An Object-Oriented Dynamic Bayesian network for Adaptive Management of the Victorian Western Grasslands Reserve

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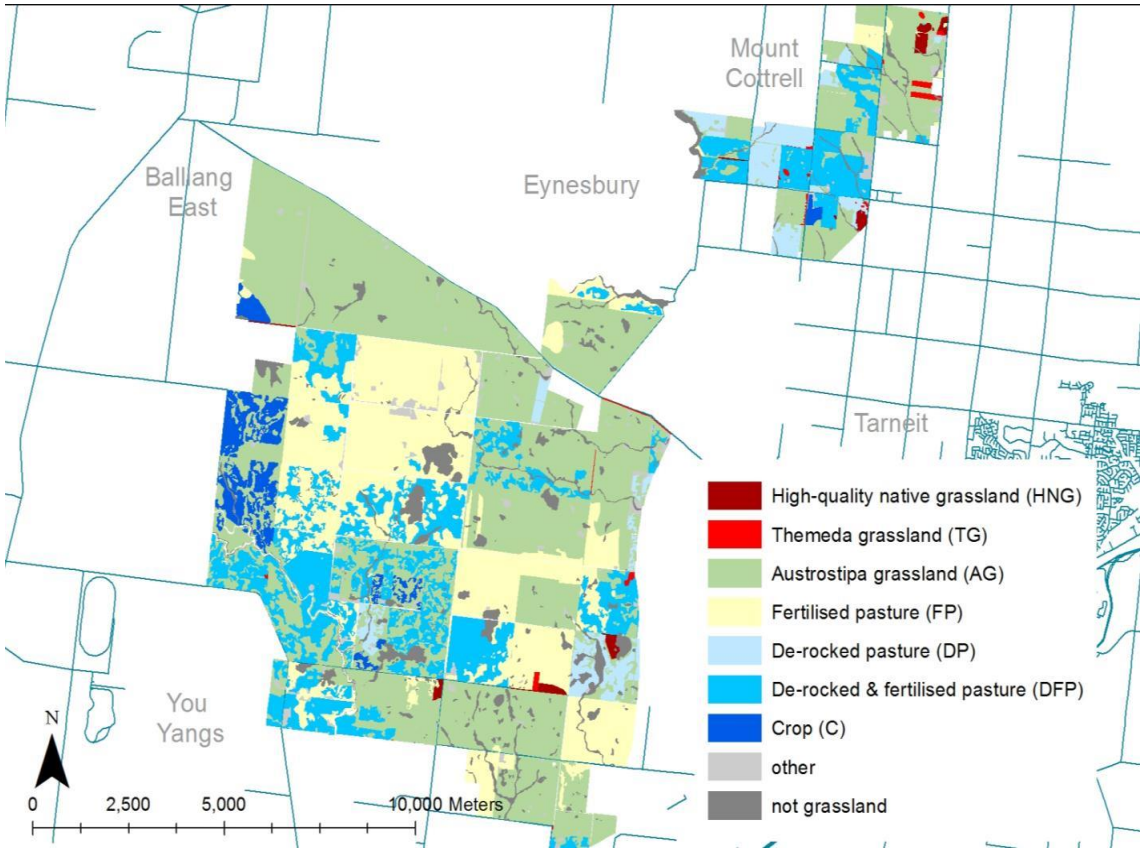
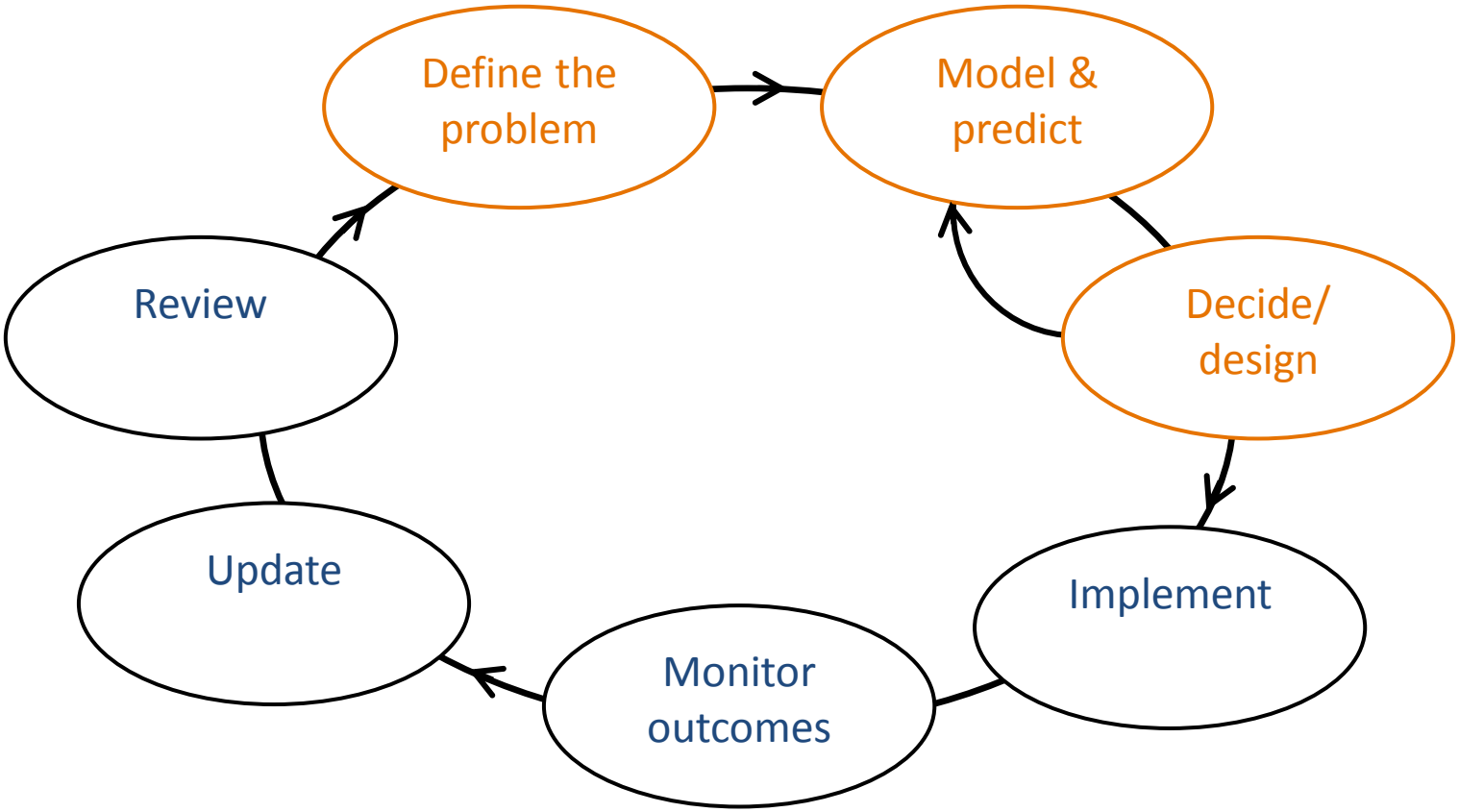
Background

- 15,000 ha. reserved to offset urban development
- Adaptive management to guide:
  - Restoration
  - Management



