Integrated Landscape Assessment Project (ILAP)
VDDT/Path State-and-Transition Model Documentation
Oregon and Washington (USFS Region 6)
Arid Lands (nonforests)

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Contents

Introduction

The Integrated Landscape Assessment Project (ILAP) supports watershed-level prioritization of land management actions across all lands in Arizona, New Mexico, Oregon, and Washington. The project explores the dynamics of broad-scale, multi-ownership landscapes by integrating and evaluating information about current and future vegetation and fuel conditions, climate change, wildlife habitat, watershed conditions, and fuel treatment economics. The heart of these integrations occurs through output generated with state and transition models using the Vegetation Dynamics Development Tool (VDDT) and the Path Landscape Model (Path), developed by ESSA Technologies and ApexRMS. More information on this integration can be found on the ILAP ftp site (ftp://131.252.97.79/ILAP/Index.html) and the Western Landscapes Explorer website (available summer of 2012).

Purpose of this document

The purpose of this document is to document state and transition model definitions, construction, and assumptions. This document will not detail every transition that occurs in each state or define each probability. Rather, we hope to provide sufficient user information to illustrate the major components and assumptions of the model, and enable users to comfortably begin to use or modify the models to address their own questions. This document also assumes a basic understanding of the VDDT and Path modeling programs.

The model set described in this document was developed to model arid land dynamics of Washington and Oregon ecosystems as part of ILAP. Each model corresponds to one potential vegetation type (PVT) – a unit describing the potential vegetation of a site based on biophysical site characteristics, dominant plant associations, and historic and contemporary disturbance regimes. See the PVT mapping documentation on the ILAP website for more information.

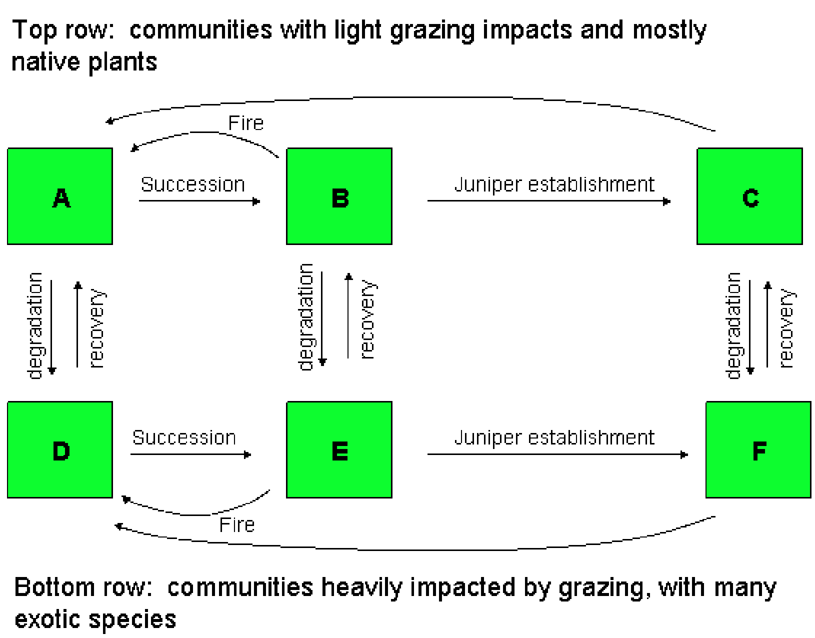
The ILAP project divided the four-state study region into smaller modeling regions that were manageable for model runs in Path. These regions roughly correspond to Bailey's ecoregions but are bounded by 5th field (10-digit) watersheds (Hydrologic unit codes, HUCs). The modeling regions covered by this document include:

OBM – Oregon Blue Mountains
OEC – Oregon East Cascades
OSE – Oregon Southeast
WCB – Washington Columbia Basin
WEC – Washington East Cascades
WNE – Washington Northeast

Model Structure and Assumptions

STMs are commonly used in land management to conceptualize vegetation dynamics and thresholds and project future vegetation condition. In VDDT and Path, users divide the landscape into distinct combinations of vegetation cover and structure (states, or boxes), linked together by processes (transitions, or arrows) such as succession, disturbance, and management activities. Transitions can be deterministic and occur after a specified number of years (often used to model succession), or probabilistic, where users define its annual probability of occurring. The landscape is divided into a number of simulation cells, and models project future vegetation condition based on the initial proportion of cells in each state and the transition pathways and probabilities defined in the model. STMs used in ILAP are non-spatial, and tracks each simulation cell independently of neighboring cells. Monte Carlo simulations generate variability among model runs.

Most VDDT models were adapted from existing models (see **Model Sources**). The final model set was intended to be broadly applicable in characterizing the dynamics of arid ecosystems and other nonforested vegetation types across all of Washington and Oregon, with variation in fire probabilities among modeling regions (see **Fire Probabilities**). The basic design of the models is summarized in the schematic diagram below. Each column represents a dominant structural type, with succession proceeding from left to right. Fires and other major disturbances return cells to earlier successional states. Rows contain classes with similar condition; upper rows represent states in more pristine condition and lower rows represent areas that are highly modified by grazing-related degradation or other management (i.e., seeding of exotic plants). Grazing-related degradation transitions down a row, while recovery through succession or re-seeding of native plants transitions up a row (Figure from D. Swanson, USFS).



Various management treatments are built into the models (see **Probabilistic Transitions** table). However, for the base ILAP model projections we use a No Management scenario, which deactivates all management transitions (e.g. active restoration treatments) using a static transition multiplier of 0. Under the No Management scenario, we also assume that all types of grazing occur, including grazing-related degradation. Alternative management scenarios describing various combinations of grazing and management treatments were run for only a small portion of the landscape. All models were developed using VDDT and were run in Path.

Model Sources

ILAP used existing VDDT models from a variety of sources and adapted the models for use across multiple land ownerships throughout the Region 6 (Oregon and Washington) arid lands. Final models often incorporated information from multiple sources and expert opinion. Model sources include:

Forest Service (USFS) models for the Blue Mountains, Northeastern Oregon:

The USFS models were a primary source for ILAP models because the original model set covered most of the major PVTs in Eastern Washington and Oregon, and the models were thoroughly documented by the original model creators. The models were originally developed by Dave Swanson and Jennifer Huchinson (GFV model), ecologists at USFS in Baker City, OR, in 2006. They are based primarily on unpublished monitoring data collected over many years on the Malheur, Umatilla, and Wallowa-Whitman National Forests by Charlie Johnson, Fred Hall, and co-workers. Some models were only slightly modified from the base USFS model, and in those cases most of the documentation presented here is taken directly from the original USFS model documentation. Many of the original models used landscape feedback multipliers to simulate annual grass and juniper establishment. However, landscape feedback cannot currently be used in the Path modeling framework, and was therefore excluded in the final set of ILAP models.

Bureau of Land Management (BLM) models for the Malheur High Plateau, southeast Oregon:

Two models were developed by Louisa Evers (BLM) as part of her doctoral thesis to characterize current sage grouse habitat in the Malheur High Plateau (Evers 2010). The CM (cool moist) model describes upland, productive sites dominated by mountain big sagebrush/Idaho fescue, and corresponds most closely to our SMB model (mountain big sagebrush with juniper). This model was also used heavily to inform our mountain sage – no juniper (SMN) and low sage (SLN and SLW) models. The WD (warm dry) model describes warm, less productive sites dominated by Wyoming big sagebrush / Bluebunch wheatgrass-Thurber's needlegrass, and corresponds most closely to our SWN model (Wyoming big sagebrush – no juniper). This model was also used to inform our Wyoming sage with juniper (SWB) model. We also used the temporal multiplier parameter values for cyclical transitions that were derived from these models without any modification (see **Temporal Multipliers** section).

The Nature Conservancy (TNC) models:

The Nature Conservancy of Nevada (TNC-NV) developed a set of VDDT models for the Great Basin, which were used in part to develop the salt desert (SSD and SSU) models. Models were provided by Louis Provencher, Director of Science.

The Nature Conservancy of Idaho (TNC-ID) developed a set of VDDT models for southern Idaho as part of the Landscape Toolbox project (www.landscapetoolbox.org). In developing our three-tip sage (S3S) model for ILAP, we used information from the Three-tip sage TNC-ID model developed for the Wildhorse Case Study in south-central Idaho.

Model Parameter Definitions

Cover Types

Cover types provide basic information about the composition of species and functional groups in each state class. Below is a list of cover types that can be used singly or in combination to characterize vegetation composition. For instance, the "Eg" cover type (exotic annual grass) can appear on its own as simply "Eg" (exotic annual grass monoculture) or in combination with other cover types, eg. "MsEgFb" (mixture of mountain big sage, exotic annual grasses, and forbs). See the document "R6_AridLand_StateClass_Crosswalk_Definitions" provided with the ILAP arid land modeling region rollouts for the full crosswalk of thresholds values used in assigning the current vegetation map pixels to state classes in the VDDT models.

Name		Description
Shrubs		
Bt	Bitterbrush	Bitterbrush (*Purshia tridentata*) shrublands
Ls	LowSage	Low sagebrush (*Artemisia arbuscula*) communities characterized by shallow soils
Mm	Mountain Mahogany	Mountain mahogany (*Cercocarpus ledifolius*) communities
Ms	MountainBig Sage	Mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*) found in upland sites
Rs	RigidSage	Rigid sagebrush (*Artemisia rigida*) found in xeric scablands with shallow soils. Note that xeric low sage (*Artemesia arbuscula*) is modeled as rigid sagebrush
Sd	SaltDesertShrub	Salt desert shrub species such as greasewood (*Sarcobatus vermiculatus*), shadscale saltbush (*Atriplex confertifolia*), bud sagebrush (*Picrothamnus desertorum*), spiny hopsage (*Grayia spinosa*), and horsebrush (*Tetradymia* species)
Sh	MountainShrub	Mountain shrub systems dominated by species such as mallow ninebark (*Physocarpus malvaceu*) and common snowberry (*Symphoricarpus albus*)
Ts	ThreeTipSage	Three-tip sagebrush (*Artemisia tripartita*). Three-tip is a sagebrush species that resprouts following disturbance and grows in deep, productive soils
Ws	WyomingBig Sage	Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) communities in dry, lowland sites that are often highly susceptible to invasion by exotic annual grasses
Herbs		
Eg	ExoticAnnual Grass	Exotic annual grasses, such as cheatgrass (*Bromus tectorum*) and other exotic bromes, Ventenata (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusae*). These grasses usually invade following disturbance, tend to outcompete native bunchgrasses in many systems, and can substantially increase fire frequency

Fb	Forb	Perennial or annual forbs. Forb dominance often indicates semi-degraded conditions where grass species have been overgrazed
Ng	NativePerennial Grass	Native perennial bunchgrasses, such as Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoregeneria spicata*), green fescue (*Festuca viridula*), several ricegrass/needlegrass species (*Achnatherum* species), and others. Many of these species are intolerant of heavy grazing and are indicators of pristine condition
Rg	RobustGrass	Native perennial bunchgrasses that are robust to grazing pressures, such as Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*), saltgrass (*Distichlis spicata*) and others. Dominance of these species often indicates semi-degraded conditions
Sg	SeededGrass	Seeded exotic grasses, such as crested wheatgrass (*Agropyron cristatum*) and intermediate wheatgrass (*Agropyron desertorum*)
Trees		
Co	Conifer	Conifer (various species) tree invasion into montane grasslands and shrublands
Ju	Juniper	Western juniper (*Juniperus occidentalis*). This cover type is used in historic juniper woodlands (model SWJ) and juniper invasion into historic shrublands (models SWB, SMB, SLW, SPT)
Other		
AGR	Agriculture	Native community converted to agriculture
B	BareGround	Degraded conditions with low cover of any plant species, often accompanied by increased soil erosion and pedestaling around remaining plants

Structural Stages

Structural stages define the structural characteristics of a state class, with a single structural stage assigned to each state class. The following list of structural classes defines the structural stages used in arid land models. Structural stages are consistent across all arid land modeling regions in Region 6.

Symbol	Name	Description
AGR	Agricultural	Cultivated crops. Agricultural states are only used in the GFK model
HB	Herbland	Grassland with few shrubs and trees (shrub cover <5%, tree cover <2%). Shrub cover cutoff follows Karl & Sadowski (2005) classes 1 and 2
HBo	OpenHerbland	Open grassland (Herbaceous cover <30%, shrub cover <5%, tree cover <2%). This state is only used in the GFV model
HBc	ClosedHerbland	Closed grassland (Herbaceous cover >=30%, shrub cover <5%, tree cover <2%). This state is only used in the GFV model

SHo	OpenShrub	Open shrub steppe (Shrub cover >=5-15%, tree cover <2%). Shrub cover cutoff follows Karl & Sadowski (2005) class 3
SHm	MidShrub	Mid shrub steppe (Shrub cover >=15-25%, tree cover <2%). Shrub cover cutoffs follow Karl & Sadowski (2005) class 4
SHom	Open-MidShrub	Open-mid shrub steppe (Shrub cover >=5-25%, tree cover <2%). Shrub cover cutoff follows Karl & Sadowski (2005) and combines classes 3 and 4
SHc	ClosedShrub	Closed shrub steppe (Shrub cover >=25%, tree cover <2%). Shrub cover cutoff follows Karl & Sadowski (2005) class 5
SHd	DepletedShrub	Depleted shrubland with high shrub cover and overgrazed herbaceous layer (Shrub cover >=25%, herb cover <5%, tree cover <2%). Shrub cover cutoff follows Karl & Sadowski (2005) class 5, but this class also has low herbaceous cover. This state is assumed to be caused by overgrazing, and will not occur through succession alone
W-PI	Woodland-PhaseI	Phase I juniper invasion (Miller et al. 2005), consisting of shrub steppe with shrubs and/or grasses dominant and scattered juniper (Juniper cover >=2-10%). Although this stage is dominated by shrubs/grasses, it is named as a woodland state because juniper is expected to increase in density once is has colonized
W-PII	Woodland-PhaseII	Phase II juniper invasion (Miller et al. 2005), with shrubs/grasses codominant with juniper (juniper cover >=10-20%)
W-PIII	Woodland-PhaseIII	Phase III juniper invasion (Miller et al. 2005) – juniper woodland with herbaceous understory and few shrubs (juniper cover >=20%)
FSI	StandInitiation Forest	Montane stand initiation forest (tree cover >=2-10%). Forest states are only used in GFV and SMS models
FYM	YoungMulti-strata Forest	Open montane forest (tree cover >=10%). Forest states are only used in GFV and SMS models

Probabilistic Transitions

Probabilistic transitions define the probability of moving from one state class to another within a VDDT model. Probabilistic transition types for all arid land models are listed below, with an explanation and source for the transition probabilities. Actual transition probabilities are not included in this table, as they vary among VDDT models and among state classes within each model.

