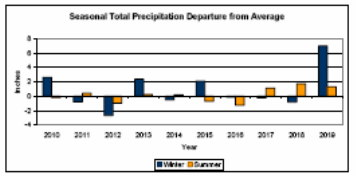




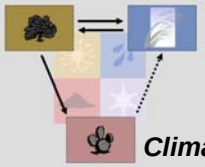
Year	Winter Avg Temp (°F)	Winter Temp Departure from Avg (°F)	Winter Temp Rank	Summer Avg Temps (°F)	Summer Temp Departure from Avg (°F)	Summer Temp Rank
2010	44.6	-3.1	cool	70.7	-1.5	cool
2011	44.0	-3.6	cool	72.2	0.0	near average
2012	51.1	3.4	very warm	72.6	0.4	near average
2013	48.3	0.6	moderately warm	71.2	-1.0	cool
2014	48.4	0.7	moderately warm	73.0	0.8	near average
2015	45.4	-2.2	cool	73.6	1.3	moderately warm
2016	49.1	1.5	moderately warm	72.3	0.1	near average
2017	46.9	-0.8	near average	72.4	0.1	near average
2018	50.4	2.7	very warm	73.9	1.7	moderately warm
2019	48.3	0.6	moderately warm	70.3	-1.9	cool

Precipitation



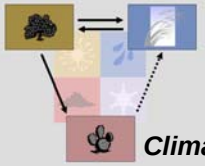


Year	Winter Total Precip (in)	Winter Precip Departure from Avg (in)	Winter Precip Rank	Summer Total Precip (in)	Summer Precip Departure from Avg (in)	Summer Precip Rank
2010	8.5	2.64	very wet	6.5	-0.18	average
2011	5.1	-0.79	average	7.1	0.43	wet
2012	3.2	-2.67	very dry	5.8	-0.96	dry
2013	8.2	2.38	very wet	7.0	0.26	average
2014	5.4	-0.49	average	6.9	0.21	average
2015	8.0	2.11	very wet	6.0	-0.69	dry
2016	5.7	-0.12	average	5.5	-1.22	dry
2017	5.6	-0.24	average	7.9	1.14	wet
2018	5.0	-0.81	average	8.5	1.73	very wet
2019	12.8	6.96	very wet	8.0	1.33	very wet



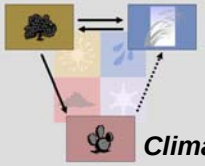
Overview

- **Use a state & transition model as the framework to discuss the complex interactions between climate and management actions.**
  - **Assigned initial state**
  - **10-year decision windows**
  - **Disturbances and financial condition are determined by chance for each decision**



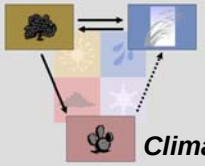
Overview

- **Climate data are presented in 10-year decision periods**
  - **Artificial future time series created from real Arizona climate data**
  - **Same precipitation time-series structure (interannual/interdecadal variability)**
  - **1° F/decade trend in temperature imposed on historical Arizona time series**

