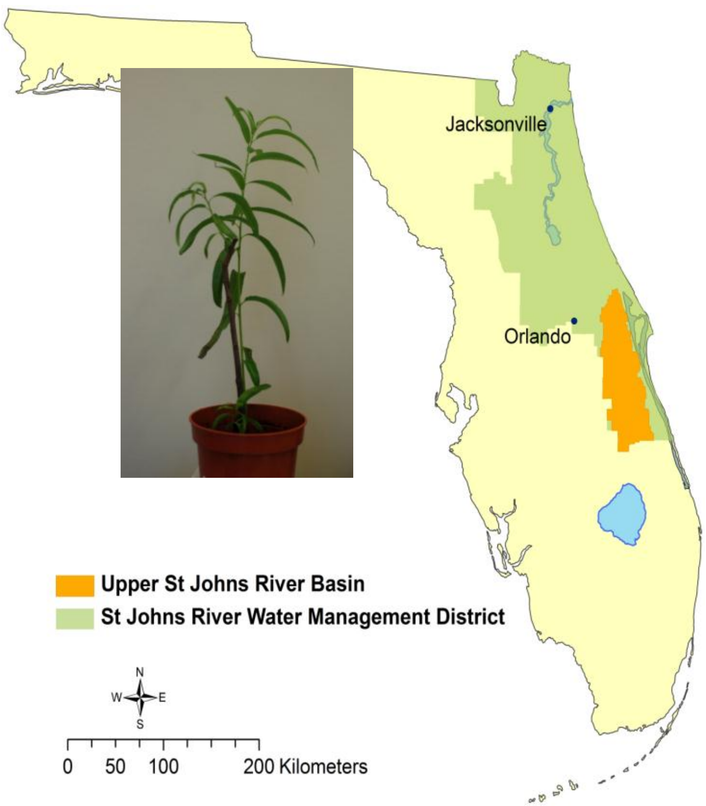
A State-Transition DBN for Management of Willows in an American Heritage River Catchment



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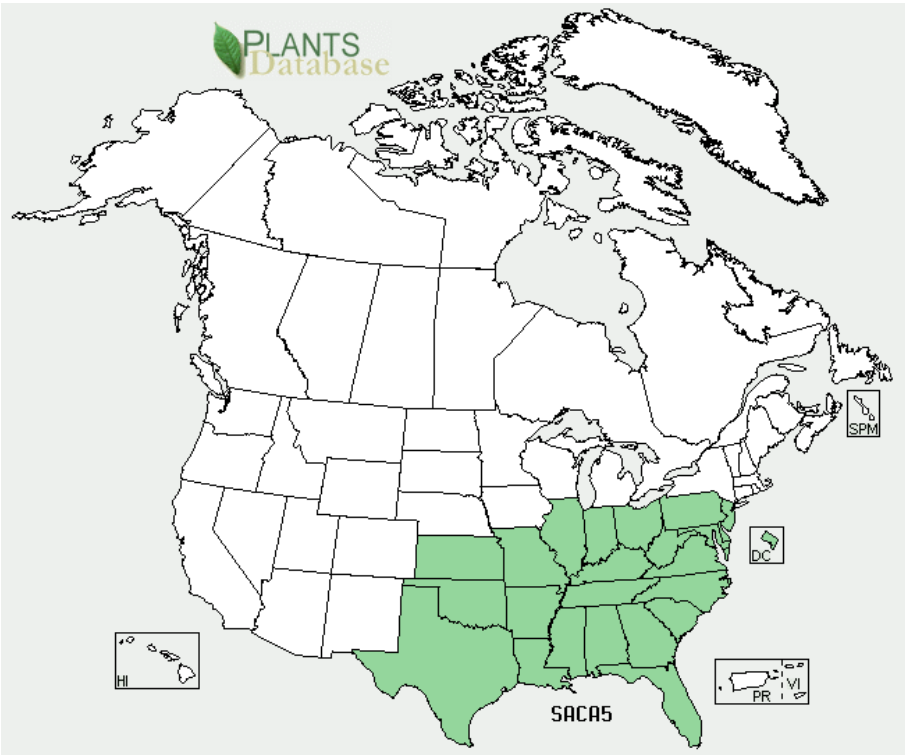
On sabbatical in Melbourne, March-May 2012

Willow: *Salix caroliniana* Michx..



Native to the southeastern United Sates, Mexico and parts of Central America and the Caribbean.

Woody plant

Dioecious

Flowers in Spring

Obligate wetland

St. John's River, Florida, USA

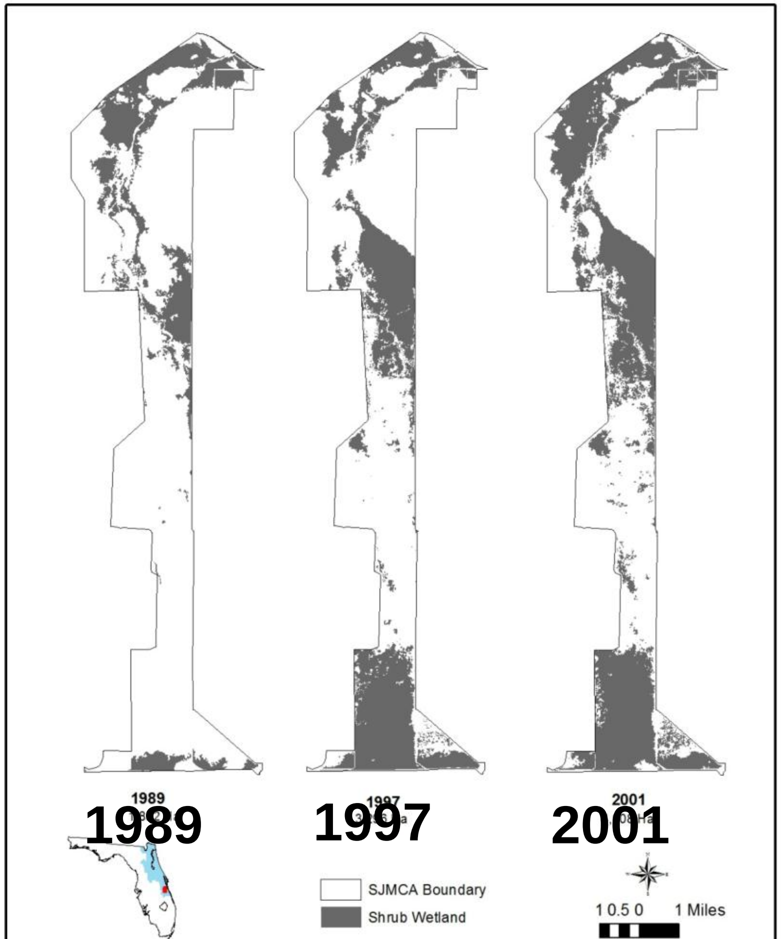


Figure 2. Expansion of shrub wetland communities in the St. Johns Marsh Conservation Area for 1989, 1997, and 2001.

S. caroliniana can convert herbaceous wetlands to forested wetlands.

Major hypothesis explaining willow expansion

- Change in water management and level of fluctuation
- Decline in grazing intensity
- Increase in nutrient availability
- Alteration of fire regime

Framework

- Reduction should minimize future reinvasion and expansion.
- There are areas with different value; some can have more conservation value and management interest
- There will be different goals for different areas.
- Willow is a native species so its elimination is not a desired outcome (nor a reachable goal).