Name	Explanation	Source
Natural and Grazing Transitions		
AltSucc	Automatic (P = 1) recovery of herb layer to 1st row box by succession. This transition only occurs if there is no grazing disturbance in the last 30 yrs by time since disturbance (TSD).	USFS models
Browse	Prevents establishment of palatable shrubs (by TSD) and delays succession to tall closed shrub states (by relative age). This transition is used only in the mountain mahogany model.	USFS models
Drought	A multi-year drought that, when combined with grazing, may result in degradation. Drought transitions loop to the same box, and direct effects of drought either increase shrub cover (positive relative age), delay shrub succession (negative relative age), or may have no effect other than marking that a drought disturbance has occurred (zero relative age), depending on the model. In some models, GzeDegradeP transitions can occur within 2 years of drought through TSD.	Knapp et al (2004)
GzeBrowse	Simulates wildlife or cattle browsing on palatable shrubs that kills the regenerating shrubs but does not degrade the herb layer. This transition is used only in the bitterbrush model.	USFS models
GzeDegrade	This transition describes grazing-related degradation (movement toward annual grass states). The transition probability is 10x lower than GzeDegradeP because grazing degradation is generally less severe when grasses are not stressed by another disturbance. In some models, GzeDegrade is used to delay the deterministic transition from annual grass states to semi-degraded states (row 3 to row 2), and portrays heavy overgrazing that prevents recovery of the herbaceous layer. In most cases this transition is unrelated to disturbance, but in some models it is set with a minimum TSD of 3 years (following GzeDegradeP at TSD 0-2 years).	USFS models; expert opinion
GzeDegradeP	This transition describes grazing-related degradation (movement toward annual grass states) within 2 years of fire or drought disturbance. GzeDegradeP is modeled with a 10x higher probability than GzeDegrade because the combination of grazing with other disturbance is presumed to increase the probability of degradation. GzeDegradeP is linked to grazing and fire disturbances through TSD.	USFS and BLM models; expert opinion
GzeMaint	Maintenance grazing that does not affect vegetation composition or structure. This transition always loops to the same box with a relative age of 0, and does not have any effect except on transitions dependent on time since grazing disturbance. GzeMaint is set at a low probability of 0.001 so transitions that are dependent on time since grazing disturbance are only minimally affected by GzeMaint.	Expert review

Name	Explanation	Source
GzeMod	Moderate grazing that decreases herbaceous cover and alters succession, but does not cause degradation. This transition returns to the same box with a relative age of 1 or -1, depending on the model, or transitions cells from mid or closed shrub to depleted shrub. A relative age of 1 (generally used in shrub models) delays succession and increases shrub dominance by adding 1 extra year to the successional age, whereas a relative age of -1 (generally used in grassland models) delays succession by one time step.	BLM models; expert opinion
InsectDisease	Insects and/or disease that can kill shrubs or trees. This transition is not used in sagebrush models, where InsectBC and InsectPeak are used instead.	USFS models
InsectBC	InsectBC represents buildup and crash phases of a typical multi-year insect outbreak of sagebrush-defoliating insects (e.g. aroga moth). It occurs only in closed or depleted sagebrush states and returns to the first time step of the state class. Multipliers are used to activate this transition for a 2 year period immediately preceding and following a peak outbreak year (InsectPeak), which occurs every 20-48 years. The InsectBC transition probability is high (0.2943) in years it occurs.	BLM models
InsectPeak	The InsectPeak transition models the peak phase of a typical multi-year insect outbreak of sagebrush-defoliating insects (e.g. aroga moth). It occurs only in closed or depleted sagebrush states and returns to open shrub states. Multipliers are used to activate this transition only for a 1-2 year window every 20-48 years (and the Insect BC transition immediately precedes and follows a peak outbreak year). The InsectPeak transition probability is very high (0.4388) in years that it occurs.	BLM models
NRFir	Douglas fir or subalpine fir establishment by natural regeneration (seeding).	USFS models
NRHerb	This transition describes the recovery (natural seeding) of the herbaceous layer from degraded conditions to more pristine conditions (e.g. colonization of perennial grasses in states with exotic annual grass). The transition usually results in movement upward by one row. In some models, this transition is prevented by time since grazing disturbance.	USFS models; expert opinion
NRJun	Natural regeneration (seeding) of juniper. This transition only occurs in closed shrub states (except in the juniper woodland model) because juniper seedlings tend to establish under existing sagebrush plants.	BLM models; expert opinion
NRMM	Natural mountain mahogany establishment by seeding. This can occur only if time since grazing or browsing disturbance is 30 years or more.	USFS models
NRPutr	Natural bitterbrush establishment by seeding. This transition can only occur if time since grazing disturbance is 10 years or more.	USFS models
NRSarc	Establishment of greasewood by natural regeneration (seeding). This transition is not limited by grazing as in the bitterbrush and mountain-mahogany models.	USFS models
SevDrought	Severe drought that can kill shrubs. This transition is set to occur only once every 100-200 years, but when it occurs it moves shrubs from closed to open states with a high probability of 0.3750. Transition probabilities are taken directly from the BLM CM and WD models.	BLM models

Name	Explanation	Source
ShrubRejuv	ShrubRejuv is used in mountain mahogany and bitterbrush models to simulate regeneration of these palatable shrubs. Mountain mahogany and bitterbrush dies out after 200 or 70 yrs (respectively) unless the clock is reset by a ShrubRejuv event; ShrubRejuv requires 30 or 10 yrs (respectively) with no grazing by TSD to occur.	USFS models
WFMS	Wildfire of mixed-severity that results in a heterogeneous burn pattern. Mixed-severity fires usually reset cells to the beginning time step of the same state in which they occurred.	MTBS data
WFNL	Nonlethal (surface) fire in phase III woodland states with exotic grass understory. This transition does not burn the woodland canopy layer and moves cells to the first time step of the same state.	MTBS data
WFSR	Wildfire that results in stand replacement. This transition always leads to an herbaceous state.	MTBS data
Management Transitions – built into models but deactivated for ILAP model runs		
MechTrtJun	Mechanical treatment (i.e. chainsawing) of juniper. This transition leads to the open shrub state within the same row.	Default P = 0.01
MechTrt Shrub	Mechanical treatment of sagebrush, leading an open sagebrush stand. We assume that about 10% sagebrush cover will survive the treatment.	Default P = 0.01
PFSR	Prescribed fire that results in stand replacement.	Default P = 0.01
SeedExotic	Artificial seeding of nonnative grass (i.e. crested wheatgrass).	Default P = 0.01
SeedNative	Mechanical or herbicide treatment of degraded site and artificial seeding of native plants.	Default P = 0.01
SodBusting	Conversion of native vegetation to agricultural land.	Default P = 0.01
Wheat Farming	Maintains agricultural land in its current state. Without this disturbance the land succeeds to exotic annual grass.	Default P = 0.01

Individual Model Descriptions

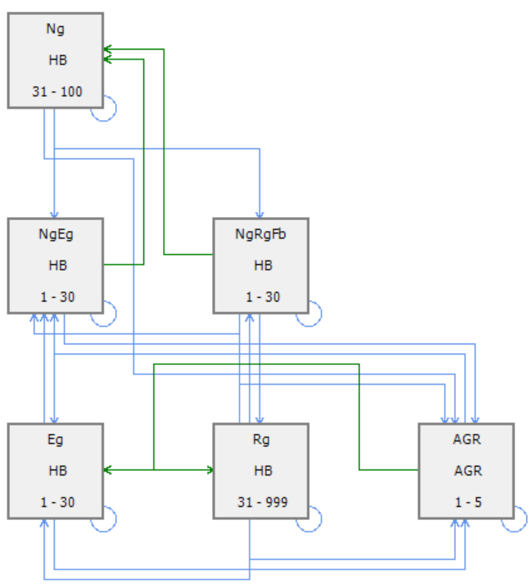
Below we have provided a description of each state-and-transition model for each of the 19 nonforested PVTs we identified in eastern Oregon and Washington. These include information about the model source, structure, and a description of the model dynamics. Diagrams of model structure are shown as screenshots from Path. Note that the current version of Path (2.2.0) does not use letters as state class identifiers, although they are used to refer to states in the documentation below.

Model GFK – Idaho fescue - Prairie junegrass

Source:

This model was taken directly from the USFS FEID_KOMA model, and represents Idaho fescue (*Festuca idahoensis*) grasslands. Bluebunch wheatgrass (*Pseudoregeneria spicata*) is also present, and prairie junegrass (*Koeleria macrantha*) is an important indicator species but is rarely dominant. Note that the original USFS FEID_KOMA model used landscape feedback multipliers for annual grass invasion rates, but feedback multipliers were not used in ILAP models.

Structure:



State Classes:

A	Ng	HB	Pristine Idaho fescue/bluebunch wheatgrass/prairie junegrass grassland.
B	NgEg	HB	Reduced native perennial grass cover, replaced by robust grasses, more bare soil, and annuals
C	NgRgFb	HB	Reduced native grass cover, replaced by perennial forbs and Kentucky Bluegrass (*Poa pratensis*)
D	Eg	HB	Exotic annual grasses, primarily cheatgrass (*Bromus tectorum*) and Ventenata (*Ventenata dubia*)
E	Rg	HB	Robust grasses, such as Kentucky bluegrass, and unpalatable perennial forbs
F	AGR	AGR	Agricultural land

Description:

Deterministic transitions in this model lead from semi-degraded states (row 2) to native fescue/ wheatgrass (row 1) after 30 years. Exotic grass (Eg) also transitions to Kentucky bluegrass (Rg) after 30 years by deterministic transition. All states can transition to agriculture (AGR) through the sodbusting transition (tillage of soil), but the AGR class is not populated in ILAP models, as agricultural land is masked out of ILAP analyses.

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Stand-replacing fires in this model return cells to the beginning time step of the same state, and no mixed-severity or nonlethal fires are modeled. Fire alone does not lead to changes in state class, but fire followed by grazing within 2 years (GzeDegradeP) can lead to degradation down one row (see **Grazing Effects**). Wildfire is prevented from occurring within 2 years of the last fire by times since disturbance (TSD) for all states except D (annual grass).

Grazing Effects

Grazing-related degradation moves cells toward a degraded state (from row 1 to row 2 or from Rg to Eg), representing deterioration of range condition and increased dominance of exotic annual grasses. Continued degradation of rows 1 and 2 leads to the 3rd row. GzeDegrade is set to a probability of 0.005, and GzeDegradeP is set at P=0.05 within 2 years of fire or drought by TSD. Probabilities of GzeDegrade and GzeDegradeP are taken directly from the USFS models. GzeDegrade and GzeDegradeP transitions from Ng are split between states NgEg and NgRgFb (proportion of 0.5 allocated to each). In Rg, GzeDegrade and GzeDegradeP can change bluegrass sod to exotic annual grass (Eg). Drought probability is set at 0.033 based on Knapp (2004). Moderate grazing (GzeMod) in boxes NgEg and NgRgFb sets the age of the cell back by 1 year, delaying the deterministic transition to box Ng. GzeMaint, proper grazing that has no effect on structure or composition, can occur in all states with a probability of 0.001.

Other Transitions

Drought is modeled in most states as a transition looping back to the same box with no effect on succession (relative age of 0) but an increased probability of grazing-related degradation within 2 years of drought.

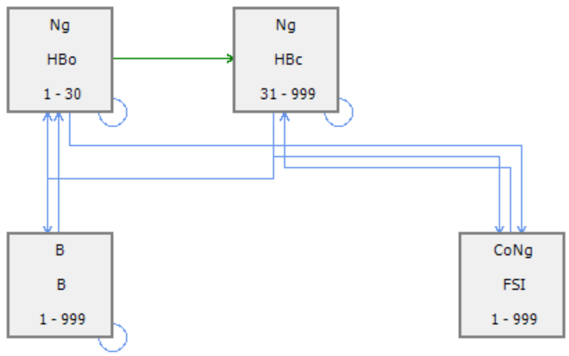
Artificial restoration of highly degraded sites (Rg and Eg) or agricultural land (AGR) by seeding of native grasses (SeedNative) leads to box NgEg, which portrays a partly successful seeding with some problems of infestation by annuals. Natural recovery of highly degraded sites (Rg and Eg) occurs by the probabilistic seeding event NRHerb with a probability of 0.01). This transition is only possible after 10 years rest from grazing by TSD. This includes the GzeMod and GzeMaint disturbances, which has no effect other than to sets back the clock for this transition. Wheat farming maintains AGR as an agricultural state with P = 1. If a multiplier is used to reduce this (simulating farmland abandoned) then succession occurs to annual grasses.

Model GFV – Subalpine meadows - green fescue

Source:

This model was taken from the USFS FEVI model, which was based in part on Johnson (2003). It represents subalpine grasslands where green fescue (*Festuca viridula*) is an important indicator species. Subalpine fir can invade parts of the subalpine meadow PVT.

Structure:



State Classes:

A	CoNg	FSI	Subalpine fir (*Abies lasiocarpa*)/green fescue (*Festuca viridula*), including all seral phases of conifer encroachment, representing conifer invasion into parkland
B	Ng	HBc	Pristine green fescue herbland with closed cover and few forbs or other graminoids
C	Ng	HBo	Degraded green fescue with patches of bare ground and an increase in disturbance-tolerant forbs, sedges, and needlegrass. Erosion is represented by some pedastaling of green fescue
D	B	B	Degraded sites with low plant cover and high erosion potential. Disturbance-tolerant forbs dominate, green fescue dies as pedestals erode. Soil depth decreases and site becomes increasingly drier

Description:

This model was modified very little from the USFS FEVI model. MTBS data were not used to derive fire probabilities, and the probability of wildfire for CoNg was thus set at 0.005 (200 year FRI) based on the USFS FEVI model. The fire return interval for herbaceous communities is probably lower than for CoNg, set arbitrarily at 0.002. Fire is unlikely in bare ground states due to lack of fuel.

The NRFir transition simulates trees seeding into grassland, with a probability set at 0.002 after a sensitivity analysis conducted by the USFS showed an equilibrium tree cover of about 15%. NRFir requires 50 years since fire (by TSD) to give seedlings time to establish and grow into trees. Conifer-encroached states can transition to parkland by fire or insects/disease. NRHerb is reseeding of native (green-fescue dominated) vegetation. This transition requires 10 years of time since grazing disturbance to occur.

Grazing is modeled in Ng states (boxes B and C). GzeDegrade decreases grass cover to bare ground, and GzeMod delays succession by one time step (relative age of -1). GzeMaint, as in other models, has no effect on structure or composition and simulates properly managed grazing.

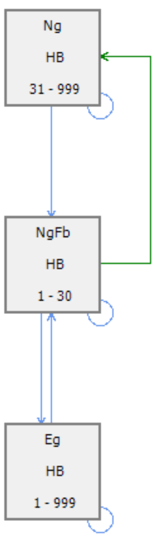
InsectDisease is assumed to completely kill small groves of trees in this stressed environment, resulting in change from CoNg to Ng.

Model GPP – Bluebunch wheatgrass - Sandberg bluegrass

Source:

This model was taken directly from the USFS PSSPS_POSE model, and represents Bluebunch wheatgrass (*Pseudoregeneria spicata*)-Sandberg bluegrass (*Poa secunda*) grasslands. Note that the original PSSPS_POSE model used landscape feedback multipliers for annual grass invasion rates, but feedback multipliers were not used in ILAP models.

Structure:



State Classes:

A	Ng	HB	Native grassland usually dominated by bluebunch wheatgrass, with forbs and Sandberg's bluegrass less abundant
B	NgFb	HB	Mixture of native forbs, perennial grasses and robust grasses, with lower grass cover than class A. Often Sandberg's bluegrass, forbs, and bluebunch wheatgrass codominate. Bluebunch wheatgrass is subordinate but still present in amounts adequate to recover readily
C	Eg	HB	Exotic annual grasses, sometimes with unpalatable forbs

Description:

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Stand-replacing fire returns cells to the beginning time step of the same state. No mixed-severity fires are modeled. Fire alone does not lead to changes in state class, but fire followed by grazing within 2 years (GzeDegradeP) can lead to degradation down one row (see **Grazing Effects** below). Wildfire is prevented from occurring within 2 years of the last fire by time since disturbance (TSD) for all states except Eg.

