Case Study: Native Prairie Adaptive Management in the USFWS Refuge System

Model Development

Case Study Module B

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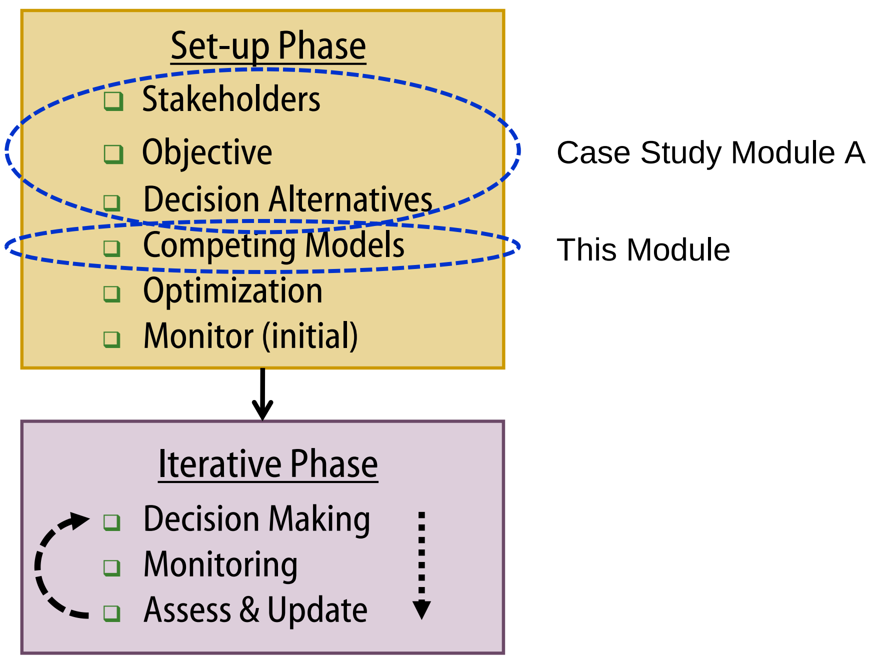
NPAM Framework Components



Objectives of Case Study Module B – Model Development

- Illustrate NPAM model structure for decision making
    - Links decision alternatives to objective by predicting the consequences of each decision with respect to the measureable attribute of the objective
- Discuss uncertainty that makes decision making difficult and identify main structural uncertainties
- Demonstrate expression of structural uncertainty via competing models
- Present an analysis of EVPI
- Express structural uncertainty via model confidence

Native Prairie Adaptive Management

- The Resource Problem
    - Loss of native prairie to cool-season invasive grasses, smooth brome and Kentucky bluegrass
- Area of focus
    - Native sod on Service-owned lands across the Prairie Pothole Region in USFWS Regions 3 and 6
    - Cooperators from 19 different refuge complexes across 4 states, with 120 management units (81 mixed, 39 tall)
- Spatial unit of focus
    - Management unit

Objective & Decision Alternatives

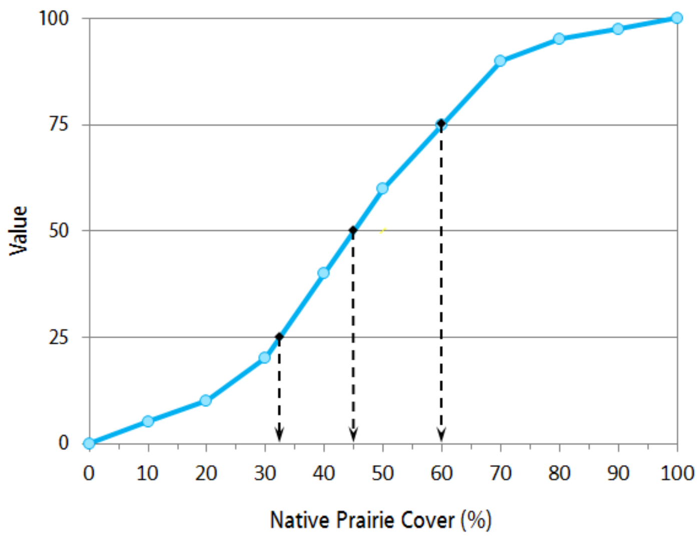
- Management objective
    - Increase the cover of native grasses and forbs at the least cost
- Menu of management action alternatives
    - Rest
    - Graze
    - Burn
    - Burn / Graze
- Management Cycle
    - Decisions made on an annual basis
    - Management year is 1 Sep – 31 Aug

Describing the System – Vegetation

Native Cover	Dominant Invasive: SB	CO	KB	RM
60 - 100%	1	2	3	4
45 - 60%	5	6	7	8
30 - 45%	9	10	11	12
0 - 30%	13	14	15	16

Native Cover	Dominant Invasive: SB	CO	KB	RM
60 - 100%	1	2	3	4
45 - 60%	5	6	7	8
30 - 45%	9	10	11	12
0 - 30%	13	14	15	16

Eliciting Vegetation Structure



Describing the System – Defoliation History

- Based on a 7-year window of past management actions
    - Two components:
        - Defoliation level: low, medium, high
        - Years since last defoliated: 1, 2 - 4 , 5+

Years Since Defoliation		Defoliation Level: Low	Med	High
	5+	1		
	2 – 4	2	3	4
	1	5	6	7

Full System State Structure

Vegetation State Structure

Dominant Invasive (columns); Native Cover (rows)

Native Cover	SB	CO	KB	RM
60 – 100%	1	2	3	4
45 – 60%	5	6	7	8
30 – 45%	9	10	11	12
0 – 30%	13	14	15	16

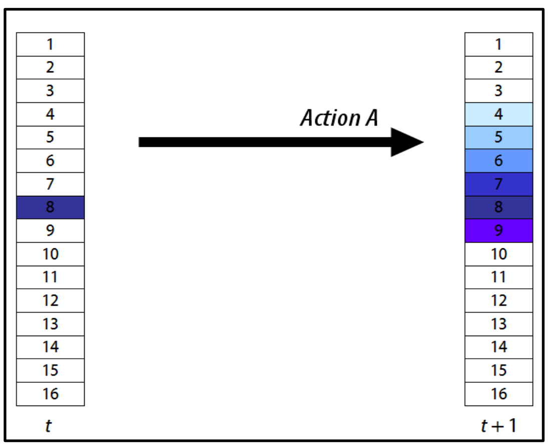
Defoliation State Structure

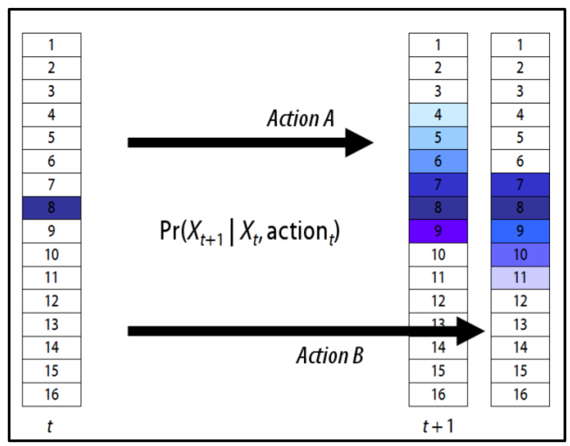
Defoliation Level (columns); Years Since Defoliation (rows)

Years Since Defoliation	Low	Med	High
5+	1		
2 – 4	2	3	4
1	5	6	7

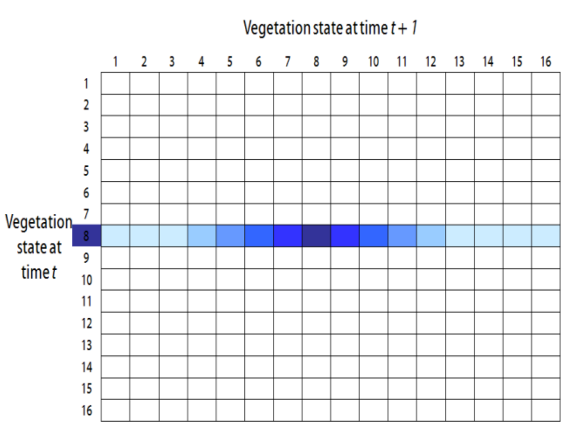
- Combined, there are 16 x 7 = 112 possible discrete states that a unit can be in at any one time

State Transition Model - Vegetation

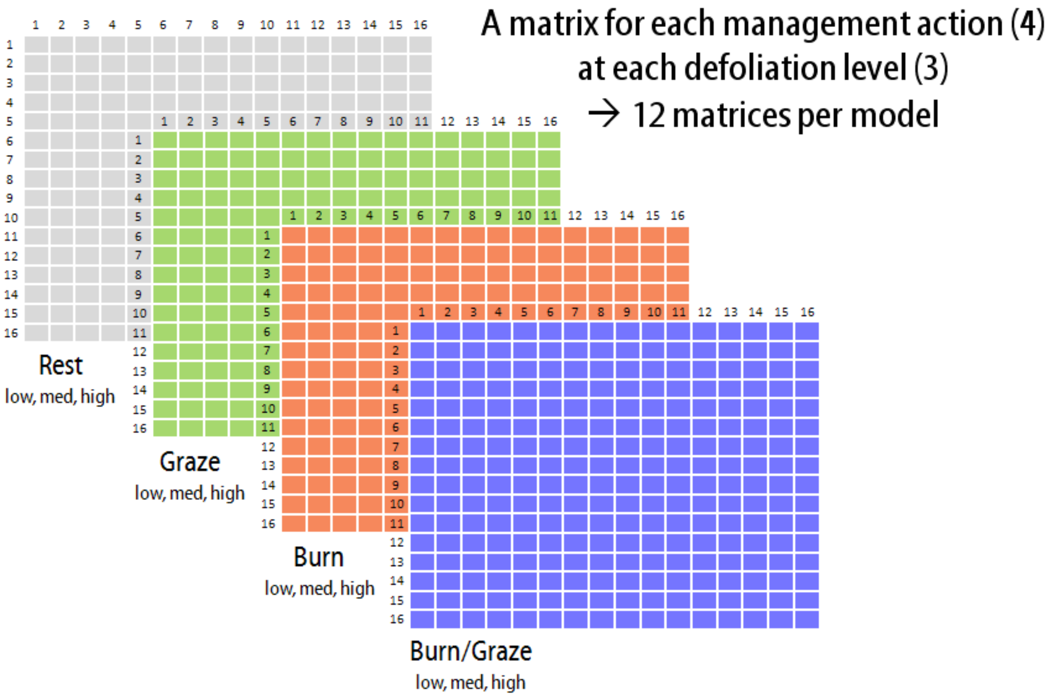




State Transition Matrix – Vegetation

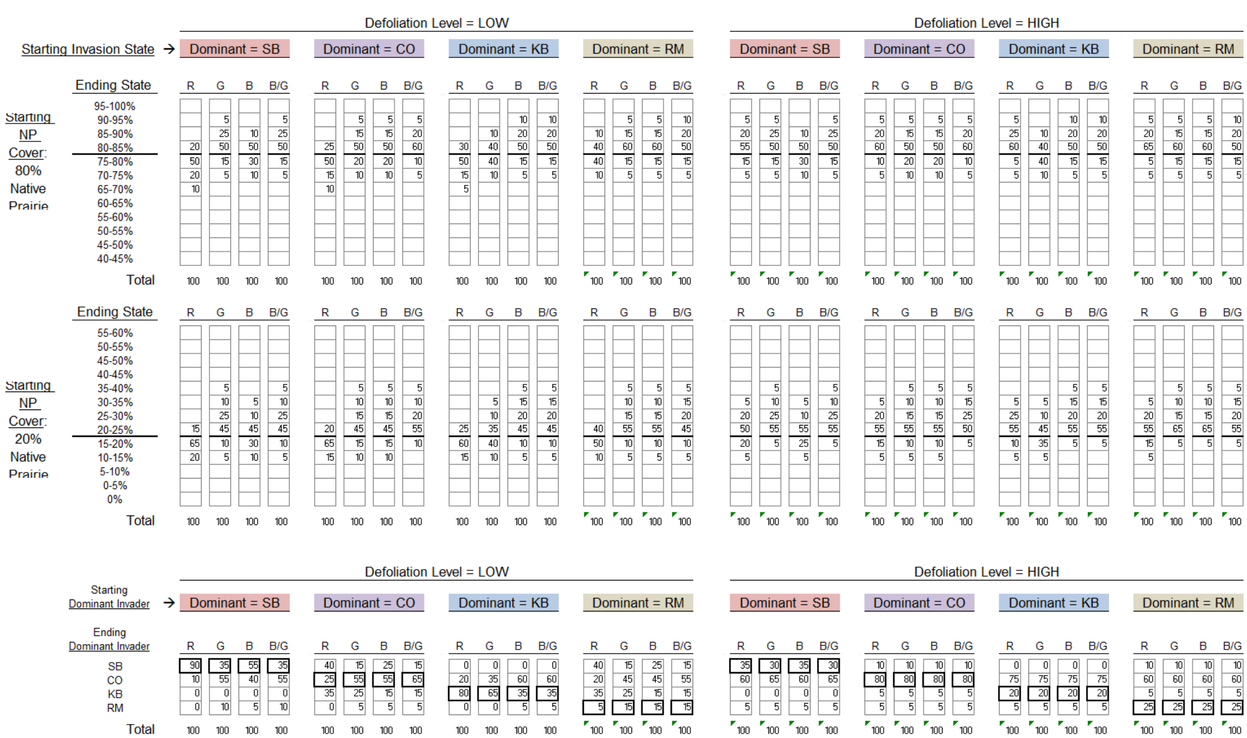


Complete Model – Vegetation



Model Parameterization

- Elicitation of expert opinion



Model Parameterization

- Linear-logistic and linear-polytomous regression models
- Transition probabilities among vegetation states given:
    - Defoliation level (low, med, high)
    - Management action (Rest, Graze, Burn, Burn/Graze)