Adaptive Management



Adaptive Management

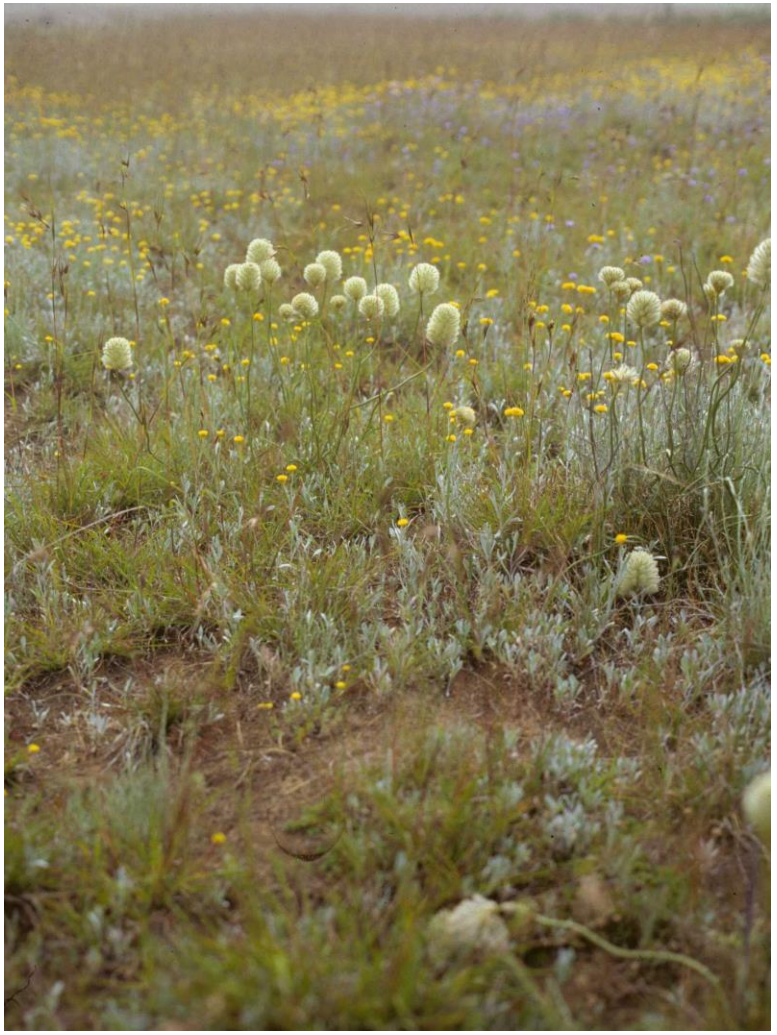
- Set measurable goals
- Be explicit about how we think our system works
- Identify critical uncertainties
- Plan & implement management
- Monitor to target uncertainty
- Alter management after learning

Expert Workshops

- Series of 7 small expert workshops, focusing on different aspects of the system
  - Discussing:
    - Important variables
    - Structure
    - Nature of relationships
    - Costs and environment value
- Follow up work performed by lead domain expert and BN expert

Grass/Herb Species

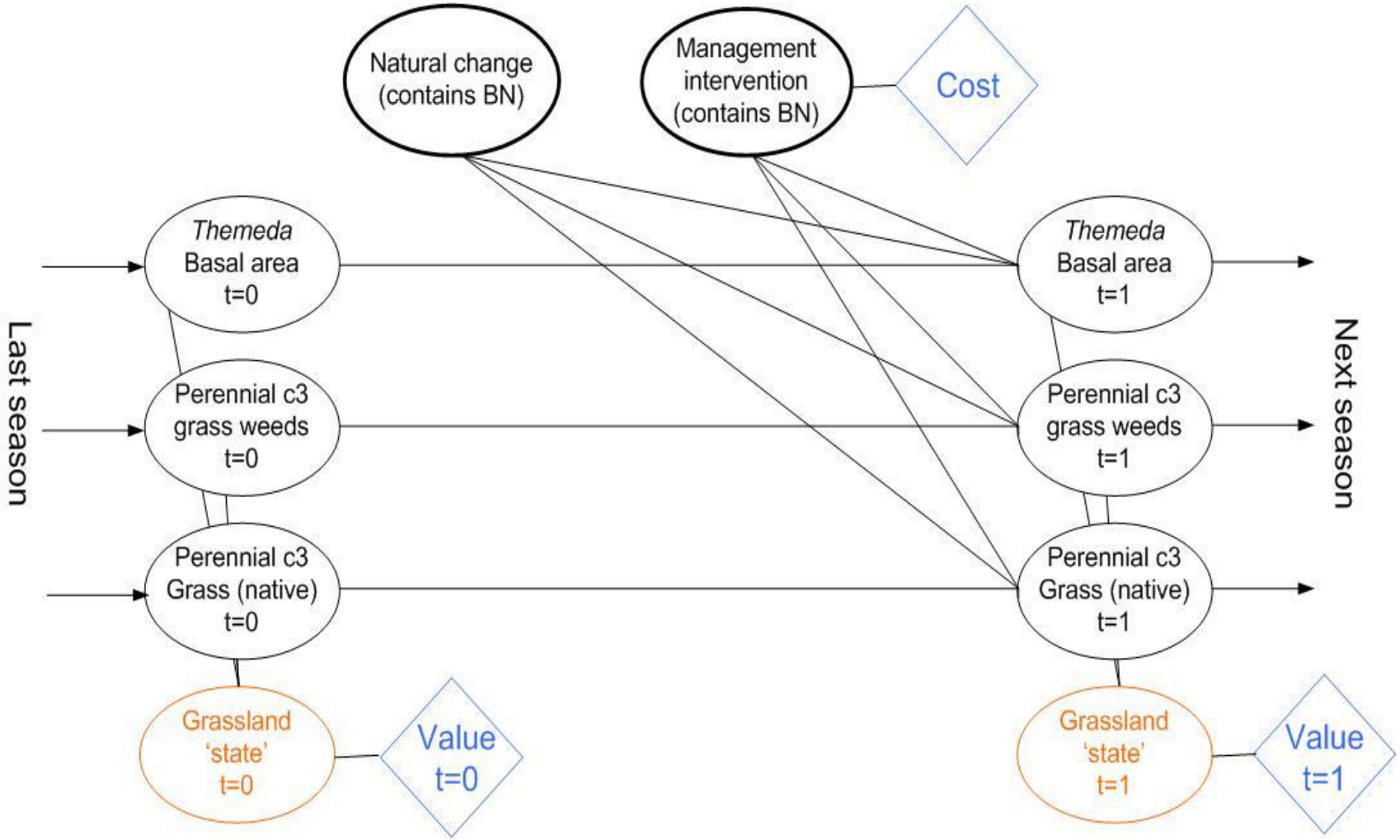
- 15 species grouping identified:
  - Kangaroo Grass
  - Red-Leg Grass
  - Windmill Grass and Panics
  - Spear Grasses
  - Wallaby Grasses
  - Serrated Tussock
  - Needle Grasses
  - Exotic Annual Grasses
  - Grain Crop
  - Sens. Native Herbs
  - Hardy Native Herbs
  - Native Ruderals
  - Blanket Weed
  - Broadleaf Weeds
  - Onion Grass



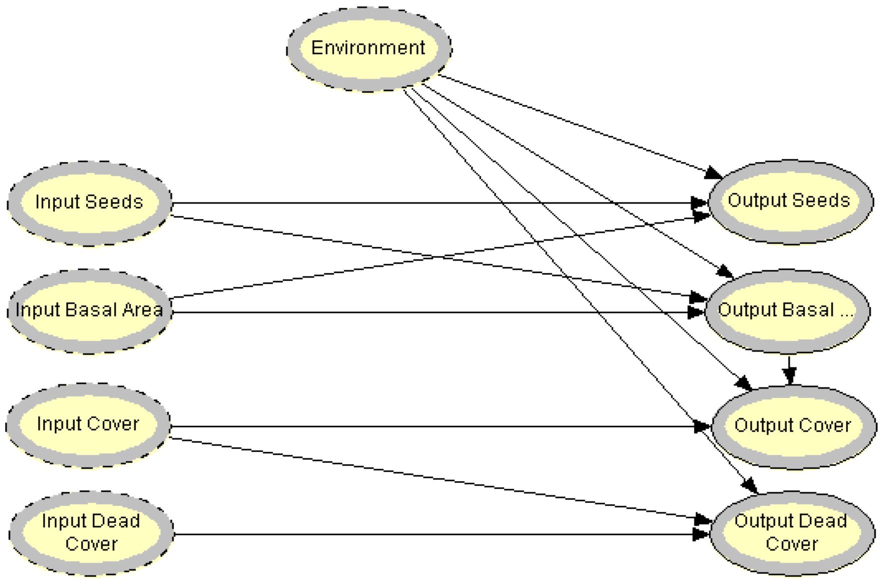
Interventions

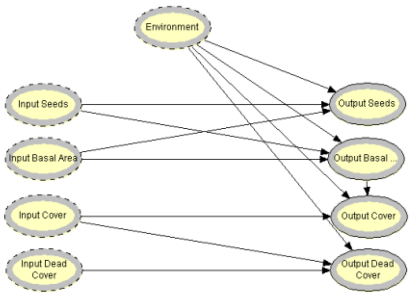
- 8 Interventions (with subtypes):
  - Burn
  - Cattle Graze
  - Herbicide
  - Remove Top Soil
  - Scarify
  - Sow Themeda
  - Plant Themeda
  - Carbon Boost

