Population management in the face of evolution

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May 24, 2016

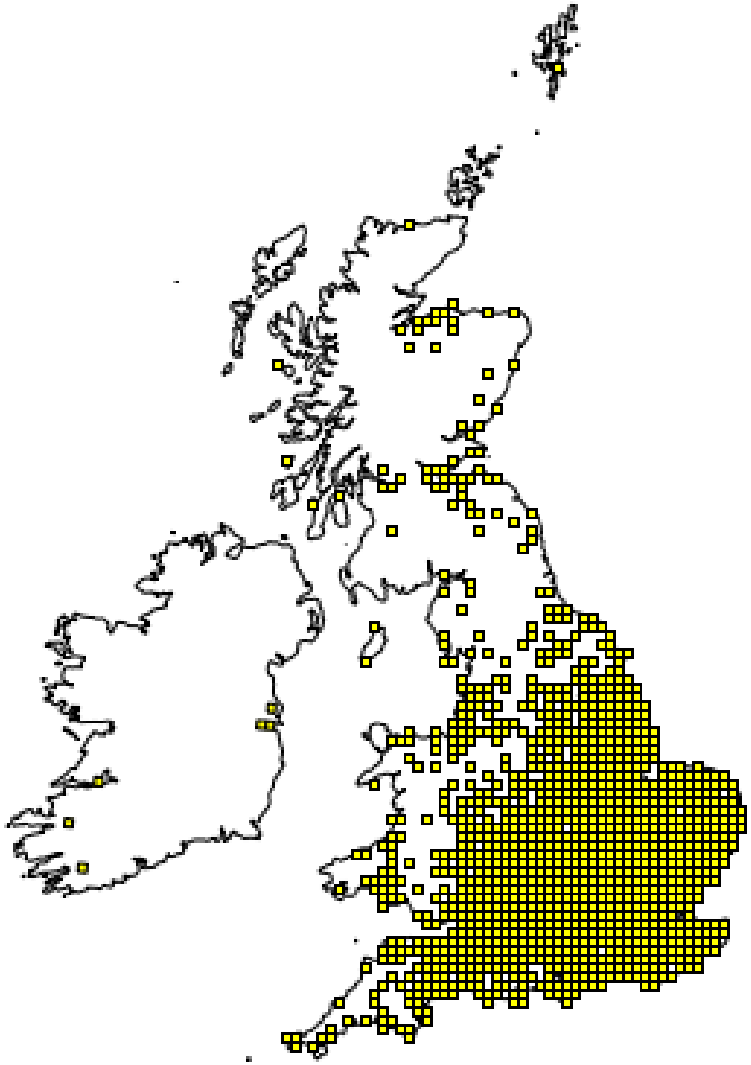
Herbicide is great

more weeds $\Rightarrow$ less crops

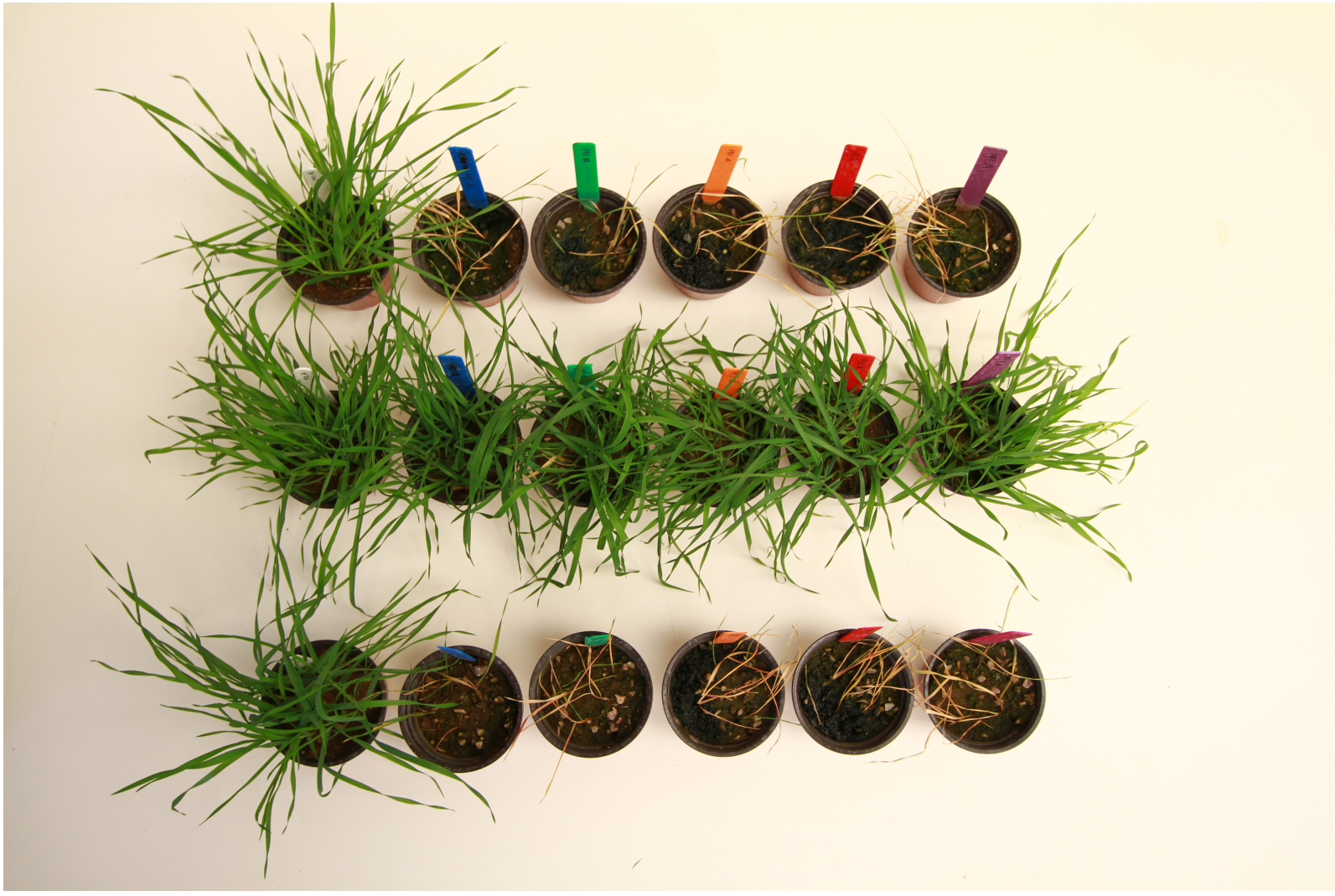
hand weeding fields estimated at 60hr / ha (http://www.ncfar.org/ncfar_africa.pdf)

crop rotations and fallow periods