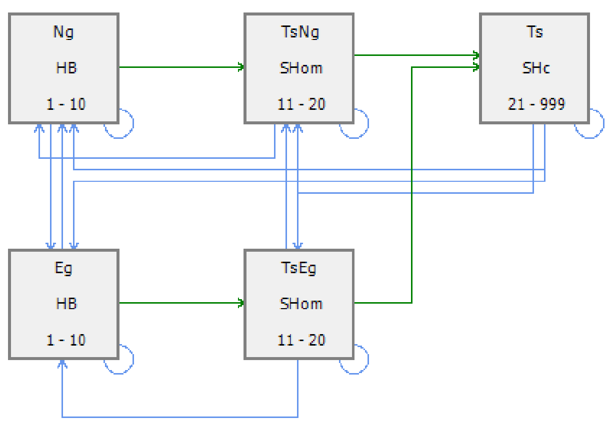
Grazing-related degradation is modeled as GzeDegrade and GzeDegradeP, as in other models. An enhanced probability of grazing-related degradation (GzeDegradeP) is possible within two years of a fire (note that drought is not included in this model, so grazing degradation is not related to drought as in most other models). Recovery from semi-degraded state NgFb is deterministic after 30 years to Ng (hindered by relative age of -1 with the GzeMod disturbance). Recovery from Eg can occur by natural seeding (NRHerb) or artificial seeding (SeedNative). The former is dependent on TSD grazing of 10 years and leads up one level to moderately degraded NgFb. Artificial seeding (SeedNative) leads to good condition state Ng.

Model S3S – Threetip sage

Source:

The three-tip sage model was created for ILAP based on expert opinion and the TNC-Idaho Landscape Toolbox three-tip sage model developed for south-central Idaho. It models sites dominated by three-tip sagebrush (*Artemisia tripartita*), many of which have been converted to agriculture. The key difference between other sagebrush species and three-tip sagebrush is that three-tip can resprout following disturbance.

Structure:



State Classes:

A	Ng	HB	Native bunchgrasses dominate due to post-fire reduction in three-tip sage
B	TsNg	SHom	Three-tip sage with native native perennial grass understory
C	Ts	SHc	Closed three-tip sage
D	Eg	HB	Exotic annual grasses, sometimes mixed with unpalatable forbs
E	TsEg	SHom	Three-tip sage with exotic annual grass understory

Description:

Because three-tip sage can resprout following disturbance, successional stages are fairly short. Ages for each state (0-10, 11-20, and 21-999) were taken directly from the TNC-Idaho model, while keeping the basic model structure of the USFS sagebrush models.

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Stand-replacing fires (WFSR) return cells to herbaceous states, and mixed-severity fire is not modeled in this system. Stand-replacing fire in closed three-tip (Ts) can transition to either exotic annual grasses (Eg) or native perennial grasses (Ng) with equal probability, set as a proportion of 0.5 for each WFSR transition.

Grazing effects were modeled with GzeDegrade, GzeMod and GzeMaint transitions. GzeMod accelerates succession by 1 year using a relative age of 1, and GzeMaint has no effect on succession. We used the same probability for grazing effects in other sagebrush models (GzeMod P=0.1118, based on the BLM WD and CM models, and GzeMaint P=0.001). GzeDegrade simulated degradation from the first to second rows in the model, and was also kept at the same P=0.005 as in the other shrub models. No GzeDegradeP (post-disturbance) transitions were included in this model because of the resprouting ability of the plants, allowing them to regenerate quickly following disturbance.

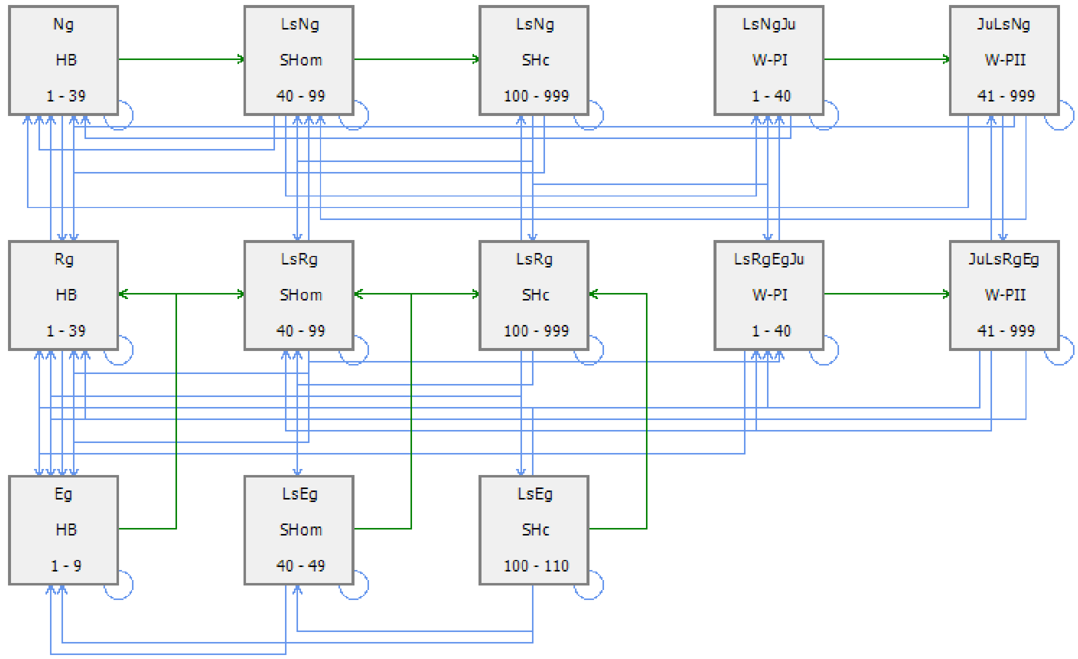
NRHerb represents recovery of the herbaceous layer from row 2 to row 1. It is assigned a 0.05 probability after 10 years time since grazing disturbance. InsectDisease can thin three-tip sage by returning cells to the first time step of open-mid shrub (TsNg) with a probability of 0.013, taken directly from the TNC-Idaho model.

Model SLW – Low sage - mesic, with juniper

Source:

This model was adapted from USFS LOW_SAGE and BLM CM models, and represents low sagebrush (*Artemisia arbuscula*) sites with western juniper (*Juniperus occidentalis*) invasion potential. Grass species include Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Pseudoregeneria spicata*) as indicators of pristine conditions, and Sandberg bluegrass (*Poa secunda*) as a more grazing-tolerant grass. Note that this model is not intended for very xeric, low productivity low sagebrush sites, which are included in the rigid sage (SRS) model. The original USFS LOW_SAGE model used landscape feedback multipliers for annual grass and juniper invasion rates, but feedback multipliers were not used in ILAP models.

Structure:



State Classes:

A	Ng	HB	Native bunchgrasses, including bluebunch wheatgrass, Sandberg's bluegrass, and Idaho fescue, with few shrubs
B	LsNg	SHom	Open-mid low sage steppe with native bunchgrasses
C	LsNg	SHc	Closed low sage steppe with native bunchgrasses
D	Rg	HB	Grazing-impacted herbaceous community with grazing-intolerant large bunchgrasses suppressed and community dominated by robust grasses such as Sandberg's bluegrass
E	LsRg	SHom	Open-mid low sage steppe with robust (grazing-tolerant) grasses dominating the herbaceous layer
F	LsRg	SHc	Closed low sage steppe with robust grasses dominating the herbaceous layer
G	Eg	HB	Dominated by exotic annual grass (cheatgrass, Ventenata, and/or medusahead), or bare soil ready to be invaded by annuals, with few native perennial bunchgrasses
H	LsEg	SHom	Open-mid low sage steppe with exotic grasses dominating the herbaceous layer
I	LsEg	SHc	Closed low sage steppe with exotic grasses dominating the herbaceous layer
J	LsNgJu	W-PI	Sage steppe with scattered juniper (phase I juniper invasion), native bunchgrasses dominate the herbaceous layer
K	JuLsNg	W-PII	Phase II juniper invasion, native bunchgrasses dominate the herbaceous layer, low sage present but declines with increasing juniper cover
L	LsRgEgJu	W-PI	Sage steppe with scattered juniper (phase I juniper invasion), exotic annual grass and robust grasses (Poa secunda) dominate the herbaceous layer
M	JuLsRgEg	W-PII	Phase II juniper invasion, exotic annual grass and Poa secunda dominate the herbaceous layer, low sage present but declines with increasing juniper cover

Description:

The SLW model is very similar to the mountain big sage model (SMB), assuming that sites are similarly mesic but with shallower soils. The main difference is longer successional stages and lack of phase III woodlands reflect poorer growing conditions on shallow soils. The age cutoff used for HB states (40 years) is a compromise between the faster regeneration rates used in the USFS LOW_SAGE model (20 years) and the longer regeneration time in the BLM shallow dry model (55 years). The creators of the USFS models used local monitoring data and Baker (2006) to generate their successional stages, but recognized that post-fire establishment rates reported in the literature vary substantially (LANDFIRE, Steinberg 2002). Many transition probabilities were taken directly from the BLM CM model. As in the mountain big sage model (SMB) but unlike other shrub models (SWB, SPT, etc), recovery from annual grass states is automatic after 9 years via a deterministic transition. Only heavy grazing-related degradation will retain cells in annual grasses (see **Grazing Effects** section below).

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Each state is assigned an overall fire probability and different fire severities or fire pathways are allocated using proportions from USFS and BLM models. Where exotic annual grasses dominate the herbaceous layer, stand-replacing fire leads to the Eg state. The probability of fire-related degradation (fire pathway leading downward one row) increases with increasing juniper density. Fire proportions are allocated as 0.7 mixed-severity and 0.3 stand-replacing for shrub steppe states (and W-PI, since that is still essentially shrub steppe). Stand-replacing fires are prevented from occurring within 2 years of a previous fire in herbaceous states Ng and Rg by TSD.

Grazing Effects

Moderate grazing (GzeMod) in this model increases establishment of shrubs in herbaceous and open shrub states. We assume that multiple factors are usually necessary for significant degradation of range condition, and that fire, drought or grazing alone will not generally result in herbaceous degradation (with the exception of GzeDegrade, which is set at a low probability of 0.005). GzeDegradeP and GzeDegrade model degradation due to improper grazing, and are set at P=0.05 and P=0.005, respectively, for most states. See the description of each type of grazing in the **Probabilistic Transitions** section for more detail about grazing transitions. Because higher elevation sites are more resistant to annual grass invasion, we assume automatic recovery of the herbaceous layer in annual grass cells (row 3) after 9 years via a deterministic transition to row 2. Note that all grazing transitions also prevent improvement in condition by NRHerb in many states where recovery is linked to time since grazing disturbance. The overall probability of moderate grazing decreases in old juniper states as the juniper canopy closes, and no GzeDegrade or GzeDegradeP transitions are modeled here. The probability for GzeMod to accelerate succession toward shrub dominance is set at 0.1118 for herbaceous states, open-mid shrub states, and closed shrub states (taken directly from the BLM WD and CM models).

Juniper Invasion

Juniper invasion stages follow Miller et al. (2005). Phase III juniper is not modeled because low sage sites are generally limited in their juniper potential due to shallow soils, and we assume that most sites will not become dominated by juniper. Juniper age classes were set at 1-40 for W-PI states and 41-120 for W-PII states based on Miller's conceptual model of time periods required to reach each stage in warm dry sites (Miller et al. 2005); although we are assuming that low sage sites are fairly cool and moist, we expect colonization of juniper to be slower in low sage communities compared to big sage due to soil depth limitations. Juniper invasion occurs by probabilistic seeding into closed or depleted sagebrush. The probability of juniper seeding is set at 0.05 in closed shrub and 0.025 in open shrub states, assuming that open shrub states provide fewer sagebrush as nurse plants for juniper establishment. These probabilities are lower than seeding in big sage communities (SWB and SMB models) because low sage sites tend to have fewer soil resources available to support juniper invasion.

Other Transitions

InsectBC and InsectPeak transitions are modeled as cyclical transitions that occur in closed (SHc) shrub states. InsectBC loops to the beginning time step of the same state, and InsectPeak moves to an open shrub (SHo) state within the same row. Probabilities for insect-related transitions are very high, but are deactivated in most years to mimic cyclical dynamics (see **Probabilistic Transitions** section).

Drought transitions loop back to the same box and have no effect other than marking that a drought disturbance has occurred, which allows the GzeDegradeP transition to occur within a 2-year window. Drought has a probability of 0.033, which was derived from the average moderate severity drought frequency across eastern Oregon in Knapp (2004). Severe drought (SevDrought) can occur in shrub states and resets cells to the herbaceous state within the same row for native states (top row), and moves cells directly to annual grass from the second and third rows. SevDrought is controlled by a cyclical multiplier that activates the transition only once every 100-200 years, at which point the probability of transitioning is very high (0.375).

NRHerb is natural recovery of the herbaceous layer by re-seeding of native species, and leads up one row. Many NRHerb transitions are linked to time since grazing disturbance, but not all. NRHerb does not occur in depleted shrub (Shd) or old juniper (W-PIII) states.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

MechTrtShrub transitions lead from depleted shrubs with an overgrazed herbaceous layer (Shd) to an open sagebrush stand (LsRg or LsEg, with equal proportions).

MechTrtJun is mechanical treatment (i.e. chainsawing) of juniper, leading to open shrubs (column 2) within the same row. CutBurnJun is a combined cut and burn treatment in juniper stands, designed to provide ladder fuels from cut trees to connect grass and canopy layers. If successful, this treatment results in a stand-replacing fire and returns cells to an herbaceous state.

SeedNative occurs only in Eg and returns cells to native bunchgrasses (Ng). This transition can only occur within 1 year of a fire, representing the window of opportunity following fire for reseeding before a site becomes dominated by exotic annuals, particularly cheatgrass.

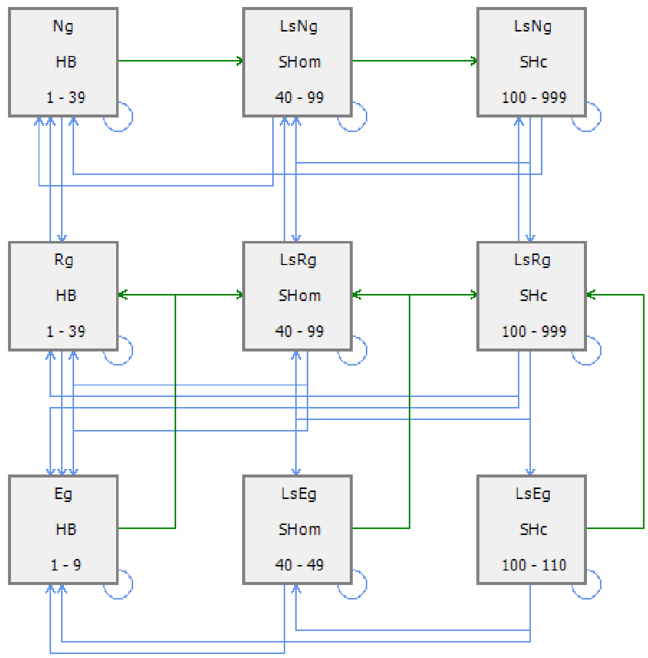
Prescribed fire is applied only in depleted shrub (SHd) and woodland states. It returns cells to the herbaceous state within the same row. The probability of grazing-related degradation is elevated through the GzeDegradeP transition following any type of fire, including prescribed fire.

Model SLN – Low sage – mesic, no juniper

Source:

This model was adapted from USFS LOW_SAGE and BLM CM models and represents low sagebrush (*Artemisia arbuscula*) without juniper invasion potential. The model was adapted directly from the low sagebrush with juniper model (SLW), with all juniper-related states and transitions removed. Note that the most xeric low sagebrush sites are covered by the rigid sage (SRS) model.