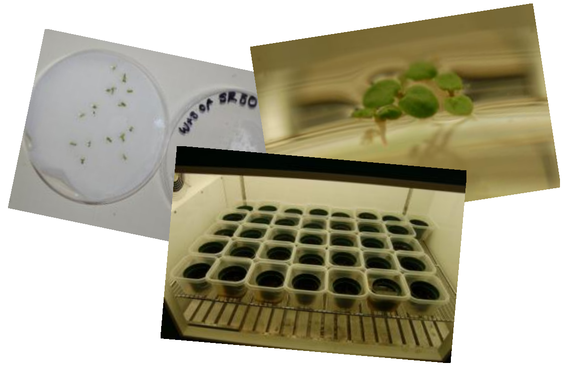
Goal

- Rather than a return to an historical point in time, our goals would reflect a desired cover and distribution of willow
- Mixed landscape of different vegetation types with a successional dynamics.

Experimental research program 2009-2011

Plant and seed collection

Evaluating germination



Artificial Islands

Transplanting

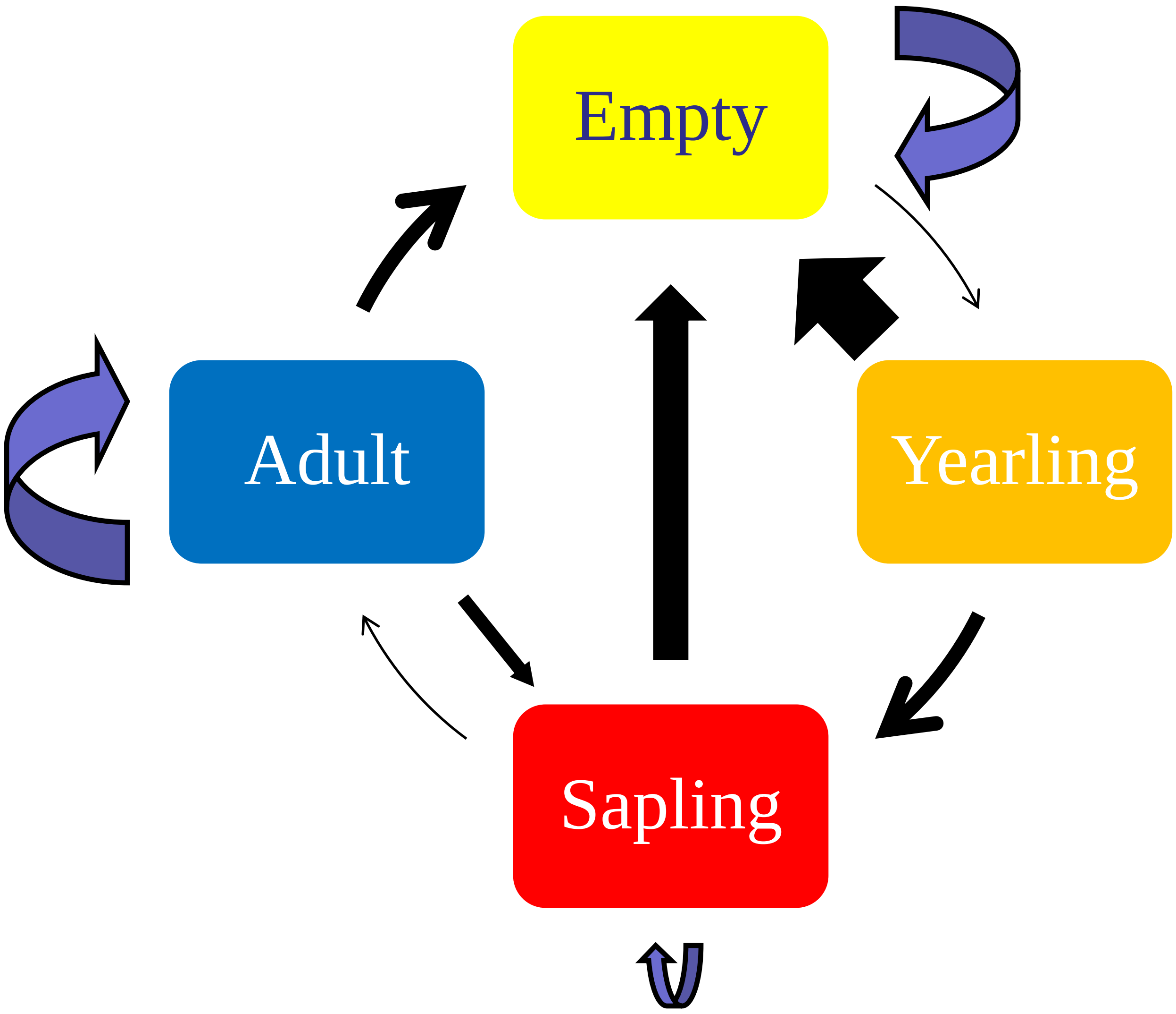
Changes in water depth

Artificial Ponds

Grazing

Greenhouse expts

Willow Lifecycle



Natural Events

Natural event	Effect/Hazard/Stressor/	Primary effect	Secondary effects
Precipitation	Determines demographic change	Affects germination, seed and seedling survival	Affects chances of burning, herbicide application and mechanical treatment
Vegetation type	Determines demographic change	Affects germination, seed, seedling and adult survival	Affects chances of burning herbicide application and mechanical treatment
Soil	Determines demographic change	Affects germination and seedling survival	Affects chances of burning, herbicide application and mechanical treatment

Management Actions

Management Action	Effect/Hazard/Stressor	Primary effect	Secondary effects
Fire	Varying results depending on intensity of fire, size of willow, understory composition, water levels, etc.	Usually just reduces stature; doesn't result in wide-spread mortality	Can't apply in willow stands with little or no burnable understory
Grazing	It occurs on sandy soil or areas with less risk of invasion	Reduces biomass	Unintended impacts (trampling plants, amphibians, mobilizing nutrients, etc)
Hydrology	Hydrologic criteria and flood schedules must be adhered to	Kills seedlings and saplings affects germination and dispersal	Downstream water supply concerns

How did the Willows BN project start?