Black grass (*Alopecurus myosuroides*)

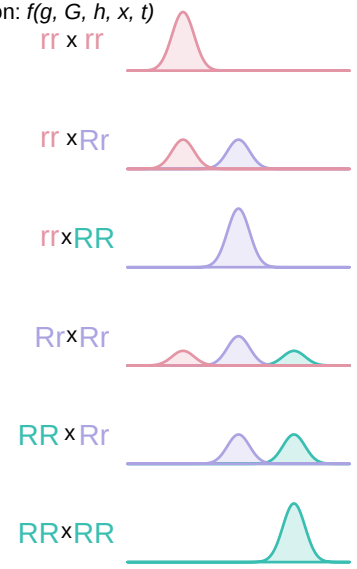


https://data.nbn.org.uk



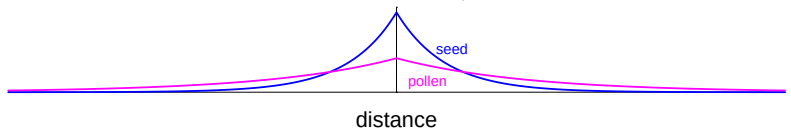
herbicide resistance

offspring distribution: $f(g, G, h, x, t)$

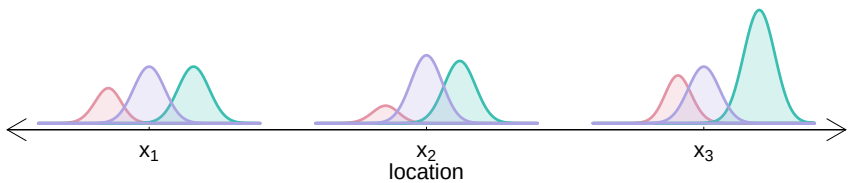


Offspring distributions of each genotype G, produced by each combination of parent genotypes G x G.