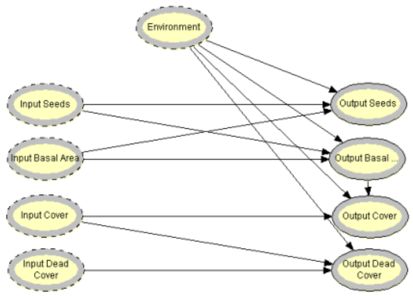
Dynamic Bayesian Network

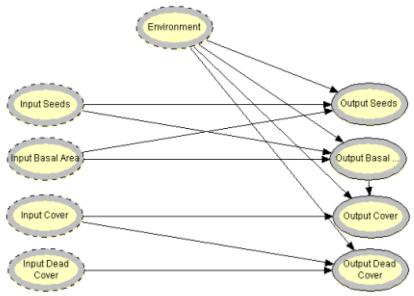


Managing Complexity
Object-Oriented Approach

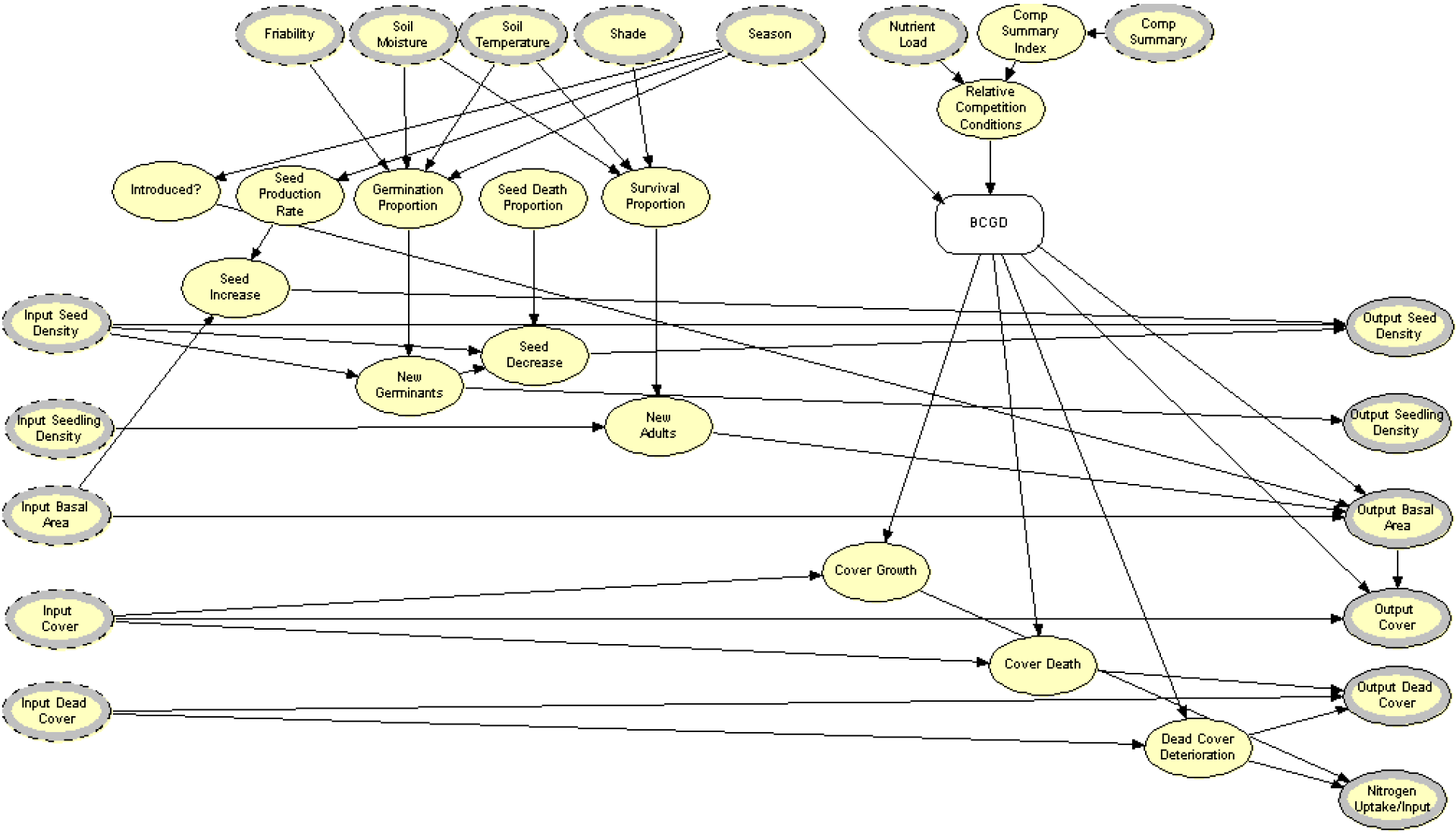




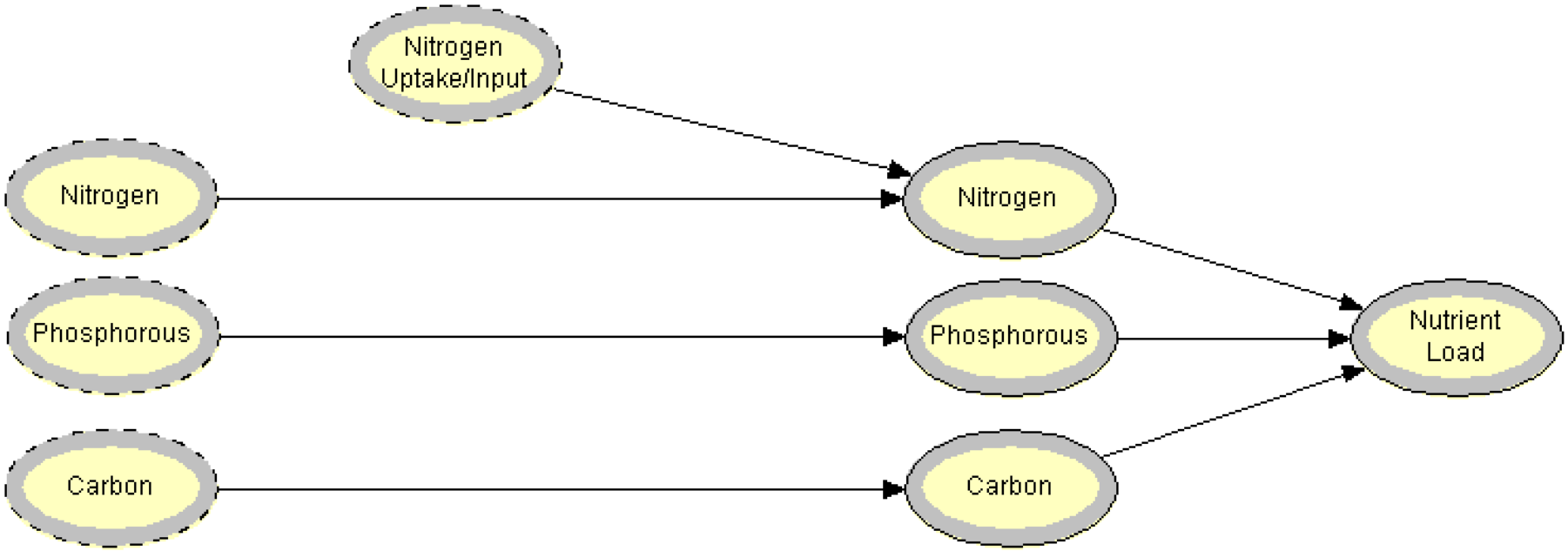




Themeda Natural Transition

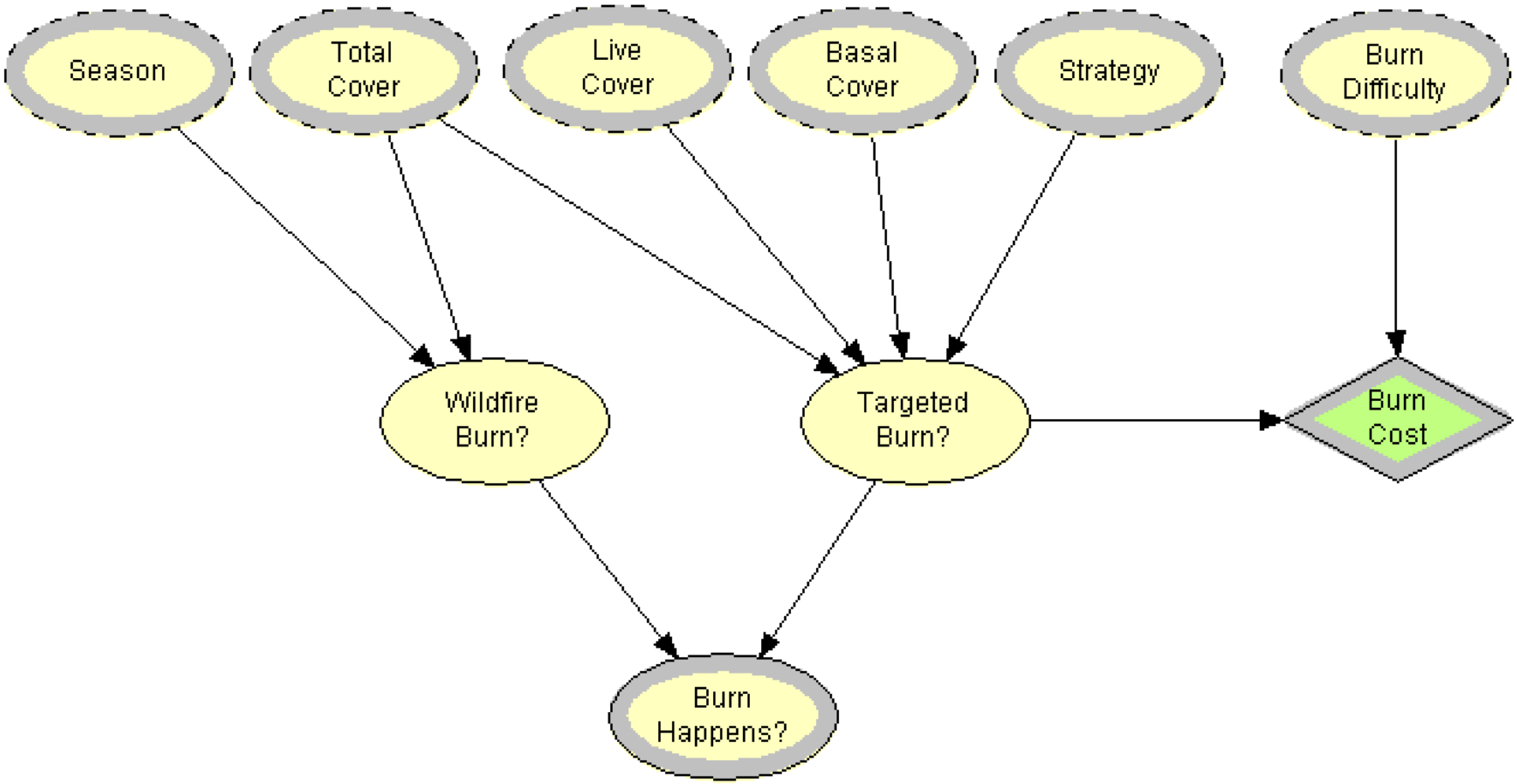


Soil Nutrient Transition

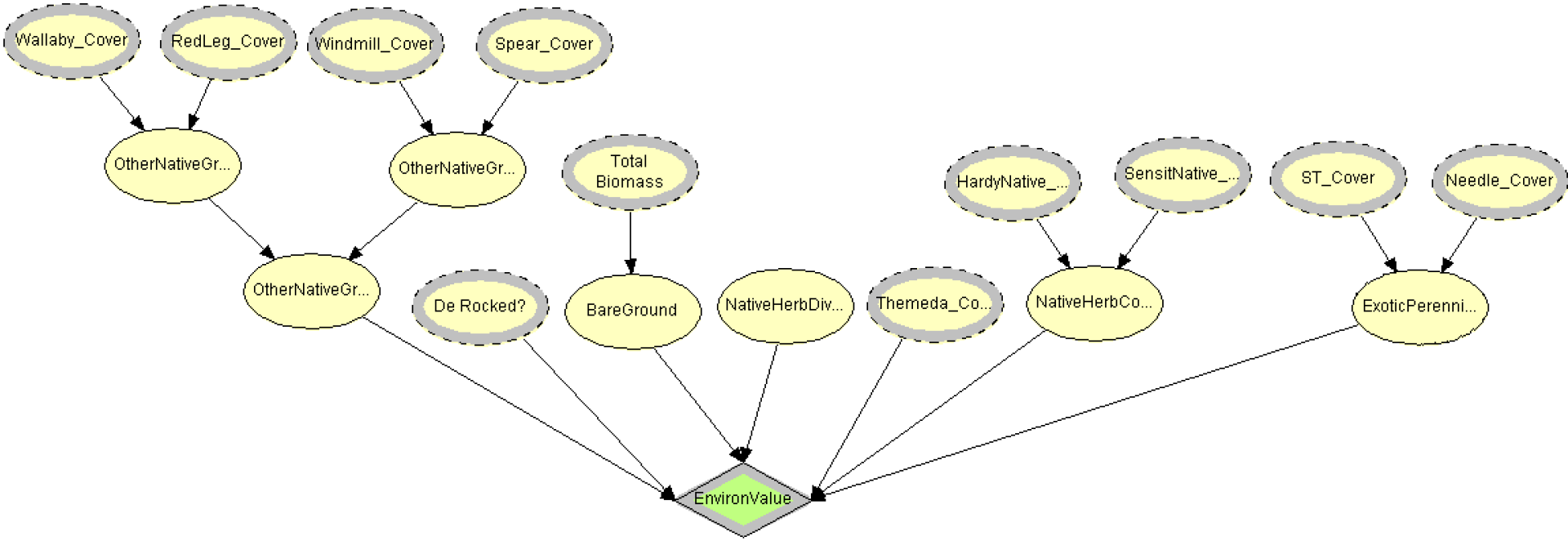


Burn Transition

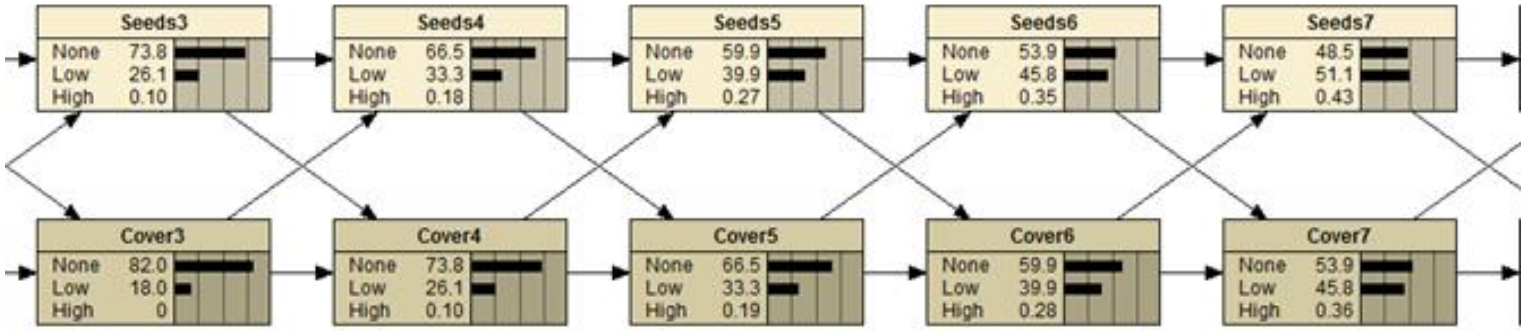
Burn Intervention



Environmental Value



Inference Issues



Control Input

Category	Active	Natural	Burn	Graze	Scarify	Herbicide
Biomass1	TRUE	BiomassSummaries	BiomassSummaries	BiomassSummaries		
Biomass2	TRUE	BiomassNatural		BiomassNatural		
EnvValue	TRUE	EnvValue				
Intervention	TRUE		BurnIntervention	GrazeIntervention	ScarifyIntervention	HerbicideIntervention
Soil	TRUE	SoilNatural		SoilGraze	SoilScarify	
Themeda	TRUE	ThemedaNatural	TolerantFire	ThemedaGraze	TenaciousScarify1	C4GrassHerbicide
RedLeg	TRUE	RedLegNatural	TolerantFire	RedLegGraze	TenaciousScarify1	C4GrassHerbicide
Windmill	TRUE	WindmillNatural	ModerateFire	WindmillGraze	FragileScarify3	C4GrassHerbicide
Spear	TRUE	SpearNatural	SensitiveFire	SpearGraze	TenaciousScarify1	C3GrassHerbicide
Wallaby	TRUE	WallabyNatural	ModerateFire	WallabyGraze	TenaciousScarify1	C3GrassHerbicide