Structure:



Description:

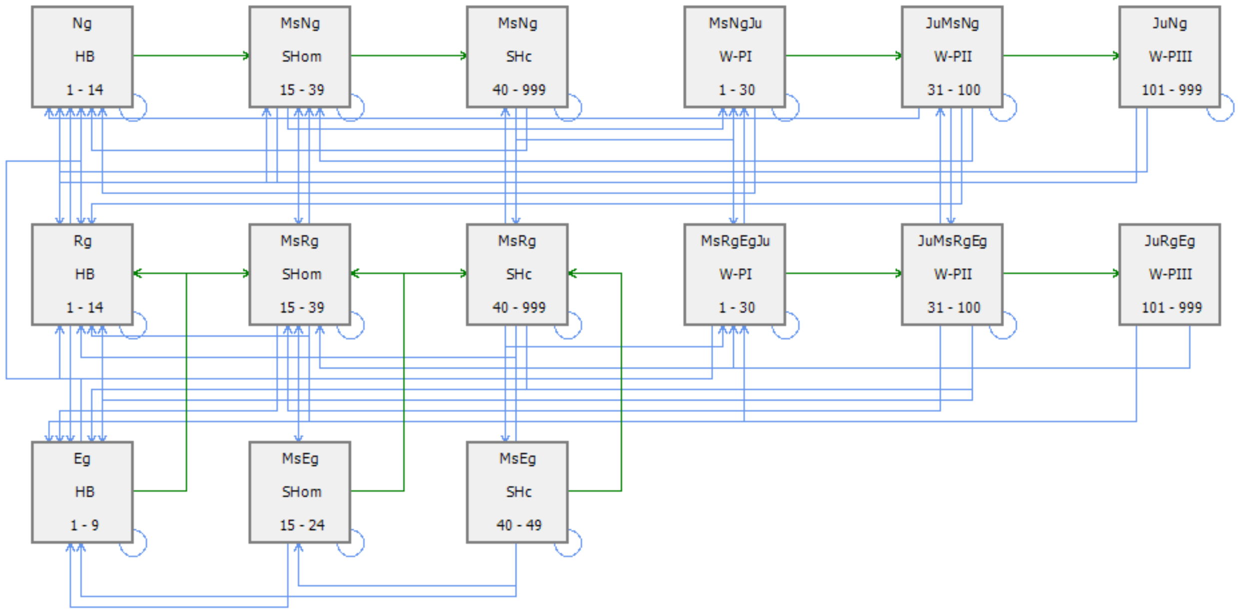
This model is identical to the SLW model with juniper states and transitions removed. Refer to the documentation for model SLW for details.

Model SMB – Mountain big sage - with juniper

Source:

This model was adapted from USFS MTN_BIG_SAGE and BLM CM models for ILAP. It represents mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) upland sites with western juniper (*Juniperus occidentalis*) invasion potential. Indicator herbaceous species include Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Pseudoregeneria spicata*). We use this model for all mountain big sagebrush sites in Oregon, assuming that juniper can invade throughout its distribution.

Structure:



State Classes:

A	Ng	HB	Native bunchgrass grassland dominated by bluebunch wheatgrass and Idaho fescue in good condition, few sagebrush
B	MsNg	SHom	Open-mid sage steppe over native bunchgrass in good condition
C	MsNg	SHc	Closed sage steppe over native bunchgrass in good condition
D	Rg	HB	Semi-degraded herbaceous layer composed of robust grasses and shallow-rooted grasses
E	MsRg	SHom	Open-mid sage steppe with semi-degraded grass layer (see class D)
F	MsRg	SHc	Closed sage steppe with semi-degraded grass layer (see class D)
G	Eg	HB	Exotic annual grasses and unpalatable forbs with few sagebrush
H	MsEg	SHom	Open-mid sage steppe with exotic annual grasses and unpalatable forbs
I	MsEg	SHc	Closed sage steppe with exotic annual grasses and unpalatable forbs
J	MsNgJu	W-PI	Phase I juniper encroachment, consisting of native sagebrush steppe with scattered juniper
K	JuMsNg	W-PII	Phase II juniper encroachment with juniper codominant with shrubs and perennial grasses
L	JuNg	W-PIII	Phase III juniper, dominated by juniper and perennial bunchgrasses, with few sagebrush remaining
M	MsRgEgJu	W-PI	Phase I juniper encroachment, consisting of semi-degraded sagebrush steppe with scattered juniper
N	JuMsRgEg	W-PII	Phase II juniper encroachment where juniper is codominant with semi-degraded shrub steppe
O	JuEgFb	W-PIII	Phase III juniper, dominated by juniper and semi-degraded herbaceous layer (exotic grasses and forbs), with few sagebrush remaining

Description:

Successional stages follow the USFS model, which were developed based on USFS Blue Mountains monitoring data and Baker (2006). These successional stages are shorter than in the BLM CM model but were more consistent with other model sources (TNC and LANDFIRE). Many transition probabilities were taken directly from the BLM CM model. Unlike many of the other shrub models (e.g. Wyoming sage and bitterbrush), recovery from annual grass states is automatic after 9 years via a deterministic transition. Only heavy grazing-related degradation will retain cells in annual grasses (see **Grazing Effects** below). The original USFS MTN_BIG_SAGE model used landscape feedback multipliers for annual grass and juniper invasion rates, but feedback multipliers were not used in ILAP models.

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Each state is assigned an overall fire probability and different fire severities or fire pathways are allocated using proportions from USFS and BLM models. Where exotic annual grasses dominate the herbaceous layer, stand-replacing fire leads to the Eg state. The probability of fire-related degradation (fire pathway leading downward one row) increases with increasing juniper density. Fire proportions are allocated as 0.7 mixed-severity and 0.3 stand-replacing for shrub steppe states (and W-PI, since that is still essentially shrub steppe). Mixed-severity fire does not occur in phase III woodlands due to lack of ladder fuels. Stand-replacing fires are prevented from occurring within 2 years of a previous fire in herbaceous states Ng and Rg by TSD.

Grazing Effects

Moderate grazing (GzeMod) in this model increases establishment of shrubs in herbaceous and open shrub states. We assume that multiple factors are usually necessary for significant degradation of range condition, and that fire, drought or grazing alone will not generally result in herbaceous degradation (with the exception of GzeDegrade, which is set at a low probability of 0.005). GzeDegradeP and GzeDegrade model degradation due to improper grazing, and are set at P=0.05 and P=0.005, respectively, for most states. See the description of each type of grazing in the **Probabilistic Transitions** section of this document for more detail about grazing transitions. Because mountain big sage sites are more resistant to annual grass invasion, we assume automatic recovery of the herbaceous layer in annual grass cells (row 3) after 9 years via a deterministic transition to row 2. Note that all grazing transitions also prevent improvement in condition by NRHerb in many states where recovery is linked to time since grazing disturbance. The probability of moderate grazing decreases in old juniper states as the juniper canopy closes, and no grazing transitions are modeled in phase III woodlands. The probability for GzeMod is set at 0.1118 for herbaceous states, open shrub states, and closed shrub states (taken directly from the BLM WD and CM models).

Juniper Invasion

Juniper invasion stages follow Miller et al. (2005). Juniper age classes were set at 1-30 for W-PI states, 31-100 for W-PII states, and >101 for W-PIII states based on Miller's conceptual model of approximate time required to reach each stage in cool moist sites (Miller et al. 2005). Juniper invasion occurs by probabilistic seeding into sagebrush states. The probability of juniper seeding is set at 0.1 for closed sagebrush and 0.05 for open-mid sagebrush, since increasing shrub cover provides more nurse plants for juniper establishment. These probabilities were modified from the BLM CM model values of 0.1579, which transitioned most sagebrush steppe into juniper woodlands very rapidly.

Other Transitions

InsectBC and InsectPeak transitions are modeled as cyclical transitions that occur in closed (SHc) shrub states. InsectBC loops to the beginning time step of the same state, and InsectPeak moves to an open shrub (SHo) state within the same row. Probabilities for insect-related transitions are very high, but are deactivated in most years to mimic cyclical dynamics (see **Probabilistic Transitions** section).

Drought transitions loop back to the same box and have no effect other than marking that a drought disturbance has occurred, which allows the GzeDegradeP transition to occur within a 2-year window. Drought has a probability of 0.033, which was derived from the average moderate severity drought frequency across eastern Oregon in Knapp (2004). Severe drought (SevDrought) can occur in shrub states and resets cells to the herbaceous state within the same row for native states (top row), and moves cells directly to annual grass from the second and third rows. SevDrought is controlled by a cyclical multiplier that activates the transition only once every 100-200 years, at which point the probability of transitioning is very high (0.375).

NRHerb is natural recovery of the herbaceous layer by re-seeding of native species, and leads up one row. Many NRHerb transitions are linked to time since grazing disturbance, but not all. NRHerb does not occur in depleted shrub or phase III juniper states.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

MechTrtShrub transitions lead from depleted shrubs with an overgrazed herbaceous layer (Shd) to an open sagebrush stand (MsRg or MsEg, with equal proportions).

MechTrtJun is mechanical treatment (i.e. chainsawing) of juniper, leading to open shrubs (column 2) within the same row. CutBurnJun is a combined cut and burn treatment in juniper stands, designed to provide ladder fuels from cut trees to connect grass and canopy layers. If successful, this treatment results in a stand-replacing fire and returns cells to an herbaceous state.

SeedNative occurs only in Eg and returns cells to native bunchgrasses (Ng). This transition can only occur within 1 year of a fire, representing the window of opportunity following fire for reseeding before a site becomes dominated by exotic annuals, particularly cheatgrass.

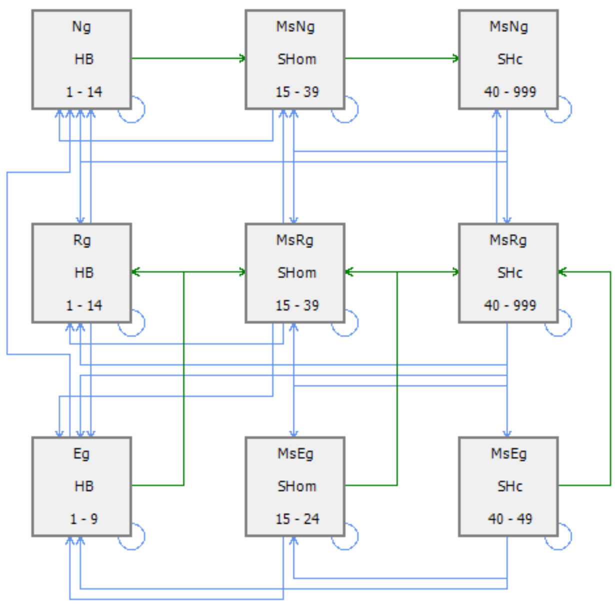
Prescribed fire is applied only in depleted shrub (SHd) and woodland states. It returns cells to the herbaceous state within the same row for P-I and P-II woodlands, and down one row for prescribed fire in P-III juniper. The probability of grazing-related degradation is elevated through the GzeDegradeP transition following any type of fire, including prescribed fire.

Model SMN – Mountain big sage - no juniper

Source:

This model was adapted from the USFS MTN_BIG_SAGE and BLM CM models. It is intended for upland mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) sites in Washington, beyond the range of Western juniper.

Structure:



Description:

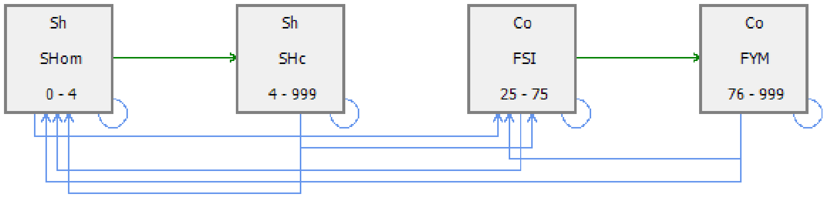
This model is identical to the Mountain big sagebrush with juniper (SMB) model, except that all juniper states and transitions were removed. See the documentation for model SMB for details about this model.

Model SMS – Montane and canyon shrubland

Source:

This model was taken directly from the USFS MONTANE_SHRUB model and represents high-elevation shrublands. It is primarily meant to mainly cover the mallow ninebark (*Physocarpus malvaceu*)-snowberry (*Symphoricarpos albus*) plant association but also includes in part communities successional to Douglas-fir (*Pseudotsuga menzesii*) where forest succession is chronically shortcut by fires or delayed by lack of seed source. It could also applied to common snowberry (*Symphoricarpos albus*) shrublands. This PVT often occurs in moist swales within a matrix of subalpine grasslands (model GFV).

Structure:



State Classes:

A	Sh	SHom	Postfire resprouting of shrubs and herbs.
B	Sh	SHc	Mature persistent closed shrub stage
C	Co	FSI	Scattered open pole-sized conifers (primarily Douglas fir) over closed shrubs
D	Co	FYM	Conifer trees (Douglas fir) increasing in cover – still sparse but a few big enough (>50 yrs) to survive moderate fires

Description:

MTBS fire data were not used for this model, and fire probability is set as 0.04 (25 year fire return interval), taken directly from the USFS model. This probability is based on the occurrence of these communities as stringers in grasslands thought to burn at about 5 to 20 yr intervals, assuming some instances where fire skips over the moist swales where montane shrubs occur. Fires change from all stand-replacement in early succession (SHom) to part mixed as the community ages, and stand-replacement and mixed equal in probability in the FYM structural stage. Mixed severity fires recycle cells to the same class, and represents low-severity burn conditions where the shrub layer survives largely intact.

The GzeMod transition represents a hypothesized concentration of herbivores (deer, elk, cattle, sheep) in a burned area that maintains open shrubs. Based on USFS observations, this is probably rare; these vigorous shrubs are not highly preferred as browse and are typically able to attain dense cover.

InsectDisease represents an insect/disease event that kills trees and sends cells from FYM to FSI, with a hypothesized probability of 0.005.

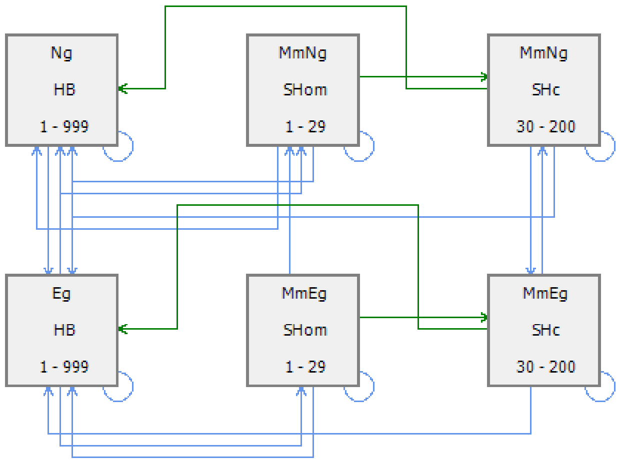
Douglas fir establishment is by natural seeding through the NRFir transition. The probability of fir establishment is greatest (0.05) right after fire and before shrubs take over, and then declines to 0.005.

Model SMM – Mountain mahogany

Source:

This model was taken directly from the USFS MTN_MAHOGANY model and is designed to cover curl-leaf mountain mahogany (*Cercocarpus ledifolius*) communities that have existed for a century or more due to natural firebreaks or light fuels, but is also applied to more recent mahogany expansion. Common components of the herbaceous layer include Sandberg's bluegrass (*Poa secunda*), Wheeler's bluegrass (*Poa nervosa*), elk sedge (*Carex garberi*), bluebunch wheatgrass (*Pseudoregeneria spicata*), and Idaho fescue (*Festuca idahoensis*).

Structure:



State Classes:

A	Ng	HB	Herbaceous community dominated by native grasses and sedges (Sandberg's bluegrass, Wheeler's bluegrass, elk sedge, bluebunch wheatgrass, Idaho fescue)
B	MmNg	SHom	Mountain mahogany regeneration over native grasses and sedges
C	MmNg	SHc	Closed old mountain mahogany (tall enough to escape browsing) over relatively pristine native herbaceous layer
D	Eg	HB	Herbaceous community dominated by exotic annual grasses, unpalatable perennial forbs, and Sandberg's bluegrass
E	MmEg	SHo	Mountain mahogany regeneration, degraded herbaceous layer as in class D. Mahogany is low and hedged.
F	MmEg	SHc	Closed old mountain-mahogany (tall enough to escape browsing but with an obvious browse line) over degraded herbaceous layer.