Showing transition matrices for Rest, Graze, Burn, and Burn/Graze at Low Defoliation

Defoliation Level	Mgmt Action	NP Cover	Dominant Invader	60-100,SB	60-100,CO	60-100,KB	60-100,RM	45-60,SB	45-60,CO	45-60,KB	45-60,RM	30-45,SB	30-45,CO	30-45,KB	30-45,RM	0-30,SB	0-30,CO	0-30,KB	0-30,RM
Low	Rest	60-100	SB	0.814428	0.067121	7.84E-07	4.83E-07	0.108008	0.008901	1.04E-07	6.4E-08	0.001423	0.000117	1.37E-09	8.43E-10	0	0	0	0
Low	Rest	60-100	CO	0.365092	0.175613	0.341116	8.45E-06	0.048283	0.023224	0.045112	1.12E-06	0.000642	0.000309	0.0006	1.49E-08	0	0	0	0
Low	Rest	60-100	KB	8.32E-07	0.142702	0.771896	1.08E-06	7.71E-08	0.013225	0.071535	1E-07	5.82E-10	9.99E-05	0.00054	7.55E-10	0	0	0	0
Low	Rest	60-100	RM	0.396423	0.15269	0.370577	0.036609	0.018086	0.006966	0.016907	0.00167	2.9E-05	1.12E-05	2.71E-05	2.68E-06	0	0	0	0
Low	Rest	45-60	SB	0.047662	0.003928	4.59E-08	2.82E-08	0.567665	0.046784	5.47E-07	3.36E-07	0.305474	0.025176	2.94E-07	1.81E-07	0.003058	0.000252	2.95E-09	1.81E-09
Low	Rest	45-60	CO	0.021049	0.010125	0.019666	4.87E-07	0.253013	0.121702	0.236398	5.86E-06	0.138629	0.066682	0.129525	3.21E-06	0.001325	0.000637	0.001238	3.07E-08
Low	Rest	45-60	KB	7.66E-08	0.013145	0.071105	9.94E-08	6.01E-07	0.103158	0.558	7.8E-07	2.3E-07	0.039531	0.213829	2.99E-07	1.12E-09	0.000192	0.001038	1.45E-09
Low	Rest	45-60	RM	0.066575	0.025643	0.062234	0.006148	0.282579	0.108841	0.264155	0.026096	0.065298	0.025151	0.061041	0.00603	8.71E-05	3.35E-05	8.14E-05	8.04E-06
Low	Rest	30-45	SB	2.77E-05	2.28E-06	2.67E-11	1.64E-11	0.040872	0.003368	3.94E-08	2.42E-08	0.59467	0.049009	5.73E-07	3.52E-07	0.28829	0.023759	2.78E-07	1.71E-07
Low	Rest	30-45	CO	2.48E-05	1.19E-05	2.32E-05	5.75E-10	0.019181	0.009226	0.017922	4.44E-07	0.266759	0.128314	0.249241	6.17E-06	0.128051	0.061594	0.119642	2.96E-06
Low	Rest	30-45	KB	7.28E-11	1.25E-05	6.75E-05	9.44E-11	6.27E-08	0.010755	0.058175	8.14E-08	6.22E-07	0.10676	0.577479	8.08E-07	2.24E-07	0.0385	0.20825	2.91E-07
Low	Rest	30-45	RM	0.000162	6.23E-05	0.000151	1.49E-05	0.050698	0.019527	0.047393	0.004682	0.294957	0.113608	0.275726	0.027239	0.068722	0.02647	0.064242	0.006346
Low	Rest	0-30	SB	0	0	0	0	3.7E-05	3.05E-06	3.56E-11	2.19E-11	0.024242	0.001998	2.34E-08	1.44E-08	0.89958	0.074138	8.67E-07	5.33E-07
Low	Rest	0-30	CO	0	0	0	0	4.14E-06	1.99E-06	3.87E-06	9.58E-11	0.012843	0.006178	0.011999	2.97E-07	0.401169	0.192967	0.374825	9.29E-06
Low	Rest	0-30	KB	0	0	0	0	9.09E-12	1.56E-06	8.44E-06	1.18E-11	3.08E-08	0.005278	0.028552	3.99E-08	8.79E-07	0.150746	0.815412	1.14E-06
Low	Rest	0-30	RM	0	0	0	0	1.24E-05	4.79E-06	1.16E-05	1.15E-06	0.019338	0.007449	0.018077	0.001786	0.395188	0.152214	0.369423	0.036495
Low	Graze	60-100	SB	0.347405	0.531468	3E-06	0.104504	0.005864	0.008971	5.06E-08	0.001764	7.07E-06	1.08E-05	6.1E-11	2.13E-06	0	0	0	0
Low	Graze	60-100	CO	0.145918	0.49917	0.282674	0.046188	0.003897	0.013331	0.007549	0.001233	5.99E-06	2.05E-05	1.16E-05	1.9E-06	0	0	0	0
Low	Graze	60-100	KB	3.14E-06	0.285616	0.66703	3.72E-07	1.55E-07	0.014139	0.033021	1.84E-08	6.26E-10	5.7E-05	0.000133	7.41E-11	0	0	0	0
Low	Graze	60-100	RM	0.146833	0.413842	0.285094	0.133081	0.003167	0.008925	0.006148	0.00287	6E-06	1.69E-05	1.17E-05	5.44E-06	0	0	0	0
Low	Graze	45-60	SB	0.119669	0.183072	1.03E-06	0.035998	0.216081	0.330566	1.87E-06	0.065	0.017522	0.026806	1.51E-07	0.005271	3.53E-06	5.4E-06	3.05E-11	1.06E-06
Low	Graze	45-60	CO	0.039434	0.134901	0.076393	0.012482	0.098531	0.337065	0.190875	0.031188	0.011846	0.040525	0.022949	0.00375	8.99E-06	3.08E-05	1.74E-05	2.85E-06
Low	Graze	45-60	KB	5.45E-07	0.049583	0.115796	6.45E-08	2.26E-06	0.205296	0.479451	2.67E-07	4.93E-07	0.044819	0.104671	5.83E-08	1.25E-09	0.000114	0.000266	1.48E-10
Low	Graze	45-60	RM	0.046089	0.1299	0.089488	0.041773	0.094823	0.267254	0.18411	0.085942	0.00909	0.025621	0.01765	0.008239	3E-06	8.46E-06	5.83E-06	2.72E-06
Low	Graze	30-45	SB	0.001424	0.002178	1.23E-08	0.000428	0.112497	0.172101	9.71E-07	0.033841	0.224811	0.343921	1.94E-06	0.067626	0.014544	0.02225	1.26E-07	0.004375
Low	Graze	30-45	CO	0.000291	0.000994	0.000563	9.2E-05	0.036555	0.12505	0.070814	0.011571	0.102821	0.351738	0.199185	0.032546	0.010155	0.034739	0.019672	0.003214
Low	Graze	30-45	KB	1.28E-09	0.000117	0.000273	1.52E-10	4.76E-07	0.043296	0.101114	5.63E-08	2.36E-06	0.214465	0.500863	2.79E-07	4.61E-07	0.041935	0.097935	5.46E-08
Low	Graze	30-45	RM	0.000494	0.001391	0.000958	0.000447	0.043161	0.121647	0.083802	0.039119	0.098816	0.278509	0.191863	0.089562	0.007535	0.021236	0.01463	0.006829
Low	Graze	0-30	SB	0	0	0	0	0.000671	0.001027	5.8E-09	0.000202	0.062152	0.095081	5.37E-07	0.018696	0.290453	0.444342	2.51E-06	0.087372
Low	Graze	0-30	CO	0	0	0	0	0.000154	0.000528	0.000299	4.88E-05	0.021475	0.073465	0.041602	0.006798	0.128191	0.438529	0.248333	0.040577
Low	Graze	0-30	KB	0	0	0	0	5.6E-10	5.1E-05	0.000119	6.63E-11	2.61E-07	0.02373	0.05542	3.09E-08	3.03E-06	0.276031	0.644646	3.59E-07
Low	Graze	0-30	RM	0	0	0	0	0.000224	0.00063	0.000434	0.000203	0.024235	0.068305	0.047055	0.021965	0.125547	0.353849	0.243765	0.113789
Low	Burn	60-100	SB	0.551118	0.361127	2.5E-06	0.046423	0.023679	0.015516	1.08E-07	0.001995	8.05E-05	5.27E-05	3.65E-10	6.78E-06	0	0	0	0
Low	Burn	60-100	CO	0.261957	0.503952	0.159766	0.047065	0.007328	0.014097	0.004469	0.001317	1.35E-05	2.59E-05	8.21E-06	2.42E-06	0	0	0	0
Low	Burn	60-100	KB	2.82E-06	0.574461	0.362284	0.047932	4.38E-08	0.008926	0.005629	0.000745	5.73E-11	1.17E-05	7.36E-06	9.74E-07	0	0	0	0
Low	Burn	60-100	RM	0.264812	0.418595	0.161842	0.13451	0.005462	0.008635	0.003338	0.002775	8.11E-06	1.28E-05	4.96E-06	4.12E-06	0	0	0	0
Low	Burn	45-60	SB	0.107105	0.070182	4.86E-07	0.009022	0.393406	0.257784	1.79E-06	0.033138	0.07428	0.048673	3.37E-07	0.006257	8.62E-05	5.65E-05	3.92E-10	7.26E-06
Low	Burn	45-60	CO	0.071342	0.137248	0.043511	0.012818	0.176999	0.34051	0.107951	0.031801	0.020941	0.040285	0.012772	0.003762	1.62E-05	3.11E-05	9.85E-06	2.9E-06
Low	Burn	45-60	KB	1.01E-06	0.204977	0.129269	0.017103	1.73E-06	0.351422	0.221624	0.029322	1.32E-07	0.026976	0.017013	0.002251	1.15E-10	2.33E-05	1.47E-05	1.95E-06
Low	Burn	45-60	RM	0.083623	0.132185	0.051107	0.042476	0.17037	0.269308	0.104123	0.086539	0.016282	0.025737	0.009951	0.00827	8.11E-06	1.28E-05	4.96E-06	4.12E-06
Low	Burn	30-45	SB	0.000477	0.000313	2.17E-09	4.02E-05	0.093107	0.06101	4.23E-07	0.007843	0.410779	0.269168	1.87E-06	0.034601	0.070514	0.046206	3.2E-07	0.00594
Low	Burn	30-45	CO	0.000528	0.001015	0.000322	9.48E-05	0.066317	0.127581	0.040447	0.011915	0.183782	0.35356	0.112088	0.033019	0.01867	0.035918	0.011387	0.003354
Low	Burn	30-45	KB	1.44E-08	0.002923	0.001843	0.000244	9.39E-07	0.191291	0.120637	0.015961	1.79E-06	0.365552	0.230535	0.030501	1.16E-07	0.023633	0.014904	0.001972
Low	Burn	30-45	RM	0.000889	0.001406	0.000543	0.000452	0.076725	0.121281	0.046891	0.038972	0.178838	0.282694	0.109298	0.09084	0.01383	0.021862	0.008453	0.007025
Low	Burn	0-30	SB	0	0	0	0	0.000149	9.79E-05	6.79E-10	1.26E-05	0.050221	0.032908	2.28E-07	0.00423	0.524507	0.34369	2.38E-06	0.044181
Low	Burn	0-30	CO	0	0	0	0	0.000253	0.000487	0.000154	4.55E-05	0.037904	0.072919	0.023117	0.00681	0.231141	0.444669	0.140972	0.041528
Low	Burn	0-30	KB	0	0	0	0	6.33E-09	0.001289	0.000813	0.000108	5.17E-07	0.105222	0.066358	0.00878	2.34E-06	0.476887	0.300749	0.039791
Low	Burn	0-30	RM	0	0	0	0	0.000387	0.000611	0.000236	0.000196	0.044283	0.069999	0.027064	0.022493	0.225613	0.356632	0.137885	0.114599
Low	B/G	60-100	SB	0.347603	0.530794	3.08E-06	0.10446	0.006062	0.009256	5.37E-08	0.001822	0	0	0	0	0	0	0	0
Low	B/G	60-100	CO	0.149987	0.622058	0.163465	0.04764	0.002569	0.010655	0.0028	0.000816	1.53E-06	6.33E-06	1.66E-06	4.85E-07	0	0	0	0
Low	B/G	60-100	KB	4.28E-06	0.574732	0.36321	0.047775	6.18E-08	0.008309	0.005251	0.000691	1.3E-10	1.75E-05	1.11E-05	1.45E-06	0	0	0	0
Low	B/G	60-100	RM	0.15142	0.532761	0.164305	0.136544	0.0023	0.008091	0.002495	0.002074	1.54E-06	5.41E-06	1.67E-06	1.39E-06	0	0	0	0
Low	B/G	45-60	SB	0.118676	0.181219	1.05E-06	0.035664	0.216984	0.331337	1.92E-06	0.065207	0.017994	0.027478	1.59E-07	0.005408	1.06E-05	1.62E-05	9.39E-11	3.19E-06
Low	B/G	45-60	CO	0.052195	0.216472	0.056885	0.016579	0.092773	0.384769	0.10111	0.029468	0.00759	0.031478	0.008272	0.002411	0	0	0	0
Low	B/G	45-60	KB	1.56E-06	0.209504	0.132399	0.017415	2.59E-06	0.348301	0.220114	0.028953	1.88E-07	0.025246	0.015955	0.002099	4.34E-11	5.83E-06	3.68E-06	4.85E-07
Low	B/G	45-60	RM	0.054662	0.192323	0.059313	0.049292	0.09219	0.324363	0.100034	0.083133	0.006867	0.02416	0.007451	0.006192	3.07E-06	1.08E-05	3.34E-06	2.77E-06
Low	B/G	30-45	SB	0.001538	0.002349	1.36E-08	0.000462	0.110902	0.169349	9.82E-07	0.033328	0.226233	0.345459	2E-06	0.067986	0.014992	0.022893	1.33E-07	0.004505
Low	B/G	30-45	CO	0.000719	0.00298	0.000783	0.000228	0.049075	0.203533	0.053484	0.015588	0.096406	0.399834	0.105069	0.030621	0.006359	0.026372	0.00693	0.00202
Low	B/G	30-45	KB	2.1E-08	0.002828	0.001787	0.000235	1.45E-06	0.194496	0.122915	0.016168	2.71E-06	0.364184	0.230151	0.030273	1.6E-07	0.02155	0.013619	0.001791
Low	B/G	30-45	RM	0.000778	0.002737	0.000844	0.000701	0.05098	0.17937	0.055318	0.045972	0.096099	0.338117	0.104276	0.086658	0.005864	0.020634	0.006363	0.005288
Low	B/G	0-30	SB	0	0	0	0	0.000658	0.001004	5.82E-09	0.000198	0.06256	0.09553	5.54E-07	0.0188	0.290448	0.443516	2.57E-06	0.087283
Low	B/G	0-30	CO	0	0	0	0	0.000359	0.001487	0.000391	0.000114	0.028528	0.118319	0.031092	0.009061	0.123671	0.512914	0.134784	0.039282
Low	B/G	0-30	KB	0	0	0	0	1.01E-08	0.001353	0.000855	0.000112	7.95E-07	0.106869	0.067537	0.008883	3.53E-06	0.474836	0.300079	0.039471
Low	B/G	0-30	RM	0	0	0	0	0.000334	0.001174	0.000362	0.000301	0.027925	0.098252	0.030301	0.025182	0.125463	0.441432	0.136139	0.113137

