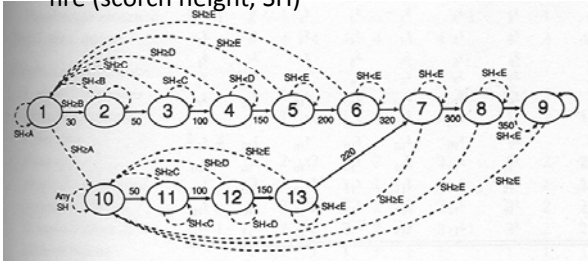


### Successional Pattern for 13 Montana Habitat Types (Van Wagner 1973)

- Transitions are determined by stand age or fire (scorch height, SH)



Shugart 1998

### Successional Pattern for 13 Montana Habitat Types

- State-transition matrix for successional changes
- System has 7 operators
- $T_{time}$  = passage of time
- $T_{<A}$  = fire with scorch height < A
- $T_{AB}$  = fire with scorch height between A and B
- likewise  $T_{BC}$ ,  $T_{CD}$ ,  $T_{DE}$ ,  $T_{>E}$

System states	Operators						
	$T_{time}$	$T_{<A}$	$T_{AB}$	$T_{BC}$	$T_{CD}$	$T_{DE}$	$T_{>E}$
$S_1$	$S_1$	$S_1$	$S_1$	$S_1$	$S_1$	$S_1$	$S_1$
$S_2$	$S_2$	$S_2$	$S_2$	$S_2$	$S_2$	$S_2$	$S_2$
$S_3$	$S_3$	$S_3$	$S_3$	$S_3$	$S_3$	$S_3$	$S_3$
$S_4$	$S_4$	$S_4$	$S_4$	$S_4$	$S_4$	$S_4$	$S_4$
$S_5$	$S_5$	$S_5$	$S_5$	$S_5$	$S_5$	$S_5$	$S_5$
$S_6$	$S_6$	$S_6$	$S_6$	$S_6$	$S_6$	$S_6$	$S_6$
$S_7$	$S_7$	$S_7$	$S_7$	$S_7$	$S_7$	$S_7$	$S_7$
$S_8$	$S_8$	$S_8$	$S_8$	$S_8$	$S_8$	$S_8$	$S_8$
$S_9$	$S_9$	$S_9$	$S_9$	$S_9$	$S_9$	$S_9$	$S_9$
$S_{10}$	$S_{10}$	$S_{10}$	$S_{10}$	$S_{10}$	$S_{10}$	$S_{10}$	$S_{10}$
$S_{11}$	$S_{11}$	$S_{11}$	$S_{11}$	$S_{11}$	$S_{11}$	$S_{11}$	$S_{11}$
$S_{12}$	$S_{12}$	$S_{12}$	$S_{12}$	$S_{12}$	$S_{12}$	$S_{12}$	$S_{12}$
$S_{13}$	$S_{13}$	$S_{13}$	$S_{13}$	$S_{13}$	$S_{13}$	$S_{13}$	$S_{13}$

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### Successional Pattern for 13 Montana Habitat Types

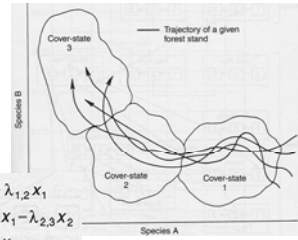
- Table with relative abundance of species in successional states
- Trees (> or <1.4m height), shrubs and subshrubs, forbs and grasses