Description:

Succession in this model (as in the bitterbrush models – SPT and SPN) is not deterministic from herbaceous to shrub states due to high browsing pressure by native ungulates and livestock in many parts of its range (see **Grazing Effects**). Note that the original MTN_MAHOGANY model used landscape feedback multipliers for annual grass invasion rates, but feedback multipliers were not used in ILAP models.

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Only stand-replacing fire is modeled in this PVT, returning cells to the herbaceous state within the same row.

Grazing Effects

Due to heavy grazing pressure in many parts of its range, there is no deterministic transition between herbaceous states (Ng, Eg) and shrub states. Open-mid shrub states undergo deterministic succession to closed shrub states after 30 years. Mature mountain-mahogany classes (SHc) undergo succession to classes lacking mahogany (Ng and Eg) at an age of 200 years old by deterministic transition (representing dieoff of existing shrubs) unless a ShrubRejuv event delays this deterministic transition. ShrubRejuv has a TSD requirement of 30 yrs with no grazing or browsing, under the assumption that mahogany will live about 200 years but some time during that period it needs a 30-yr break from significant grazing/browsing to allow regeneration and growth to a sufficient height that browsers cannot reach all foliage. This is based on the USFS anecdotal observations of about 4 in/yr growth of mountain-mahogany and presumed minimum safe height of about 9 ft. The browse disturbance sets the successional clock back one year in classes B and E at each occurrence, slowing or preventing this succession. Note that rejuvenation can be prevented by all types of grazing and browsing.

Grazing-related degradation (GzeDegrade) leads to a shift down from relatively pristine row (row 1) to the more impacted second row. Recovery from grazing degradation from the 2nd row back to the 1st row is by AltSucc. This occurs automatically (P = 1) after 30 years rest from grazing, under the assumption that these communities never become so degraded that a probabilistic re-seeding event is required to restore them (for example, the rocky ground with sparse forage might discourage cattle grazing).

Other Transitions

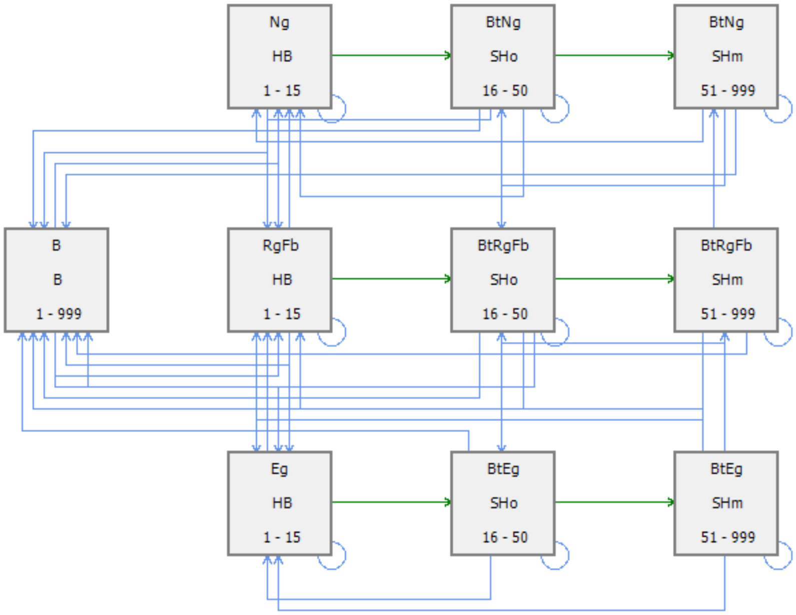
Regeneration of mountain mahogany is modeled as a probabilistic seeding event (NRMM) that is prevented from occurring by browsing and grazing disturbance (TSD = 10).

Model SPS – Bitterbrush - sand

Source:

This model was created based on expert opinion for ILAP to characterize sandy dune bitterbrush shrublands found in the southern Columbia basin of Washington and Oregon near the Columbia River. This system is characterized by needle-and-thread (*Hesperostipa comata*) and Indian rice grass (*Achnatherum hymenoides*) grasslands, with bitterbrush (*Purshia tridentata*) as the dominant shrub and some Wyoming big sagebrush (*Artemisia tridentata ssp. Wyomingensis*). Some areas support some Sandberg bluegrass (*Poa secunda*) and bluebunch wheatgrass (*Pseudoregeneria spicata*). This PVT is highly fragmented among agricultural landscapes of south-central Washington and north-central Oregon across most of its distribution.

Structure:



State Classes:

A	Ng	HB	Native perennial bunchgrass (Needle-and-thread and Indian rice grass) with little bitterbrush
B	BtNg	SHo	Open bitterbrush cover with native bunchgrass understory
C	BtNg	SHm	Mid bitterbrush cover with native bunchgrass understory
D	B	B	Open sand with little vegetation, usually caused by a severe wind disturbance that uproots most grasses and shrubs
E	RgFb	HB	Semi-degraded conditions dominated by robust grasses and forbs, with some exotic annual grass
F	BtRgFb	SHo	Open bitterbrush cover with robust grass, forb, and exotic grass understory
G	BtRgFb	SHm	Open bitterbrush cover with robust grass, forb, and exotic grass understory
H	Eg	HB	Exotic annual grass
I	BtEg	SHo	Open bitterbrush cover with exotic annual grass understory
J	BtEg	SHm	Mid bitterbrush cover with exotic annual grass understory

Description:

Successional stages in this model are based on expert opinion and have longer age ranges due to the arid environment and sandy soils limiting site productivity. Unlike the other bitterbrush models (SPN and SPT), bitterbrush seeding from herbaceous states is deterministic in this model. The dunes of the southern Columbia basin do not experience the levels of browsing by native ungulates in the Blue Mountains, where the SPN and SPT models were developed. No closed shrub states exist in this model, as the dry climate and well-drained soils do not tend to support high plant cover.

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections).

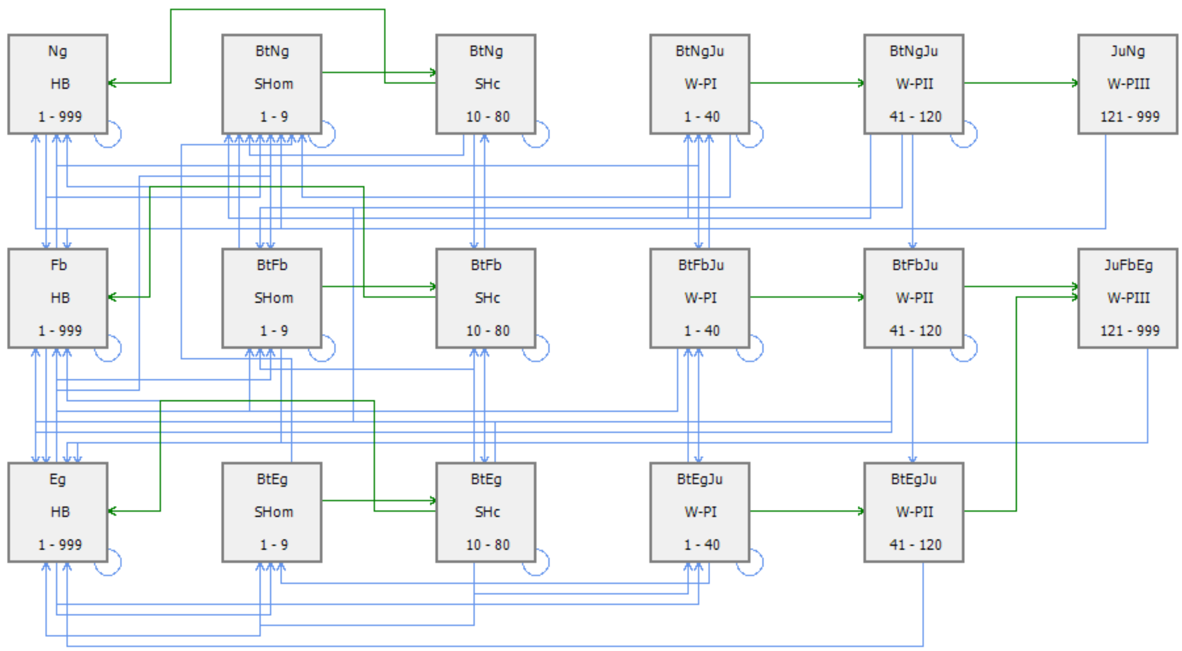
Wind disturbance can be an important part of these ecosystems, as sandy soils and dunes can experience strong winds that are sometimes of sufficient strength to uproot plants and create scours and deposits. Grazing-related degradation in this model leads from perennial to annual grasses, as in other models, but with a higher probability than in other systems because dune systems are more susceptible to degradation than sage steppe. GzeMaint, a grazing transition with no effect on vegetation structure or composition, is not included in this model because this system is highly susceptible to grazing-related degradation and maintenance grazing is very difficult to achieve. GzeMod probability is set at 0.1118, taken from BLM sagebrush models.

Model SPT – Bitterbrush - with juniper

Source:

This model was taken from the USFS PUTR model with few modifications and represents antelope bitterbrush (*Purshia tridentata*) communities that have potential for juniper invasion.

Structure:



State Classes:

A	Ng	HB	Native bunchgrass (Idaho fescue and bluebunch wheatgrass) post-fire community with little bitterbrush
B	BtNg	SHc	Closed bitterbrush, native perennial grasses, bitterbrush is often hedged and not regenerating
C	BtNgJu	W-PI	Phase I juniper encroachment, consisting of native bitterbrush shrub steppe with scattered juniper
D	BtNgJu	W-PII	Phase II juniper encroachment with shrubs and grasses (bitterbrush, Idaho fescue, and bluebunch wheatgrass) codominant with juniper
E	Fb	HB	Semi-degraded post-fire community with little bitterbrush, native bunchgrasses reduced, and perennial forbs dominant

F	BtFb	SHc	Closed bitterbrush, semi-degraded herbaceous layer dominated by forbs, bitterbrush is often hedged and not regenerating
G	BtFbJu	W-PI	Phase I juniper encroachment, consisting of scattered juniper over bitterbrush shrubs and a semi-deegraded herbaceous layer
H	BtFbJu	W-PII	Phase II juniper encroachment with juniper codominant with hedged bitterbrush and a forb-dominated understory
I	Eg	HB	Post-fire degraded grassland dominated by exotic annual grasses and some perennial forbs
J	BtEg	SHc	Closed bitterbrush, annual grasses, bitterbrush is often hedged and not regenerating
K	BtEgJu	W-PI	Phase I juniper encroachment, consisting of scattered juniper over bitterbrush shrubs and a degraded exotic annual herbaceous layer
L	BtEgJu	W-PII	Phase II juniper encroachment with juniper codominant with hedged bitterbrush and a exotic annual grasses dominating understory
M	BtNg	SHom	Perennial bunchgrass with post-fire resprouting or reseeding bitterbrush at open-mid cover.
N	BtFb	SHom	Bitterbrush resprouting or reseeding to open-mid cover with forb-dominanted semi-degraded herbaceous layer
O	BtEg	SHom	Regenerating bitterbrush at open-mid cover over a degraded herbaceous layer dominated by exotic annual grasses
P	JuNg	W-PIII	Phase III juniper encroachment with juniper dominant, low cover of hedged bitterbrush persisting, and a mostly native herbaceous layer
Q	JuFbEg	W-PIII	Phase III juniper encroachment with juniper dominant, low cover of hedged bitterbrush persisting, and a forb and exotic grass-dominated understory

Description:

Succession in this model (as in the mountain mahogany (SMM) model) is not deterministic from herbaceous to shrub states due to high browsing pressure by native ungulates and livestock in many parts of its range (see **Grazing Effects**). Note that the original PUTR model used landscape feedback multipliers for annual grass and juniper invasion rates, but feedback multipliers were not used in ILAP models.

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). With fire, bitterbrush shrubs with and without juniper go to open-mid shrub (SHom) states (bitterbrush regeneration communities). They move back to closed shrub (SHc) in 10 years unless the GzeBrowse disturbance kills the bitterbrush and moves it to an herbaceous state. Older, denser juniper are assumed to have some mixed fires that do not cause a change in structure except for the communities with abundant annual grasses (BtEgJu) where fire leads to phase I juniper. Stand replacement fires in dense juniper cause degradation of herb layer (move down one row), due to a very hot fire in a weakened stand of grass. We assume that bitterbrush can still regenerate from the good condition stand, so the stand-replacement fires in native juniper states lead to regenerating bitterbrush (SHom). From phase III juniper with exotic grass understory, we assume that bitterbrush is too weak and dies out, resulting in exotic grasses.

Grazing Effects

Bitterbrush is heavily browsed by native ungulates and livestock in many parts of its range, resulting in very little regeneration to renew aging decadent bitterbrush stands. Because of the heavy grazing pressure, there is no deterministic transition between herbaceous states and states containing shrubs. Young bitterbrush stands (SHom) transition from open-mid to closed shrub deterministically after 9 years, and after an assumed average lifespan of 80 years, decadent bitterbrush shrubs die out and return to herbaceous states. ShrubRejuv can prevent the deterministic transition back to herbaceous states with a relative age of -70 but requires 10 yrs with no grazing by TSD.

GzeBrowse is a disturbance that simulates wildlife or cattle browsing in the bitterbrush-regenerating boxes (SHom) that does not degrade the herb layer but does kill the regenerating bitterbrush, so you move 1 column left to A, E, I. Grazing degradation leads down one row and as in other models is broken down into post-fire GzeDegradeP and later GzeDegrade. In this model the GzeDegrade transitions also causes loss of bitterbrush in bitterbrush-regenerating classes, so GzeDegrade moves cells down a row and left 1 column. GzeMod loops to the same box with a relative age of -1, slowing succession by one year in each time step it occurs.

Juniper Invasion

Juniper invasion (NRJun) is probabilistic natural juniper seeding establishment. Herbaceous states require a time since fire disturbance of 10 years for juniper invasion to occur. Open-mid shrub states are transient post-fire communities and thus aren't susceptible to juniper invasion. The probability of juniper invasion from HB and SHc states is 0.01, taken directly from the USFS models.

The original USFS model creators identified one problem with this model: juniper invasion of herbaceous states leads to juniper communities defined as having a bitterbrush understory. Strictly speaking it should lead to a juniper community with no bitterbrush, but this complication was not added to the model.

Other Transitions

Recovery of the herbaceous layer in moderately degraded row 2 is by AltSucc, with automatic recovery (a probability of 1) after 30 years time since grazing disturbance. This transition doesn't occur with dense juniper. From the more degraded condition of row 3, recovery of bunchgrasses is by probabilistic natural seeding NRHerb, 10 years of time since grazing disturbance. SeedNative is artificial seeding of native plants, including bitterbrush, into non-juniper classes of row 3, and leads to regenerating stand in good condition.