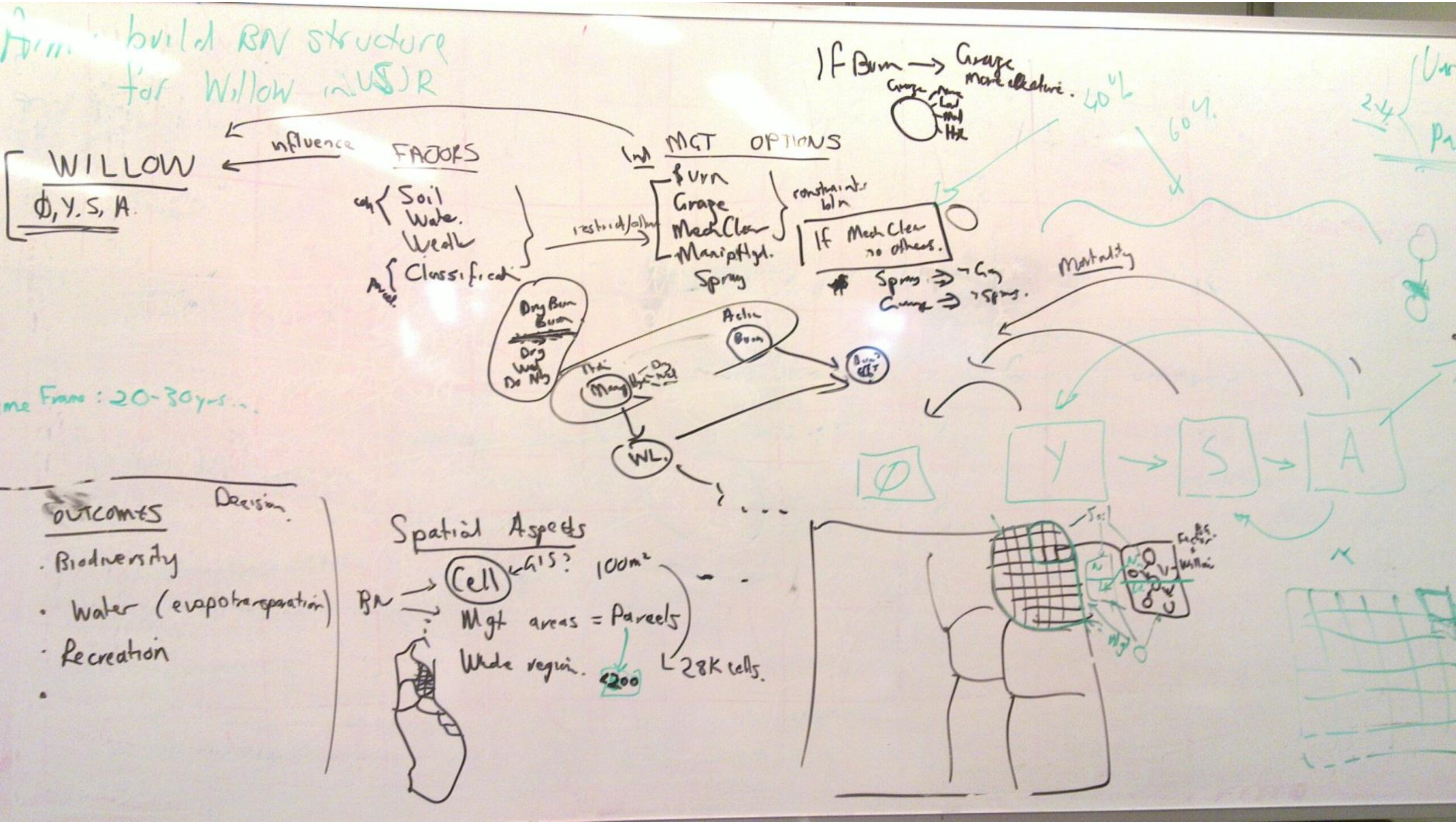
March 2012: Pedro on sabbatical at ACERA (Uni. of Melbourne)

BN Knowledge Engineering Process

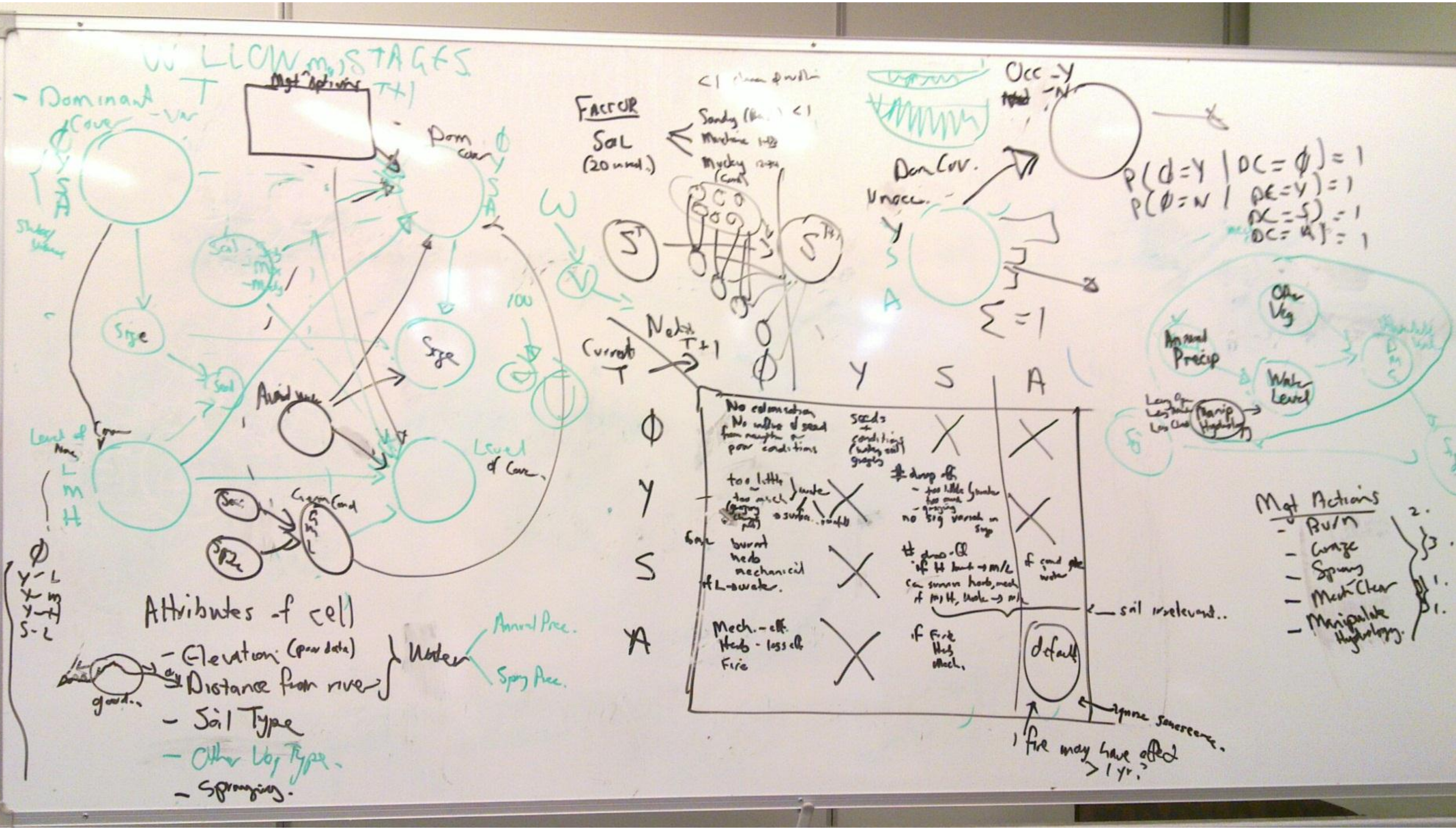
Day 1 (5-6 hrs) (22nd March)

- Explain domain (expert → KE)
- Introduce BNs (KE → domain expert)
- Identify
  - State variables, states, state transitions
  - Influencing factors (water levels, soil type, seed availability, etc)
  - Subset of management actions for prototype
  - Appropriate time and spatial scales
  - Appropriate architecture