Showing all 12, 16x16 transition matrices (4 actions x 3 defoliation levels) for a complete vegetation model

Defoliation Level	Mgmt Action	NP Cover	Dominant Invader	60-100,SB	60-100,CO	60-100,KB	60-100,RM	45-60,SB	45-60,CO	45-60,KB	45-60,RM	30-45,SB	30-45,CO	30-45,KB	30-45,RM	0-30,SB	0-30,CO	0-30,KB	0-30,RM
Low	Rest	60-100	SB	0.814428	0.067121	7.84E-07	4.83E-07	0.108008	0.008901	1.04E-07	6.4E-08	0.001423	0.000117	1.37E-09	8.43E-10	0	0	0	0
Low	Rest	60-100	CO	0.365092	0.175613	0.341116	8.45E-06	0.048283	0.023224	0.045112	1.12E-06	0.000642	0.000309	0.0006	1.49E-08	0	0	0	0
Low	Rest	60-100	KB	8.32E-07	0.142702	0.771896	1.08E-06	7.71E-08	0.013225	0.071535	1E-07	5.82E-10	9.99E-05	0.00054	7.55E-10	0	0	0	0
Low	Rest	60-100	RM	0.396423	0.15269	0.370577	0.036609	0.018086	0.006966	0.016907	0.00167	2.9E-05	1.12E-05	2.71E-05	2.68E-06	0	0	0	0
Low	Rest	45-60	SB	0.047662	0.003928	4.59E-08	2.82E-08	0.567665	0.046784	5.47E-07	3.36E-07	0.305474	0.025176	2.94E-07	1.81E-07	0.003058	0.000252	2.95E-09	1.81E-09
Low	Rest	45-60	CO	0.021049	0.010125	0.019666	4.87E-07	0.253013	0.121702	0.236398	5.86E-06	0.138629	0.066682	0.129525	3.21E-06	0.001325	0.000637	0.001238	3.07E-08
Low	Rest	45-60	KB	7.66E-08	0.013145	0.071105	9.94E-08	6.01E-07	0.103158	0.558	7.8E-07	2.3E-07	0.039531	0.213829	2.99E-07	1.12E-09	0.000192	0.001038	1.45E-09
Low	Rest	45-60	RM	0.066575	0.025643	0.062234	0.006148	0.282579	0.108841	0.264155	0.026096	0.065298	0.025151	0.061041	0.00603	8.71E-05	3.35E-05	8.14E-05	8.04E-06
Low	Rest	30-45	SB	2.77E-05	2.28E-06	2.67E-11	1.64E-11	0.040872	0.003368	3.94E-08	2.42E-08	0.59467	0.049009	5.73E-07	3.52E-07	0.28829	0.023759	2.78E-07	1.71E-07
Low	Rest	30-45	CO	2.48E-05	1.19E-05	2.32E-05	5.75E-10	0.019181	0.009226	0.017922	4.44E-07	0.266759	0.128314	0.249241	6.17E-06	0.128051	0.061594	0.119642	2.96E-06
Low	Rest	30-45	KB	7.28E-11	1.25E-05	6.75E-05	9.44E-11	6.27E-08	0.010755	0.058175	8.14E-08	6.22E-07	0.10676	0.577479	8.08E-07	2.24E-07	0.0385	0.20825	2.91E-07
Low	Rest	30-45	RM	0.000162	6.23E-05	0.000151	1.49E-05	0.050698	0.019527	0.047393	0.004682	0.294957	0.113608	0.275726	0.027239	0.068722	0.02647	0.064242	0.006346
Low	Rest	0-30	SB	0	0	0	0	3.7E-05	3.05E-06	3.56E-11	2.19E-11	0.024242	0.001998	2.34E-08	1.44E-08	0.89958	0.074138	8.67E-07	5.33E-07
Low	Rest	0-30	CO	0	0	0	0	4.14E-06	1.99E-06	3.87E-06	9.58E-11	0.012843	0.006178	0.011999	2.97E-07	0.401169	0.192967	0.374825	9.29E-06
Low	Rest	0-30	KB	0	0	0	0	9.09E-12	1.56E-06	8.44E-06	1.18E-11	3.08E-08	0.005278	0.028552	3.99E-08	8.79E-07	0.150746	0.815412	1.14E-06
Low	Rest	0-30	RM	0	0	0	0	1.24E-05	4.79E-06	1.16E-05	1.15E-06	0.019338	0.007449	0.018077	0.001786	0.395188	0.152214	0.369423	0.036495
Low	Graze	60-100	SB	0.347405	0.531468	3E-06	0.104504	0.005864	0.008971	5.06E-08	0.001764	7.07E-06	1.08E-05	6.1E-11	2.13E-06	0	0	0	0
Low	Graze	60-100	CO	0.145918	0.49917	0.282674	0.046188	0.003897	0.013331	0.007549	0.001233	5.99E-06	2.05E-05	1.16E-05	1.9E-06	0	0	0	0
Low	Graze	60-100	KB	3.14E-06	0.285616	0.66703	3.72E-07	1.55E-07	0.014139	0.033021	1.84E-08	6.26E-10	5.7E-05	0.000133	7.41E-11	0	0	0	0
Low	Graze	60-100	RM	0.146833	0.413842	0.285094	0.133081	0.003167	0.008925	0.006148	0.00287	6E-06	1.69E-05	1.17E-05	5.44E-06	0	0	0	0
Low	Graze	45-60	SB	0.119669	0.183072	1.03E-06	0.035998	0.216081	0.330566	1.87E-06	0.065	0.017522	0.026806	1.51E-07	0.005271	3.53E-06	5.4E-06	3.05E-11	1.06E-06
Low	Graze	45-60	CO	0.039434	0.134901	0.076393	0.012482	0.098531	0.337065	0.190875	0.031188	0.011846	0.040525	0.022949	0.00375	8.99E-06	3.08E-05	1.74E-05	2.85E-06
Low	Graze	45-60	KB	5.45E-07	0.049583	0.115796	6.45E-08	2.26E-06	0.205296	0.479451	2.67E-07	4.93E-07	0.044819	0.104671	5.83E-08	1.25E-09	0.000114	0.000266	1.48E-10
Low	Graze	45-60	RM	0.046089	0.1299	0.089488	0.041773	0.094823	0.267254	0.18411	0.085942	0.00909	0.025621	0.01765	0.008239	3E-06	8.46E-06	5.83E-06	2.72E-06
Low	Graze	30-45	SB	0.001424	0.002178	1.23E-08	0.000428	0.112497	0.172101	9.71E-07	0.033841	0.224811	0.343921	1.94E-06	0.067626	0.014544	0.02225	1.26E-07	0.004375
Low	Graze	30-45	CO	0.000291	0.000994	0.000563	9.2E-05	0.036555	0.12505	0.070814	0.011571	0.102821	0.351738	0.199185	0.032546	0.010155	0.034739	0.019672	0.003214
Low	Graze	30-45	KB	1.28E-09	0.000117	0.000273	1.52E-10	4.76E-07	0.043296	0.101114	5.63E-08	2.36E-06	0.214465	0.500863	2.79E-07	4.61E-07	0.041935	0.097935	5.46E-08
Low	Graze	30-45	RM	0.000494	0.001391	0.000958	0.000447	0.043161	0.121647	0.083802	0.039119	0.098816	0.278509	0.191863	0.089562	0.007535	0.021236	0.01463	0.006829
Low	Graze	0-30	SB	0	0	0	0	0.000671	0.001027	5.8E-09	0.000202	0.062152	0.095081	5.37E-07	0.018696	0.290453	0.444342	2.51E-06	0.087372
Low	Graze	0-30	CO	0	0	0	0	0.000154	0.000528	0.000299	4.88E-05	0.021475	0.073465	0.041602	0.006798	0.128191	0.438529	0.248333	0.040577
Low	Graze	0-30	KB	0	0	0	0	5.6E-10	5.1E-05	0.000119	6.63E-11	2.61E-07	0.02373	0.05542	3.09E-08	3.03E-06	0.276031	0.644646	3.59E-07
Low	Graze	0-30	RM	0	0	0	0	0.000224	0.00063	0.000434	0.000203	0.024235	0.068305	0.047055	0.021965	0.125547	0.353849	0.243765	0.113789
Low	Burn	60-100	SB	0.551118	0.361127	2.5E-06	0.046423	0.023679	0.015516	1.08E-07	0.001995	8.05E-05	5.27E-05	3.65E-10	6.78E-06	0	0	0	0
Low	Burn	60-100	CO	0.261957	0.503952	0.159766	0.047065	0.007328	0.014097	0.004469	0.001317	1.35E-05	2.59E-05	8.21E-06	2.42E-06	0	0	0	0
Low	Burn	60-100	KB	2.82E-06	0.574461	0.362284	0.047932	4.38E-08	0.008926	0.005629	0.000745	5.73E-11	1.17E-05	7.36E-06	9.74E-07	0	0	0	0
Low	Burn	60-100	RM	0.264812	0.418595	0.161842	0.13451	0.005462	0.008635	0.003338	0.002775	8.11E-06	1.28E-05	4.96E-06	4.12E-06	0	0	0	0
Low	Burn	45-60	SB	0.107105	0.070182	4.86E-07	0.009022	0.393406	0.257784	1.79E-06	0.033138	0.07428	0.048673	3.37E-07	0.006257	8.62E-05	5.65E-05	3.92E-10	7.26E-06
Low	Burn	45-60	CO	0.071342	0.137248	0.043511	0.012818	0.176999	0.34051	0.107951	0.031801	0.020941	0.040285	0.012772	0.003762	1.62E-05	3.11E-05	9.85E-06	2.9E-06
Low	Burn	45-60	KB	1.01E-06	0.204977	0.129269	0.017103	1.73E-06	0.351422	0.221624	0.029322	1.32E-07	0.026976	0.017013	0.002251	1.15E-10	2.33E-05	1.47E-05	1.95E-06
Low	Burn	45-60	RM	0.083623	0.132185	0.051107	0.042476	0.17037	0.269308	0.104123	0.086539	0.016282	0.025737	0.009951	0.00827	8.11E-06	1.28E-05	4.96E-06	4.12E-06
Low	Burn	30-45	SB	0.000477	0.000313	2.17E-09	4.02E-05	0.093107	0.06101	4.23E-07	0.007843	0.410779	0.269168	1.87E-06	0.034601	0.070514	0.046206	3.2E-07	0.00594
Low	Burn	30-45	CO	0.000528	0.001015	0.000322	9.48E-05	0.066317	0.127581	0.040447	0.011915	0.183782	0.35356	0.112088	0.033019	0.01867	0.035918	0.011387	0.003354
Low	Burn	30-45	KB	1.44E-08	0.002923	0.001843	0.000244	9.39E-07	0.191291	0.120637	0.015961	1.79E-06	0.365552	0.230535	0.030501	1.16E-07	0.023633	0.014904	0.001972
Low	Burn	30-45	RM	0.000889	0.001406	0.000543	0.000452	0.076725	0.121281	0.046891	0.038972	0.178838	0.282694	0.109298	0.09084	0.01383	0.021862	0.008453	0.007025
Low	Burn	0-30	SB	0	0	0	0	0.000149	9.79E-05	6.79E-10	1.26E-05	0.050221	0.032908	2.28E-07	0.00423	0.524507	0.34369	2.38E-06	0.044181
Low	Burn	0-30	CO	0	0	0	0	0.000253	0.000487	0.000154	4.55E-05	0.037904	0.072919	0.023117	0.00681	0.231141	0.444669	0.140972	0.041528
Low	Burn	0-30	KB	0	0	0	0	6.33E-09	0.001289	0.000813	0.000108	5.17E-07	0.105222	0.066358	0.00878	2.34E-06	0.476887	0.300749	0.039791
Low	Burn	0-30	RM	0	0	0	0	0.000387	0.000611	0.000236	0.000196	0.044283	0.069999	0.027064	0.022493	0.225613	0.356632	0.137885	0.114599
Low	B/G	60-100	SB	0.347603	0.530794	3.08E-06	0.10446	0.006062	0.009256	5.37E-08	0.001822	0	0	0	0	0	0	0	0
Low	B/G	60-100	CO	0.149987	0.622058	0.163465	0.04764	0.002569	0.010655	0.0028	0.000816	1.53E-06	6.33E-06	1.66E-06	4.85E-07	0	0	0	0
Low	B/G	60-100	KB	4.28E-06	0.574732	0.36321	0.047775	6.18E-08	0.008309	0.005251	0.000691	1.3E-10	1.75E-05	1.11E-05	1.45E-06	0	0	0	0
Low	B/G	60-100	RM	0.15142	0.532761	0.164305	0.136544	0.0023	0.008091	0.002495	0.002074	1.54E-06	5.41E-06	1.67E-06	1.39E-06	0	0	0	0
Low	B/G	45-60	SB	0.118676	0.181219	1.05E-06	0.035664	0.216984	0.331337	1.92E-06	0.065207	0.017994	0.027478	1.59E-07	0.005408	1.06E-05	1.62E-05	9.39E-11	3.19E-06
Low	B/G	45-60	CO	0.052195	0.216472	0.056885	0.016579	0.092773	0.384769	0.10111	0.029468	0.00759	0.031478	0.008272	0.002411	0	0	0	0
Low	B/G	45-60	KB	1.56E-06	0.209504	0.132399	0.017415	2.59E-06	0.348301	0.220114	0.028953	1.88E-07	0.025246	0.015955	0.002099	4.34E-11	5.83E-06	3.68E-06	4.85E-07
Low	B/G	45-60	RM	0.054662	0.192323	0.059313	0.049292	0.09219	0.324363	0.100034	0.083133	0.006867	0.02416	0.007451	0.006192	3.07E-06	1.08E-05	3.34E-06	2.77E-06
Low	B/G	30-45	SB	0.001538	0.002349	1.36E-08	0.000462	0.110902	0.169349	9.82E-07	0.033328	0.226233	0.345459	2E-06	0.067986	0.014992	0.022893	1.33E-07	0.004505
Low	B/G	30-45	CO	0.000719	0.00298	0.000783	0.000228	0.049075	0.203533	0.053484	0.015588	0.096406	0.399834	0.105069	0.030621	0.006359	0.026372	0.00693	0.00202
Low	B/G	30-45	KB	2.1E-08	0.002828	0.001787	0.000235	1.45E-06	0.194496	0.122915	0.016168	2.71E-06	0.364184	0.230151	0.030273	1.6E-07	0.02155	0.013619	0.001791
Low	B/G	30-45	RM	0.000778	0.002737	0.000844	0.000701	0.05098	0.17937	0.055318	0.045972	0.096099	0.338117	0.104276	0.086658	0.005864	0.020634	0.006363	0.005288
Low	B/G	0-30	SB	0	0	0	0	0.000658	0.001004	5.82E-09	0.000198	0.06256	0.09553	5.54E-07	0.0188	0.290448	0.443516	2.57E-06	0.087283
Low	B/G	0-30	CO	0	0	0	0	0.000359	0.001487	0.000391	0.000114	0.028528	0.118319	0.031092	0.009061	0.123671	0.512914	0.134784	0.039282