NRPutr is bitterbrush establishment by natural seeding. This can occur even in a degraded community but only after 10 years time since grazing disturbance. The probability is set at 0.10 from the USFS model.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

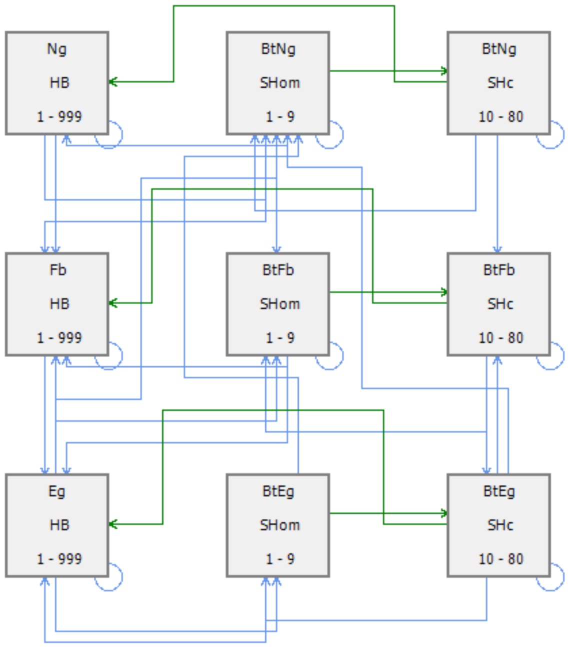
MechTrtJun is mechanical treatment (i.e. chainsawing) of juniper, leading to open shrubs (column 2) within the same row.

Model SPN – Bitterbrush - no juniper

Source:

This model was taken from the USFS PUTR model, with all juniper states and transitions removed. It represents antelope bitterbrush (*Purshia tridentata*) communities in Washington, beyond the range of Western juniper.

Structure:



Description:

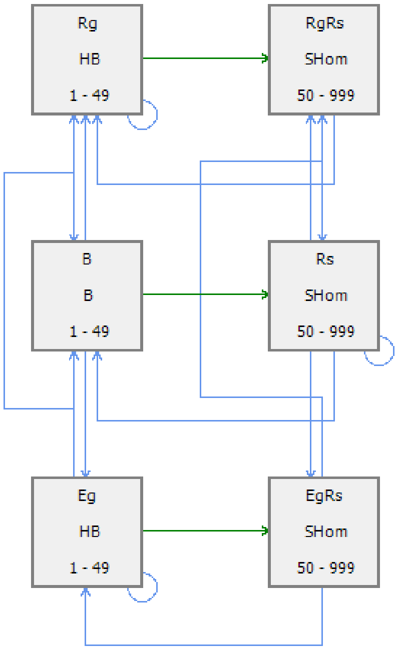
This model was adapted directly from the bitterbrush with juniper (SPT) model, with all juniper states and transitions removed. See documentation for model SPT for details about this model.

Model SRS – Rigid sage

Source:

This model was taken directly from the USFS RIGID_SAGE model. It represents rigid sagebrush (*Artemisia rigida*) and xeric low sagebrush (*Artemisia arbuscula*) scabland communities. These communities tend to be dry with shallow, rocky soils, and consequently form sparse cover. It is taken from the USFS RIGID_SAGE model with few modifications for ILAP.

Structure:



State Classes:

A	Rg	HB	Native bunchgrasses (esp. Sandberg's bluegrass), few shrubs
B	RgRs	SHom	Open-mid rigid sagebrush and native bunchgrass (total cover usually sparse)
C	B	B	Sparse cover of unpalatable perennial forbs with much bare soil and little cryptogam cover. This is a degraded version of box A.
D	Rs	SHom	Open-mid rigid sage with sparse unpalatable forbs and few native bunchgrasses, often hedged by browsing
E	Eg	HB	Dominated by exotic annual grasses such as cheatgrass, Ventenata and/or medusahead
F	EgRs	SHom	Open-mid rigid sagebrush with exotic annual grasses

Description:

Rigid sage sites have very limited site productivity and support only low cover of shrubs and grasses. Therefore, no closed shrub states are modeled, and open-mid shrub cover is included in a single state, representing sparse sagebrush.

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). The rate of recovery of rigid sagebrush after fire is poorly known, and the slow rate in the model (50 years to reach open shrub cover) was taken directly from the USFS model.

Grazing-related degradation is modeled using the GzeDegrade transition, with no GzeDegradeP (post-disturbance) included in this model. The probability of grazing-related degradation is 10-fold greater in the bare ground state (C), because states with low plant cover are assumed to be more susceptible to invasive species.

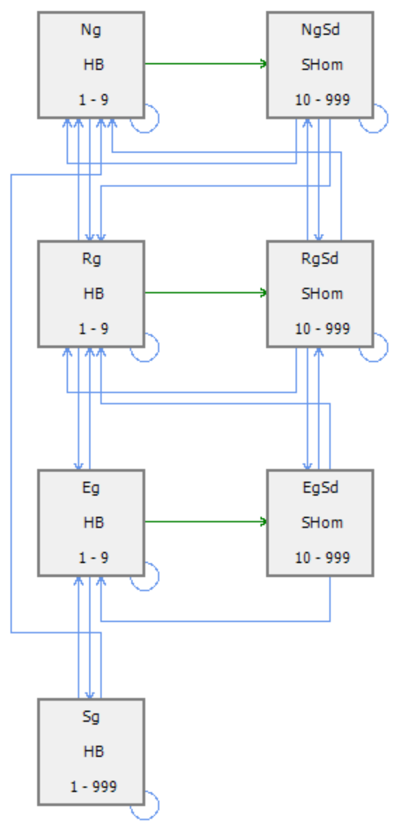
Recovery of the herbaceous layer occurs by AltSucc, which moves cells in the second row to the top row if no grazing disturbance has occurred in the last 30 years by TSD.

Model SSD – Salt desert shrub - lowland

Source:

This model was built for ILAP based on the USFS SAVE_DISP model, TNC-NV greasewood model, and expert opinion. It is intended for alkaline lowlands dominated by greasewood (*Sarcobatus vermiculatus*) shrubs with saltgrass (*Distichlis spicata*) or basin wildrye (*Leymus cinereus*) understory. This type is often interspersed with irrigated agriculture.

Structure:



State Classes:

A	Ng	HB	Perennial grasses, especially basin wildrye, with few shrubs
B	NgSd	SHom	Open-mid shrub cover dominated by greasewood and other salt desert species, and basin wildrye as the dominant grass species
C	Rg	HB	Robust grasses, particularly saltgrass, with few or no shrubs
D	RgSd	SHom	Open-mid shrub cover dominated by greasewood with saltgrass and other robust grasses in the understory
E	Eg	HB	Exotic annual grasses with a minor component of salt grasses and other robust native grass species
F	EgSd	SHom	Exotic annual grasses (some saltgrass) with open-mid shrub cover dominated by

			greasewood and other salt desert species
G	Sg	HB	Seeded exotic pasture grasses

Description:

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Greasewood and grasses both resprout after fire, and thus it only takes 10 years for greasewood to regain open cover in herbaceous states.

Flooding is modeled with a frequency of 0.007 based on the TNC-NV model, returning cells from open-mid shrub (SHom) states to Rg (robust grass, i.e. saltgrass). GzeDegrade moves cells down one row toward annual grasses (third row). Saltgrass and seeded wheatgrasses are both resistant to grazing, so the probability of grazing-related degradation is 10-fold lower (P=0.0005) than basin wildrye states (top row) (P=0.005). No GzeDegradeP or GzeMod transitions are included in this model.

Natural recovery of the herbaceous layer improves condition from annual grasses to saltgrass or basin wildrye through NRHerb. The probability is set arbitrarily at 0.01.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

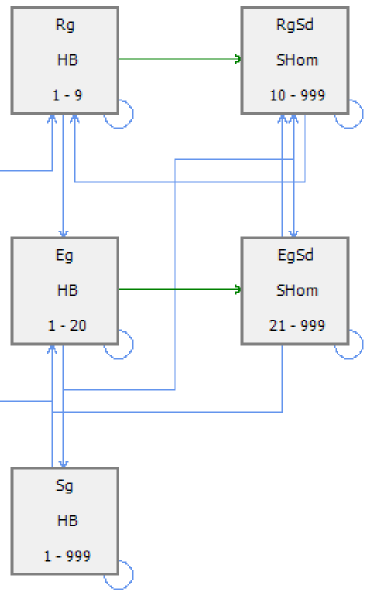
SeedExotic is the only management transition in this model, moving cells from annual grass (Eg) to seeded wheatgrass (Sg).

Model SSU – Salt desert shrub - upland

Source:

This model was built for ILAP based on expert opinion and the TNC-NV mixed salt desert model, which provided parameter values for some transitions. It is intended for salt desert shrub areas such as alkaline ash beds and alkaline hills around playas. Typical shrub species include shadscale saltbush (Atriplex confertifolia), bud sagebrush (Picrothamnus desertorum), spiny hopsage (Grayia spinosa), and horsebrush (Tetradymia species). Common grass species include Indian ricegrass (Achnatherum hymenoides), thickspike wheatgrass (Elymus lanceolatus), western wheatgrass (Pascopyrum smithii), and Sandberg's bluegrass (Poa secunda). These systems grade into Wyoming big sagebrush, and most transitional areas are included in the SWN model.

Structure:



State Classes:

A	Rg	HB	Native perennial and robust grasses with few shrubs
B	RgSd	SHom	Mixed salt desert shrub with open-mid shrub cover and native/robust perennial grass layer
C	Eg	HB	Exotic annual grasses
D	EgSd	SHom	Exotic annual grasses with mixed salt desert shrubs at open-mid cover
E	Sg	HB	Seeded exotic wheatgrass and other pasture grasses

Description:

Succession leads from Rg to RgSd after 9 years, based on the USFS SAVE_DISP model. We assume that it takes longer for shrub species to recolonize annual grass-dominated areas, and thus it takes 20 years to transition from Eg to EgSd via succession.

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections).

Drought frequency is 0.0180, taken directly from the TNC-NV model. Drought prevents cells from moving from herbaceous to shrub states by looping back to the beginning time step of herbaceous states, and can kill shrubs and move cells from shrub to herbaceous states. GzeDegrade causes degradation from the top row toward exotic annual grasses (second row), as in other models. GzeDegradeP and GzeMod not used in this model.

Natural recovery of the herbaceous layer in box D can occur at a probability of 0.005, moving cells upward to box B. Seeded states (E) can recover to salt desert shrub (B) through alternative succession, at a probability of 0.001.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

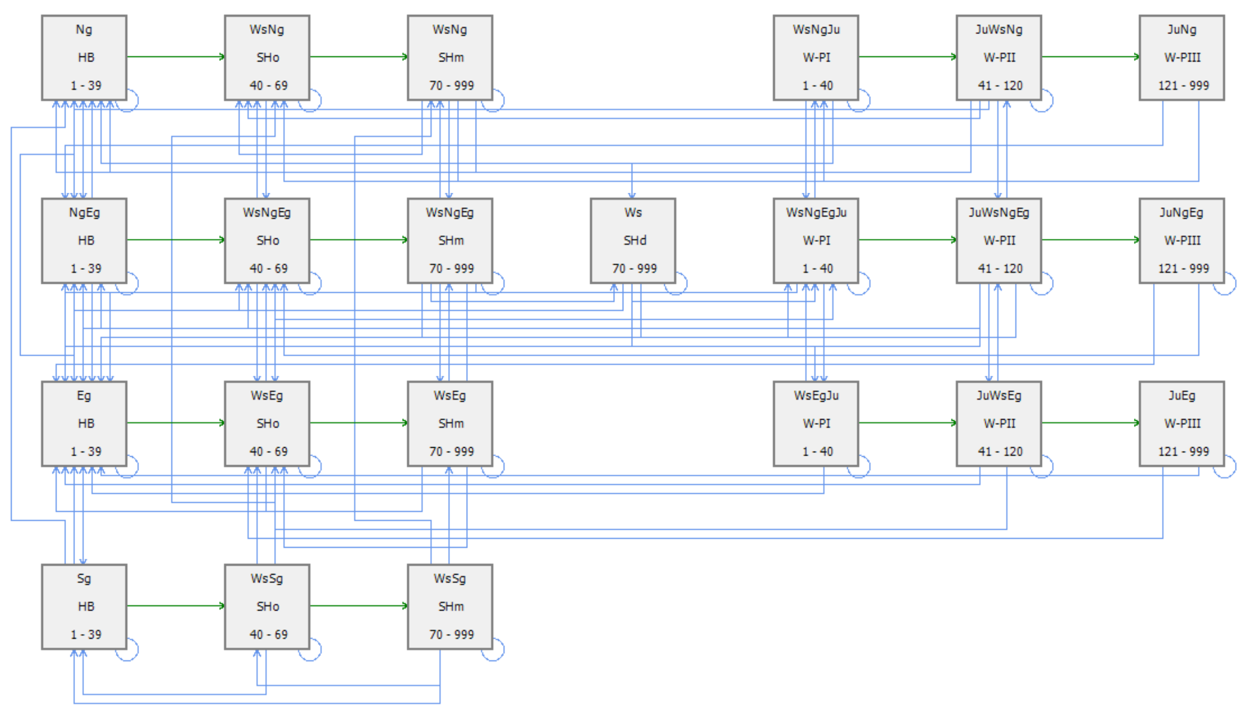
SeedExotic is the only management transition in this model, moving cells from Eg to seeded wheatgrass (Sg).

Model SWB – Wyoming big sage - with juniper

Source:

This model was created from the USFS WYO_BIG_SAGE and BLM WD and CM models. It is intended for drier sites where Wyoming big sage (*Artemisia tridentata* ssp. *wyomingensis*) or basin big sage (*Artemisia tridentata* ssp. *tridentata*) is the primary shrub species, but where enough moisture is present that juniper invasion potential exists. It is intended mainly for environments too dry to support Idaho fescue, replaced by bluebunch wheatgrass (*Pseudoregenria spicata*), Thurber needlegrass (*Achnatherum thurberianum*), bottlebrush squirreltail (*Elymus elymoides*), or needle-and-thread grass (*Hesperostipa comata*).

Structure:



State Classes:

A	Ng	HB	Perennial native bunchgrass
B	WsNg	SHo	Open sage steppe with perennial native bunchgrass understory
C	WsNg	SHm	Mid-cover sage steppe with perennial native bunchgrass understory
D	NgEg	HB	Semi-degraded grasses: perennial and exotic annual grasses codominate

			the herbaceous layer
E	WsNgEg	SHo	Open sage steppe with semi-degraded grass layer (see class D)
F	WsNgEg	SHm	Mid-cover sage steppe with semi-degraded grass layer (see class D)
G	Eg	HB	Exotic annual grasses and unpalatable forbs with large native bunchgrasses eliminated
H	WsEg	SHo	Open sage steppe with understory dominated by exotic annuals
I	WsEg	SHm	Mid-cover sage steppe with understory dominated by exotic annuals
J	Ws	SHd	Depleted shrub (dense shrub cover and low grass cover) due to grazing of herbaceous species
K	Sg	HB	Seeded exotic wheatgrass, especially crested wheatgrass
L	WsSg	SHo	Seeded exotic wheatgrass with invading (open) sagebrush
M	WsSg	SHm	Seeded exotic wheatgrass with mid cover of sagebrush
N	WsNgJu	W-PI	Phase I juniper invasion – sage steppe with scattered juniper, native bunchgrasses dominate the herbaceous layer
O	JuWsNg	W-PII	Phase II juniper invasion where juniper is codominant with shrub/grass layer, native perennial grasses
P	JuNg	W-PIII	Phase III juniper invasion, where juniper is dominant, few sagebrush are present, and perennial bunchgrasses dominate the understory
Q	WsNgEgJu	W-PI	Phase I juniper invasion, consisting of sage steppe with low cover of juniper. Grass layer is semi-degraded with a mix of annual and perennial grasses
R	JuWsNgEg	W-PII	Phase II juniper invasion where juniper is codominant with shrub/grass layer, herbaceous layer is mixed exotic annual and native perennial grasses
S	JuNgEg	W-PIII	Phase III juniper invasion, where juniper is dominant, few sagebrush are present, and a mix of perennial and annual grasses compose the understory
T	WsEgJu	W-PI	Phase I juniper invasion, sage steppe with scattered juniper at low cover, herbaceous layer is dominated by annuals
U	JuWsEg	W-PII	Phase II juniper invasion where juniper is codominant with shrub/grass layer, exotic annual grasses in understory
V	JuEg	W-PIII	Phase III juniper invasion – juniper is dominant, few sagebrush are present, and exotic annual grasses dominate the understory

Description:

Successional stages follow the USFS model, which were shorter than the BLM-WD and CM models but were more consistent with other model sources (TNC and LANDFIRE models). The structure of the left half of the model is similar to both the BLM WD model and the USFS WYO_BIG_SAGE model, and juniper states (right half of the model) were retained from the USFS model and modified based on the BLM CM model. Seeded states (fourth row) were retained from the USFS model because post-fire seeding of exotic perennials has been a common practice in these environments. Note that the original WYO_BIG_SAGE model used landscape feedback multipliers for annual grass and juniper invasion rates, but feedback multipliers were not used in ILAP models.

