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

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Abstract

Expansion of willows in the naturally mixed landscape of vegetation types in the Upper St. Johns River Basin in Florida, USA, impacts upon biodiversity, aesthetic and recreational values. Managers need an integrated knowledge base to support decisions on where, when and how to control willows. Modelling the spread of willows over space and time requires spatially explicit data on willow occupancy, an understanding of dispersal mechanisms and how the various life-history stages of willows respond to environmental factors and management actions. We describe an architecture for a management tool that integrates environmental spatial data from GIS, dispersal dynamics from a process model and Bayesian Networks (BNs) for modelling the influence of environmental and management actions on the key life-history stages of willows. In this paper we focus on modelling temporal changes in willow stages using a form of Dynamic Bayesian Network (DBN). Starting from a state-transition (ST) model of the willow's lifecyle, from germination to seed-producing adult, we describe the expert elicitation process used to develop a ST-DBN structure, that follows the template described by Nicholson and Flores (2011). We present a scenario-based evaluation of the prototype ST-DBN model.

1 INTRODUCTION

The Upper St. Johns River (USJR) basin in east-central Florida (Figure 1) covers an area of 4890km^2 of which 1620km^2 was originally floodplain marsh dominated by forested wetlands, shrub swamps and herbaceous wetlands. By the 1970s, about two-thirds of the historical marshlands had been drained for agriculture and other purposes. The natural hydrological regime was severely altered by the loss of marshlands, and networks of canals, ditches and levees. This led to loss of floodplain storage capacity, increased flood susceptibility and severity, degraded water quality, extensive habitat loss and declines in fish, wading birds, waterfowl and other wildlife. In 1988, the St. Johns River Water Management District (SJRWMD) and the US Army Corps of Engineers began restoration of 607 km^2 of the USJR basin by acquiring land, building storages and plugging drainage canals. The St. Johns River was designated an American Heritage River in 1998.

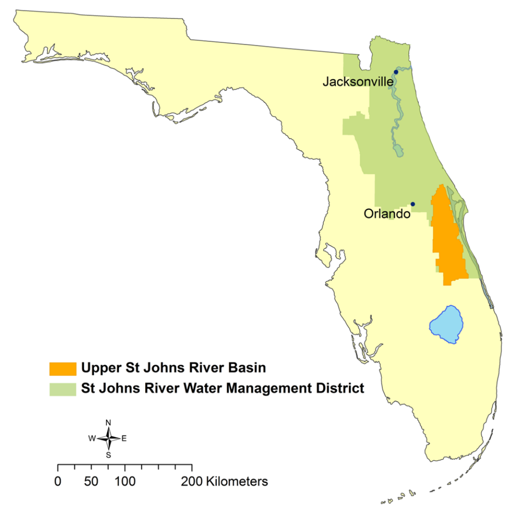

Figure 1: Location of the St. Johns River Water Management District (SJRWMD) and Upper St. Johns River basin in east-central Florida, USA.

In the last 50 years, woody shrubs, primarily, Carolina willow (*Salix caroliniana* Michx.), have invaded areas that were historically herbaceous marsh (Kinser et al., 1997). In some management compartments, the area of willows has more than doubled between 1989 and 2001 (Quintana-Ascencio and Fauth, 2010). This change to the historical composition of mixed vegetation types is considered undesirable, as extensive willow thickets detract from biodiversity, aesthetic and recreational values. Overabundance of willows reduces local vegetation heterogeneity and habitat diversity. People also prefer open wetlands that offer a viewshed, navigable access and scope for recreation activities such as wildlife viewing, fishing and hunting.

Managing the spread of willows over space and time requires spatially explicit data on willow occupancy, an understanding of dispersal mechanisms and how the various life-history stages of willows respond to environmental factors and management actions. We describe an architecture for a management tool that integrates environmental spatial data from a Geographical Information System (GIS), dispersal dynamics from a process model and state-transition Dynamic Bayesian Networks (ST-DBNs) (Nicholson and Flores, 2011) for modelling the influence of environmental and management actions on the key life-history stages of willows.

State-transition (ST) models are a convenient means of organising information and synthesising understanding to represent system states and transitions that are of management interest. We build on recent studies that combine ST models with BNs to incorporate uncertainty in hypothesised states and transitions, and enable sensitivity, diagnostic and scenario analysis for decision support in ecosystem management (e.g. Bashari et al., 2009; Rumpff et al., 2011). Our approach uses the template described by Nicholson and Flores (2011) to explicitly model temporal changes in willow stages.