ST	TRUE	STNatural	TolerantFire	STGraze	TenaciousScarify1	C3GrassTargetHerbicide1
Needle	TRUE	NeedleNatural	TolerantFire	NeedleGraze	TenaciousScarify1	C3GrassTargetHerbicide2
ExoticAnnual	TRUE	ExoticAnnualNatural	KilledFire1	ExoticAnnualGraze	FragileScarify1	AnnualGrassHerbicide1
Grain	TRUE	GrainNatural	KilledFire2	GrainGraze	FragileScarify2	AnnualGrassHerbicide2
SensitNative	TRUE	SensitNativeNatural	TolerantFire	SensitNativeGraze	TenaciousScarify1	BroadleafHerbicide1
HardyNative	TRUE	HardyNativeNatural	TolerantFire	HardyNativeGraze	TenaciousScarify1	BroadleafHerbicide1
Ruderals	TRUE	RuderNatural	TolerantFire	RuderGraze	FragileScarify3	BroadleafHerbicide1
Blanket	TRUE	BlanketNatural	KilledFire2	BlanketGraze	TenaciousScarify2	BroadleafTargetHerbicide1
BroadWeeds	TRUE	BroadWeedsNatural	TolerantFire	BroadWeedsGraze	TenaciousScarify1	BroadleafTargetHerbicide2
Onion	TRUE	OnionNatural	TolerantFire	OnionGraze	TenaciousScarify1	BroadleafHerbicide2
NUI	TRUE	NuiAdder	NuiAdder			
Nutrient	TRUE	NutrientNatural	NutrientFire	NutrientGraze		

Control Input

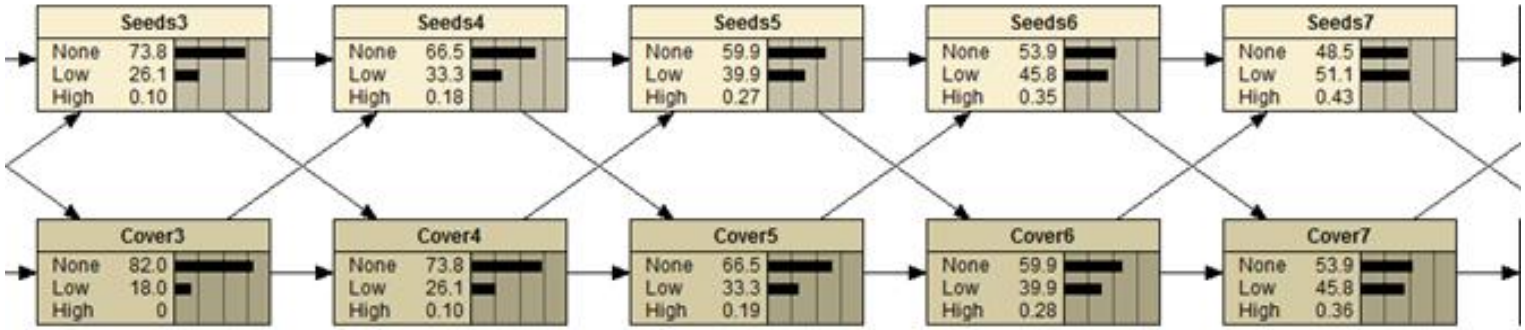
SpeciesName	Seeds	Basal	Cover	Dead	
Themeda		1000	10	20	10
RedLeg		200	2	5	3
Windmill		0	0	0	0
Spear		0	0	0	0
Wallaby		0	0	0	0
ST		10000	1	5	2
Needle		5000	3	10	5
ExoticAnnual		0	0	0	0
Grain		0	0	0	0
SensitNative		0	2	5	0