Fire Effects

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Where exotic annual grasses dominate the herbaceous layer, stand-replacing fire leads to the Eg state. The probability of fire-related degradation (fire pathway leading downward one row) increases with increasing shrub density and juniper density. Fire proportions are allocated as 0.7 mixed-severity and 0.3 stand-replacing for shrub steppe states (and W-PI, since that is still essentially shrub steppe). Mixed-severity fire does not occur in phase III woodlands due to lack of ladder fuels. Nonlethal fire (surface fire) was modeled in Phase-III juniper states with a semi-degraded or highly degraded herbaceous layer (JuNgEg and JuEg), representing burning of the herbaceous layer that does not reach the tree canopy and resets to the first time step of the same state. We assume that 80% of the fires in these degraded phase-III woodland states are nonlethal and 20% of the fires are stand-replacing, returning cells to Eg. Stand-replacing fires are prevented from occurring within 2 years of a previous fire in herbaceous states Ng and NgEg by TSD.

Grazing Effects

Moderate grazing (GzeMod) in this model increases establishment of shrubs in herbaceous and open shrub states, and probabilistically transitions cells to depleted shrubs (SHd) in closed shrub states. We assume that multiple factors are usually necessary for significant degradation of range condition, and that fire, drought or grazing alone will not generally result in herbaceous degradation (with the exception of GzeDegrade, which is set at a low probability of 0.005). GzeDegradeP and GzeDegrade model degradation due to improper grazing, and are set at P=0.05 and P=0.005, respectively, for most states. See the description of each type of grazing in the **Probabilistic Transitions** section of this document for more detail about grazing transitions. Because seeded exotic grasses (fourth row) are actually more resistant to grazing-related degradation than native bunchgrasses, the GzeDegrade and GzeDegradeP transitions are set to one tenth of the probability of degradation in native states. Note that all grazing transitions also prevent improvement in condition by NRHerb in many states where recovery is linked to time since grazing disturbance. The probability of moderate grazing decreases in old juniper states as the juniper canopy closes, and no grazing transitions are modeled in phase III woodlands. The probability for GzeMod is set at 0.1118 for herbaceous states, open shrub states, and closed shrub states (taken directly from the BLM WD and CM models), but is lowered to 0.05 for closed shrub states transitioning to depleted shrub (SHd).

Juniper Invasion

Juniper invasion stages follow Miller et al. (2005). Juniper age classes were set at 1-40 for W-PI states, 41-100 for W-PII states, and >121 for W-PIII states based on Miller's conceptual model of approximate time required to reach each stage in warm, dry sites (Miller et al. 2005). Juniper invasion occurs by probabilistic seeding into sagebrush states. The probability of juniper seeding is set at 0.1 for depleted sagebrush and 0.08 for mid sagebrush, since increasing shrub cover provides more nurse plants for juniper establishment. No juniper seeding can occur into open shrub states due to lack of sufficient nurse plants. These probabilities were modified from the BLM CM model values of 0.1579, which transitioned most sagebrush steppe into juniper woodlands very rapidly and are developed for much more mesic sites.

Other Transitions

Note that many disturbance transitions in the depleted shrub state (SHd) are split between semi-degraded and annual grass rows. Insect peak, severe drought, and mechanical shrub treatments split cells equally between open shrub WsNgEg/SHo and WsEg/SHo, and juniper seeding splits cells between phase I juniper in rows 2 and 3. Stand-replacing fires, however, returns cells only to Eg.

InsectBC and InsectPeak transitions are modeled as cyclical transitions that occur in mid (SHm) shrub and depleted shrub (SHd) states. InsectBC loops to the beginning time step of the same state, and InsectPeak moves to an open shrub (SHo) state within the same row. Probabilities for insect-related transitions are very high, but are deactivated in most years to mimic cyclical dynamics (see **Probabilistic Transitions** section).

Drought transitions loop back to the same box and have no effect other than marking that a drought disturbance has occurred, which allows the GzeDegradeP transition to occur within a 2-year window. Drought has a probability of 0.033, which was derived from the average moderate severity drought frequency across eastern Oregon in Knapp (2004). Severe drought (SevDrought) can occur in shrub states and resets cells to the herbaceous state within the same row for native states (top row), and moves cells directly to annual grass from the second and third rows. SevDrought is controlled by a cyclical multiplier that activates the transition only once every 100-200 years, at which point the probability of transitioning is high (0.375).

Natural regeneration of the herbaceous layer (NRHerb) can move cells toward less degraded states (upward one row). The probability of NRHerb is set at 0.01 and requires 30 years time since grazing disturbance to occur. NRHerb does not occur in depleted shrub (SHd) or phase III juniper states where little herbaceous cover exists.

Management Transitions

All management transitions are set with a default probability of 0.01 that can be altered using multipliers. The default ILAP scenarios were run with no management activities (except grazing), and therefore multipliers are set to 0 for all management transitions, preventing them from occurring.

MechTrtShrub transitions lead from depleted shrubs with an overgrazed herbaceous layer (Shd) to an open sagebrush stand (WsNgEg or WsEg, with equal proportions).

MechTrtJun is mechanical treatment (i.e. chainsawing) of juniper, leading to open shrubs (column 2) within the same row. CutBurnJun is a combined cut and burn treatment in juniper stands, designed to provide ladder fuels from cut trees to connect grass and canopy layers. If successful, this treatment results in a stand-replacing fire and returns cells to an herbaceous state.

SeedNative occurs only in Eg and returns cells to native bunchgrasses (Ng). This transition can only occur within 1 year of a fire, representing the window of opportunity following fire for reseeding before a site becomes dominated by exotic annuals, particularly cheatgrass. SeedExotic moves cells from Eg to Sg, and also can only occur within 1 year of a fire.

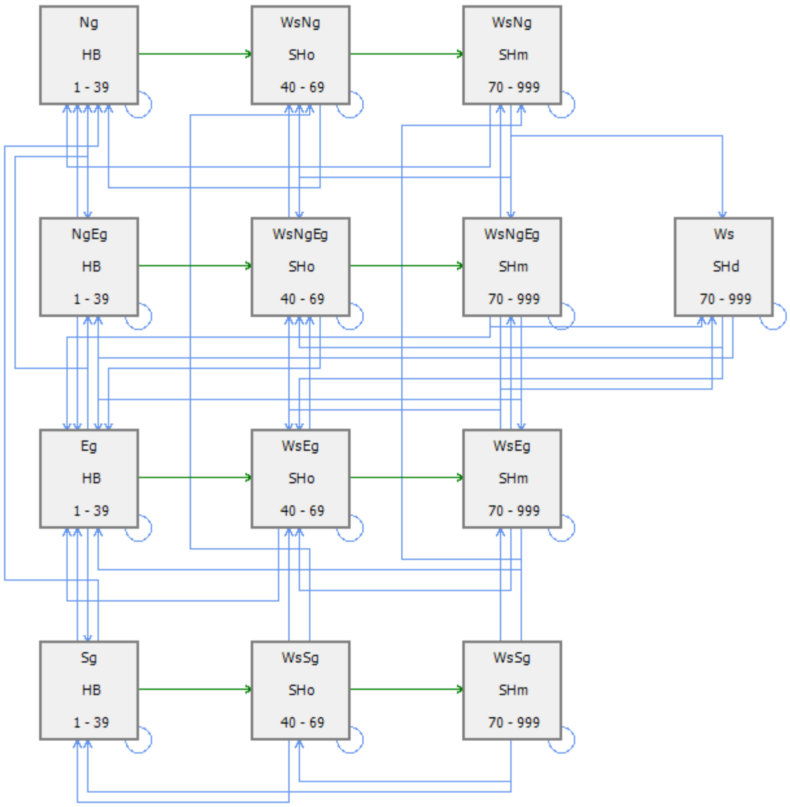
Prescribed fire is applied only in depleted shrub and woodland states. It returns cells to the herbaceous state within the same row for P-I and P-II woodlands, and down one row for prescribed fire in P-III juniper. The probability of grazing-related degradation is elevated through the GzeDegradeP transition following any type of fire, including prescribed fire.

Model SWN – Wyoming big sage - no juniper

Source:

This model was created from the USFS WYO_BIG_SAGE and BLM WD and CM models. This model is intended for low-elevation big sagebrush, predominantly the Wyoming subspecies *Artemisia tridentata* subsp. *Wyomingensis* but also including some basin big sage (*Artemisia tridentata* ssp. *tridentata*). It is intended mainly for environments too dry to support Idaho fescue, such as Wyoming big sagebrush over bluebunch wheatgrass, Thurber needlegrass (*Achnatherum thurberianum*), bottlebrush squirreltail (*Elymus elymoides*), or needle-and-thread grass (*Hesperostipa comata*), and environments that are too dry to support juniper.

Structure:



Description:

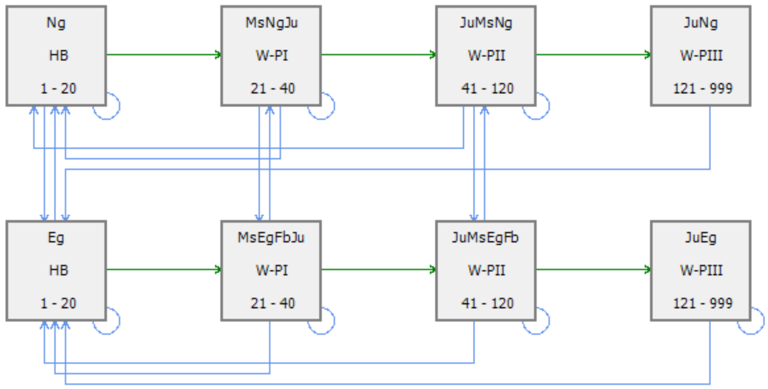
The Wyoming big sagebrush model is identical to the Wyoming sagebrush with juniper model (SWB), but without any juniper states or transitions. See the documentation for the SWB model for details about this model.

Model SWJ – Western juniper woodland

Source:

The western juniper woodland model was taken from the USFS OLD_JUNIPER model. This model covers juniper (*Juniperus occidentalis*) communities that have existed for a century or more due to light fuels or natural firebreaks, not the result of recent juniper expansion. Note that juniper woodland states also occur in the SMB, SWB, SLW, and SPT shrub models, where there is potential for contemporary expansion of juniper.

Structure:



State Classes:

A	Ng	HB	Herbaceous community dominated by native bunchgrasses, i.e. Sandberg's bluegrass, bluebunch wheatgrass, and Idaho fescue.
B	NgJu	W-PI	Phase I juniper – shrub steppe with scattered juniper
C	JuNg	W-PII	Phase II juniper, consisting of juniper codominant with native bunchgrass and mountain or Wyoming big sagebrush
D	Eg	HB	Herbaceous community dominated by exotic annual grasses, unpalatable perennial forbs, and Sandberg's bluegrass
E	EgJu	W-PI	Phase I juniper – scattered juniper throughout shrub steppe with degraded grass layer
F	JuEg	W-PII	Phase II juniper, consisting of juniper codominant with mountain or Wyoming big sagebrush and exotic annual grasses
G	JuNg	W-PIII	Phase III juniper over native bunchgrass herb layer. Juniper cover may not close due to site limitations, but trees are old
H	JuEg	W-PIII	Phase III juniper over degraded herb layer of exotic annual grasses. Juniper cover may not close due to site limitations, but trees are old

Description:

This model was modified from the original USFS model by adding an additional column of state classes to account for all three phases of juniper invasion for consistency with the sagebrush/juniper models and Miller et al (2005). The time for juniper re-establishment after stand-replacement fire is derived from the estimates in Miller et al. (2005), using the slow end of the colonization range given there to reflect drier sites.

Fire

Probability values and temporal multipliers for fire transitions were derived from Monitoring Trends in Burn Severity (MTBS) data and vary by modeling region and model state class (see **Fire Probabilities** and **Temporal Multipliers** sections). Fires cannot occur in herbaceous states within 2 years of the last fire by TSD. Mixed-severity fire loops back to the beginning time step of the same state, and only occurs in phase I and II woodland states. Stand-replacing fire returns to the beginning box within the same row, except in phase-III juniper with native understory (JuNg), where stand-replacing fire with native understory often results in bare soil available to weed invasion (Eg). Nonlethal fire (surface fire) can occur in phase-III juniper woodlands with an exotic annual grass understory (JuEg), representing a surface fire of exotic grasses that does not burn established trees. This transition recycles cells to the first time step of the state. We assume that 80% of the fires in the JuEg/W-PIII are nonlethal and 20% of the fires are stand-replacing, returning cells to Eg.

Grazing

Moderate grazing is only modeled in the second row as preventing recovery of the herbaceous layer (see below). No post-disturbance grazing (GzeDegradeP) is modeled in juniper woodlands because they tend to provide less forage than sage steppe systems.

Other transitions

Recovery from degraded states (row 2) can occur automatically by alternative succession after 30 years of time since grazing disturbance.

Fire Probabilities

We used data from the Monitoring Trends in Burn Severity (MTBS) data set (www.mtbs.gov) to derive fire probabilities and fire transition multipliers for arid land models. The MTBS data set records fire perimeters and fire severity for all fires over 1000 acres that burned between 1984 and 2008. Fire perimeters were overlayed with burn groups (groups of PVTs; see table and left figure below) and annual grass groups (see right figure below), and the annual number of acres burned in each combination of PVT group/annual grass group was calculated for each modeling region. For ILAP analyses, burn severity information was not used – only fire presence or absence. Note that MTBS data were used only to derive overall fire probabilities for each burn group / annual grass group combination. The pathway of fire transitions (from box and to box) and the proportional representation of different fire transition types (WFSR, WFMS, WFNL) in each state class were derived from existing models, literature, and expert opinion.