2 BACKGROUND

2.1 WILLOWS IN UPPER ST. JOHNS RIVER CATCHMENT

S.caroliana is one of four willow species native to the SJRWMD. It occurs over a wide range of saturated soil types along lakeshores and stream banks, and in swamps and marshes. *S.caroliana* produces a very large number of small seeds that disperse by wind and water. Fecundity increases with size, but an average adult can produce 165,000 seeds annually (Quintana-Ascencio et al., unpublished data).

Seeds do not exhibit dormancy and have only a short period of viability. For good germination and establishment to occur, the seedbed must be unshaded and free of competition (i.e. bare) and consistently moist but not inundated (Kinser et al., 1997; Pezeshi et al., 1998; Lee, Ponzio et al., 2005). Such conditions can result from natural and human disturbances such as extended spring drawdown of slough areas, natural and controlled burns, grazing and mechanical clearing. Early seedling establishment and survival is governed by the soil moisture regime and degree of competition from other plants. Soil moisture in turn, depends on water-table elevation and soil characteristics such as texture and organic matter content (Pezeshki et al., 1998). However, even under favourable conditions establishment and survival rates are very low. Experimental data for seedling establishment in mucky (high organic matter) soil resulted in survival rates of 7%, whilst seedlings in mixed and sandy soil had negligible survival rates (Quintana-Ascencio and Fauth, 2010).

Once germinants become a yearling or sapling, survival rates are much higher (in the region of 50-100%) and varies depending on the hydrological regime, with prolonged inundation having an adverse impact on survival rates (Quintana-Ascencio and Fauth, 2010).

Like other willow species, *S.caroliana* is thin-barked and fire-sensitive. However, its response to fire can be complex and is mediated by factors such as burn intensity and conditions during and after burning. For instance, if water levels during a burn are sufficient to protect a portion of the willow stem, resprouting may follow after the burn. On the other hand, intense fires in unflooded marshlands can result in willow mortality (Kinser et al., 1997).

Managers seek to control the overall extent of willows, their rate of expansion into other extant wetland types and encroachment into recently restored floodplain habitats. They recognise that different areas differ in terms of their "invasibility" as well as biodiversity, aesthetic and recreational value. Furthermore, different management interventions are subject to different spatial, environmental and operational constraints, and induce different effects on willows, depending on willow life-history stage and level of cover at the time of treatment. The application of prescribed fire depends on water levels and the quantity of burnable understorey vegetation; mechanical treatment requires dry/drought conditions and suitable substrate that can support the weight of heavy equipment. Fire can produce a range of subtle and complex responses, whereas mechanical clearing obliterates extant vegetation, returning an area to an unoccupied state, regardless of the willow stage at time of treatment. The architecture of our management tool aims to explicitly accommodate these spatial characteristics and management considerations in modelling the temporal dynamics of willow population structure and cover.

2.2 BAYESIAN NETWORKS FOR ENVIRONMENTAL MODELLING

Bayesian networks (Pearl, 1988) are becoming increasingly popular for environmental and ecological modelling and risk assessment. There have been several recent surveys: Uusitalo (2007); Hart and Pollino (2009); Korb and Nicholson (2010); Aguilera et al. (2011), and guidelines for building BNs for environmental applications (e.g. Varis and Kuikka, 1999; Marcot et al., 2006; Kuhnert et al., 2010). A typical early application involved building a model of the response of a particular species or landscape, to environmental conditions and/or management actions, in a limited area; e.g. modeling the effects of eutrophication (excessive nutrients) in the Neuse River watershed (Borsuk et al., 2004), or predicting future abundance and diversity of native fish in the Goulburn River in south-eastern Australia (Pollino et al., 2007). Such models often had no explicit representation of time, other than that implicit in the causal process; or a single time-scale node was used to "flip" the BN's prediction from one time-scale to another (e.g. in Pollino et al. (2007), from 1-year to 5-years). However, some environmental applications concerned with system behaviour over time and/or space have used DBNs and Object-oriented Bayesian Networks (OOBNs) to support this explicitly.