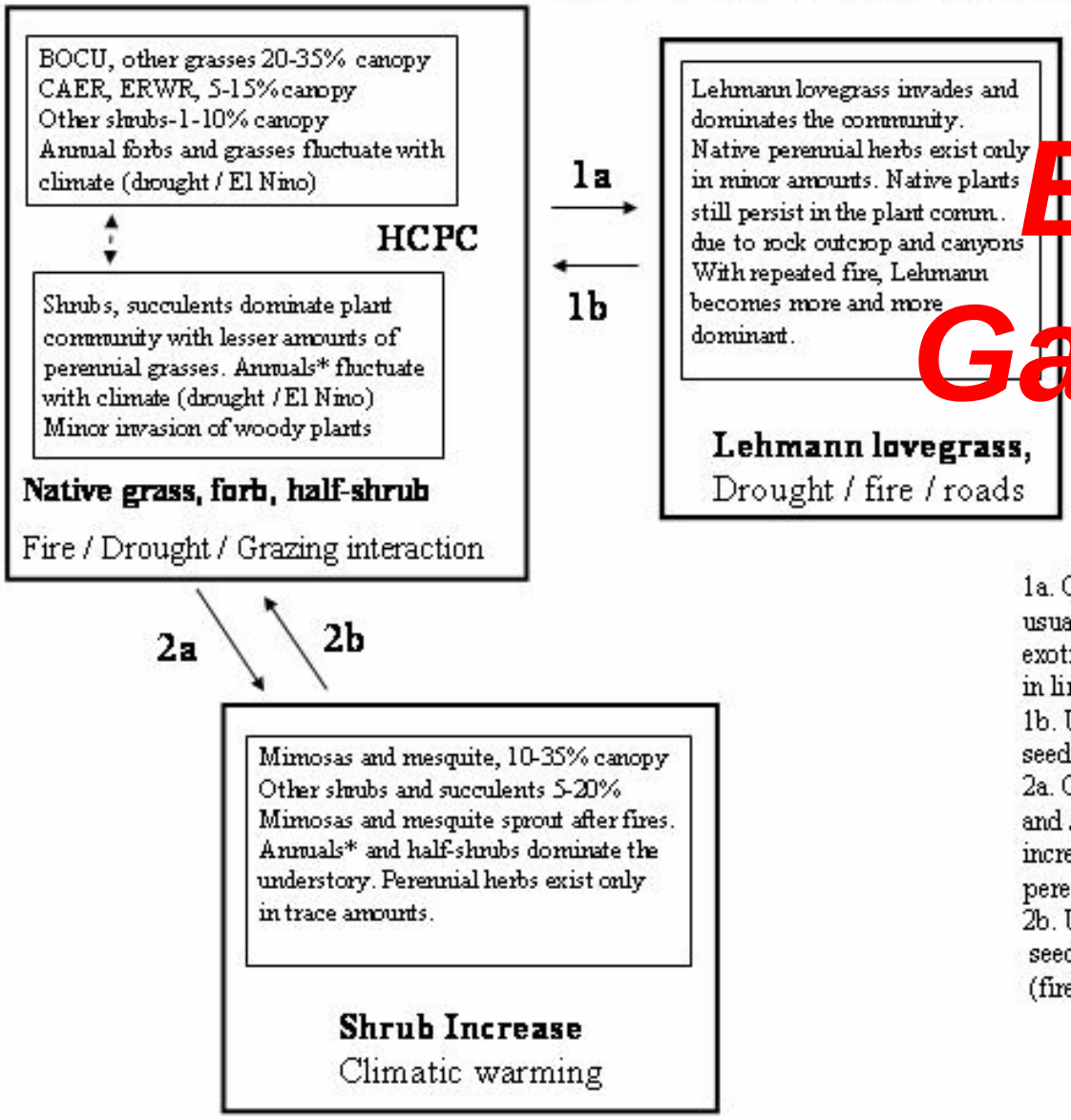


Overview

- **Transitions are determined by analyzing the climate time series for each decision period**
  - **Patterns in temperature and precipitation (wet vs. dry periods)**
  - **Seasonality (winter vs. summer)**
  - **Interactions between temperature and precipitation (higher temperatures mean higher evapotranspiration rates)**
  - **Interactions with disturbances and management actions (financial condition governs possible management actions)**
- **Results from each group are discussed and transcribed at the end of the breakout period.**



MLRA 41-3 (12-16"), Granitic Hills



Example Game Board

1a. CHG, introduction of a seed source of Lehmann lovegrass usually from roads or jeep trails through areas of the site. Other exotic perennial grasses like Natal grass and fountain grass occur in limited areas.
1b. Unknown. Possible herbicide treatment of exotics species and seeding of native grasses.
2a. CHG with drought, climatic warming. Increase by mimosas and / or mesquite. Other shrubs and succulents can increase also. Shrubs quickly re-sprout after fire. Remnant perennial grasses cannot re-colonize areas with shrub competition.
2b. Unknown, PG/NG with herbicide shrub control. Possible seeding of native grasses, maintenance treatments for shrubs (fire, herbicide).