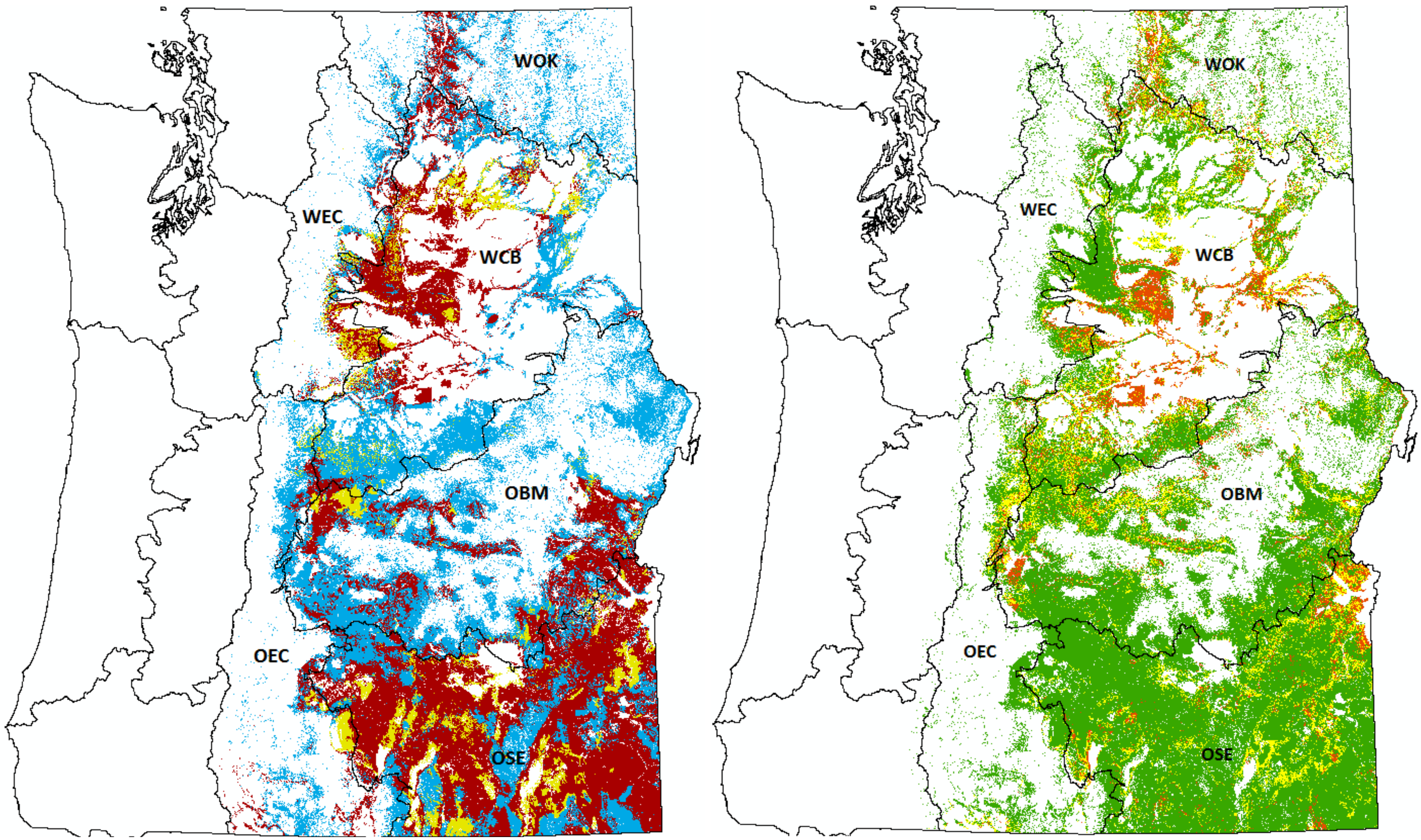
The following example illustrates how MTBS data are allocated among wildfire transitions for a given state class. For a given state class, we may derive a 100 year fire return interval from the MTBS data, corresponding to an annual probability of 0.01 (or 1/100). If we assumed that one third of the fire in that state was mixed-severity returning to the same state, one-third was stand-replacing returning to native grass, and one-third was stand-replacing leading to exotic grass, we would use proportions of 0.33 for each fire transition. *Each* of the three fire transitions would each have a probability of 0.01, a proportion of 0.33, and an overall return of ~300 years (probability × proportion = 0.0033). The three probability × proportion values for each pathway add up to the original fire return of 0.01 for the state.

PVTs were divided into burn groups based on site productivity and fuel potential, ranging from sparse (arid sites with few fine fuels) to semi-desert (intermediate) and upland (mesic, productive sites). The table below indicates which PVTs were assigned to the three major burn groups used in MTBS analysis. Fire probabilities were not modified based on MTBS data for the GFV and SMS PVTs, assuming that the montane PVTs are more affected by fire in surrounding forests than by fire in other nonforested arid PVTs. Original fire probabilities from the Blue Mountain models were used in these cases.

PVT code	PVT description	Burn group
gfv	Subalpine meadows - Green fescue	none
sms	Montane and canyon shrubland	none
sps	Bitterbrush - sand	semi-desert
swn	Wyoming big sage - no juniper	semi-desert
swb	Wyoming big sage - with juniper	semi-desert
srs	Rigid sage	sparse
ssd	Salt desert shrub - lowland	sparse
ssu	Salt desert shrub - upland	sparse
sma	Aspen	upland
spn	Bitterbrush - no juniper	upland
spt	Bitterbrush - with juniper	upland
gpp	Bluebunch wheatgrass - Sandberg bluegrass	upland
gfk	Idaho fescue - Prairie junegrass	upland
sln	Low sage - no juniper	upland
slw	Low sage - with juniper	upland
smn	Mountain big sage - no juniper	upland
smb	Mountain big sage - with juniper	upland
smm	Mountain mahogany	upland
s3s	Threetip sage	upland
swj	Western juniper woodland	upland

To increase the sample size of fires in each group, modeling regions OBM and OEC were lumped together, and regions WCB, WEC and WOK were combined.

Annual grass groups were specified based on cover of exotic annual grasses in our current vegetation map, and were combined into groups of 0-10% cover, >10-25% cover, and >25% cover. We assume that 0-10% annual grass group is likely to consist of scattered individuals that will not affect ecological integrity or burn conditions, whereas 10-25% annual grass cover will represent larger and more continuous clumps that may affect fine fuel continuity. At greater than 25% annual grass cover, fuel continuity is likely to alter the burn pattern and severity. These classes correspond to rows in the VDDT models, as detailed below.



Above is a map depicting the spatial extent of groups used for MTBS fire analyses. The left panel shows a map of PVT burn groups, separated into semi-desert (red), sparse (yellow) and upland (blue). The table above lists the PVTs that are included in each burn group. The right panel shows a map of annual grass classes, with 0-10% annual grass in green, >10-25% annual grass in yellow, and >25% annual grass in orange. Modeling regions are separated with black lines and labeled with their three-digit code.

The annual fire probabilities and corresponding fire return intervals (FRI) for each combination of modeling region (or combined regions), PVT burn group, and annual grass group used in the models are presented in the table below.

	Upland PVTs			**Semi-desert PVTs**			**Sparse PVTs**		
	0-10% AG	**10-25% AG**	**>25% AG**	**0-10% AG**	**10-25% AG**	**>25% AG**	**0-10% AG**	**10-25% AG**	**>25% AG**
OSE modeling region									
Annual Probability	0.0068	0.0089	0.0173	0.0063	0.0114	0.0179	0.0037	0.0075	0.0085
FRI	**148**	**112**	**58**	**160**	**88**	**56**	**269**	**134**	**117**
OBM and OEC modeling regions									
Annual Probability	0.0057	0.0081	0.0072	0.0030	0.0062	0.0045	0.0023	0.0057	0.0053
FRI	**176**	**124**	**140**	**334**	**160**	**221**	**433**	**175**	**190**
WCB, WEC and WNE modeling regions									
Annual Probability	0.0049	0.0068	0.0068	0.0086	0.0123	0.0174	0.0039	0.0071	0.0196
FRI	**205**	**147**	**148**	**116**	**82**	**57**	**254**	**141**	**51**

Fire probabilities were allocated into states in the VDDT models based on their modeling region, PVT burn group, and level of annual grass invasion. See the maps above for spatial depictions of modeling regions and a table of PVTs in each burn group. The annual grass groups were allocated among states in each individual VDDT model by the level of degradation (usually indicated by the row). States in the top row represent relatively pristine conditions and were assigned the fire probability from the 0-10% annual grass grouping, states in the second row represent semi-degraded states that were allocated the fire probability from the 10-25% annual grass group, and states in the third row represent high cover of annual grasses and were assigned fire probabilities based on the >25% annual grass group. Where there were only two rows in the model (SWJ, SMM, S3S), the 0-10% and 10-25% annual grass fire probabilities were averaged to assign the fire probability in first row boxes, and the >25% annual grass fire probability used for the second row states representing degraded conditions. In models that contained a fourth row representing seeded grasses, the 0-10% annual grass probability was used, assuming that seeded grasses burn at roughly the same interval as native grasses. Occasional exceptions to these rules are found in some models (e.g., bare ground states have no fire, regardless of the row). We assign all states to the same fire probability within a row for simplicity, but realize that states with different structures likely vary in their fire probability. Given the low sensitivity of the models to small changes in parameter values, however, we think that our methods capture the most important variation in fire frequency among PVT groups, geographic locations (modeling regions), and level of annual grass invasion. See **Temporal Multipliers** section below for information about fire multipliers derived from MTBS data.

Other Model Features

Temporal Multipliers

Temporal multipliers were used to model stochastic fire transitions (WFSR, WFMS, WFNL) and mimic cyclical patterns of insect outbreaks (InsectBC, InsectPeak) and severe drought (SevDrought) frequencies. Temporal multipliers were applied to the models in Path using a .MCM text file that was built using the BuildMCM tool that comes with the VDDT program. All multiplier parameters for InsectBC, InsectPeak, and SevDrought transitions are the same across all modeling regions, but fire multipliers were derived from regional MTBS analysis and varied among modeling regions. Note that multipliers can be imported into VDDT or Path in table form; they do not need to be generated using the MCM tool.

The following parameters (contained in the .PAR file) were used to create temporal multipliers in the MCMBuilder tool:

	Fire	DrghtShrub	Insects
Random	Yes	No	No
Min outbreak	0	1	0
Max outbreak	0	1	2
Min interval	0	100	20
Max interval	0	200	48
Last outbreak	0	3	15
Pre/Post years	0	0	2

The VDDT User Guide provides only sparse information for the MCM files and little support is expected to be provided for this feature. The parameters for the MCM file are defined as:

- Random: Yes = the year-sequence-group is random; No = the year-sequence-group is not random
- Min outbreak: minimum outbreak length
- Max outbreak: maximum outbreak length
- Min interval: minimum return interval
- Max interval: maximum return interval
- Last outbreak: constraint that determines the amount of time that passes between outbreaks
- Pre/post years: amount of time required for an outbreak to reach its peak

Fire Transition Multipliers

Fire transition multipliers were specified as random (see parameters table above) to simulate stochastic variability in fire severity years. Transition multipliers for fire transitions were derived from the proportion of the landscape burned in the MTBS data that in normal (defined as the 0-85th percentile), high (defined as the 86-95th percentile) and severe (>95th percentile) fire years. Multipliers were normalized such that the average fire frequency was not affected by the multipliers but year-to-year variability mimicked natural patterns in the MTBS data. Multipliers for groups of modeling regions are shown below:

Modeling Region	Parameters	Normal	High	Severe
OSE	Fire Year Frequency	85%	15%	5%
	Normalized Multiplier	0.51	2.69	3.79
OEC/OBM	Fire Year Frequency	85%	15%	5%
	Normalized Multiplier	0.59	1.96	4.69
WCB/WEC/WNE	Fire Year Frequency	85%	15%	5%
	Normalized Multiplier	0.59	2.16	4.06

Cyclical Transition Multipliers

Insect and drought transition multipliers were specified as nonrandom (see parameters table above) to simulate cyclical patterns. Multipliers for cyclical transitions were applied in two levels: 0 (transition will not occur) and 1 (transition will occur at the probability specified in the VDDT model). See the parameters table above for information about minimum and maximum outbreak years and intervals. These parameters specified a 2-year buildup (InsectBC), 0-2 year peak (InsectPeak) and 2-year crash (InsectBC) in each outbreak cycle. Each outbreak cycle occurs once every 20-48 years. Severe drought occurs once every 100-200 years. The table below shows the proportion of years that were affected by each cyclical transition. All cyclical multiplier values were taken directly from the BLM models (Evers 2010) and were not modified for ILAP.

Insect BC	**Normal**	**High**	**Severe**
Insect Year Frequency	79%	14%	7%
Multiplier	0	1	0
Insect Peak	**Normal**	**High**	**Severe**
Insect Year Frequency	79%	14%	7%
Multiplier	0	0	1
Severe Drought	**Normal**	**High**	**Severe**
Drought Year Frequency	85%	0%	15%
Multiplier	0	0	1

Transition Groups

Transition types are grouped into Transition groups in VDDT to allow graphing and analysis of sets of transitions that are related to each other. Each transition type can be associated with up to three transition groups. A description of the transition groups used for all arid land (nonforest) models appears below. The _nf suffix on each Transition Group name denotes that the transition group is from a nonforested model type.

Transition Group	Description
Ag_nf	Agricultural transitions
AllFire_nf	All Fire in nonforested types
AllI&D_nf	All insects and disease in nonforested cover types
AllTrt_nf	All Treatments in nonforested types
AltSucc_nf	Alternative succession in nonforested cover types
Drought_nf	Drought transitions in nonforests
Fire&Drought_nf	All fire and drought transitions in nonforests
Grazing_nf	Grazing and browsing in nonforested types
MechTrt_nf	Mechanical Treatments (juniper and sage)
NatReg_nf	Natural regeneration of nonforest cover types
PFire_nf	Prescribed fire - nonforested types
SeedTrt_nf	Seeding Treatments in nonforests
Succession_nf	All succession in nonforest types
Weather&Stress_nf	Stress in nonforests
WFire_nf	Wildfire - nonforested types

Below is a list of each transition type used in the models and each associated transition group or groups. Note that the _nf suffixes for transition groups are omitted in this table for simplicity.

Transition Type	Transition Group(s)		
AltSucc	AltSucc	Succession	
Browse	Grazing		
CutBurnJun	PFire	AllFire	Fire&Drought
Drought	Weather&Stress	Drought	Fire&Drought
Flooding	Weather&Stress		
Freezekill	Weather&Stress		
GzeBrowse	Grazing		
GzeDegrade	Grazing		
GzeDegradeP	Grazing		
GzeMaint	Grazing		
GzeMod	Grazing		
HorseGze	Grazing		
InsectBC	Weather&Stress	AllI&D	
InsectDisease	Weather&Stress	AllI&D	
InsectPeak	Weather&Stress	AllI&D	
MechTrtJun	MechTrt	AllTrt	
MechTrtShrub	MechTrt	AllTrt	
NRErly	NatReg	Succession	
NRFir	NatReg	Succession	
NRHerb	NatReg	Succession	
NRJun	NatReg	Succession	
NRMM	NatReg	Succession	
NRPutr	NatReg	Succession	
NRSarc	NatReg	Succession	
PFSR	PFire	AllFire	Fire&Drought
SeedExotic	SeedTrt	AllTrt	
SeedNative	SeedTrt	AllTrt	
SevDrought	Weather&Stress	Drought	Fire&Drought
SevWind	Weather&Stress		
ShrubRejuv	Succession		
Weather&Stress	Weather&Stress		
WFMS	WFire	AllFire	Fire&Drought
WFSR	WFire	AllFire	Fire&Drought
WheatFarm	Ag		

Time-Since-Disturbance (TSD) Groups

For transitions that are dependent on a time since disturbance, a TSD group is specified in VDDT. Note that the Time-since-disturbance (TSD) feature in VDDT is renamed Time-since-transition (TST) in Path, but represents the same thing. Only transitions that use the TSD feature are listed in the table below. Note that the TSD feature is only used where a minimum or maximum TSD is specified in a particular transition within a model. For instance, WFSR is prevented from occurring within 2 years of a previous fire in some herbaceous states in some models, but only where a min TSD of 2 is specified for that specific transition in the min TSD column. In other WFSR transitions where no min or max TSD values are specified, WFSR is not dependent on time since any disturbance.

Transition Type	TSD Group
AltSucc	Grazing
GzeDegrade	Fire&Drought
GzeDegradeP	Fire&Drought
NRFir	AllFire
NRHerb	Grazing
NRJun	AllFire
NRMM	Grazing
NRPutr	Grazing
NRSarc	AllFire
PFSR	AllFire
SeedExotic	AllFire
SeedNative	AllFire
ShrubRejuv	Grazing
WFMS	AllFire
WFSR	AllFire

For more information

For more information about ILAP and to download models and data, refer to the the ILAP ftp site (ftp://131.252.97.79/ILAP/Index.html) and the Western Landscapes Explorer website (available summer 2012)

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