BNs are increasingly being coupled with Geographic Information Systems (GIS) (e.g., Stassopoulou et al., 1998; Smith et al., 2007; Johnson et al., 2012). In such applications, there is typically one copy of the BN associated with each cell in the GIS. Data layers in the GIS may be used as inputs to the BN, and outputs from one or more BN nodes may be fed back to the GIS. Our tool architecture, presented in Section 3, follows this basic structure.

Dynamic Bayesian Networks (DBNs) are a variant of ordinary BNs (Dean and Kanazawa, 1989; Kjærulff, 1992; Nicholson, 1992) that allow explicit modelling of changes over time. A typical DBN has nodes for N variables of interest, with copies of each node for each *time slice*. Links in a DBN can be divided into those between nodes in the same time slice, and those in the next time slice. While DBNs have been used in some enviromental applications (e.g. Shihab and Chalabi, 2007; Dawsey et al., 2007; Shihab, 2008), their uptake has been limited. This is perhaps because they are perceived to be "very tedious" (Uusitalo, 2007), or because DBN algorithms are available only in software resulting from research projects,[1] with DBN functionality less well supported in the more widely used commercial products.[2]

State-and-transition models (STMs) have been used to model changes over time in ecological systems that have clear transitions between distinct states (e.g., in rangelands, grasslands and woodlands, see Bestelmeyer et al., 2003; Sadler et al., 2010; Rumpff et al., 2011). In this paper, we apply the template proposed in Nicholson and Flores (2011), shown in Figure 2, which formalised and extended Bashari et al.'s model, combining BNs with the qualitative STMs. S^T represents the state of the system, has n possible values $s_1 \ldots s_n$, and may directly influence any of the environmental and management factors, which are divided into m main factors, $F_1, \ldots, F_m$ (which directly influence transitions) and other sub-factors, $X_1, \ldots, X_r$ (which influence the main factors).

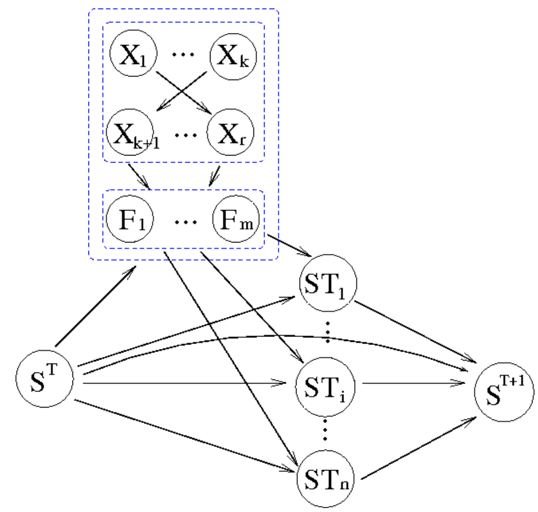

Figure 2: The generic ST-DBN combining STMs with DBNs (Nicholson & Flores, 2011, Fig.10).

The transition nodes, $ST_1, \ldots ST_i, \ldots, ST_n$ represent the transitions from each state s_i, each with at most $n+1$ values (though usually with fewer), one for each "next" state plus "impossible", giving explicit modelling of impossible transitions. As with ordinary DBNs, there is an implied δT, which can be included explicitly as a parent of all the ST nodes, if the time step varies. Each transition node ST has only some of the causal factors as parents. The CPT for the ST node is just a partition of the corresponding CPT if the problem was represented as an ordinary DBN, without the transition nodes. The next state node, S^{T+1}, has to combine the results of all the different transition nodes, given the starting state S, and thus has $n+1$ parents. However, the relationship between the transition nodes and S^{T+1} is deterministic, so the CPT can be generated from a straightforward equation.

Nicholson and Flores (2011) presented a complexity analysis of the ST-DBN, compared to an ordinary DBN (without transition nodes). This showed that any models that explicitly represent all the transitions (i.e. that have ST nodes), only remain tractable when

[1] e.g. BNT, `code.google.com/p/bnt`

[2] For example, the Netica Application (`www.norsys.com`) GUI interface has some DBN functionality, but this is not included in its API.

there are natural constraints in the domain; that is, if the underlying state transition matrix for S is sparse, and if different factors influence different transitions. Such constraints were identified for the willow management problem in the USJR basin.