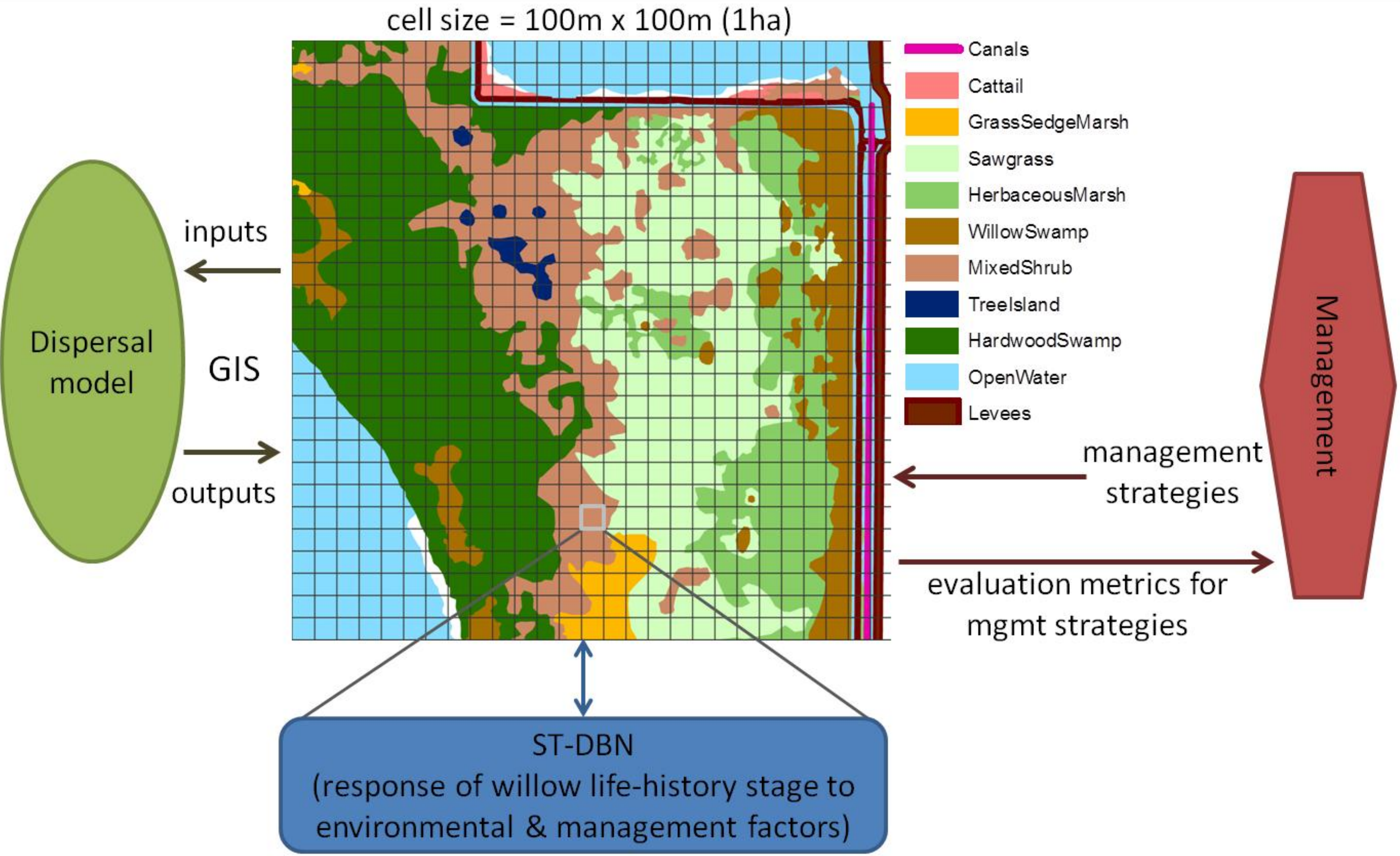
Day 1


build BN structure
for Willow
WILLOW
influence
FACTORS
Soil
Water
Weather
Classification
MGT OPTIONS
Burn
Grape
Mech Clear
Spray
If Burn → Graze
If Mech Clear no others.
Mortality
Time Frame: 20-30 yrs
OUTCOMES
Decision
Biodiversity
Water (evapotranspiration)
Recreation
Spatial Aspects
Cell
GIS?
100m²
Mgt areas = Parcels
Whole region
28K cells
Y
S
A

Day 1


WILLOW STAGES
Dominant Cover
Mgt Actions
Dom Cov
Soil
Size
Level of Cover
Attributes of cell
- Elevation (poor data)
- Distance from river
- Soil Type
- Other Veg Type
- Spraying
Water
Annual Prec.
Spring Prec.
FACTOR
Soil (20 unit)
Sandy
Mucky
Occ - Y
Dom Cov.
Unocc.
Current T
Next T+1
No colonization
No influx of seed from nearby or poor conditions
seeds + conditions
too little / too much water
burnt herb mechanical
Mech. - eff. Herb - less eff. Fire
default
soil irrelevant..
ignore senescence.
fire may have effect > 1 yr.?
Mgt Actions
- Burn
- Graze
- Spray
- Mech Clear
- Manipulate Hydrology
Annual Precip
Water Level
Other Veg

Proposed System Architecture



Structure based on ST-DBN Template
(Nicholson & Flores, 2011)

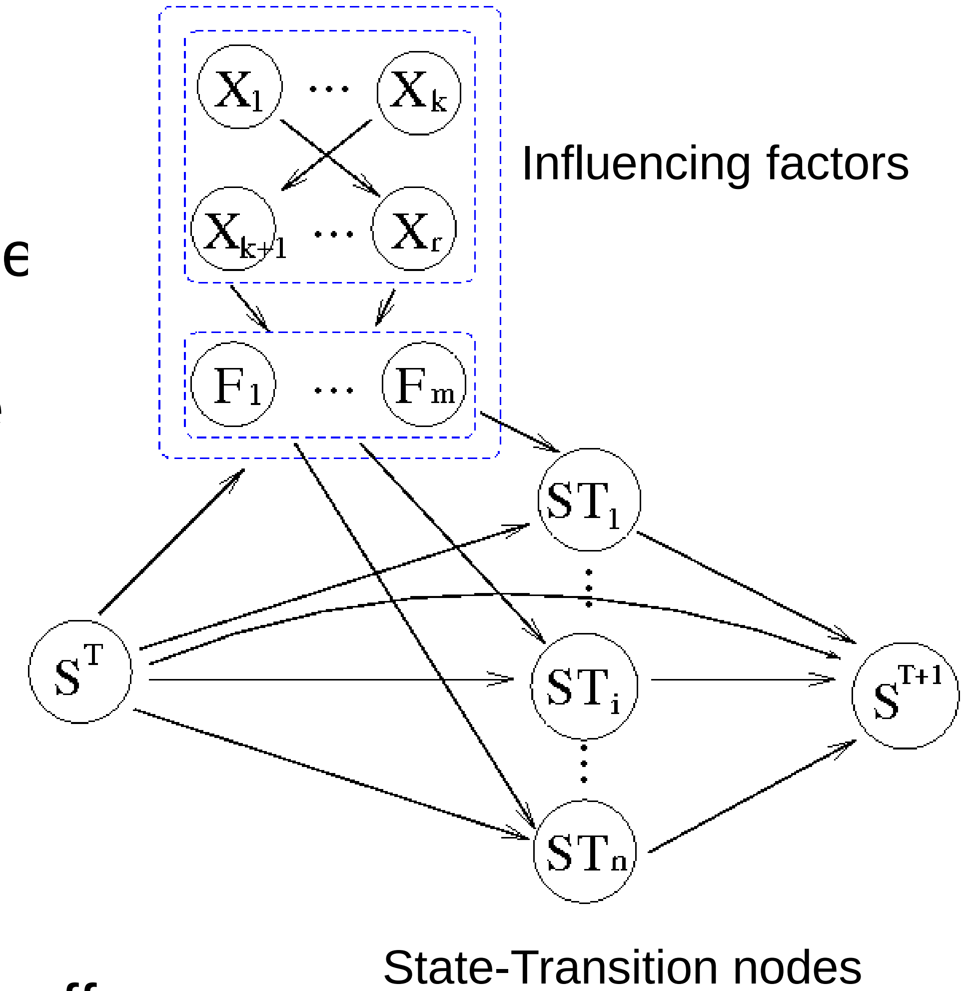
Combine:

"State-Transition Models": a semi-qualitative approach use to model changes in time in ecological systems that have clear transitions between distinct states