*Native annuals dominant, may be patches of some non-natives

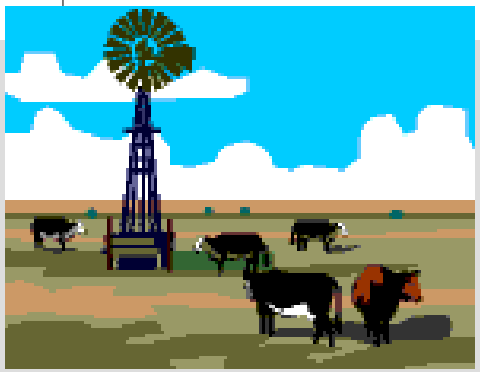
CHG – continuous heavy grazing
PG/NG – proper grazing, no grazing
CAER – false mesquite, ERWR– shrub buckwheat
BOER – black grama, BOCU – sideoats grama

Instructions

- **Get all of the game parts organized and assign one person in the group to keep notes on the worksheet.**
- **Fill out first line of worksheet**

State and Transition-Climate Worksheet Group Number 7 Management Objective *production* Desired State *native grasses*

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1						
2						



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

DESIRED PLANT COMMUNITY

- **Vegetation state that has been identified to provide uses and values desired for the site.**

- **Must provide adequate protection for the site.**

Instructions

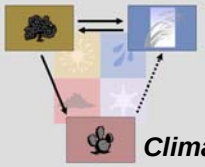
- Get all of the game parts organized and assign one person in the group to keep notes on the worksheet.
- Fill out first line of worksheet

State and Transition-Climate Worksheet Group Number 7 Management Objective *production* Desired State *native grasses*

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1						
2						

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

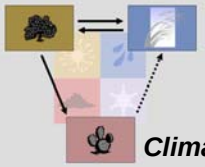


Instructions

- **Look at the first entry on your worksheet labeled '*1*' under the decision period column. If this is the first decision period, list your assigned initial state. List the ending state from the previous decision period if you are beyond first period.**

State and Transition-Climate Worksheet Group Number ***7*** Management Objective ***production*** Desired State ***native grasses***

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	native grasses					
2						



Instructions

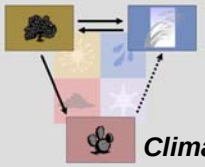
- **Roll to determine your disturbance and financial condition for the decision period**

State and Transition-Climate Worksheet Group Number 7 Management Objective *production* Desired State *native grasses*

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	native grasses	Climate & Invasives	Good			
2						

Lookup Table

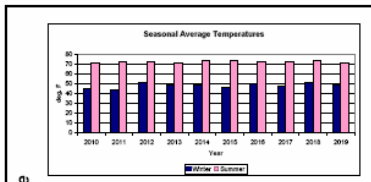
	Mgt Goals towards	Financial Standing	Disturbance
Number Rolled	Once at beginning	Every decade	Every decade
1	continued production	Good	Climate & Wildfire
2	continued production	Poor	Climate Only
3	preservation	Poor	Climate & Invasive Species Introduction
4	preservation	Good	Climate & Insect/Small Mammal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

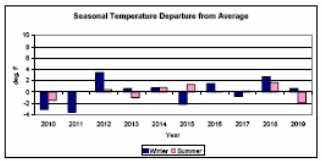


Instructions

- **Analyze climate data for decision period (don't peek ahead!)**
  - **Sequences of wet and dry years**
  - **Prolonged periods of above/below average temperature and/or precipitation**
  - **Extremes and their potential impact within the decision period**
  - **Seasonality of temperature and precipitation**

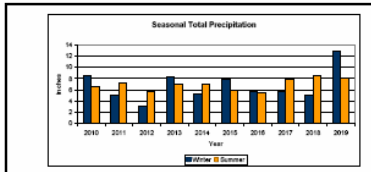
Decision Window 1: 2010-2019

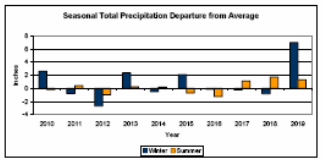




Temperature

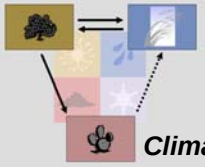
Year	Winter Avg Temp (°F)	Winter Temp Departure from Avg (°F)	Winter Temp Rank	Summer Avg Temps (°F)	Summer Temp Departure from Avg (°F)	Summer Temp Rank
2010	44.6	-3.1	cool	70.7	-1.5	cool
2011	44.0	-3.6	cool	72.2	0.0	near average
2012	51.1	3.4	very warm	72.6	0.4	near average
2013	48.3	0.6	moderately warm	71.2	-1.0	cool
2014	48.4	0.7	moderately warm	73.0	0.8	near average
2015	45.4	-2.2	cool	73.6	1.3	moderately warm
2016	49.1	1.5	moderately warm	72.3	0.1	near average
2017	46.9	-0.8	near average	72.4	0.1	near average
2018	50.4	2.7	very warm	73.9	1.7	moderately warm
2019	48.3	0.6	moderately warm	70.3	-1.9	cool