3 ARCHITECTURE

Figure 3 shows the system architecture for the integrated management tool. It includes a GIS database, a dispersal process model, a ST-DBN model of willow response to environment and management and a management framework. For each cell (modelling unit), the GIS database supplies data on environmental attributes such as soil and vegetation type and information about landscape position and context (e.g. proximity to canal structures or type of surrounding land cover). This data provides inputs to parameterise the dispersal process model, which then makes predictions on seed production that can be mapped and linked to the ST-DBN. The data on spatial context also informs the construction of management strategies (defined here as a set of spatially explicit management actions) and assists in decisions about feasible locations for applying particular management actions. We chose a cell size of 100x100 m (1 ha) to represent a modelling unit. This reflects the resolution of available data for environmental attributes, makes the computational demand associated with dispersal modelling feasible, and is a reasonable scale with respect to candidate management actions.

The ST-DBN synthesises current understanding about how environmental conditions and management actions, acting separately and in various combinations, influence transitions between the key stages of management interest. For each cell, the underlying ST-DBN takes input from the GIS database and management decisions, and predicts willow response for the next timestep. These predictions can then be mapped and aggregated across the target management area to produce evaluation metrics for managers. In this way, managers can "implement", visually compare and quantitatively evaluate different candidate management strategies (or scenarios). The remainder of this paper focuses on the development of the ST-DBN structure.

4 A ST-DBN FOR WILLOWS

The development of the ST-DBN (Figure 4), drew upon a range of sources and used a combination of knowledge derived from ecological and physiological theory, field observations, field and glasshouse experiments and experts (e.g. Kinser et al., 1997; Pezeshi et al., 1998; Lee, Ponzio et al., 2005; Lee, Synder et al., 2005; Ponzio et al., 2006; Quintana-Ascencio & Fauth, 2010). The knowledge engineering process was iterative and incremental, following Boneh (2010), using a series of workshops (2 full-day, 4 half-day) between the knowledge engineers with BN modelling expertise (the first two authors) and the domain expert (the third author), over a six week period. Between each workshop, the models were updated in the BN software, reviewed and revised.

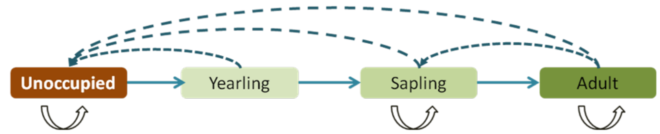

Figure 5: The four willow stages of management interest and the possible transitions of each stage. Arrows indicate the direction of possible transitions.

4.1 NODES

The key points of interest are whether willow is present in a cell or not, and if present, its lifecycle stage and its level of cover.

The stages of management interest modelled in the Stage node are: unoccupied, yearling, sapling (non-reproductive juvenile) and adult.

The possible transitions amongst these four stages are shown in Figure 5. Some stage transitions are not possible (e.g. adults and saplings cannot become yearlings and yearlings cannot remain as yearlings at the next time step). The time step across the ST-DBN was chosen to be one year. An annual time step was considered appropriate given the willow's growth and seed production cycle. Our domain expert did not see any benefit in modelling at a finer temporal scale. In particular, seedlings were only of interest from a management point of view if they survived to the yearling stage.

For these four stages or states, the BN has four corresponding transition nodes (shown in Fig. 4): UnOcc_Transition represents the possible transitions from Stage(T)=Unoccupied, Yearling_Transition represents the possible transitions from Stage(T)=Yearling, etc. Note that each S_Transition node has an additional state, NA (Not Applicable), for when Stage(T) was other than S.

Level_of_Cover refers to the proportion of area within a cell that is occupied by willows of any lifecycle stage. When the willows reach the Adult (seed-producing) stage, Size and Level_of_Cover are factors that influence Seed_Production.