Low	B/G	0-30	KB	0	0	0	0	1.01E-08	0.001353	0.000855	0.000112	7.95E-07	0.106869	0.067537	0.008883	3.53E-06	0.474836	0.300079	0.039471
Low	B/G	0-30	RM	0	0	0	0	0.000334	0.001174	0.000362	0.000301	0.027925	0.098252	0.030301	0.025182	0.125463	0.441432	0.136139	0.113137
Med	Rest	60-100	SB	0.703166	0.218702	3.1E-07	0.000172	0.05908	0.018375	2.61E-08	1.44E-05	0.000374	0.000116	1.65E-10	9.13E-08	0	0	0	0
Med	Rest	60-100	CO	0.285425	0.467242	0.20469	0.000543	0.012512	0.020482	0.008973	2.38E-05	3.28E-05	5.37E-05	2.35E-05	6.24E-08	0	0	0	0
Med	Rest	60-100	KB	3.61E-06	0.388633	0.564977	0.000187	1.75E-07	0.0188	0.027331	9.03E-06	2.27E-10	2.44E-05	3.55E-05	1.17E-08	0	0	0	0
Med	Rest	60-100	RM	0.285761	0.363436	0.205052	0.109841	0.010638	0.01353	0.007633	0.004089	5.93E-06	7.54E-06	4.25E-06	2.28E-06	0	0	0	0
Med	Rest	45-60	SB	0.072174	0.022448	3.19E-08	1.76E-05	0.509247	0.158388	2.25E-07	0.000124	0.180474	0.056132	7.97E-08	4.41E-05	0.000724	0.000225	3.2E-10	1.77E-07
Med	Rest	45-60	CO	0.053277	0.087215	0.038207	0.000101	0.204938	0.335483	0.146969	0.00039	0.039702	0.064991	0.028471	7.55E-05	5.36E-05	8.78E-05	3.85E-05	1.02E-07
Med	Rest	45-60	KB	6.21E-07	0.066868	0.097209	3.21E-05	2.6E-06	0.279968	0.407005	0.000135	5.62E-07	0.060528	0.087993	2.91E-05	8.7E-10	9.37E-05	0.000136	4.5E-08
Med	Rest	45-60	RM	0.057695	0.073378	0.0414	0.022177	0.201398	0.256142	0.144516	0.077414	0.03724	0.047363	0.026722	0.014314	7.11E-05	9.05E-05	5.1E-05	2.73E-05
Med	Rest	30-45	SB	4.58E-05	1.42E-05	2.02E-11	1.12E-08	0.05982	0.018605	2.64E-08	1.46E-05	0.532057	0.165483	2.35E-07	0.00013	0.170697	0.053091	7.53E-08	4.17E-05
Med	Rest	30-45	CO	0.000182	0.000298	0.00013	3.46E-07	0.045196	0.073986	0.032412	8.6E-05	0.214208	0.350658	0.153617	0.000408	0.038384	0.062835	0.027527	7.3E-05
Med	Rest	30-45	KB	1.59E-09	0.000171	0.000249	8.22E-08	5.16E-07	0.055585	0.080807	2.67E-05	2.72E-06	0.292864	0.425753	0.000141	5.46E-07	0.058837	0.085534	2.83E-05
Med	Rest	30-45	RM	0.000172	0.000219	0.000123	6.61E-05	0.045214	0.057503	0.032444	0.017379	0.211672	0.269207	0.151888	0.081363	0.039348	0.050043	0.028235	0.015125
Med	Rest	0-30	SB	0	0	0	0	6.1E-05	1.9E-05	2.69E-11	1.49E-08	0.041502	0.012908	1.83E-08	1.01E-05	0.721057	0.224267	3.18E-07	0.000176
Med	Rest	0-30	CO	0	0	0	0	1.49E-05	2.44E-05	1.07E-05	2.84E-08	0.018745	0.030686	0.013443	3.57E-05	0.27921	0.457067	0.200232	0.000531
Med	Rest	0-30	KB	0	0	0	0	4.92E-10	5.3E-05	7.7E-05	2.55E-08	2.53E-07	0.027222	0.039574	1.31E-05	3.53E-06	0.380182	0.552692	0.000183
Med	Rest	0-30	RM	0	0	0	0	5.93E-05	7.54E-05	4.25E-05	2.28E-05	0.021898	0.027851	0.015714	0.008417	0.274447	0.349046	0.196934	0.105492
Med	Graze	60-100	SB	0.325575	0.58357	1.81E-06	0.075363	0.005123	0.009182	2.85E-08	0.001186	0	0	0	0	0	0	0	0
Med	Graze	60-100	CO	0.130183	0.65381	0.141144	0.050223	0.003287	0.01651	0.003564	0.001268	1.33E-06	6.7E-06	1.45E-06	5.15E-07	0	0	0	0
Med	Graze	60-100	KB	3.63E-06	0.502765	0.451165	0.000136	1.75E-07	0.024167	0.021687	6.56E-06	2.67E-10	3.69E-05	3.31E-05	1E-08	0	0	0	0
Med	Graze	60-100	RM	0.131304	0.520278	0.142654	0.185754	0.00268	0.010618	0.002911	0.003791	1.34E-06	5.31E-06	1.46E-06	1.9E-06	0	0	0	0
Med	Graze	45-60	SB	0.116369	0.208583	6.48E-07	0.026937	0.199817	0.358158	1.11E-06	0.046253	0.014504	0.025998	8.08E-08	0.003357	6.61E-06	1.19E-05	3.69E-11	1.53E-06
Med	Graze	45-60	CO	0.036569	0.183656	0.039648	0.014108	0.087623	0.440063	0.095	0.033804	0.009276	0.046588	0.010057	0.003579	4E-06	2.01E-05	4.34E-06	1.54E-06
Med	Graze	45-60	KB	6.42E-07	0.088863	0.079743	2.41E-05	2.63E-06	0.363213	0.325936	9.85E-05	5.41E-07	0.074793	0.067117	2.03E-05	7.24E-10	0.0001	8.98E-05	2.72E-08
Med	Graze	45-60	RM	0.042089	0.166772	0.045727	0.059542	0.084424	0.334521	0.091722	0.119433	0.007472	0.029608	0.008118	0.010571	0	0	0	0
Med	Graze	30-45	SB	0.001584	0.002839	8.83E-09	0.000367	0.111068	0.199082	6.19E-07	0.02571	0.206593	0.370304	1.15E-06	0.047822	0.011452	0.020527	6.38E-08	0.002651
Med	Graze	30-45	CO	0.000296	0.001488	0.000321	0.000114	0.035183	0.176698	0.038145	0.013573	0.090487	0.454448	0.098106	0.034909	0.007505	0.037692	0.008137	0.002895
Med	Graze	30-45	KB	1.3E-09	0.000179	0.000161	4.86E-08	5.68E-07	0.078513	0.070455	2.13E-05	2.75E-06	0.380893	0.341801	0.000103	4.87E-07	0.067383	0.060468	1.83E-05
Med	Graze	30-45	RM	0.000472	0.001869	0.000512	0.000667	0.040355	0.159902	0.043843	0.05709	0.087132	0.345251	0.094663	0.123264	0.006027	0.02388	0.006548	0.008526
Med	Graze	0-30	SB	0	0	0	0	0.000655	0.001174	3.65E-09	0.000152	0.06187	0.110898	3.45E-07	0.014322	0.268173	0.48068	1.49E-06	0.062076
Med	Graze	0-30	CO	0	0	0	0	0.000136	0.000684	0.000148	5.25E-05	0.019993	0.100408	0.021676	0.007713	0.113343	0.569235	0.122886	0.043726
Med	Graze	0-30	KB	0	0	0	0	7.62E-10	0.000105	9.46E-05	2.86E-08	3.19E-07	0.044144	0.039614	1.2E-05	3.49E-06	0.482719	0.433177	0.000131
Med	Graze	0-30	RM	0	0	0	0	0.00023	0.000913	0.00025	0.000326	0.02348	0.093035	0.025509	0.033216	0.110275	0.436953	0.119807	0.156005
Med	Burn	60-100	SB	0.455494	0.456542	4.39E-06	0.04768	0.019108	0.019152	1.84E-07	0.002	9.49E-06	9.51E-06	9.15E-11	9.94E-07	0	0	0	0
Med	Burn	60-100	CO	0.17877	0.645273	0.100082	0.049815	0.004778	0.017246	0.002675	0.001331	5.51E-06	1.99E-05	3.08E-06	1.53E-06	0	0	0	0
Med	Burn	60-100	KB	4.87E-06	0.655195	0.281266	0.048775	7.3E-08	0.009816	0.004214	0.000731	0	0	0	0	0	0	0	0
Med	Burn	60-100	RM	0.181019	0.514861	0.101027	0.183563	0.003606	0.010256	0.002012	0.003656	0	0	0	0	0	0	0	0
Med	Burn	45-60	SB	0.0917	0.091911	8.84E-07	0.009599	0.325313	0.326061	3.14E-06	0.034053	0.057528	0.05766	5.55E-07	0.006022	7.12E-05	7.14E-05	6.86E-10	7.45E-06
Med	Burn	45-60	CO	0.049455	0.178508	0.027687	0.013781	0.120949	0.436567	0.067712	0.033703	0.013142	0.047438	0.007358	0.003662	7.34E-06	2.65E-05	4.11E-06	2.05E-06
Med	Burn	45-60	KB	1.79E-06	0.240248	0.103135	0.017885	2.95E-06	0.396679	0.170288	0.02953	2.09E-07	0.028077	0.012053	0.00209	4.94E-11	6.65E-06	2.85E-06	4.95E-07
Med	Burn	45-60	RM	0.058214	0.165575	0.032489	0.059032	0.116323	0.33085	0.06492	0.117958	0.010079	0.028666	0.005625	0.01022	9.23E-06	2.63E-05	5.15E-06	9.36E-06
Med	Burn	30-45	SB	0.000351	0.000352	3.39E-09	3.68E-05	0.081258	0.081445	7.83E-07	0.008506	0.34229	0.343077	3.3E-06	0.03583	0.050712	0.050829	4.89E-07	0.005308
Med	Burn	30-45	CO	0.000365	0.001318	0.000204	0.000102	0.047779	0.172459	0.026748	0.013314	0.124596	0.449731	0.069754	0.034719	0.010813	0.03903	0.006054	0.003013
Med	Burn	30-45	KB	2.28E-08	0.003072	0.001319	0.000229	1.67E-06	0.225345	0.096737	0.016775	3.07E-06	0.412672	0.177154	0.030721	1.78E-07	0.02392	0.010269	0.001781
Med	Burn	30-45	RM	0.000585	0.001665	0.000327	0.000593	0.055938	0.1591	0.031219	0.056724	0.119906	0.341042	0.06692	0.121592	0.008195	0.02331	0.004574	0.008311
Med	Burn	0-30	SB	0	0	0	0	0.000109	0.000109	1.05E-09	1.14E-05	0.045544	0.045648	4.39E-07	0.004767	0.428958	0.429945	4.14E-06	0.044902
Med	Burn	0-30	CO	0	0	0	0	0.000154	0.000557	8.63E-05	4.3E-05	0.027685	0.099931	0.015499	0.007715	0.155714	0.562052	0.087174	0.04339
Med	Burn	0-30	KB	0	0	0	0	1.24E-08	0.001669	0.000717	0.000124	9.64E-07	0.129684	0.055671	0.009654	3.97E-06	0.533657	0.229091	0.039727
Med	Burn	0-30	RM	0	0	0	0	0.000325	0.000924	0.000181	0.00033	0.032232	0.091675	0.017989	0.032685	0.152068	0.432518	0.084869	0.154205
Med	B/G	60-100	SB	0.325528	0.583815	1.98E-06	0.075175	0.005118	0.00918	3.12E-08	0.001182	0	0	0	0	0	0	0	0
Med	B/G	60-100	CO	0.127229	0.710116	0.098911	0.048773	0.001932	0.010785	0.001502	0.000741	1.29E-06	7.21E-06	1E-06	4.95E-07	0	0	0	0
Med	B/G	60-100	KB	3.77E-06	0.655822	0.281026	0.048788	5.49E-08	0.009555	0.004094	0.000711	0	0	0	0	0	0	0	0
Med	B/G	60-100	RM	0.128159	0.57672	0.099789	0.181462	0.001803	0.008112	0.001404	0.002552	0	0	0	0	0	0	0	0
Med	B/G	45-60	SB	0.114295	0.20498	6.96E-07	0.026394	0.20138	0.361163	1.23E-06	0.046505	0.014972	0.026851	9.12E-08	0.003457	0	0	0	0
Med	B/G	45-60	CO	0.046114	0.257379	0.03585	0.017678	0.077799	0.434225	0.060482	0.029824	0.00525	0.029305	0.004082	0.002013	0	0	0	0
Med	B/G	45-60	KB	1.39E-06	0.241439	0.103459	0.017961	2.28E-06	0.396039	0.169706	0.029462	1.6E-07	0.027893	0.011952	0.002075	3.82E-11	6.65E-06	2.85E-06	4.95E-07
Med	B/G	45-60	RM	0.04738	0.213212	0.036892	0.067086	0.077327	0.347975	0.06021	0.109488	0.005254	0.023645	0.004091	0.00744	0	0	0	0
Med	B/G	30-45	SB	0.001554	0.002787	9.47E-09	0.000359	0.108819	0.19516	6.63E-07	0.02513	0.208188	0.373373	1.27E-06	0.048077	0.012085	0.021674	7.36E-08	0.002791
Med	B/G	30-45	CO	0.000719	0.004015	0.000559	0.000276	0.045212	0.252347	0.035149	0.017332	0.079276	0.442472	0.061631	0.030391	0.003955	0.022074	0.003075	0.001516
Med	B/G	30-45	KB	1.92E-08	0.003347	0.001434	0.000249	1.31E-06	0.227739	0.097588	0.016942	2.36E-06	0.411496	0.17633	0.030612	1.31E-07	0.022796	0.009768	0.001696
Med	B/G	30-45	RM	0.000726	0.003269	0.000566	0.001029	0.044781	0.201515	0.034868	0.063406	0.080145	0.360654	0.062403	0.113478	0.00431	0.019393	0.003356	0.006102
Med	B/G	0-30	SB	0	0	0	0	0.000701	0.001257	4.27E-09	0.000162	0.062634	0.112331	3.81E-07	0.014464	0.267311	0.479406	1.63E-06	0.061731
Med	B/G	0-30	CO	0	0	0	0	0.000316	0.001766	0.000246	0.000121	0.026035	0.145313	0.02024	0.009981	0.102811	0.573829	0.079928	0.039413
Med	B/G	0-30	KB	0	0	0	0	8.41E-09	0.001464	0.000627	0.000109	7.38E-07	0.128511	0.055068	0.00956	3.08E-06	0.535403	0.229425	0.03983