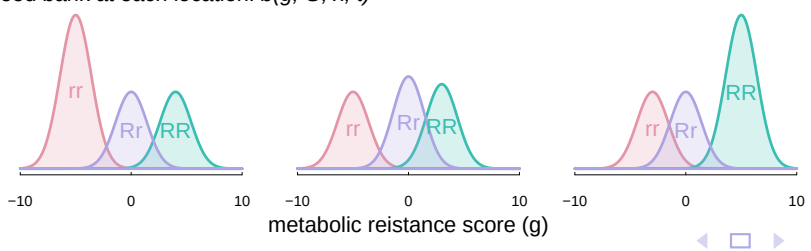
seed and pollen dispersal kernel: $d(i, j)_m$ and $d(i,j)_p$



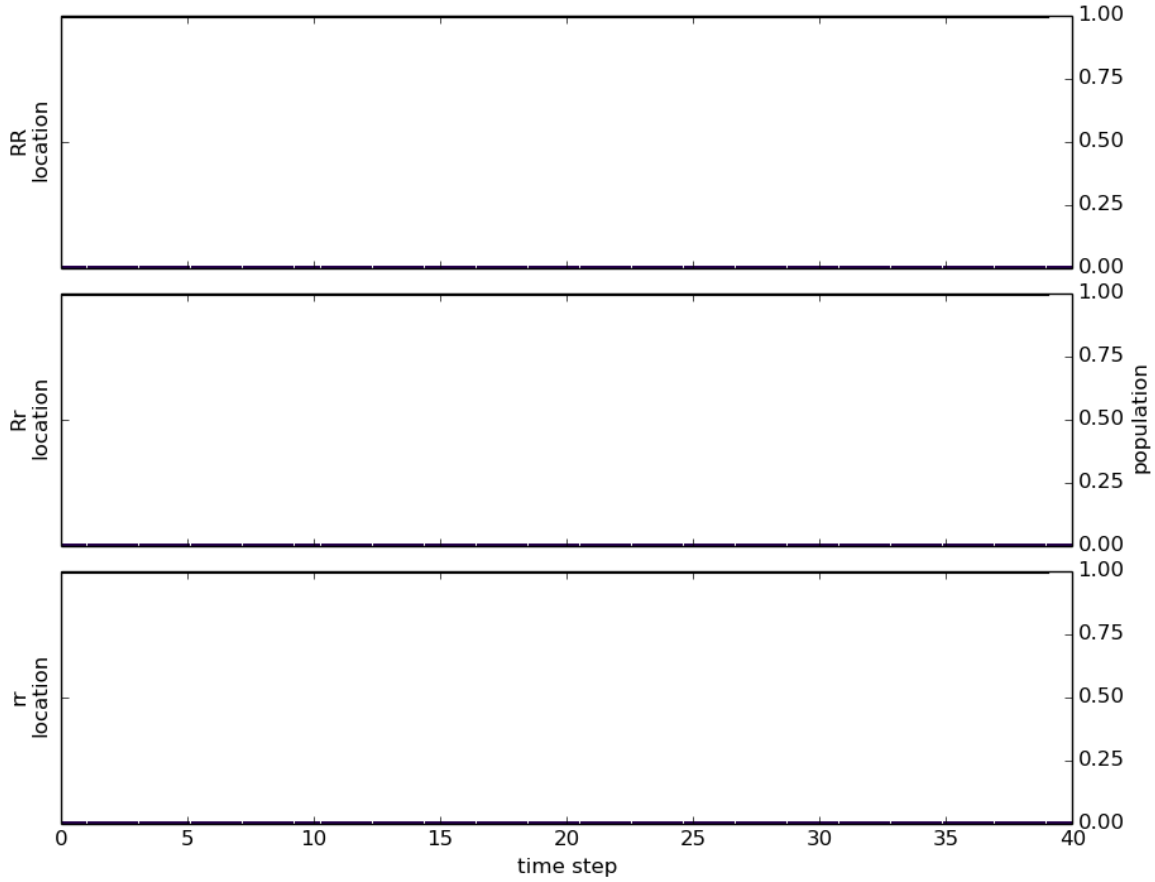
above ground population: $n(g, G, x, t)s(g, G, x, h_x)$

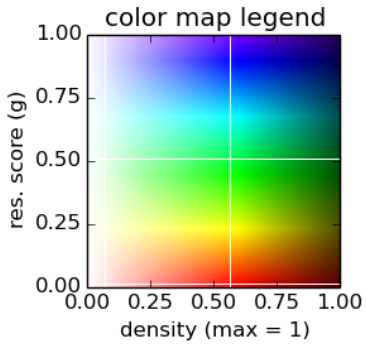


seed bank at each location: $b(g, G, x, t)$



If there are two ways to be resistant, why use both?