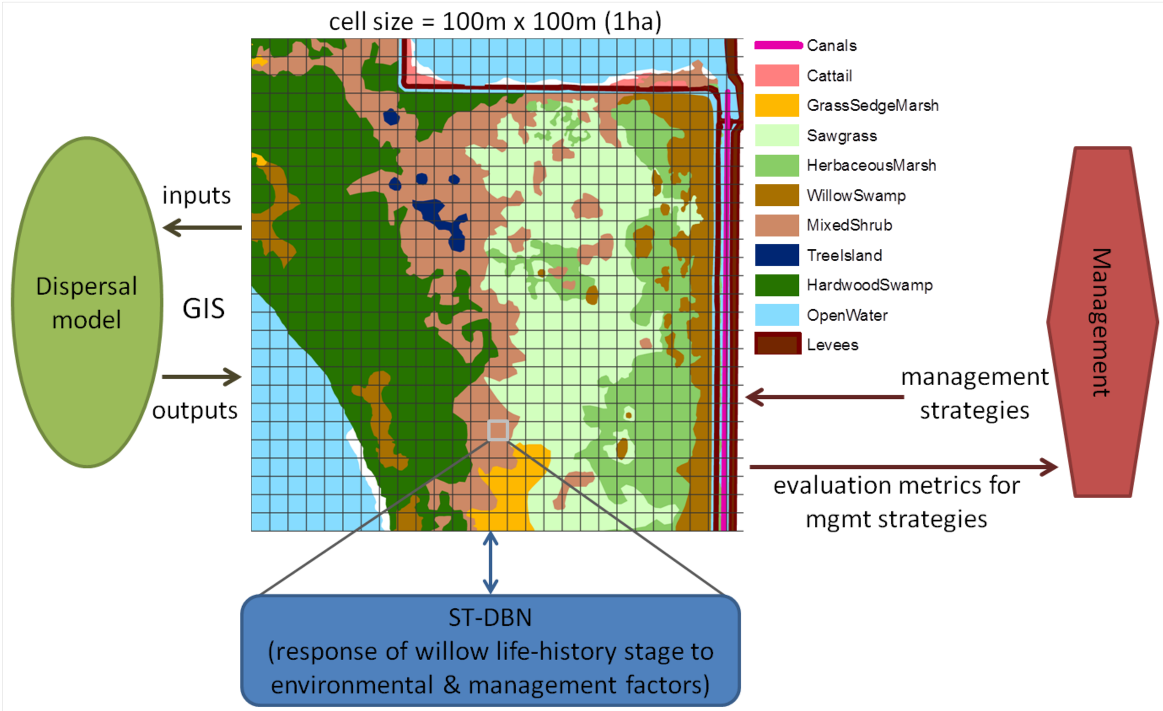

Figure 3: System architecture of the integrated management tool comprising a GIS database, a dispersal process model, a ST-DBN model of willow response to environment and management and a management framework. GIS excerpt shows a portion of the Blue Cypress Marsh Conservatioin Area within the USJR basin.

