Modeling Rangeland Community Structure in *ALCES*
Southern Alberta Sustainability Strategy (SASS)

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1. Introduction

Rangeland communities are not constant in structure (physiognomy), but change through time as they grow older, or when they are disturbed by various natural processes including fire, drought, and herbivory. Unlike forest communities, rangelands do not have to be reset to the youngest seral stage when they are affected by a natural disturbance. Instead, structural change varies depending on the intensity of the disturbance.

The purpose of modeling rangeland in SASS is to simulate and compare rangeland structure under various future land use and development scenarios, and to use these results in modeling changes to wildlife habitat values. Modeling in SASS is at a regional scale and is over a 50-year time period. The study area is more or less comprised of the South Saskatchewan watershed, which is about 20% of the total area of Alberta.

2. Modeling Approach

2.1 Overview

ALCES (Alberta Landscape Cumulative Effects Simulator) is built upon *STELLA*, a computer program that takes a plumbers' view of natural systems (stocks and flows). Stocks represent levels or amounts of things. These levels are controlled by inflow and outflow rates. Stocks in *STELLA* are aspatial, and consequently the results cannot be explicitly mapped.

Spatial land cover data, including both natural and anthropogenic elements, are organized into desired cover types for the entire study area, and then entered into a datasheet for processing. *ALCES* for SASS contains 11 rangeland cover types. Future changes in the area of each cover type due to anthropogenic factors can be simulated. *ALCES* calculates changes in the total area of each cover type during each time-step of a simulation, and updates the total area of each cover type at the end of the simulation. The results can be shown as graphs or tables, or used in *ALCES* for calculating desired outputs.

The structural dynamics of each plant community type in the SASS study area are subjectively defined as a developmental stage index from 0 to 1, where 0 represents the youngest developmental stage, and 1 represents a developmental stage with maximum structural diversity. *ALCES* models the developmental stage of 11 rangeland community types including:

1. NTG DMG – dry mixed grass (needle and thread grass - blue grama grass)
2. NWG DMG – dry mixed grass (northern wheat grass - june grass)
3. NTGSG DMG - dry mixed grass (needle and thread grass – sand grass)
4. MG - mixed grass
5. Fescue grass – fescue grassland
6. Fescue PL – fescue parkland

7. G Shrub - grassland shrub
8. F Shrub - forest shrub
9. Badlands – badlands
10. Pr Treed - prairie/trees
11. Forage - forage.

2.2. Modeling Steps

In the *ALCES* model, rangeland plant communities acquire age and structure along user-defined developmental curves up to a maximum ratio of 1.0 unless a disturbance (i.e., fire, drought, cattle grazing) occurs of sufficient intensity to reset the community back to a younger developmental stage. The user first defines the intensity and frequency of disturbances expected to occur within each cover type for each 50-year simulation (e.g., percent area burned, amount of annual rainfall compared to a long-term mean, annual stocking density compared to recommended stocking density). The model then simulates changes in structure according to the following steps:

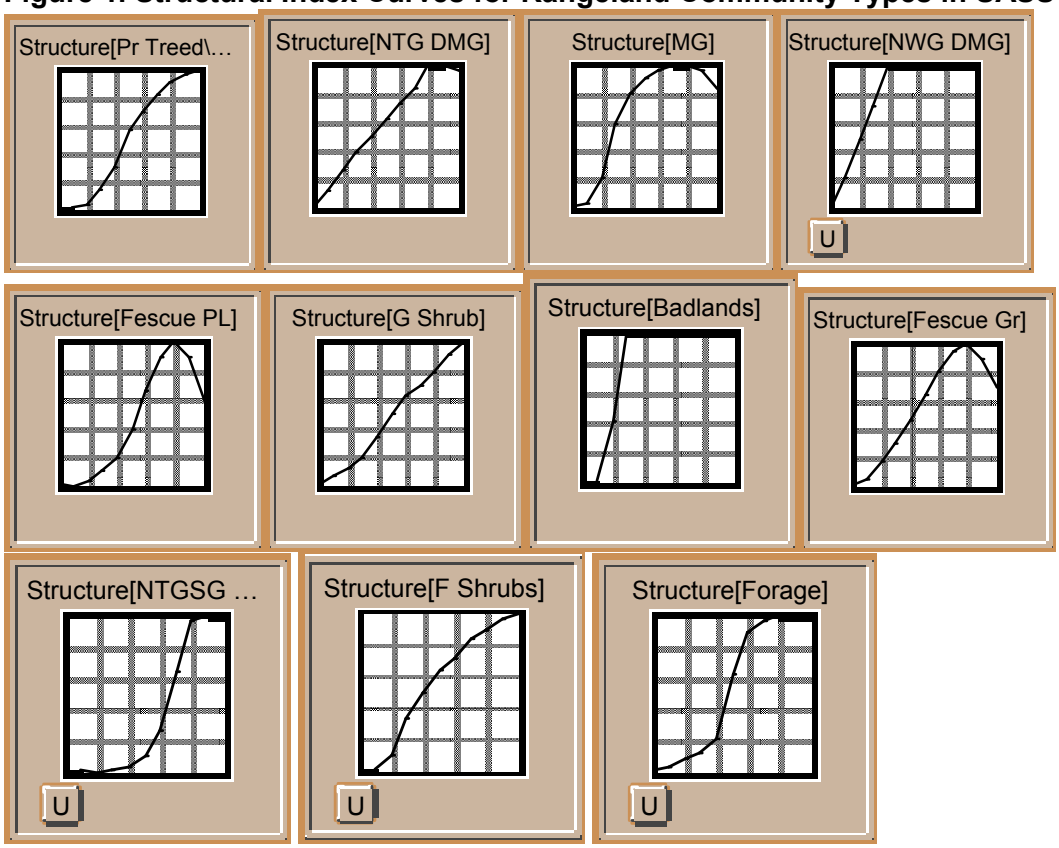
1. For each year of the simulation, the model simulates the intensity of the disturbance for each cover type
2. The effect of the disturbance intensity on a generic seral stage index is determined for each year;
3. The structural index of each community type is determined from the seral stage index; the structural stage index is updated in the same year the disturbance occurs
4. Each community type advances along its seral and structural curves to the next year; the effect of a disturbance on the seral stage index is seen in the year immediately following the disturbance.

2.3 Data

The area and composition of SASS native rangeland vegetation were calculated using a variety of data sources, including Alberta Vegetation Inventory (Forest Reserve/Cypress Hills), Parks Canada Ecological Land Classification (National Parks), Canada Woodlot Inventory (foothills), Ducks Unltd., Wetland Inventory (parkland), Native Prairie Vegetation Inventory, Native Parkland Vegetation Inventory, and Alberta Crop Insurance Database. Resolution varied from a scale of 1:20 000 in the Forest Reserve to ¼-section in the White Area. The initial developmental (seral) stage index for each community type at year 0 was estimated using expert opinion.

The structural index curves for each community type are based on unpublished data (Adams 2003), (Figure 1).

Figure 1. Structural Index Curves for Rangeland Community Types in SASS



The horizontal scales in Figure 1 are time, varying in number of years. The vertical scales are structural indices, 0 to 1.0.

Years to full recovery following major perturbation are estimated as follows:

NTG DMG	9
NWG DMG	9
NTGSG DMG	9
MG	5
Fescue grass	5
Fescue PL	8
G shrub	5
F shrub	5
Badlands	0
Pr Treed	10
Forage	0

For base case rangeland community structural analysis in SASS, *ALCES* has been populated with default settings (Table 1). Climatic data are long-term (30-year) climatic

normals (Environment Canada 2003). The area burned/year default setting for each community type is 0.005 (not shown). ***This setting is based on (source?).***