Med	B/G	0-30	RM	0	0	0	0	0.000309	0.001392	0.000241	0.000438	0.025534	0.114902	0.019881	0.036153	0.104119	0.468538	0.08107	0.147423
High	Rest	60-100	SB	0.350624	0.547085	3.54E-06	0.072448	0.010759	0.016788	1.09E-07	0.002223	2.53E-05	3.95E-05	2.56E-10	5.23E-06	0	0	0	0
High	Rest	60-100	CO	0.10312	0.763549	0.0538	0.06186	0.001853	0.013719	0.000967	0.001111	2.1E-06	1.55E-05	1.1E-06	1.26E-06	0	0	0	0
High	Rest	60-100	KB	1.38E-06	0.702236	0.207216	0.072956	2.47E-08	0.012559	0.003706	0.001305	2.82E-11	1.43E-05	4.22E-06	1.49E-06	0	0	0	0
High	Rest	60-100	RM	0.104842	0.582332	0.054396	0.237351	0.002258	0.01254	0.001171	0.005111	0	0	0	0	0	0	0	0
High	Rest	45-60	SB	0.082289	0.128397	8.32E-07	0.017003	0.242129	0.377798	2.45E-06	0.05003	0.036965	0.057677	3.74E-07	0.007638	2.53E-05	3.95E-05	2.56E-10	5.23E-06
High	Rest	45-60	CO	0.03207	0.23746	0.016732	0.019238	0.065924	0.488134	0.034394	0.039547	0.00698	0.051682	0.003642	0.004187	1.05E-06	7.77E-06	5.48E-07	6.3E-07
High	Rest	45-60	KB	4.24E-07	0.215408	0.063563	0.022379	8.88E-07	0.450974	0.133074	0.046852	9.53E-08	0.048407	0.014284	0.005029	4.22E-11	2.14E-05	6.33E-06	2.23E-06
High	Rest	45-60	RM	0.029246	0.162442	0.015174	0.066209	0.06921	0.384418	0.035908	0.156684	0.008633	0.047953	0.004479	0.019545	1.07E-05	5.95E-05	5.56E-06	2.42E-05
High	Rest	30-45	SB	0.000329	0.000513	3.32E-09	6.8E-05	0.068393	0.106715	6.91E-07	0.014132	0.255895	0.399278	2.59E-06	0.052875	0.036791	0.057406	3.72E-07	0.007602
High	Rest	30-45	CO	0.000232	0.001718	0.000121	0.000139	0.026698	0.197687	0.013929	0.016016	0.070911	0.525055	0.036996	0.042538	0.007134	0.052824	0.003722	0.00428
High	Rest	30-45	KB	3.35E-09	0.001701	0.000502	0.000177	3.59E-07	0.182469	0.053843	0.018957	9.5E-07	0.482125	0.142266	0.050088	9.56E-08	0.048514	0.014316	0.00504
High	Rest	30-45	RM	0.000162	0.000898	8.39E-05	0.000366	0.023476	0.130396	0.01218	0.053148	0.074324	0.412823	0.038562	0.168261	0.009138	0.050754	0.004741	0.020687
High	Rest	0-30	SB	0	0	0	0	0.000242	0.000378	2.45E-09	5E-05	0.043203	0.06741	4.37E-07	0.008927	0.317963	0.496124	3.21E-06	0.0657
High	Rest	0-30	CO	0	0	0	0	9.13E-05	0.000676	4.76E-05	5.48E-05	0.013253	0.098132	0.006914	0.00795	0.091631	0.678476	0.047806	0.054968
High	Rest	0-30	KB	0	0	0	0	1.77E-09	0.000901	0.000266	9.36E-05	1.92E-07	0.097371	0.028732	0.010116	1.21E-06	0.616538	0.181928	0.064053
High	Rest	0-30	RM	0	0	0	0	7.5E-05	0.000416	3.89E-05	0.00017	0.013292	0.07383	0.006896	0.030092	0.093732	0.520626	0.048632	0.2122
High	Graze	60-100	SB	0.293233	0.641617	3.08E-06	0.049176	0.00475	0.010393	5E-08	0.000797	8.94E-06	1.96E-05	9.4E-11	1.5E-06	0	0	0	0
High	Graze	60-100	CO	0.09653	0.781623	0.050174	0.047563	0.002384	0.019303	0.001239	0.001175	9.89E-07	8.01E-06	5.14E-07	4.87E-07	0	0	0	0
High	Graze	60-100	KB	3.06E-06	0.683715	0.1937	0.077252	1.45E-07	0.032393	0.009177	0.00366	3.21E-10	7.16E-05	2.03E-05	8.09E-06	0	0	0	0
High	Graze	60-100	RM	0.097984	0.590445	0.051316	0.241644	0.001857	0.011191	0.000973	0.00458	9.98E-07	6.02E-06	5.23E-07	2.46E-06	0	0	0	0
High	Graze	45-60	SB	0.10506	0.22988	1.11E-06	0.017619	0.180041	0.393944	1.89E-06	0.030193	0.012891	0.028207	1.36E-07	0.002162	0	0	0	0
High	Graze	45-60	CO	0.028276	0.228955	0.014697	0.013932	0.064114	0.519149	0.033325	0.031591	0.006521	0.052806	0.00339	0.003213	2.97E-06	2.4E-05	1.54E-06	1.46E-06
High	Graze	45-60	KB	5.74E-07	0.128225	0.036327	0.014488	2.21E-06	0.494923	0.140214	0.05592	4.16E-07	0.09291	0.026322	0.010498	5.45E-10	0.000122	3.45E-05	1.38E-05
High	Graze	45-60	RM	0.03283	0.197832	0.017194	0.080964	0.061946	0.373283	0.032443	0.152769	0.005064	0.030515	0.002652	0.012489	2E-06	1.2E-05	1.05E-06	4.92E-06
High	Graze	30-45	SB	0.001594	0.003488	1.68E-08	0.000267	0.103421	0.226294	1.09E-06	0.017344	0.183271	0.401012	1.93E-06	0.030735	0.009706	0.021237	1.02E-07	0.001628
High	Graze	30-45	CO	0.000289	0.002339	0.00015	0.000142	0.027871	0.225679	0.014487	0.013733	0.065812	0.532893	0.034208	0.032428	0.004943	0.040023	0.002569	0.002435
High	Graze	30-45	KB	1.76E-09	0.000394	0.000112	4.45E-05	5.38E-07	0.120282	0.034077	0.01359	2.31E-06	0.515685	0.146096	0.058266	3.57E-07	0.079818	0.022613	0.009019
High	Graze	30-45	RM	0.000441	0.002659	0.000231	0.001088	0.032447	0.195522	0.016993	0.080019	0.06312	0.380358	0.033057	0.155664	0.003834	0.023103	0.002008	0.009455
High	Graze	0-30	SB	0	0	0	0	0.000906	0.001982	9.53E-09	0.000152	0.061336	0.134207	6.45E-07	0.010286	0.235751	0.515841	2.48E-06	0.039536
High	Graze	0-30	CO	0	0	0	0	0.000137	0.001105	7.1E-05	6.73E-05	0.016415	0.132915	0.008532	0.008088	0.082363	0.666913	0.042811	0.040583
High	Graze	0-30	KB	0	0	0	0	9.62E-10	0.000215	6.09E-05	2.43E-05	3.13E-07	0.069856	0.019791	0.007893	2.89E-06	0.646109	0.183046	0.073003
High	Graze	0-30	RM	0	0	0	0	0.000254	0.001528	0.000133	0.000625	0.019155	0.115425	0.010032	0.047239	0.080434	0.484689	0.042125	0.198362
High	Burn	60-100	SB	0.337952	0.574305	2.27E-06	0.046941	0.014357	0.024398	9.66E-08	0.001994	1.76E-05	2.99E-05	1.19E-10	2.45E-06	0	0	0	0
High	Burn	60-100	CO	0.09793	0.780725	0.049305	0.04722	0.002491	0.019863	0.001254	0.001201	1E-06	8.01E-06	5.06E-07	4.84E-07	0	0	0	0
High	Burn	60-100	KB	3.21E-06	0.74153	0.196519	0.048048	4.52E-08	0.010445	0.002768	0.000677	3.26E-11	7.52E-06	1.99E-06	4.87E-07	0	0	0	0
High	Burn	60-100	RM	0.099387	0.590764	0.049897	0.241142	0.001903	0.011313	0.000956	0.004618	2.03E-06	1.2E-05	1.02E-06	4.92E-06	0	0	0	0
High	Burn	45-60	SB	0.070934	0.120543	4.77E-07	0.009853	0.241703	0.410743	1.63E-06	0.033572	0.039654	0.067387	2.67E-07	0.005508	3.52E-05	5.99E-05	2.37E-10	4.89E-06
High	Burn	45-60	CO	0.028595	0.22797	0.014397	0.013788	0.065309	0.520667	0.032882	0.031491	0.006511	0.051911	0.003278	0.00314	6.03E-06	4.8E-05	3.03E-06	2.91E-06
High	Burn	45-60	KB	1.21E-06	0.279444	0.074058	0.018107	1.92E-06	0.443121	0.117435	0.028712	1.27E-07	0.029418	0.007796	0.001906	0	0	0	0
High	Burn	45-60	RM	0.032669	0.194186	0.016401	0.079264	0.063205	0.375697	0.031732	0.153355	0.005417	0.0322	0.00272	0.013144	1.01E-06	6.02E-06	5.09E-07	2.46E-06
High	Burn	30-45	SB	0.000349	0.000593	2.35E-09	4.84E-05	0.066396	0.112831	4.47E-07	0.009222	0.251952	0.42816	1.7E-06	0.034996	0.03363	0.057149	2.26E-07	0.004671
High	Burn	30-45	CO	0.000291	0.002322	0.000147	0.00014	0.028338	0.22592	0.014268	0.013664	0.066755	0.532188	0.03361	0.032188	0.005038	0.040166	0.002537	0.002429
High	Burn	30-45	KB	1.85E-08	0.004264	0.00113	0.000276	1.16E-06	0.267593	0.070917	0.017339	1.98E-06	0.457296	0.121192	0.029631	9.88E-08	0.02283	0.00605	0.001479
High	Burn	30-45	RM	0.000395	0.002348	0.000198	0.000958	0.032223	0.191537	0.016178	0.078183	0.064812	0.385247	0.032539	0.157253	0.003862	0.022958	0.001939	0.009371
High	Burn	0-30	SB	0	0	0	0	0.000137	0.000234	9.25E-10	1.91E-05	0.038622	0.065633	2.6E-07	0.005365	0.313567	0.532866	2.11E-06	0.043554
High	Burn	0-30	CO	0	0	0	0	0.000128	0.001017	6.42E-05	6.15E-05	0.016884	0.134604	0.008501	0.008141	0.083411	0.664975	0.041995	0.040219
High	Burn	0-30	KB	0	0	0	0	1.14E-08	0.002632	0.000698	0.000171	6.96E-07	0.160751	0.042602	0.010416	2.55E-06	0.588599	0.15599	0.038138
High	Burn	0-30	RM	0	0	0	0	0.000256	0.001523	0.000129	0.000622	0.019521	0.116035	0.009801	0.047364	0.081515	0.484531	0.040925	0.197779
High	B/G	60-100	SB	0.293273	0.641826	2.05E-06	0.049268	0.004657	0.010191	3.26E-08	0.000782	0	0	0	0	0	0	0	0
High	B/G	60-100	CO	0.0969	0.789987	0.049785	0.047649	0.001544	0.012584	0.000793	0.000759	0	0	0	0	0	0	0	0
High	B/G	60-100	KB	3.93E-06	0.741442	0.196571	0.048102	5.53E-08	0.010429	0.002765	0.000677	3.99E-11	7.52E-06	1.99E-06	4.88E-07	0	0	0	0
High	B/G	60-100	RM	0.098233	0.595096	0.050544	0.242067	0.001401	0.008486	0.000721	0.003452	0	0	0	0	0	0	0	0
High	B/G	45-60	SB	0.106781	0.233689	7.48E-07	0.017939	0.178603	0.390871	1.25E-06	0.030004	0.01254	0.027443	8.78E-08	0.002107	5.96E-06	1.3E-05	4.17E-11	1E-06
High	B/G	45-60	CO	0.037165	0.302995	0.019095	0.018275	0.057578	0.469416	0.029582	0.028313	0.003697	0.030137	0.001899	0.001818	2.95E-06	2.41E-05	1.52E-06	1.45E-06
High	B/G	45-60	KB	1.5E-06	0.283548	0.075174	0.018396	2.33E-06	0.439759	0.116589	0.02853	1.52E-07	0.028564	0.007573	0.001853	3.99E-11	7.52E-06	1.99E-06	4.88E-07
High	B/G	45-60	RM	0.03713	0.224931	0.019104	0.091495	0.058662	0.355377	0.030184	0.144557	0.003842	0.023274	0.001977	0.009467	0	0	0	0
High	B/G	30-45	SB	0.00163	0.003567	1.14E-08	0.000274	0.104782	0.229314	7.34E-07	0.017603	0.182393	0.399165	1.28E-06	0.030641	0.009126	0.019971	6.39E-08	0.001533
High	B/G	30-45	CO	0.000697	0.005682	0.000358	0.000343	0.037618	0.306687	0.019327	0.018498	0.057573	0.469368	0.029579	0.02831	0.002556	0.020835	0.001313	0.001257
High	B/G	30-45	KB	2.31E-08	0.004361	0.001156	0.000283	1.47E-06	0.277112	0.073468	0.017978	2.38E-06	0.448556	0.118921	0.029101	1.16E-07	0.02185	0.005793	0.001418
High	B/G	30-45	RM	0.000566	0.003428	0.000291	0.001395	0.035804	0.216904	0.018422	0.08823	0.060275	0.365149	0.031013	0.148532	0.002988	0.018101	0.001537	0.007363
High	B/G	0-30	SB	0	0	0	0	0.000822	0.0018	5.76E-09	0.000138	0.061704	0.135039	4.32E-07	0.010366	0.235403	0.515178	1.65E-06	0.039547
High	B/G	0-30	CO	0	0	0	0	0.000402	0.003274	0.000206	0.000198	0.021874	0.178331	0.011238	0.010756	0.076167	0.620965	0.039133	0.037454
High	B/G	0-30	KB	0	0	0	0	1.38E-08	0.002594	0.000688	0.000168	8.49E-07	0.160037	0.042429	0.010383	3.13E-06	0.589247	0.156221	0.038228
High	B/G	0-30	RM	0	0	0	0	0.000321	0.001944	0.000165	0.000791	0.021288	0.128961	0.010953	0.052458	0.078025	0.472678	0.040146	0.192271