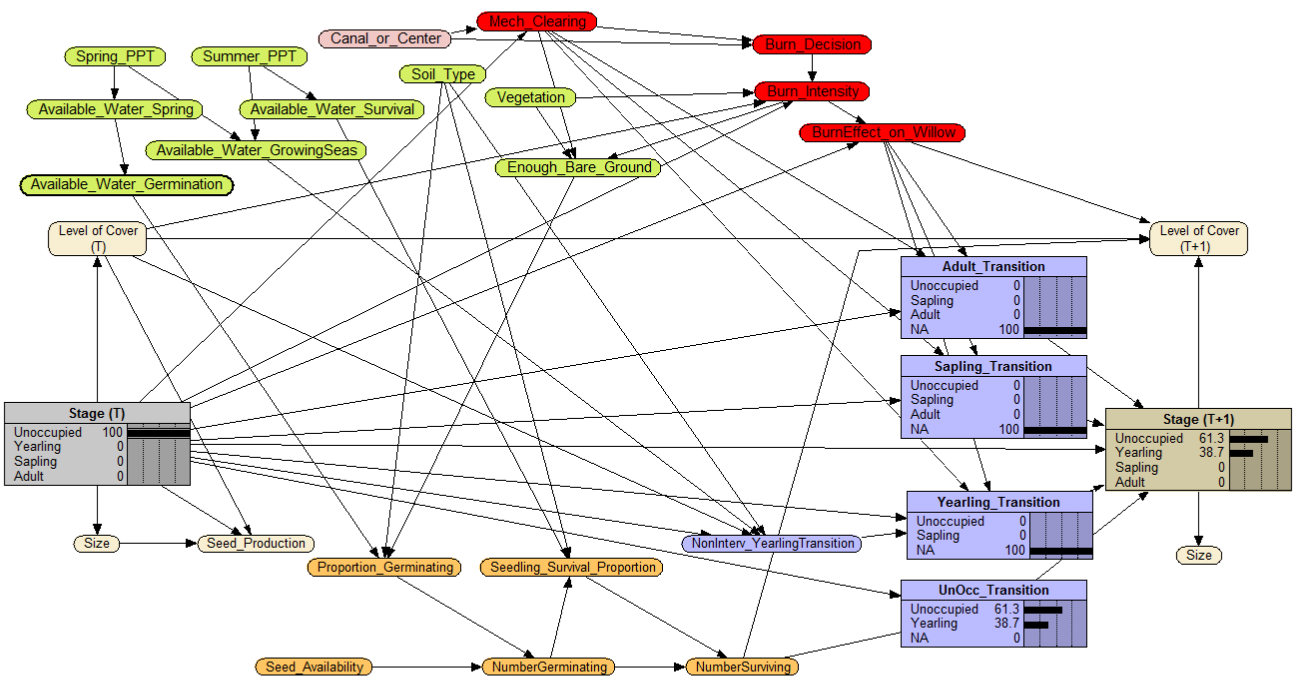

Figure 4: Willows ST-DBN, showing posteriors for Stage and transition nodes for the scenario starting with the cell Unoccupied by willows, with favourable conditions for the transition to Yearling: high seed availability, just right spring (germination) and summer (survival) precipitation, "mucky" (organic, water holding) soil, enough bare ground, no mechanical clearing or prescribed burn.

Stage transitions are governed by environmental and management factors, acting alone or in some combination. Environmental factors include soil type, amount of bare ground, spring and summer precipitation and local vegetation type. Candidate management actions include mechanical clearing (roller-chopping), burning, grazing, herbicide application and hydrological manipulation. Each are subject to different spatial, environmental and operational constraints, and induce different effects on willows, depending on willow life-history stage and level of cover at the time of treatment. For this prototype model, we concentrate on mechanical clearing and burning. Table 1 gives a full listing of the Willow ST-DBN nodes, grouped into (colour-coded) categories. Continuous variables were discretised for implementation in Netica, with discretisation breakpoints determined by a combination of empirical data and expert judgement.

4.2 ARCS

Next, we describe the nature and influences on the possible transitions, represented by the arcs in the Willow ST-DBN (shown in Fig. 4).

Unoccupied areas can become occupied by yearlings if they are successfully colonised within a time step. Successful colonisation depends upon seed availability (which is determined by seed production in and influx from neighbouring cells) and environmentally favourable conditions for seed germination and subsequent seedling survival. Otherwise, unoccupied areas remain unoccupied. Figure 4 shows the Willow ST-DBN starting as Unoccupied, under favourable conditions. Note that the UnOcc_Transition is split between staying Unoccupied (61.3%) and transitioning to Yearling (38.7%), while all the other Transition nodes show are 100% NA (Not Applicable).

Early survival is low, but yearlings can become saplings when environmental conditions are favourable for growth and they are not impacted by mechanical clearing or burning. Otherwise, mortality will cause areas occupied by yearlings to revert to the unoccupied stage.

As saplings grow, they can become reproductive adults, provided they are not impacted by mechanical clearing or burning. Otherwise, they may remain in the non-reproductive sapling stage, if burn impact is minor, or revert to the unoccupied stage if burn impact is major or if mechanical clearing occurs.

In the absence of mechanical clearing or burning, adults stay in the adult stage. Clearing results in almost complete mortality and reversion to an unoccupied stage. The effect of fire depends upon its burn intensity. If sufficiently severe, it can cause mortality and convert areas occupied by adults back to an unoccupied stage, or it might kill off large stems and reduce canopy cover (Lee, Ponzio et al., 2005; Lee, Synder et al., 2005). When adults are damaged in this way, they become non-reproductive for a period as they attempt to recover by resprouting post-fire. For this period, they functionally resemble saplings and we represent this in our ST-DBN by a transition from adult back to the sapling stage.

The initial Level_of_Cover is determined by the number of seedlings that survive when the Stage transitions from unoccupied to yearling. Stages from yearling onwards are robust to environmental variability (e.g. fluctuations in precipitation and inundation), but they are affected by mechanical clearing (which always returns the cell to Unoccupied) or burning (depending on the burn effectiveness).

Again, following the Nicholson and Flores ST-DBN template, the four transition nodes are all parents of the subsequent Stage(T+1) node.