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
2010	8.5	2.64	very wet	6.5	-0.18	average
2011	5.1	-0.79	average	7.1	0.43	wet
2012	3.2	-2.67	very dry	5.8	-0.96	dry
2013	8.2	2.38	very wet	7.0	0.26	average
2014	5.4	-0.49	average	6.9	0.21	average
2015	8.0	2.11	very wet	6.0	-0.69	dry
2016	5.7	-0.12	average	5.5	-1.22	dry
2017	5.6	-0.24	average	7.9	1.14	wet
2018	5.0	-0.81	average	8.5	1.73	very wet
2019	12.8	6.96	very wet	8.0	1.33	very wet



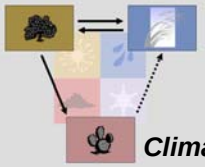
Instructions

- **Disturbance within decision period? (*Determine when you think the disturbance is most likely to occur with respect to the climate information given and use this in your discussions)***

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



Instructions

- Use management options on lookup table
  - Manage to move to another state or stay at current state
  - Use management options in concert with climate data and potential disturbances
  - You can not use expensive management options during a decision period if you are in poor financial standing!

Lookup Table

	Mgt Goals towards	*Financial Standing*	*Disturbance*
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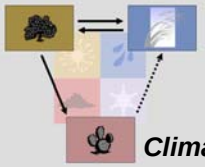

Putting it all together!

Management Options	Relative Cost
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Earthen retention dams	Medium
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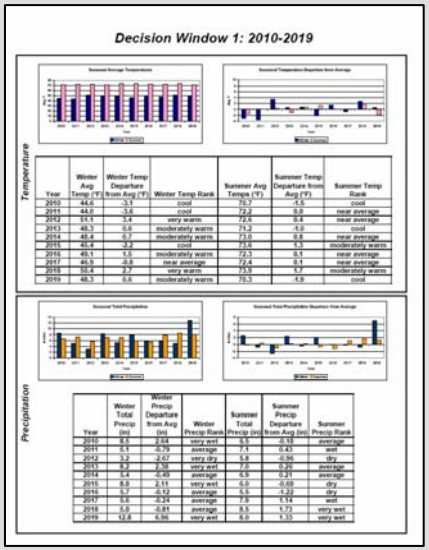
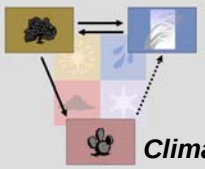


State and Transition-Climate Worksheet Group Number 7 Management Objective ***production*** Desired State ***native grasses***

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	native grasses	Climate & Invasives	Good	Herbicide control of non-native species	No change; adequate precip through period; herbicide control effective	native grasses
2						

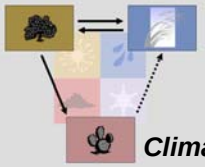


Move on to next decision period…

- Discuss as a group the interaction between the climate time series, the disturbance, management options used and the state & transition model. This is a thought exercise with no right answers, so be creative!
- When finished with a decision period, move on to the next (repeat steps 4-7). There are a total of six decision periods that cover the period from 2010 to 2069.
- After all groups are finished with as many decision periods as possible in the time allotted, we will discuss results from each group worksheet.

State and Transition-Climate Worksheet Group Number ***7*** Management Objective ***production*** Desired State ***native grasses***

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	native grasses	Climate & Wildfire	Good	Rest Rotation Grazing	No change; adequate summer precip through period; quick recovery after fire	native grasses
2	native grasses					