	Importance values for system states												
	$S_1$	$S_2$	$S_3$	$S_4$	$S_5$	$S_6$	$S_7$	$S_8$	$S_9$	$S_{10}$	$S_{11}$	$S_{12}$	$S_{13}$
<b>Trees &gt; 1.4 m in height</b>													
<i>Picea canadensis</i>	3	2	1										
<i>Picea canadensis</i>	2	2	2	1	1				3	3	2		
<i>Pinus strobus</i>	4	4	5	5	5	6	6		4	4	5		
<b>Trees &lt; 1.4 m in height</b>													
<i>Picea canadensis</i>	1	1											
<i>Picea canadensis</i>	1	1							1	1	1		
<i>Pinus strobus</i>	1	1	1	1	1	1	1		1	1	1		
<b>Total tree cover</b>													
species and subshrubs	4	4	4	4	4	4	4	4	4	4	4	4	4
<i>Juniperus communis</i>	2	1							2	1			
<i>Prinosilla fruticosa</i>	1	1	1	1	1	1	1		1	1	1		
<i>Ribes</i> spp.	2	2											
<i>Spiraea canadensis</i>	1	2	2	2	2	2	2		1	2	2		
<i>Spiraea betulifolia</i>	2	2	2	2	2	2	2		2	2	2		
<i>Symphoricarpos albus</i>	1	1	2	2	2	2	2		1	2	2		
<i>Dehneria sp.</i>	1	1	1	1	1	1	1		1	1	1		
<b>Total shrub cover</b>	2	2	4	4	4	4	4	4	2	4	4	4	4
<b>Forbs and grasses</b>													
<i>Galium aparine</i>	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Carex sp.</i>	2	2	3						2	3			
<i>Pinus strobus</i>	1	1	1	1	1	1	1		1	1	1		
<i>Grassland</i>	1	1	1	1	1	1	1		1	1	1		
<i>Arca</i> spp.	2	1	1	1	1	1	1		2	1			
<i>Alnus</i> spp.	1	1	1	1	1	1	1		1	1	1		
<i>Populus</i> spp.	2	2	1	1	1	1	1		2	1	1		
<b>Total forb and grass cover</b>	5	5	5	5	5	5	5	5	5	5	5	5	5

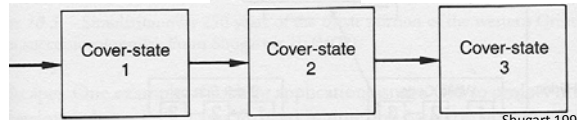
Shugart 1998

### B. Differential Equations

- Forest succession of a large region
- Stand trajectories
- Compartment diagram
- Differential equations



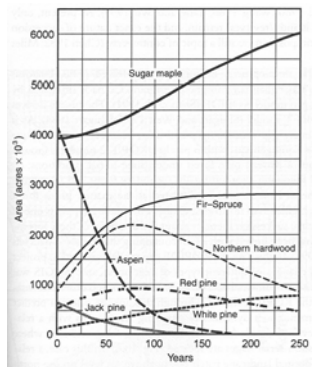
$$\begin{aligned} \dot{x}_1 &= F_1 - \lambda_{1,2} x_1 \\ \dot{x}_2 &= \lambda_{1,2} x_1 - \lambda_{2,3} x_2 \\ \dot{x}_3 &= \lambda_{2,3} x_2 \end{aligned}$$



Shugart 1998

### B. Differential Equations

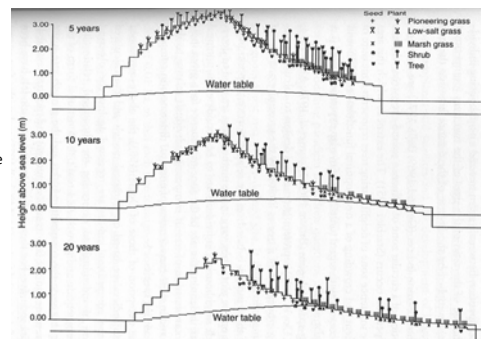
- Simulation of the mesic part of the Western Great Lakes system over 250 years



Shugart 1998

### DUNE Simulation

- Patterns and dynamics of a barrier island vegetation
- Open ocean is to the left
- Over time the island moves landward and the water table on the right side of the island forms brackish marsh with scattered shrubs
- Shugart et al. 1988



Shugart 1998