4.3 PARAMETERISATION

We have two stages to our model parameterisation. In the parameterisation for this first prototype, our aim was to represent high-level behaviour, thus the CPTs were constructed using a combination of expert elicitation of process knowledge, expert interpretation of empirical data from field and glasshouse experiments, deterministic and probabilistic functions, statistical models and expert judgement. We do not report details of these here, for reasons of space; they will be reported elsewhere.

The second phase will involve more detailed parameterisation using judgements elicited from a larger pool of domain experts. We will also use specific results from experiments already completed (see Quintana-Ascencio and Fauth, 2010) to calibrate CPTs for some nodes. The field and greenhouse experiments do not provide enough cases to learn the CPTs, nor do they cover an exhaustive range of scenarios. However, they will provide guidance for the parameterisation.

5 SCENARIO-BASED EVALUATION

For this first prototype of the Willow ST-DBN, we conducted scenario-based evaluation with our domain expert throughout the knowledge engineering process. We examined multiple scenarios designed to probe the encoded relationships for key environmentally-driven processes, such as seedling survival and expected responses to management actions, such as the effect of burning. By inputting different combinations of values

Table 1: The nodes of the Willow ST-DBN, grouped into categories with colour-coding (see Figure 4).

Category (node colour)	Nodes
Aspects of willow state (tan)	Stage, Level_of_Cover, Size and Seed_Production
Germination & seedling survival processes (orange)	Seed_Availability, Proportion_Germinating, NumberGerminating Seedling_Survival Proportion and NumberSurviving
Environmental conditions (green)	Soil_Type, Vegetation, Enough_Bare_Ground, spring and summer precipitation (Spring_PPT, Summer_PPT) seasonal water availability for germination, survival and growth (Available_Water_Spring, Available_Water_Germination, Available_Water_Survival, Available_Water_GrowingSeas Canal_or_Centre (i.e. accessibility)
Management options (red)	Mech_Clearing, Burn_Decision (and associated with this option, Burn_Intensity and BurnEffect_on_Willow)
State-transitions (purple)	UnOcc_Transition, NonInterv_YearlingTransition† , Yearling_Transition, Sapling_Transition and Adult_Transition

† Representing expected yearling transition without overlay of management actions.

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

for the relevant environment and management variables, and examining the results in key intermediate and final output nodes, we were able to identify errors in CPTs, logical inconsistencies, and nodes that needed splitting, combining or redefining.

Table 2 presents a small subset of these scenarios together with the distributions obtained for Stage(T+1), while Figure 6 shows fragments of the BN with posterior distributions for some of the variables of interest.[3] The evaluation results in Table 2 and Figure 6 are consistent with our understanding of the influence of environment and management actions on key life-history stages of willows, as described in Sections 2.1 and 4. This suggests the basic structure of the prototype ST-DBN (the nodes and their values, together with the arcs) is appropriate.

6 CONCLUSIONS

We have described an architecture for a willow management tool for the Upper St. Johns River basin, Florida, USA, that integrates environmental spatial data from GIS, dispersal dynamics from a process model and BNs for modelling the influence of environmental drivers and management actions on the key life-history stages of willows. The focus of this paper has been on modelling temporal changes in willow stages using a form of DBN. Starting from a state-transition (ST) model of the willow's lifecyle, from germination to seed-producing adult, we described the process used to develop a ST-DBN structure that follows the template described by Nicholson and Flores (2011). The high-level behaviour of this prototype Willow ST-DBN has been demonstrated through scenario-based evaluation.

Our next task is to evaluate the model and revise the parameterisation of the model using judgements from a larger pool of domain experts, together with specific experimental results, where appropriate and available. Once the ST-DBN for an individual cell passes acceptance testing by our domain experts, we will integrate it with the GIS and the seed dispersal model. This will require introducing a relationship between seed production (an output node in the ST-DBN) and seed availability (some combination of the seed production at nearby cells, as informed by the dispersal process model). Finally, the overall system will be evaluated against management options across the whole river basin.

[3]These are screenshots from the BN software, Netica, with layout of nodes compressed due to reasons of space.