Table 1. Input Variables, Default Settings for Rainfall & Stocking Rate

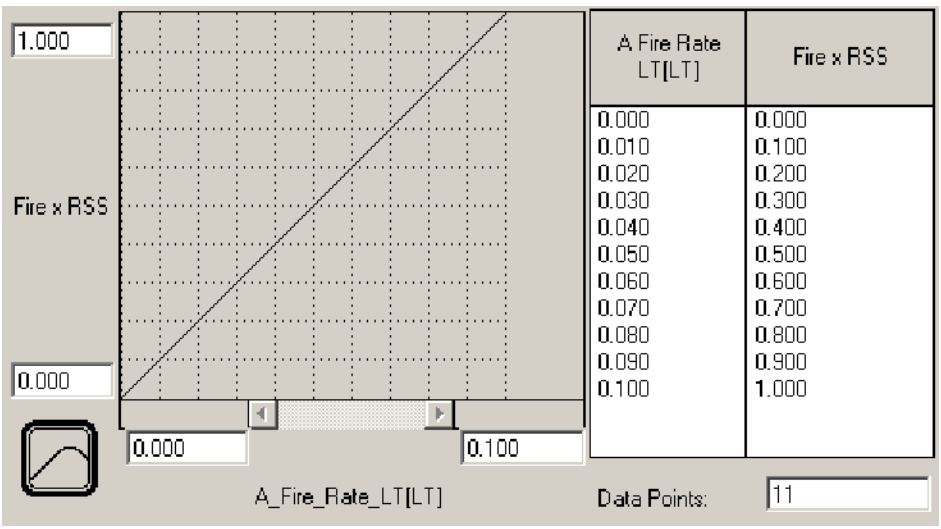
	Mean Annual Rainfall (cm)	Standard Deviation Annual Rainfall (cm)	Recommended Cattle Stocking Rate (cattle/km2)
NTG DMG	25	9	12.38
NWG DMG	25	9	8.83
NTGSG DMG	25	9	9.88
MG	30	9	18.52
Fescue grass	35	12	34.00
Fescue PL	35	12	32.00
G shrub	30	10	12.40
F shrub	40	13	7.70
Badlands	30	10	3.71
Pr Treed	40	14	12.40
Forage	40	13	100.00

2.3 Modeling the Effect of Fire on Rangeland Community Structure

The effect of fire on the community structure of each rangeland community type is modeled first through a hypothetical relationship between the portion of each plant community type that burns each year and the portion that gets set back to its youngest seral stage (Figure 2). The model assumes that fires do not overlap from year to year. Once the effect of fire rate for each community type on the seral stage index is computed, ALCES determines the structural index for each community type using the curves in Figure 1.

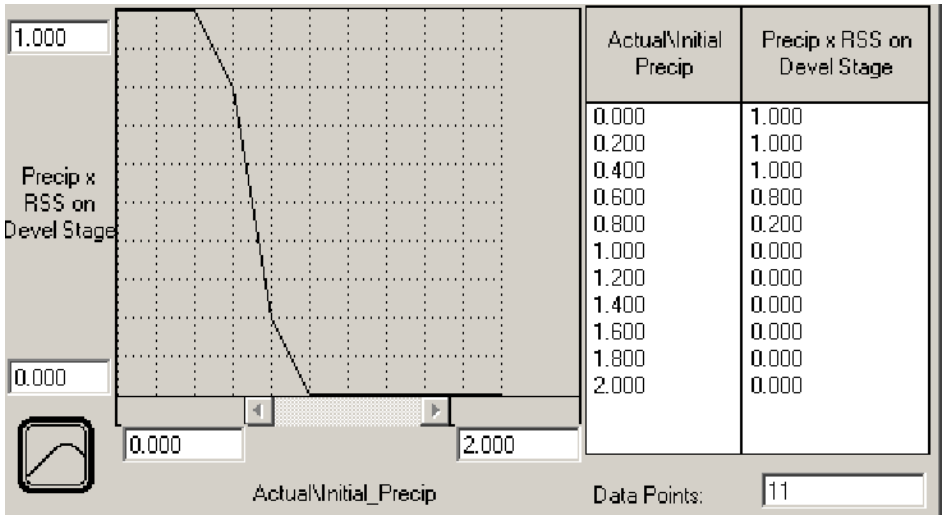
Fire rate can be set either as constant or stochastic. In stochastic mode, random events are drawn from an exponential or lognormal distribution (user-selected) whose mean is defined by average rate.