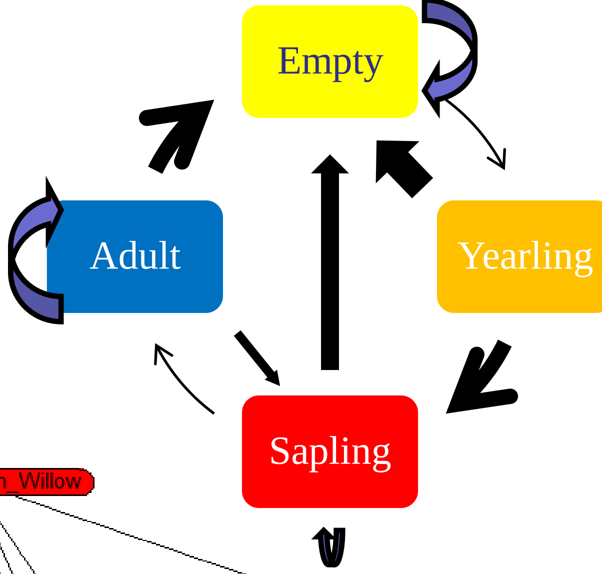
&

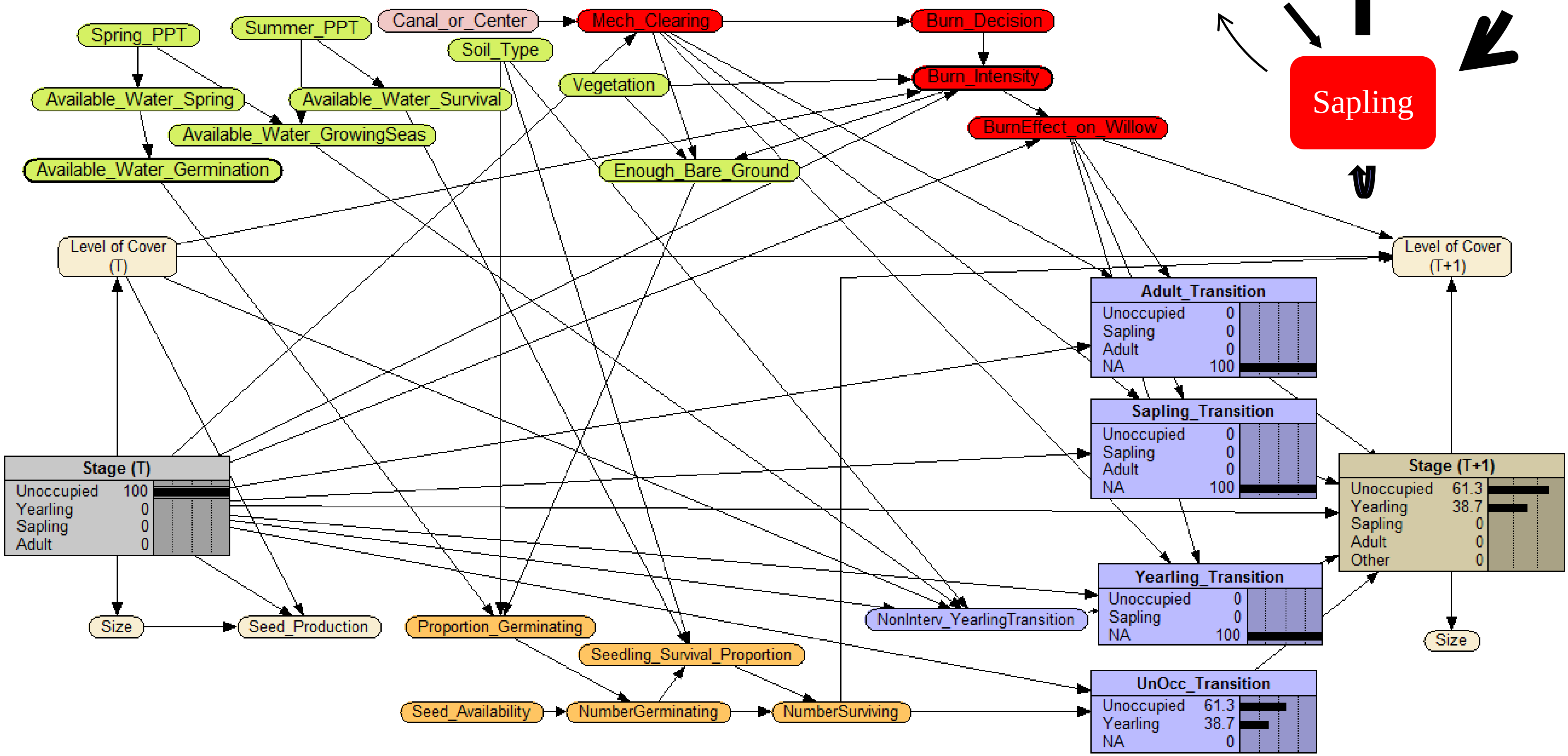
Dynamic Bayesian network (DBN) structure

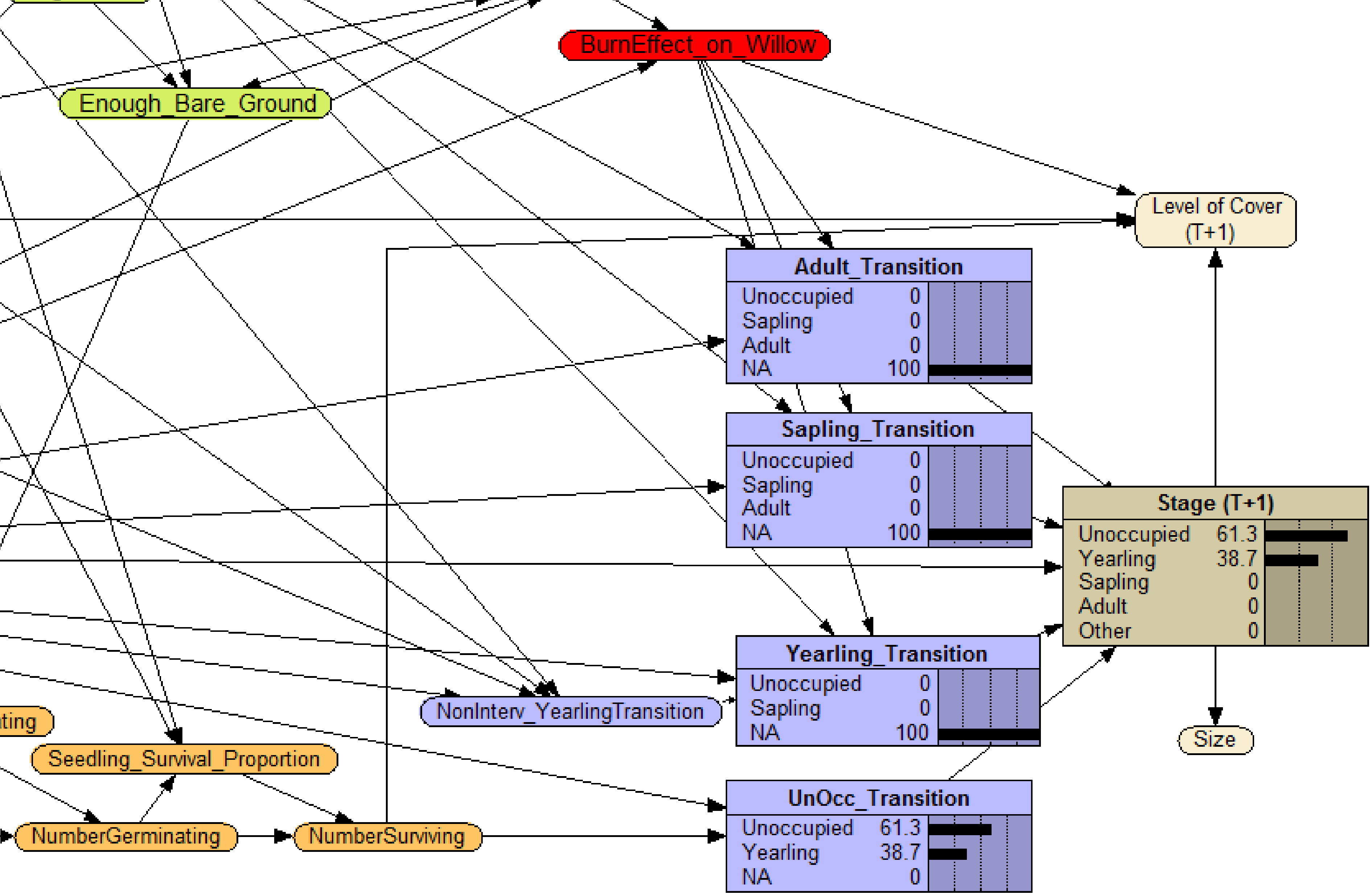
(also Bashiri et al, 2010; Rumpff et al., 2011)