Acknowledgements

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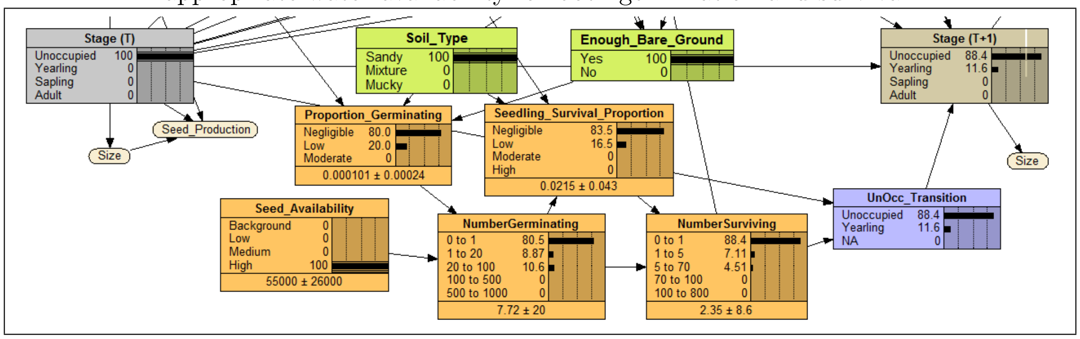
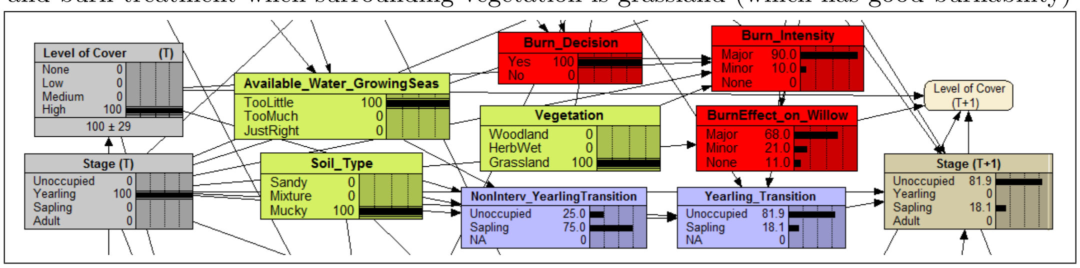
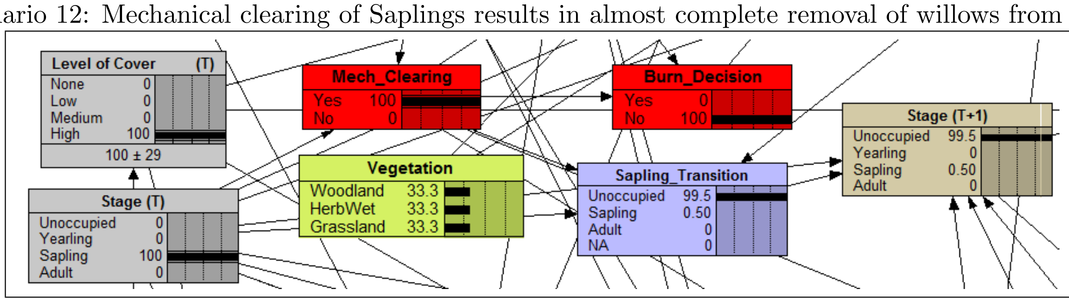
Scenario 1: High seed availability, sandy soil type, sufficient bare ground and appropriate water availability for both germination and survival.



Scenario 10: High cover of Yearlings, mucky soil type, too little water during the growing season, and 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)

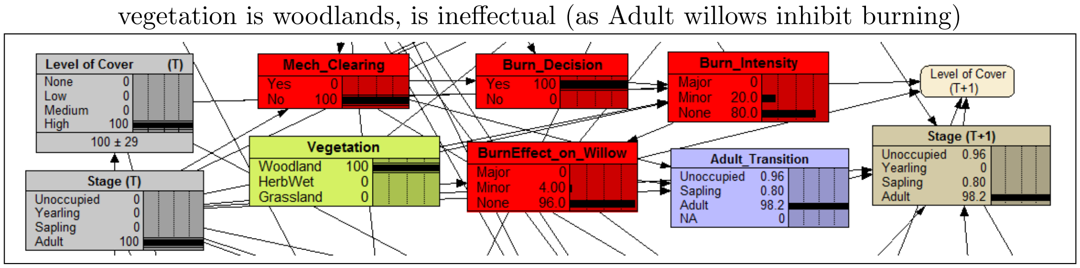


Figure 6: Fragments of the Willow ST-DBN (Netica screenshots) for scenarios 1, 10, 12 and 19 (from Table 2)

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