HardyNative		0	2	5	2
Ruderals		0	0	0	2
Blanket		0	0	0	0
BroadWeeds		0	0	0	0
Onion		0	0	0	0

Control Input

Year	Spring	Summer	Autumn	Winter
2000	Natural_Burn(BurnStrategy=None)_RemoveTopSoil_Sow(SowStrategy=Sow500)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2001	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2002	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2003	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2004	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2005	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2006	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2007	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2008	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2009	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2010	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2011	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)
2012	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)
2013	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=None)	Natural_Burn(BurnStrategy=HotBurn)_Herbicide(Product=Glyphosate,HerbicideStrategy=Spot)	Natural_Burn(BurnStrategy=None)

Inference Issues

- Intended to use “Rollup” method
  - However



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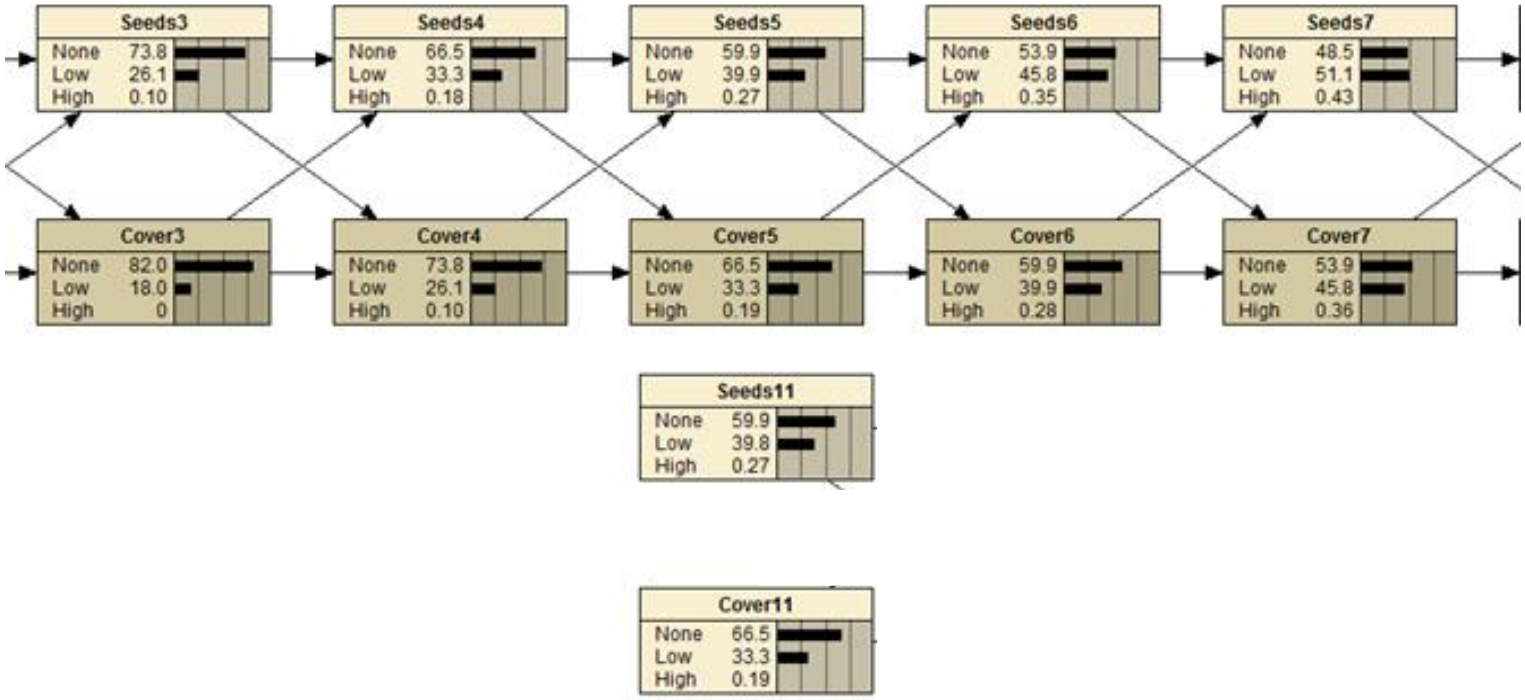