Willows ST-DBN







BurnEffect_on_Willow
Enough_Bare_Ground
Level of Cover (T+1)
Adult_Transition
Unoccupied 0
Sapling 0
Adult 0
NA 100
Sapling_Transition
Unoccupied 0
Sapling 0
Adult 0
NA 100
Stage (T+1)
Unoccupied 61.3
Yearling 38.7
Sapling 0
Adult 0
Other 0
Yearling_Transition
Unoccupied 0
Sapling 0
NA 100
NonInterv_YearlingTransition
Seedling_Survival_Proportion
Size
UnOcc_Transition
Unoccupied 61.3
Yearling 38.7
NA 0
NumberGerminating
NumberSurviving

BN Knowledge Engineering: Structure

Day 2 (5-6 hrs) (2 April)

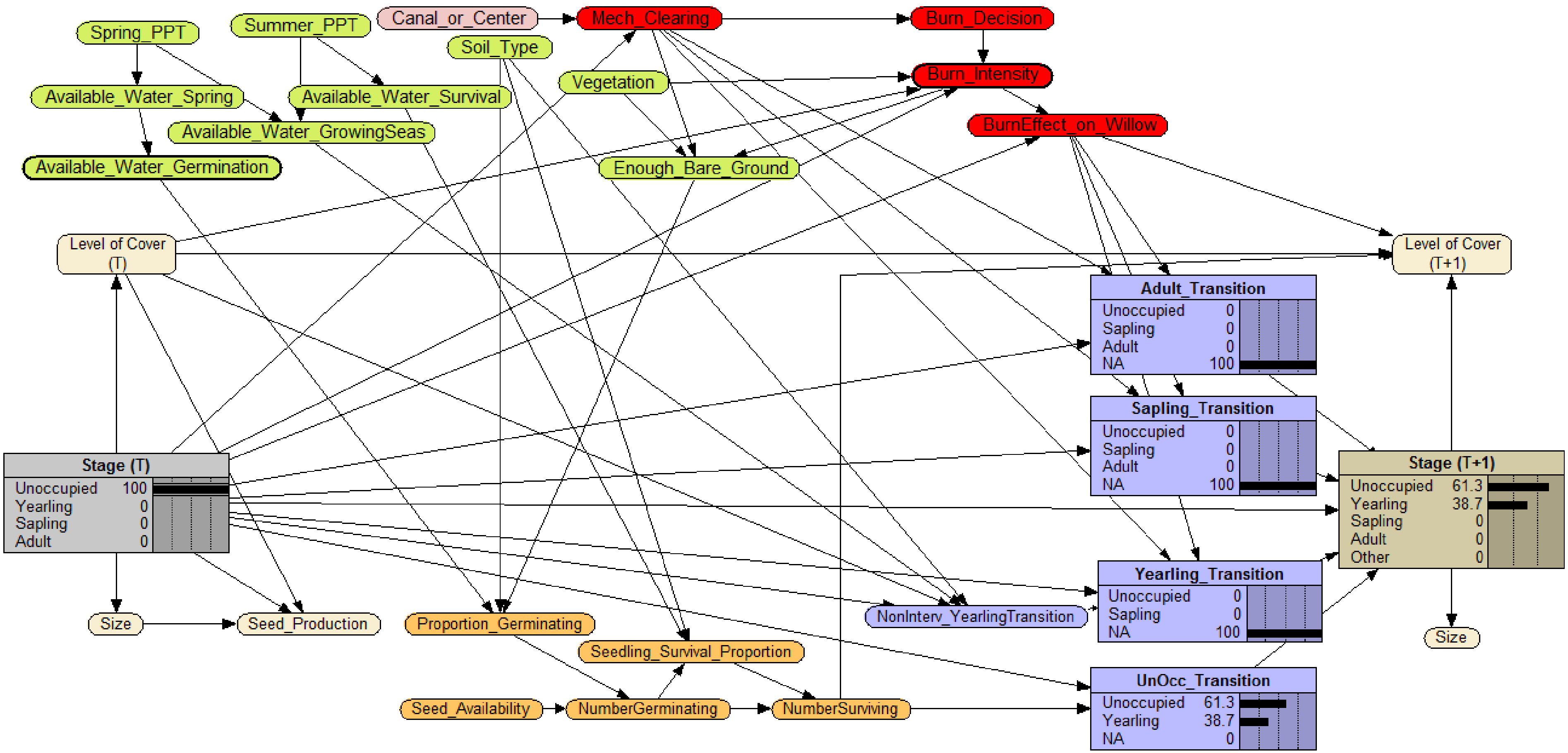
- For each state transition
  - Influencing factors
  - Discretisation
  - Qualitative description of relationship
- Explain BNs (KE $\rightarrow$ domain expert)
- Recall/revisit aspects discussed on day 1

BN Knowledge Engineering: Parameterisation

Day 3&4 (16 April, 4 May) (2-3 hrs each)

- For each state transition
    - Translate qualitative description into CPTs
    - (via equations for “continuous” nodes)
- “Reality check” evaluation via scenarios on network fragments
- Recall/revisit aspects discussed on days 1 & 2

Willows ST-DBN



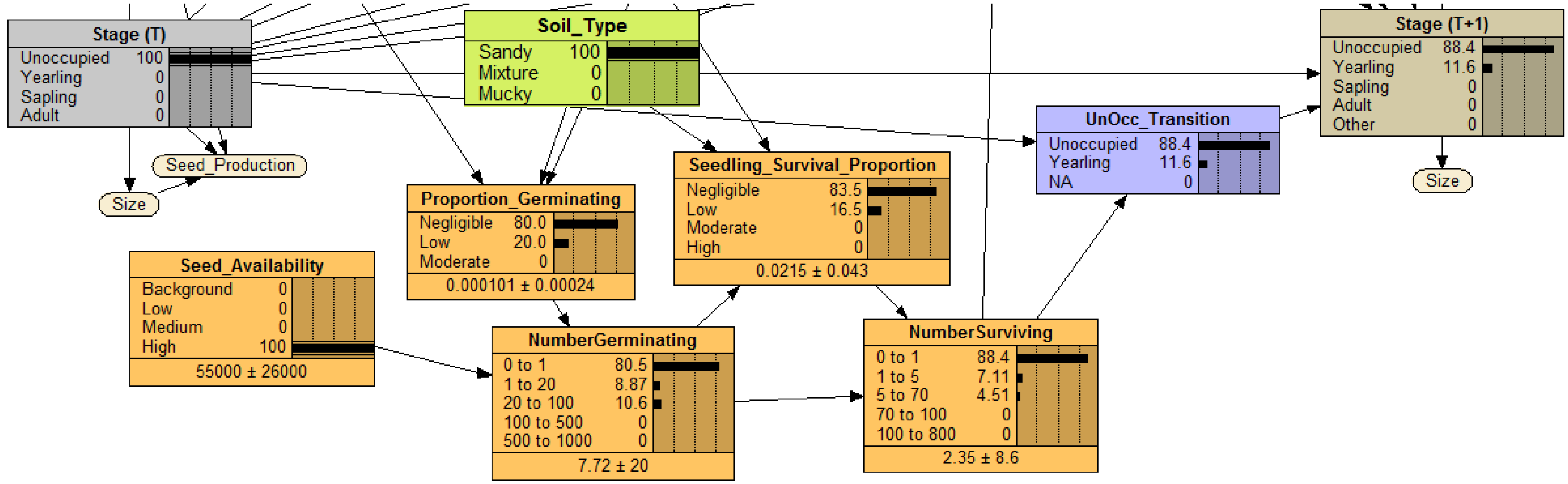
Evaluation

- Systematic “reality check” across range of scenarios (May)
  - iteratively with parameter revision