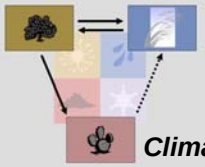


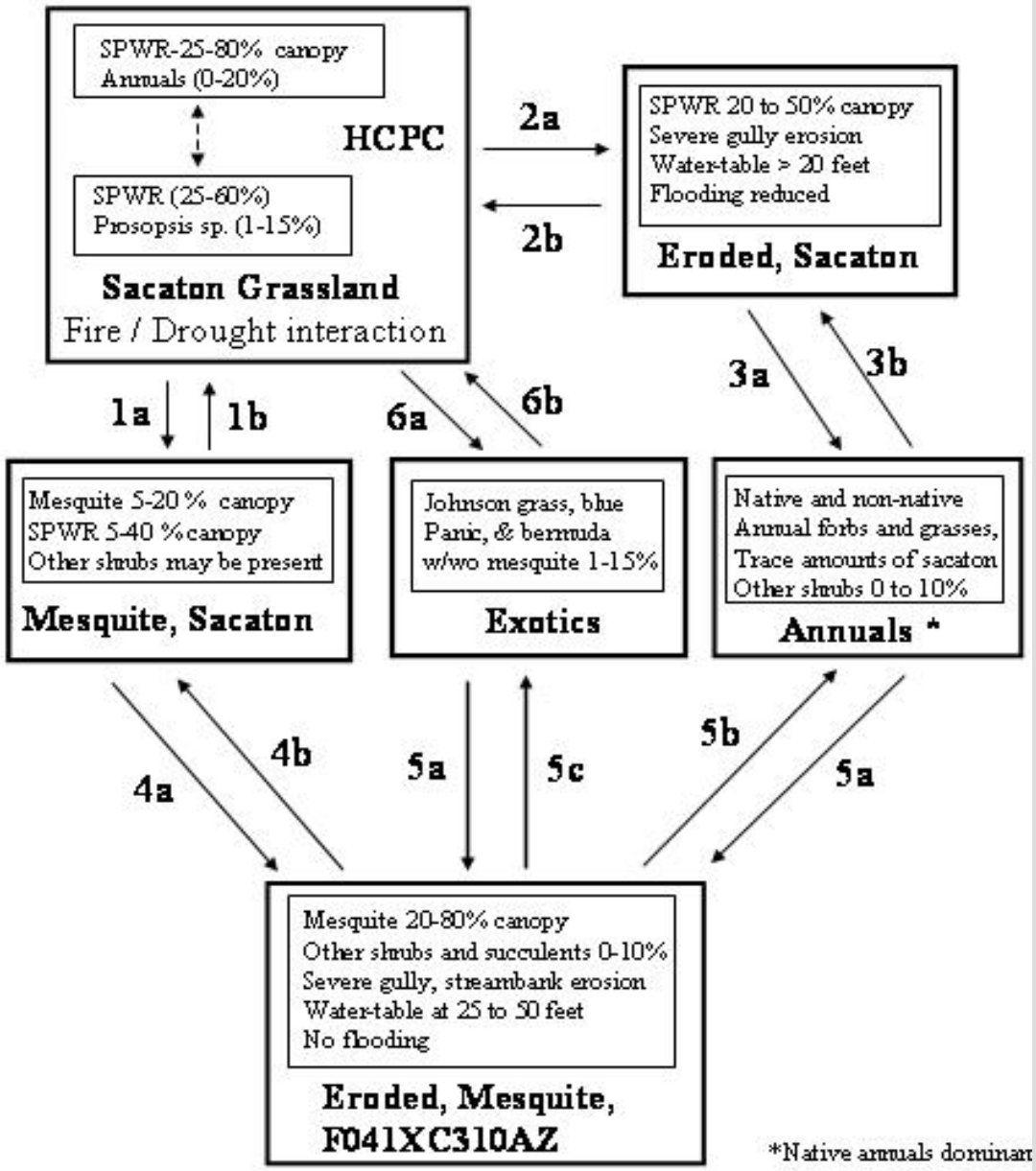
Continue with next decision period or finish up…

State and Transition-Climate Worksheet Group Number ***7*** Management Objective ***production*** Desired State ***sacaton***

Decision Period	Initial State	Disturbance	Financial Condition	Management Decisions	Reasons for Transition	Ending State
1	Sacaton Grassland	Climate & Wildfire	Good	Rest Rotation Grazing	No change; adequate summer precip through period; quick recovery after fire	Sacaton Grassland
2	Sacaton Grassland					
3						
4						
5						
6						

- When finished with a decision period, move on to the next (repeat steps 4-7). There are a total of six decision periods that cover the period from 2010 to 2069.
- After all groups are finished with as many decision periods as possible in the time allotted, we will discuss results from each group worksheet.





Sacaton Grassland

1, 7

Eroded, Sacaton

Mesquite, Sacaton

Exotics

Annuals

Eroded, Mesquite

Let the games begin!