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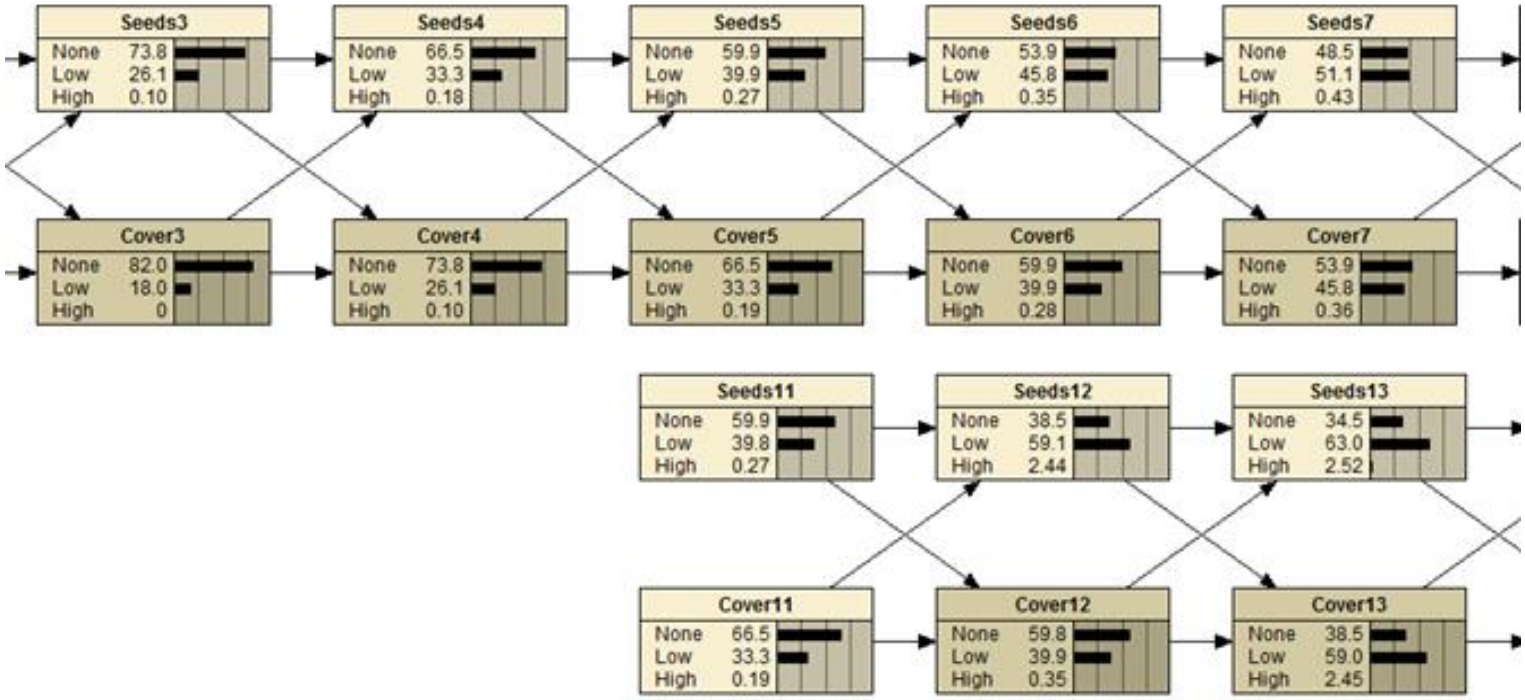
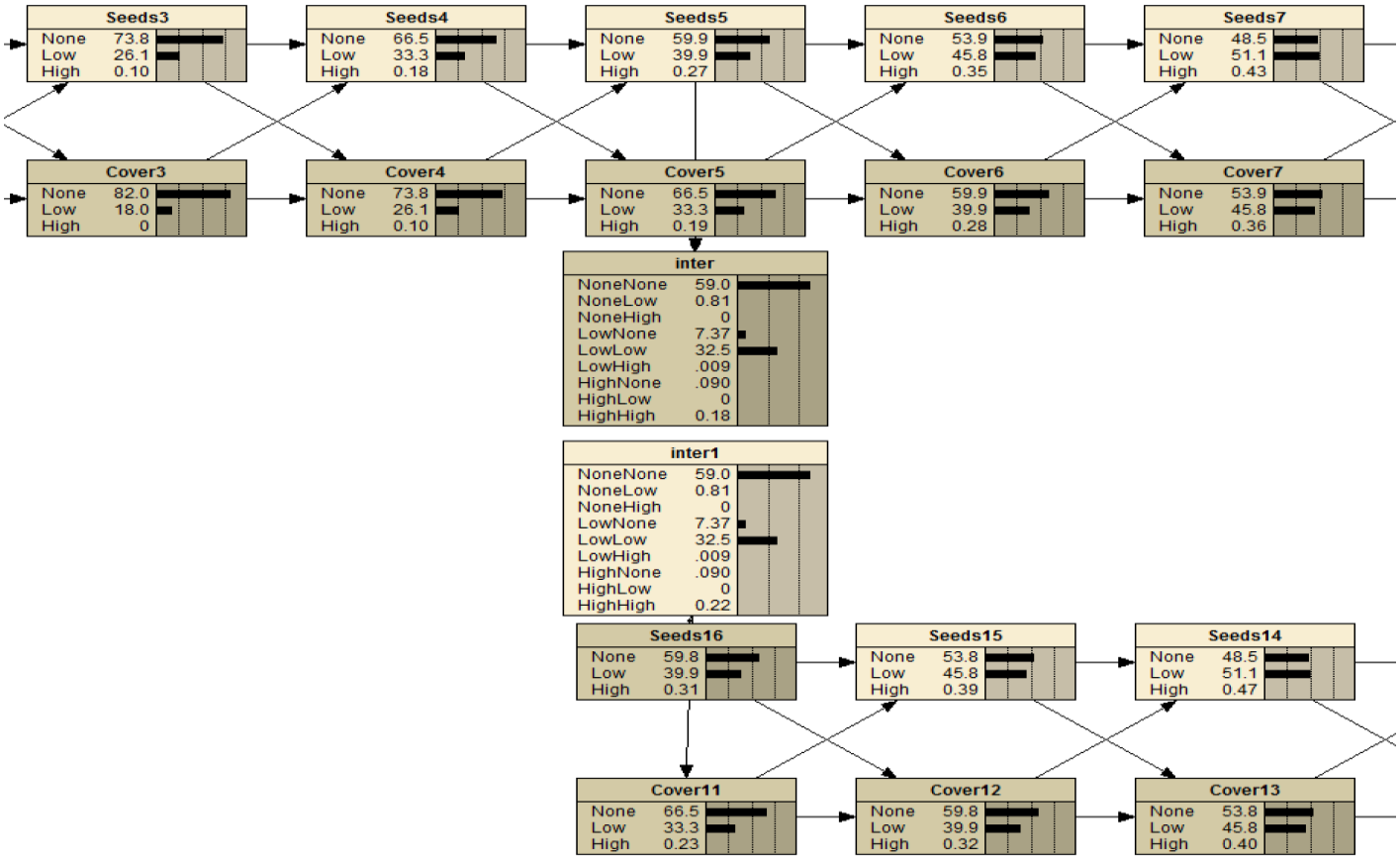