Model Prediction – Single Time Step

- Model input
  - Current vegetation state: native cover, dominant invader
  - Current defoliation level
  - Proposed management action
- Model output
  - Provides a distribution of predicted vegetation state in the next year in response to model inputs and stochastic events

NPAM Model Prediction Over a Single Time Step

Initial Starting States at time *t*

Defoliation Level (L, M, H)	Low
Management Action (R, G, B, BG)	Rest
NP Cover (0-30, 30-45, 45-60, 60-100)	45-60
Dominant Invader (SB, CO, KB, RM)	CO

Distribution of Predictions at time *t*+1

	SB	CO	KB	RM
60-100	2	1	1	0
45-60	27	13	18	0
30-45	11	5	21	0
0-30	0	0	1	0

State Transition Matrix – Defoliation

No Defoliation
(Rest)

Defoliation State time *t*+1 (columns); Defoliation State time *t* (rows)

		5+ Low	2 - 4 Low	2 - 4 Med	2 - 4 High	1 Low	1 Med	1 High
5+	Low	1	0	0	0	0	0	0
2 - 4	Low	0.3889	0.6111	0	0	0	0	0
	Med	0.0313	0.4063	0.5625	0	0	0	0
	High	0	0	1	0	0	0	0
1	Low	0	1	0	0	0	0	0
	Med	0	0.1429	0.8571	0	0	0	0
	High	0	0	0.4545	0.5455	0	0	0

Defoliation
(Graze, Burn, B/G)

Defoliation State time *t*+1 (columns); Defoliation State time *t* (rows)

		5+ Low	2 - 4 Low	2 - 4 Med	2 - 4 High	1 Low	1 Med	1 High
5+	Low	0	0	0	0	0.75	0.25	0
2 - 4	Low	0	0	0	0	0.3333	0.6667	0
	Med	0	0	0	0	0	0.8125	0.1875
	High	0	0	0	0	0	0	1
1	Low	0	0	0	0	0.2857	0.7143	0
	Med	0	0	0	0	0	0.7143	0.2857
	High	0	0	0	0	0	0	1

Model Prediction – Time Series

- Two parts that work together
  - Vegetation model
    - $P(x_{t+1}|x_t, d_t, a_t)$
  - Defoliation model
    - $P(y_{t+1}, d_{t+1}|y_t, d_t, a_t)$
- Next time step
  - Vegetation model uses the new defoliation level predicted by the defoliation model

x = vegetation state
d = defoliation level
a = management action
y = years since last defoliation

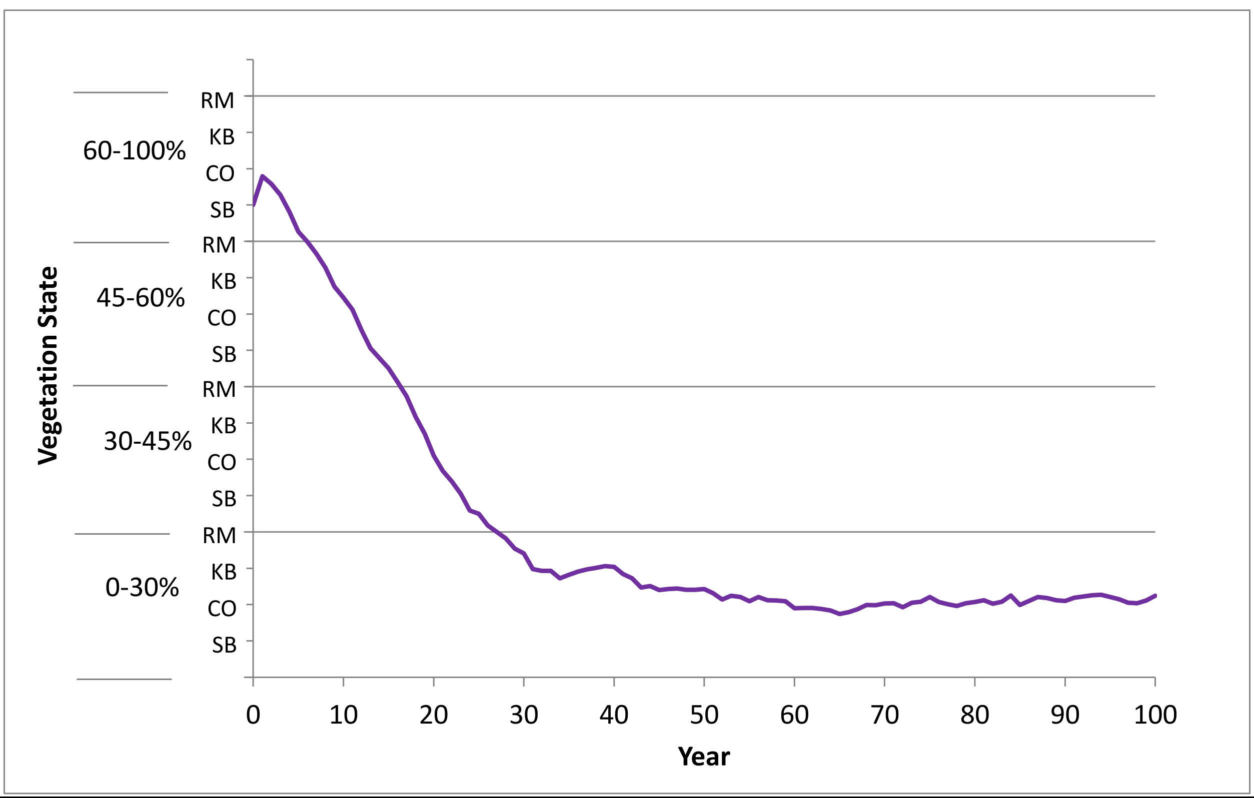
NPAM time series simulation

Initial Starting States at time *t*

Defoliation State: Yrs Since | Level	1 | High
NP Cover	60-100
Dominant Invader	SB

Management Action

Repeated Annual Action	Rest



<u>Structural Uncertainty</u>

- Decisions are difficult due to uncertainty about system behavior
    - Which management action is best to apply depends on how the system behaves
- Elicitation of uncertainties
- Identified three key uncertainties

    Does vegetation response to management depend on the:

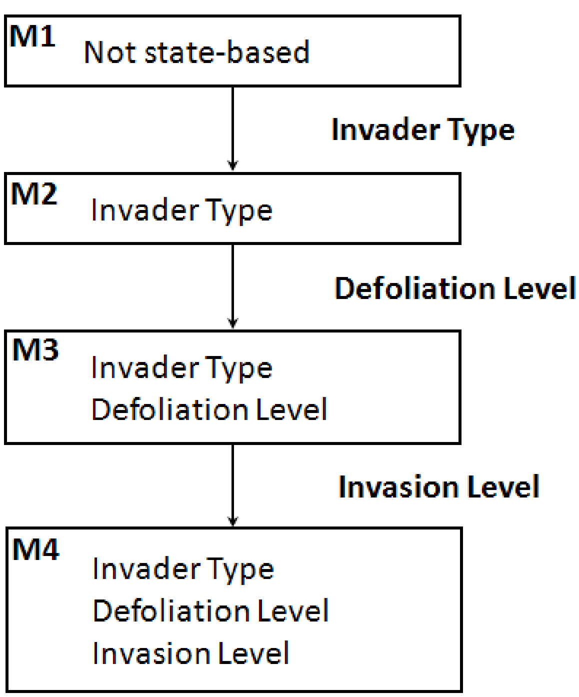
    1) Type of dominant invader
    2) Past defoliation history of the unit
    3) Level of invasion