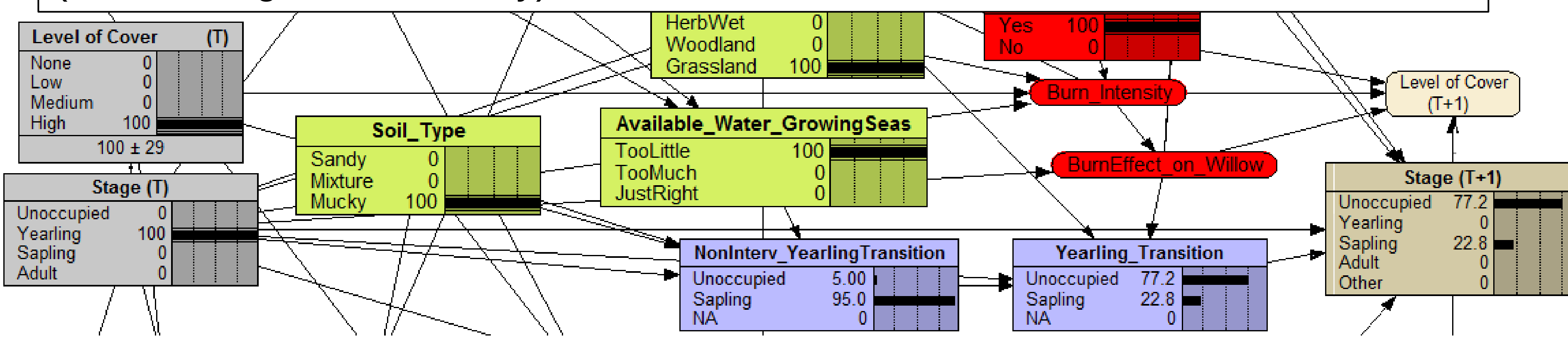
Table 2: Subset of scenario evaluation results, used to evaluate high-level behaviour of the Willow ST-DBN. For each scenario, columns on the left show the evidence entered; the 4 columns on the right show the distribution for Stage(T+1). For the Yearling, Sapling and Adult scenarios, the Level_of_Cover is High; the probabilities of transitions to UnOccupied are greater for lower levels of cover.

No.	Stage(T) (Seed Avail= High)	Soil	Avail Water Spring.	Avail Water Survival	Enough Bare Ground	Stage(T+1) UnOcc	Yearling	Sapling	Adult
1.	UnOcc	Sandy	JustRight	JustRight	Yes	88.4	11.6	0	0
2.	UnOcc	Mucky	JustRight	JustRight	Yes	61.3	38.7	0	0
3.	UnOcc	Mucky	JustRight	TooMuch	Yes	94.6	5.4	0	0
4.	UnOcc	Mucky	TooLittle	JustRight	Yes	100	0	0	0
	Stage(T)	Soil	Avail Water Growing Season	Mech. Clearing	Burn Decision (Vegetation= Grassland)	Stage(T+1) UnOcc	Yearling	Sapling	Adult
5.	Yearling	Mucky	JustRight	No	No	1	0	99.0	0
6.	Yearling	Sandy	JustRight	No	No	20.0	0	80.0	0
7.	Yearling	Sandy	TooLittle	No	No	40.0	0	60.0	0
8.	Yearling	Sandy	TooMuch	No	No	98.5	0	1.5	0
9.	Yearling	Mucky	JustRight	Yes	No	99.0	0	1.0	0
10.	Yearling	Mucky	TooLittle	No	Yes	81.9	0	18.1	0
	Stage(T)	Vegetation		Mech. Clearing	Burn Decision	Stage(T+1) UnOcc	Yearling	Sapling	Adult
11.	Sapling	[Any]		No	No	10.0	0	67.0	23.0
12.	Sapling	[Any]		Yes	No	99.5	0	0.5	0
13.	Sapling	HerbWet		No	Yes	20.0	0	71.1	8.9
14.	Sapling	Woodland		No	Yes	15.0	0	69.1	15.9
15.	Sapling	Grassland		No	Yes	22.7	0	70.9	6.4
16.	Adult	[Any]		No	No	1.0	0	0	99.0
17.	Adult	[Any]		Yes	No	99.0	0	0	1.0
18.	Adult	HerbWet		No	Yes	0.92	0	1.6	97.5
19.	Adult	Woodland		No	Yes	0.96	0	0.8	98.2
20.	Adult	Grassland		No	Yes	0.8	0	4.0	95.2

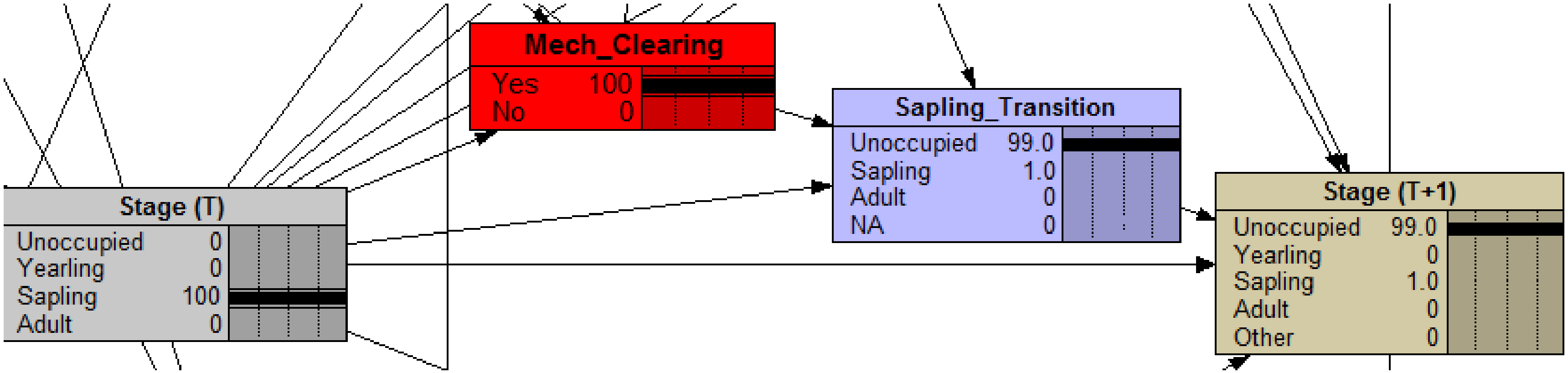
Scenario 1: High seed availability, sandy soil type, sufficient bare ground and appropriate water availability for both germination and survival