Figure 2. Effect of Fire Rate on Rangeland Seral Stage (RSS). (LT is landcover type.)



The effect of precipitation on the structural stage of each rangeland community type is modeled first through a relationship between the ratio of annual/long-term average precipitation for each community type and seral stage index (Figure 3). Then the relationship between seral stage and structural index is modeled separately for each rangeland type (Figure 4). The amount of annual rainfall is independently set for each community type.

Figure 3. Effect of Annual/Average Precipitation on Rangeland Seral (Development) Stage

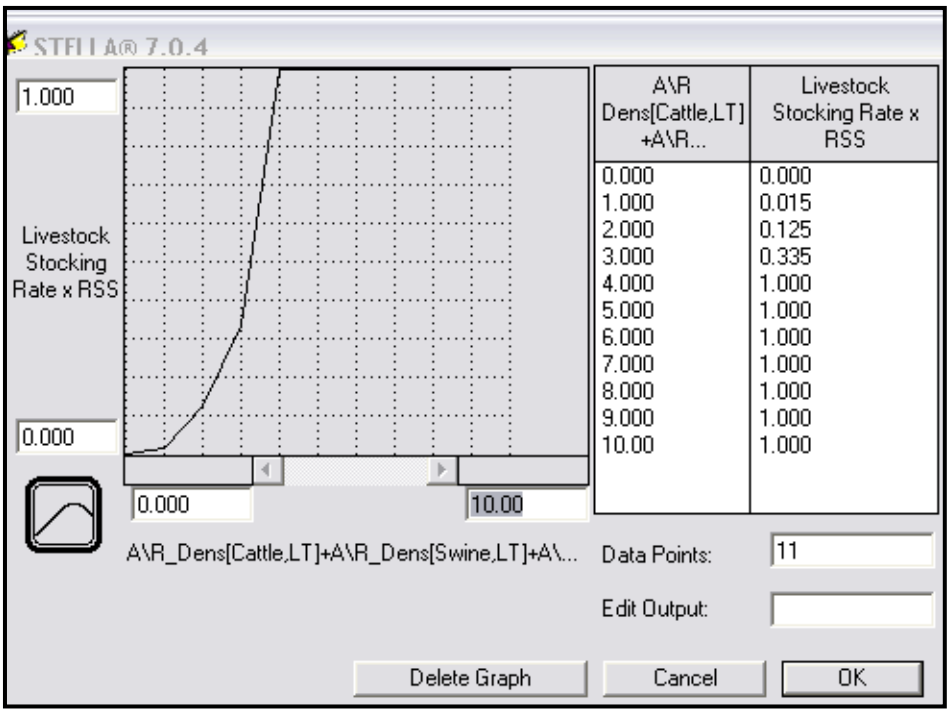


Actual\Initial Precip	Precip x RSS on Devel Stage
0.000	1.000
0.200	1.000
0.400	1.000
0.600	0.800
0.800	0.200
1.000	0.000
1.200	0.000
1.400	0.000
1.600	0.000
1.800	0.000
2.000	0.000

2.5 Modeling the Effect of Cattle Stocking Rate on Rangeland Community Structure

The effect of livestock stocking rate on the community structure of each rangeland community type is modeled first through a relationship between the ratio of actual/average livestock stocking rate and the seral stage index of the rangeland type (Figure 4). Then the relationship between seral stage and structural index is modeled separately for each rangeland type using the curves in Figure 1.

Figure 4. Effect of Cattle Stocking Rate on Rangeland Seral Stage



2.6 Modeling Results

Modeling results can be graphed (Figure 5). The graph shows the results of fire and drought on the seral stage index and structural index of fescue grassland.

Figure 5. A 50-year *ALCES* simulation for the SASS study area showing the effects on inter-annual variation in mean precipitation, drought and fire on seral stage index and structural index of fescue grassland.