Possible solution

- Add intermediate nodes and copy combined distribution

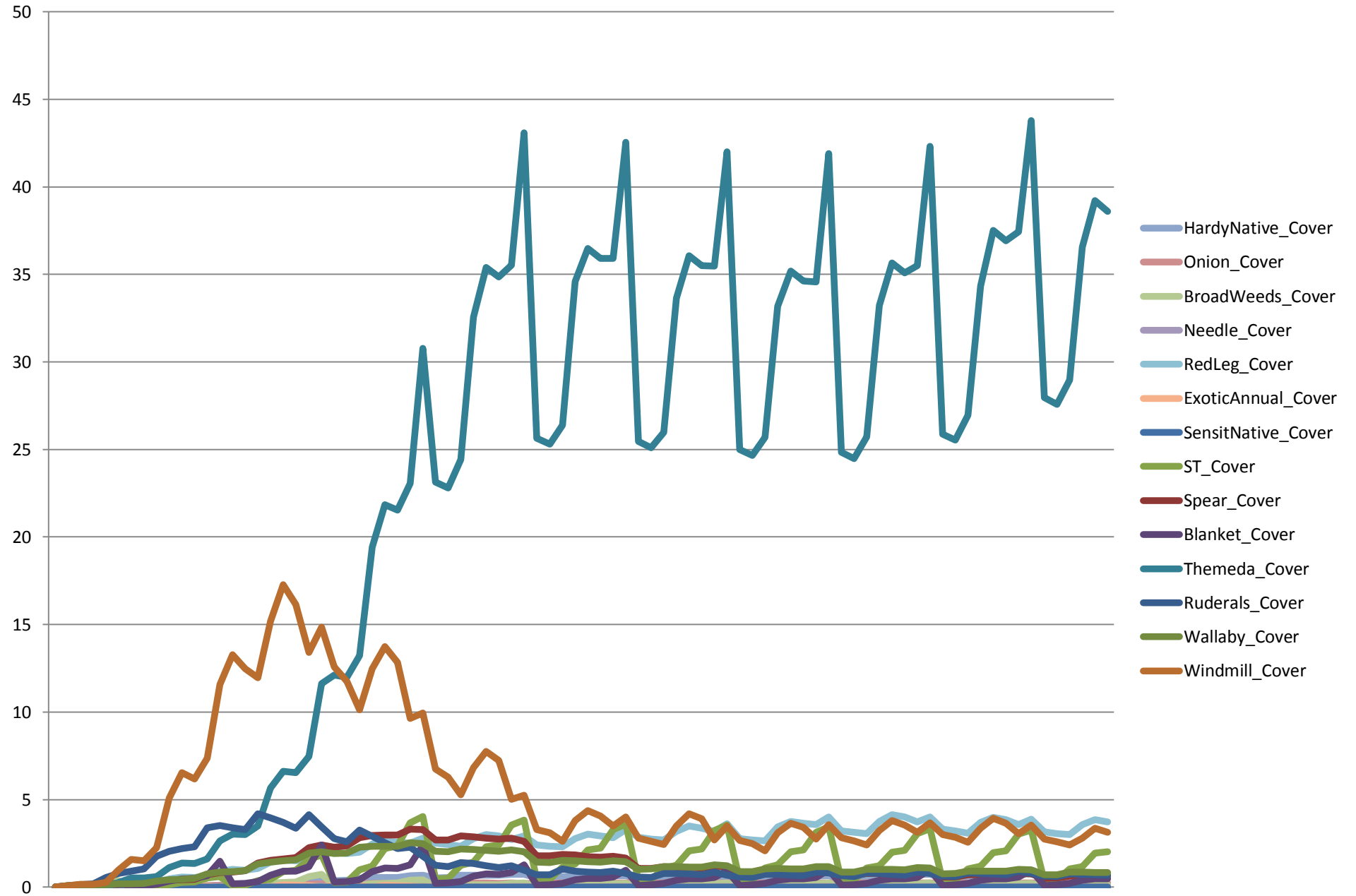


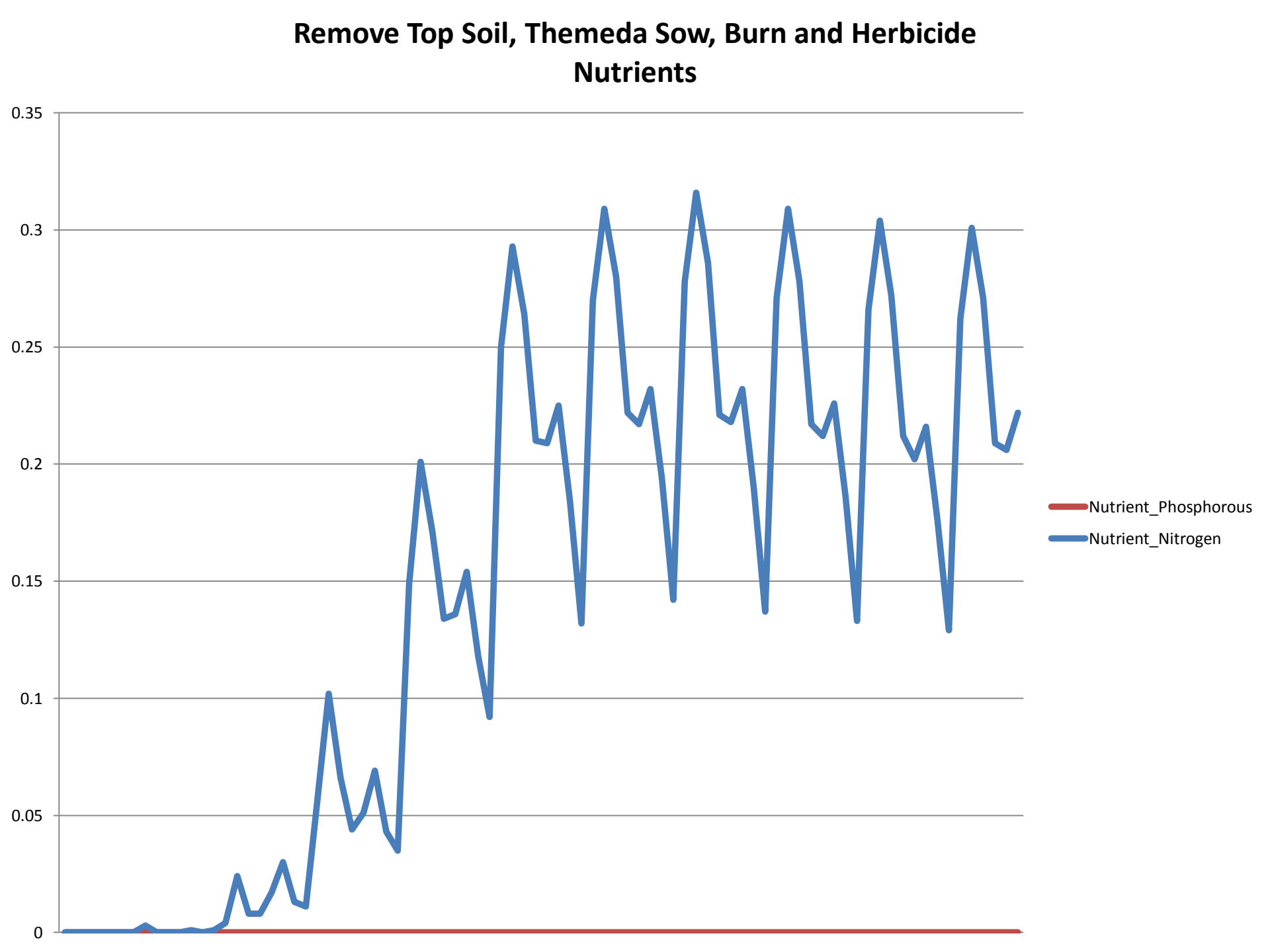
- Alternatively, use stochastic simulation (bonus for equations)