<u>Structural Uncertainty: Competing Models</u>

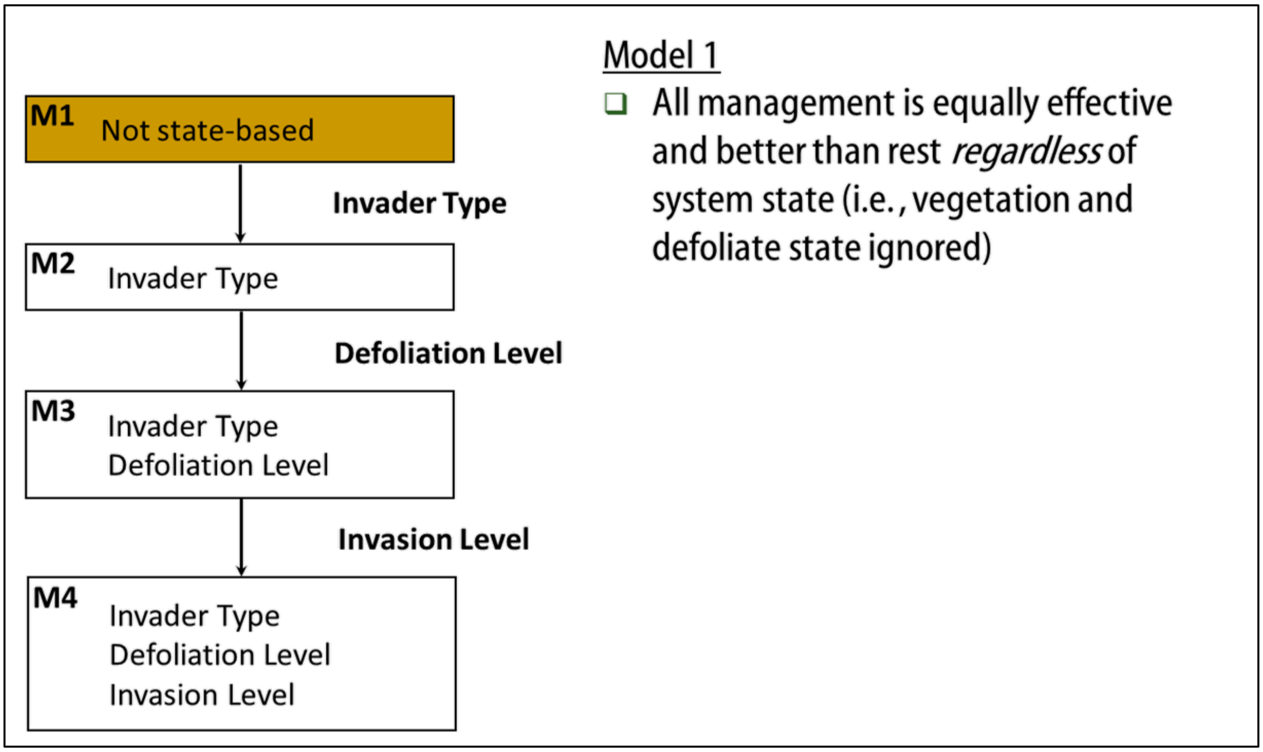
- Goal of managing under an AM framework
    - Reduce uncertainty so make better decisions based on improved understanding of system behavior
- Represent uncertainty through competing models
- Models make different predictions about how the system responds to different management actions
    - Predictions based on three identified uncertainties:

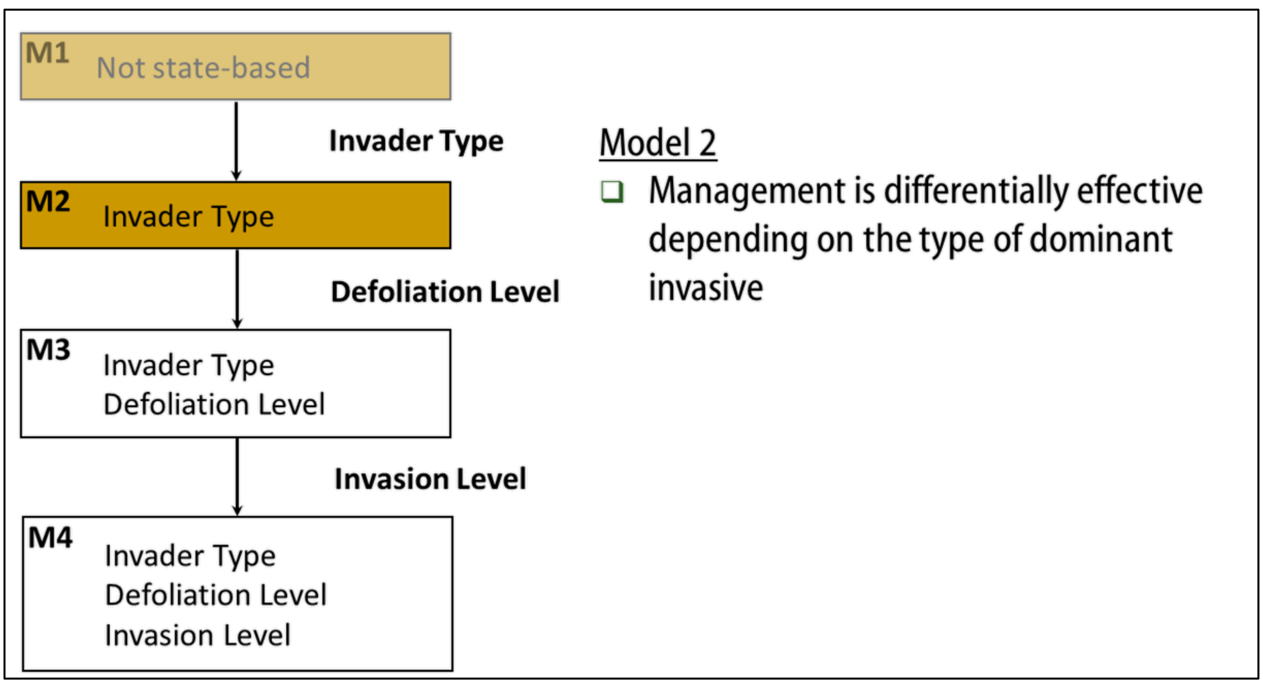
        (1) Invader type, (2) Defoliation level, (3) Invasion level

<u>Competing Model Set</u>

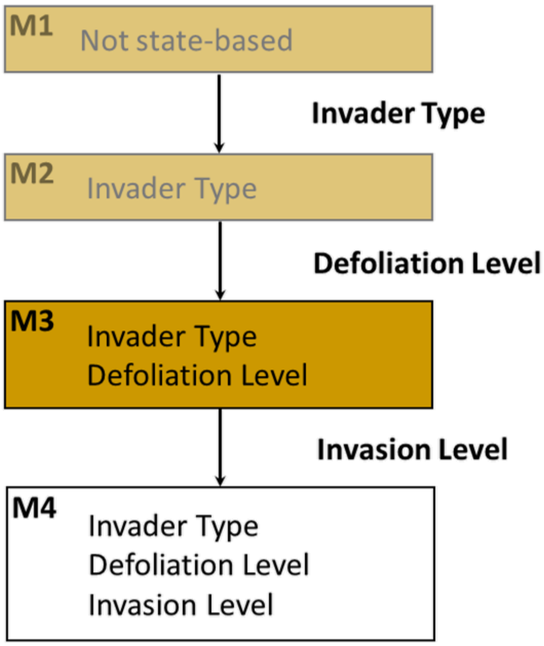


Competing Model Set



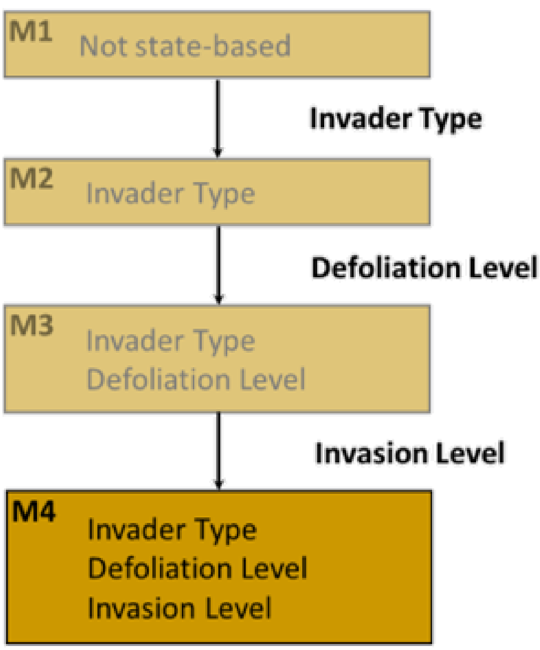


Competing Model Set (continued)



Model 3

- Management is differentially effective depending on the type of dominant invasive
- History of frequent defoliation creates momentum: rest is less detrimental, active management is more effective



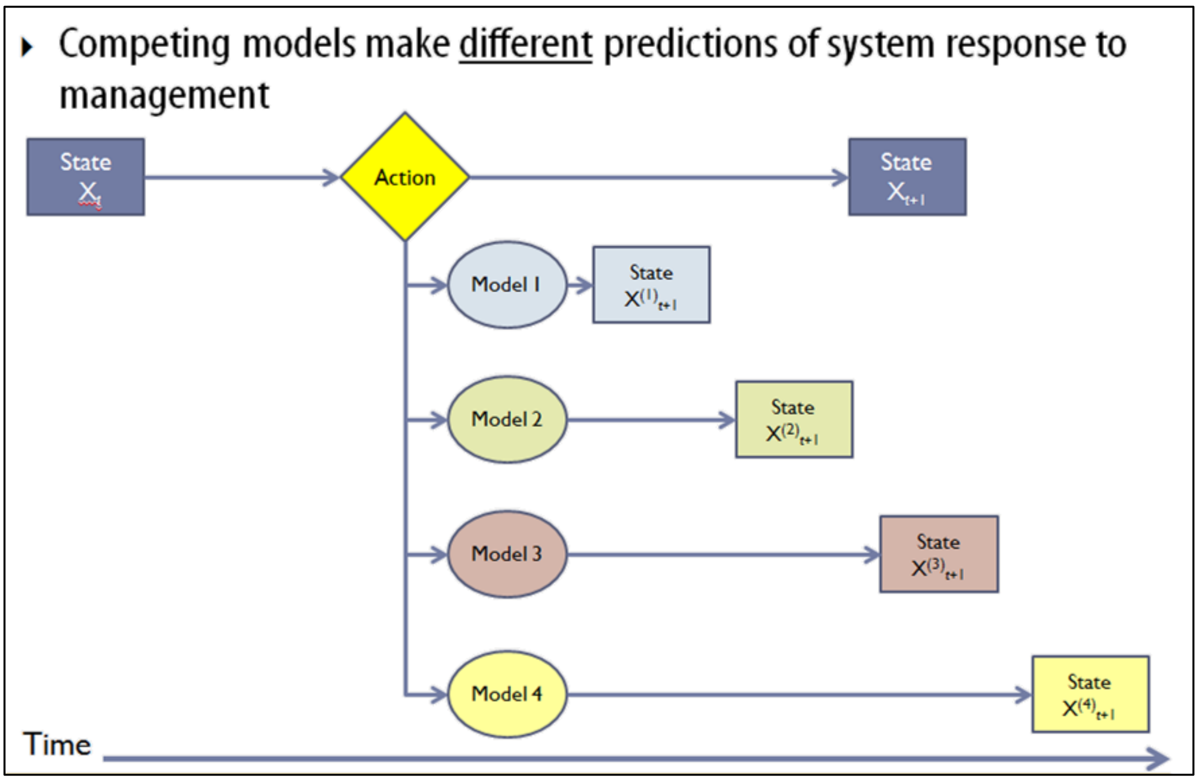
Model 4

- Management is differentially effective depending on the type of dominant invasive
- History of frequent defoliation creates momentum: rest is less detrimental, active management is more effective
- Management effectiveness declines as level of invasion increases: at high levels, active management is equivalent to rest

Parameterization of Competing Models

- Original elicitation was used to parameterize Model 3
- To parameterize Models 1, 2, and 4
  - Modified the elicited values to be consistent with the specific hypotheses
  - Like before, used the values as input in a linear-logistic and linear-polytomous regression
  - Derived parameters of the state transition probability matrices for each model (12 matrices per model)

Implications of Competing Models



Implications of Competing Models – Vegetation State

- Competing models make different predictions
  - Same starting vegetation and defoliation state
  - Same management action
  - Different predicted outcome of vegetation state
- Prediction of the resulting vegetation state depends on the model used; therefore, which management action you should select depends on the model you believe

NPAM Model Prediction Over a Single Time Step

Initial Starting States at time *t*

Defoliation Level (L, M, H)	High
NP Cover (0-30, 30-45, 45-60, 60-100)	30-45
Dominant Invader (SB, CO, KB, RM)	KB
Management Action (R, G, B, BG)	Burn