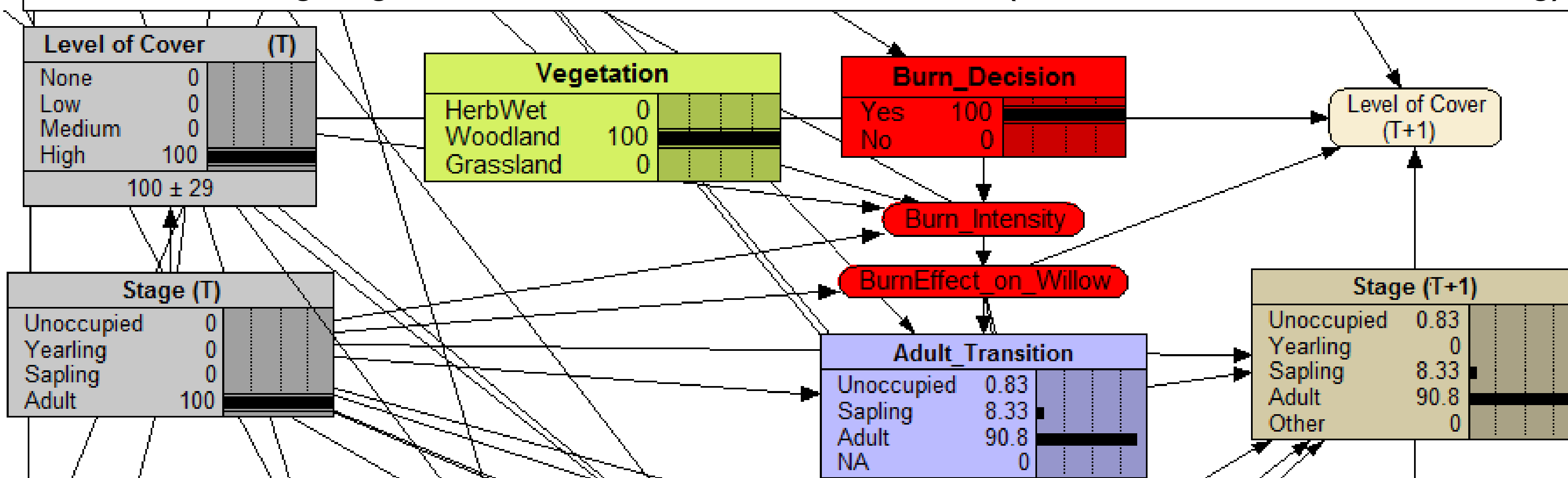
Scenario 10: High cover of Yearlings, mucky soil type, too little water during the growing season, burn treatment when surrounding vegetation is grassland (which has good burnability)



Scenario 12: Mechanical clearing of Saplings results in almost complete removal of willows from a cell

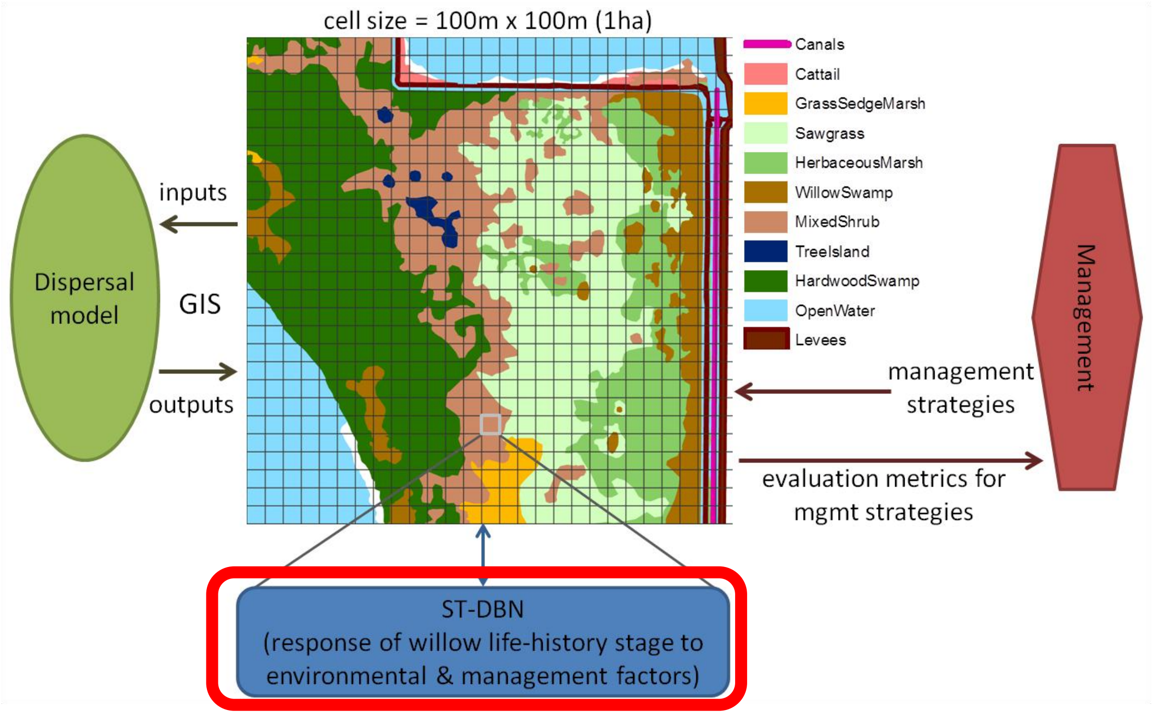


Scenario 19: Burn treatment for a cell containing high cover of willow Adults when the surrounding vegetation is woodlands, is ineffectual (as Adult willows inhibit burning)



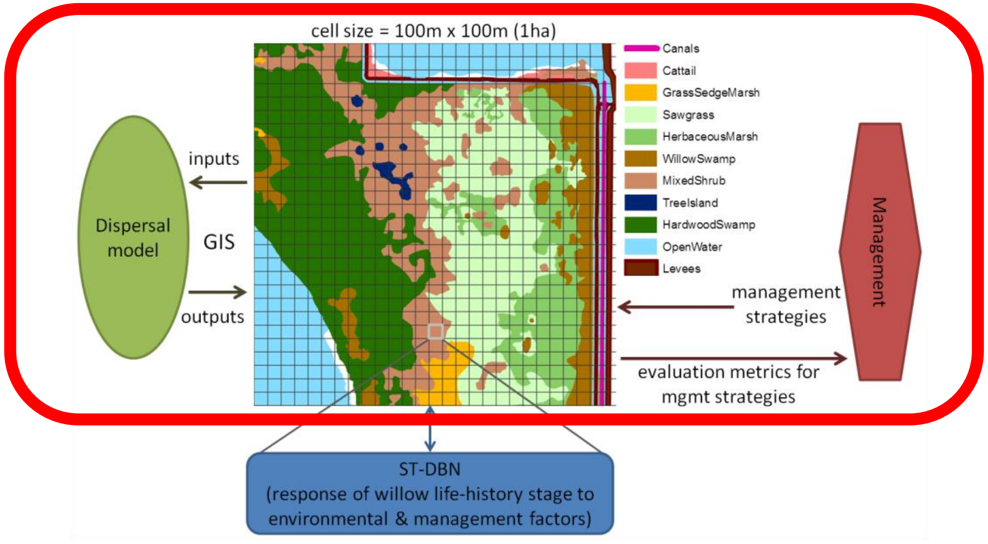
Stage 1 (Nicholson et al, 2012)

- Prototype ST-DBN for willows (single cell)
- High-level behaviour validated using scenarios (but not "calibrated")



Stage 2 (in progress)

- Evaluate and revise parameters
  - with judgments from more experts*
  - with experimental data
- Integrate with GIS and seed dispersal mode (using Hugin OOBNs)



* In USA!

Interactions with GIS