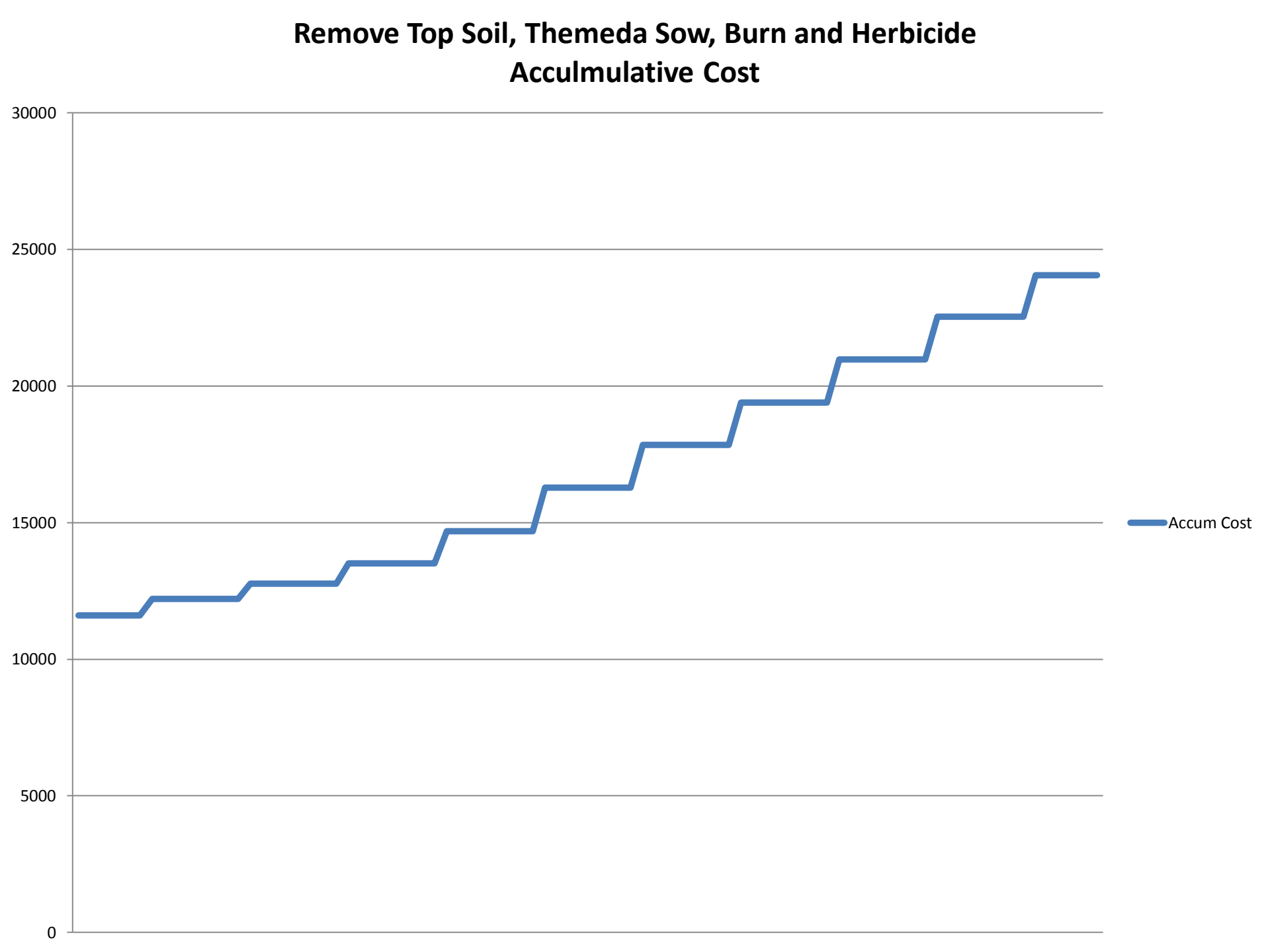
Sample Run
Clear Site and Sow Themeda Seeds

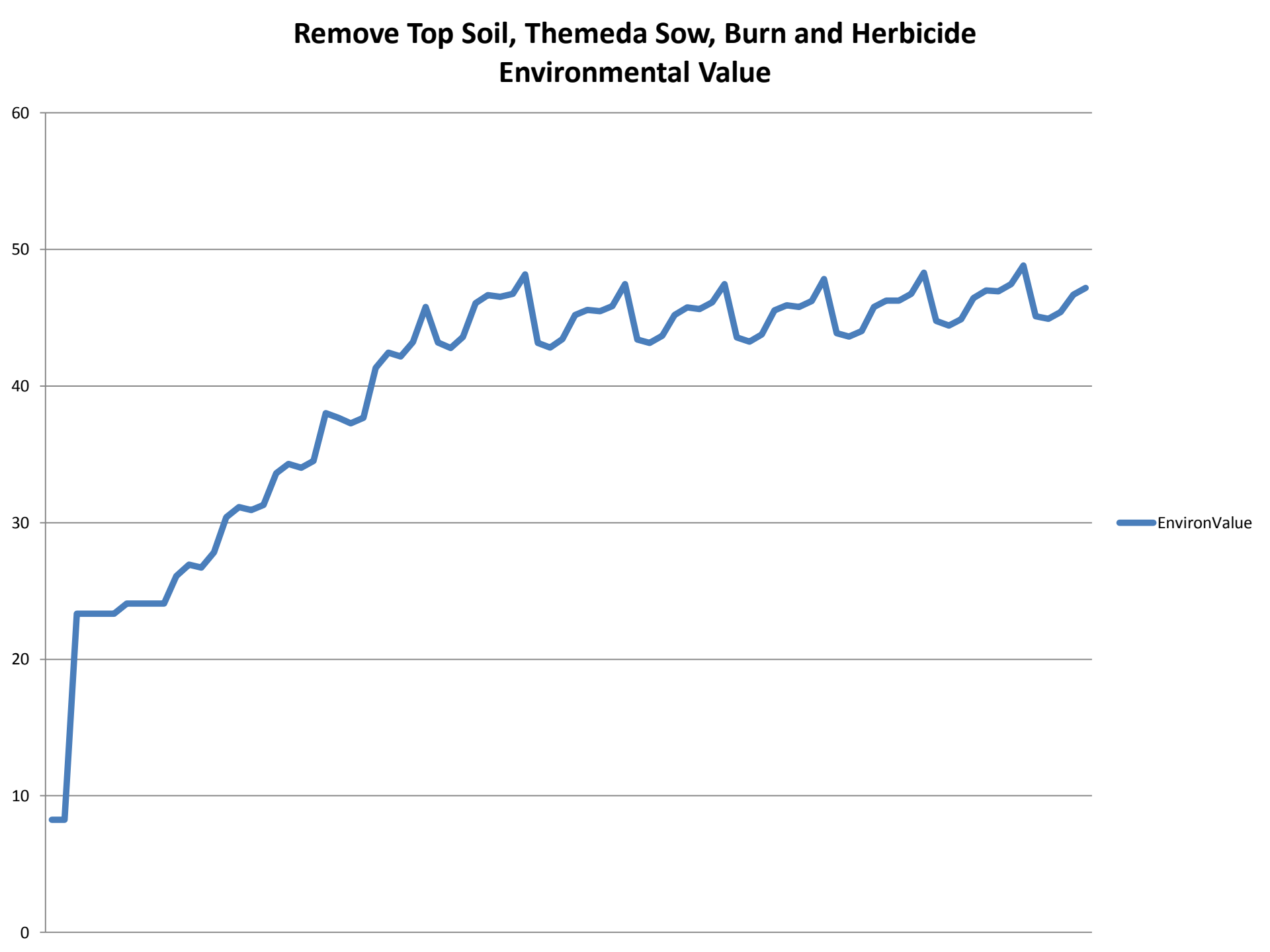
- Start Condition
  - Irrelevant
- Regime
  - Remove Top Soil and Sow Themeda Seeds in first Spring
  - Maintain with Hot Burn and Glyphosate Spot Spray every 2nd Autumn

Remove Top Soil, Themeda Sow, Burn and Herbicide Cover




Remove Top Soil, Themeda Sow, Burn and Herbicide
Nutrients
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Nutrient_Phosphorous
Nutrient_Nitrogen


Remove Top Soil, Themeda Sow, Burn and Herbicide
Acculmulative Cost
30000
25000
20000
15000
10000
5000
0
Accum Cost


Remove Top Soil, Themeda Sow, Burn and Herbicide
Environmental Value
60
50
40
30
20
10
0
EnvironValue

Questions?