Distribution of Predictions at time *t* +1

Model 1

	SB	CO	KB	RM
60-100	0	0	0	0
45-60	1	1	5	0
30-45	7	12	52	6
0-30	1	4	9	2

Model 2

	SB	CO	KB	RM
60-100	0	1	0	0
45-60	0	6	8	11
30-45	0	26	18	26
0-30	0	1	1	2

Model 3

	SB	CO	KB	RM
60-100	0	1	0	0
45-60	0	19	6	1
30-45	0	54	11	5
0-30	0	1	1	1

Model 4

	SB	CO	KB	RM
60-100	0	0	0	0
45-60	0	7	1	1
30-45	0	55	14	6
0-30	0	12	2	2

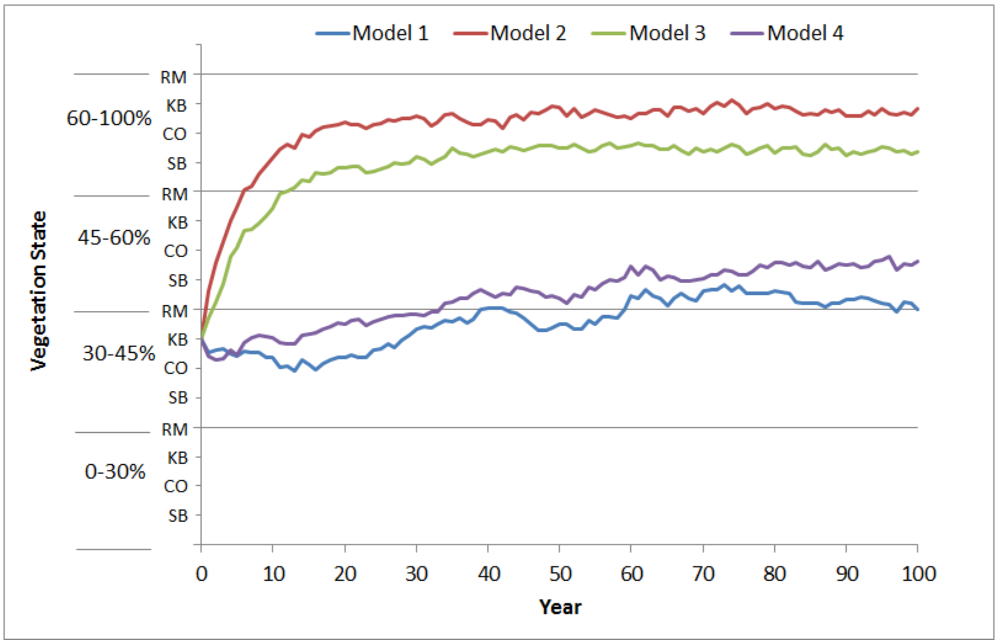
NPAM time series simulation

<u>Initial Starting States at time *t*</u>

Defoliation State: Yrs Since | Level	1 | High
NP Cover	30-45
Dominant Invader	KB

<u>Management Action</u>

Repeated Annual Action	Burn

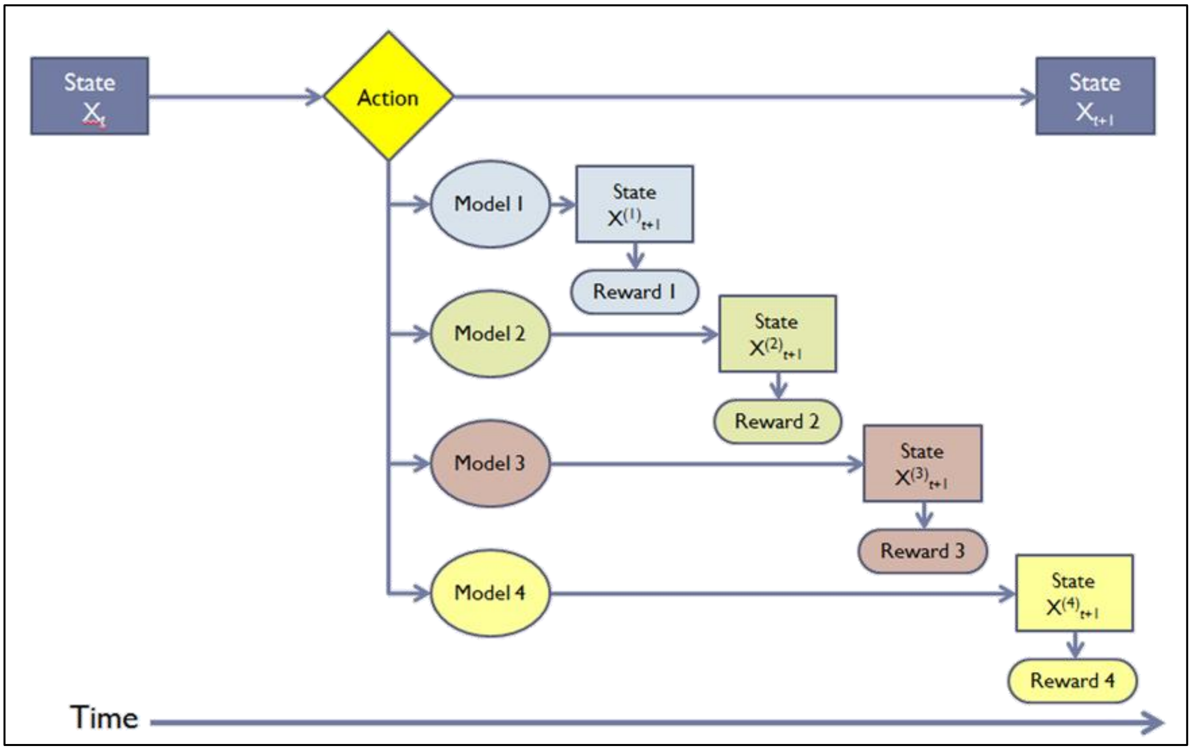


<u>Implications of Competing Models – Reward</u>

- We translate the resultant vegetation state into a value that represents the reward gained (utility)
- A subjective expression that quantifies how cooperators value the outcome produced by the action taken
- Combines both aspects of the management objective and is a function of
  - Native cover outcome relative to starting state (resource gain)
  - Management action applied (cost)
- Unitless number that ranges between 0 and 1
- Annual measure of what is received for what is invested
  - Larger the value, greater the payoff

More about utility in Case Study Module D…

Implications of Competing Models – Reward



- Because reward is a function of the starting state, management action taken, and resulting state.
- And because competing models made different predictions about the resulting state given the same input.
- It follows that competing models predict different rewards for the same input.

Implications of Competing Models – Reward

- For any given vegetation state and management action taken, competing models project different rewards
- If differences aren't trivial, as rewards accumulate through the course of decision making, competing models will indicate that the objective would be best pursued along different paths of decision making

NPAM Model Prediction Over a Single Time Step

Initial Starting States at time *t*

Defoliation Level (L, M, H)	High
NP Cover (0-30, 30-45, 45-60, 60-100)	30-45
Dominant Invader (SB, CO, KB, RM)	KB
Management Action (R, G, B, BG)	Burn

Distribution of Predictions at time *t* +1 for Competing Models

Model 1

	SB	CO	KB	RM	Sum	Utility	
60-100	0	0	0	0	0	0.4366	
45-60	2	2	4	0	8		
30-45	8	22	39	6	75		M1 v M2
0-30	1	1	13	2	17		20.3629

Model 2

	SB	CO	KB	RM	Sum	Utility	
60-100	0	2	0	0	2	0.5255	
45-60	0	6	9	22	37		
30-45	0	17	12	23	52		M2 v M3
0-30	0	2	4	3	9		2.1337

Model 3

	SB	CO	KB	RM	Sum	Utility	
60-100	0	2	0	0	2	0.5367	
45-60	0	28	10	2	40		
30-45	0	40	7	4	51		M3 v M4
0-30	0	6	0	1	7		20.0391

Model 4

	SB	CO	KB	RM	Sum	Utility
60-100	0	0	0	0	0	0.4471
45-60	0	8	5	0	13	
30-45	0	54	10	6	70	
0-30	0	8	7	2	17	

Structural Uncertainty: Expected Value of Perfect Information

- If management performance depends on the model used, best performance would be achieved by managing under the model that best reflects system behavior
  - Have 4 different models, that make 4 different predictions, and are uncertain which is the better representation of system behavior
  - Goal of managing under AM framework to reduce uncertainty
  - What is the value of resolving the uncertainty among competing models? What is sacrificed if fail to identify the most appropriate model and continue to manage under model uncertainty?
    - ➢ This is the Expected Value of Perfect Information (EVPI)

Expected Value of Perfect Information (EVPI)

- EVPI is the value of resolving uncertainty compared with continuing to manage under uncertainty
- EVPI is measured in units of the management reward, i.e., the utility
- To compute EVPI we need:
  - Expected value (utility) of managing under certainty with respect to each competing model
  - Expected value (utility) of managing under continued uncertainty with respect to all competing models

Expected Value of Perfect Information (EVPI)

(1) Expected value of management under certainty for a model
  - For a given model *m*, optimization procedure provides the expected average maximum utility for a given starting state *x*, assuming the optimal policy is followed
    - Call this value $U_m(x)$

(2) Expected value of management under continued uncertainty
  - Optimization procedure provides the expected average maximum utility by averaging all 4 model rewards
    - Call this value $U_{\bullet}(x)$

Optimization…..in brief

- A procedure that looks at all possible decision pathways through time and the accumulated rewards over the course of the different decision pathways
- Identifies the trajectory of decisions (i.e., management actions) for each time-step through time that is optimal (i.e., results in the highest accumulation of rewards)

More about optimization in Case Study Module D…

Expected Value of Perfect Information (EVPI)

- Averaging over all possible starting states, *x*

U_{m1}	U_{m2}	U_{m3}	U_{m4}	$\mathbf{Avg_{m1:m4}}$
0.71722	0.84983	0.85911	0.77048	**0.79916**

$\underbrace{\hphantom{0.71722 \quad 0.84983 \quad 0.85911 \quad 0.77048}}$

Average expected per annum utility under each respective model as if certain it is the best model (i.e., weight of 1.0)

(1) Average of the four model-certain utilities. Average expected per annum utility if resolve uncertainty among models.

U.
0.79053

(2) Average expected per annum utility if continue to manage without resolving uncertainty among models (i.e., always equal weight of 0.25 on each model)

- **EVPI =** $\mathbf{Avg_{m1:m4}}$ **– U. = 0.00862**

➢ Over all states, resolving uncertainty provides a 1.1% increase in utility over continuing to manage without resolving uncertainty
  - We get 1.1% by dividing the **EVPI** by the expected value of continuing to manage under uncertainty (i.e., the value **U.** in the green box) * 100. (0.00862/0.790534)*100 = 1.1%

EVPI Differs by System State

- Value of resolving uncertainty is greater in some states than others
  - Overall: 1.1% increase
  - Amount of native prairie vegetation

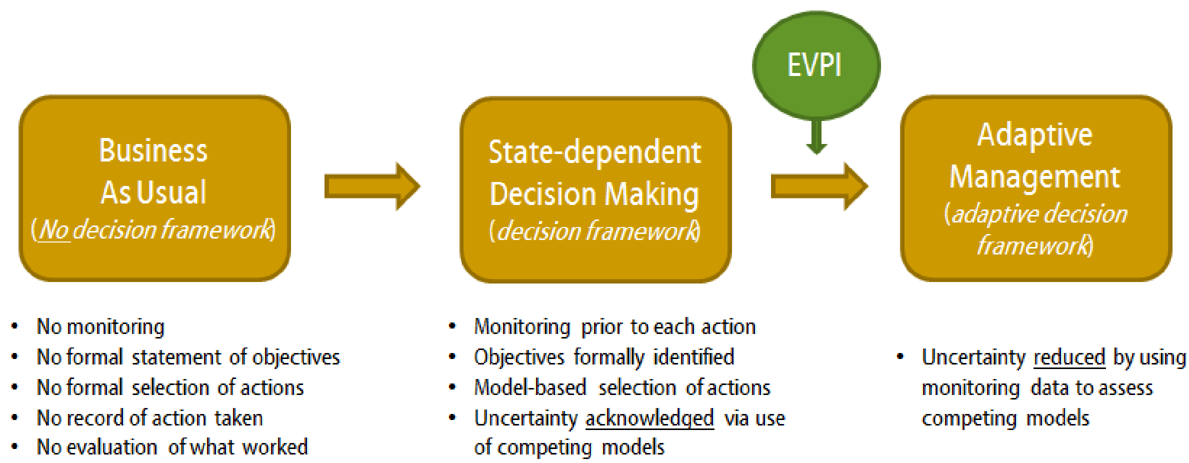
0-30%	30-45%	45-60%	60-100%
0.9%	0.7%	1.1%	1.6%

  - Level of past defoliation

Low	Medium	High
1.0%	1.1%	1.2%

EVPI is not Measuring Value of AM over 'Business As Usual'!

- Cooperators have already agreed to implement state-dependent decision making, with monitoring
    - EVPI is measuring the value of using the monitoring data to improve future management



Structural Uncertainty: Model Weighting

- If we're uncertain about choice of model, how do we move forward with a decision?
    - Assign initial model weights to each model, e.g.,
      $w_{m1} = 1/4$, $w_{m2} = 1/4$, $w_{m3} = 1/4$, $w_{m4} = 1/4$
        - This weighting reflects complete uncertainty among competing models
        - Each model initially has equal influence on the decision
    - For subsequent decisions, model weights are updated on the basis of information feedback from the monitoring program
        - Each model's influence on the decision is continually revised over time

More about this in Case Study Module C – Monitoring and Learning…

Summary: Case Study Module B - Model Development

- NPAM models project vegetation composition through time, in response to management actions and stochastic effects
- Lacking data, model parameters were derived via expert elicitation
- Response of vegetation to management is uncertain and we express structural uncertainty through competing models
- Resolution of the uncertainty among competing models is likely to translate into increased management performance
- EVPI is the expected value of resolving uncertainty compared with continuing to manage under uncertainty

Literature Cited

Gannon, J.J., T.L. Shaffer, C.T. Moore. 2013. Native Prairie Adaptive Management: A Multi Region Adaptive Approach to Invasive Plant Management on Fish and Wildlife Service Owned Native Prairies: U.S. Geological Survey Open File Report 2013-1279, 184 p. with appendixes, http://dx.doi.org/10.3133/ofr20131279