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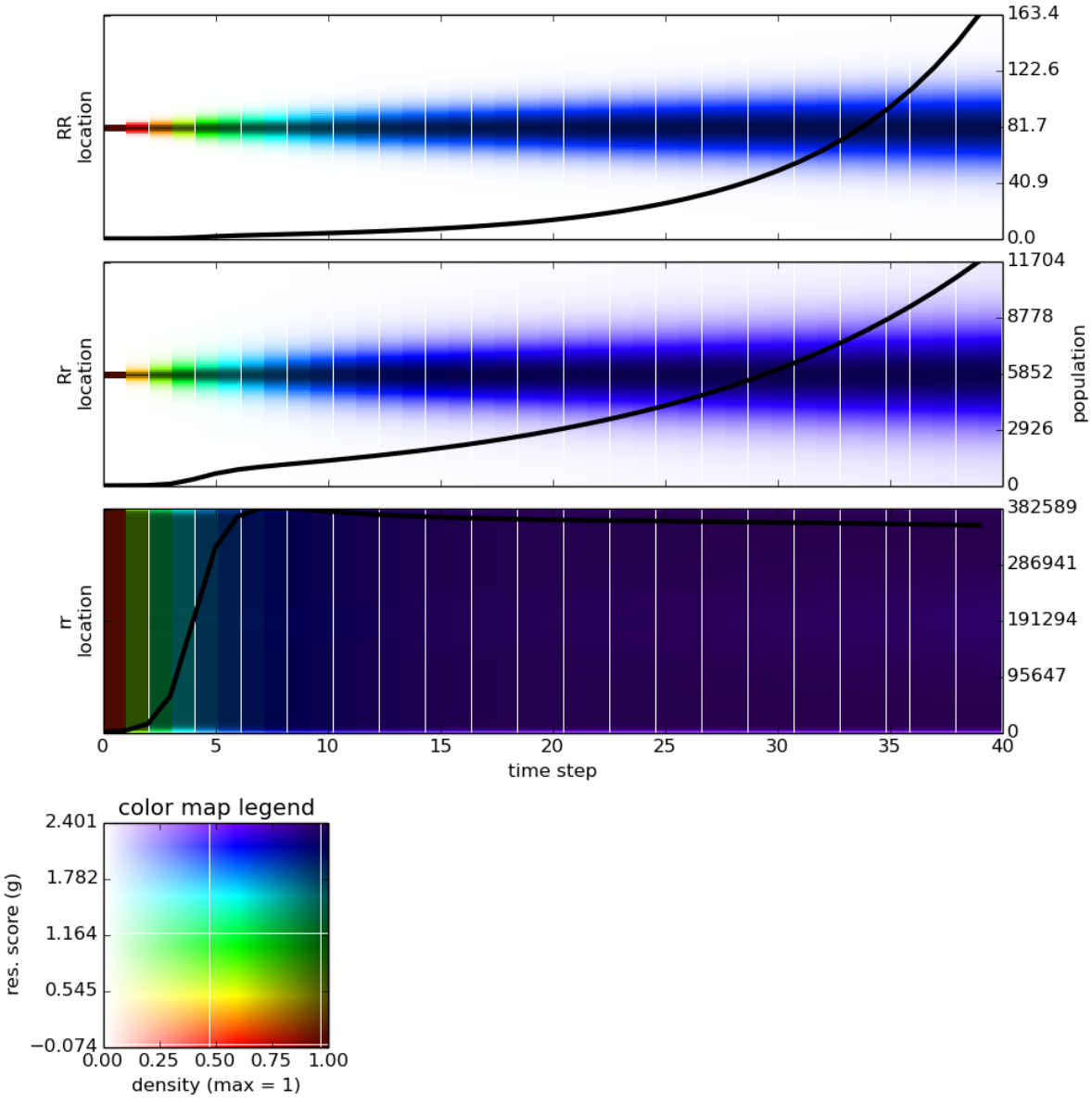

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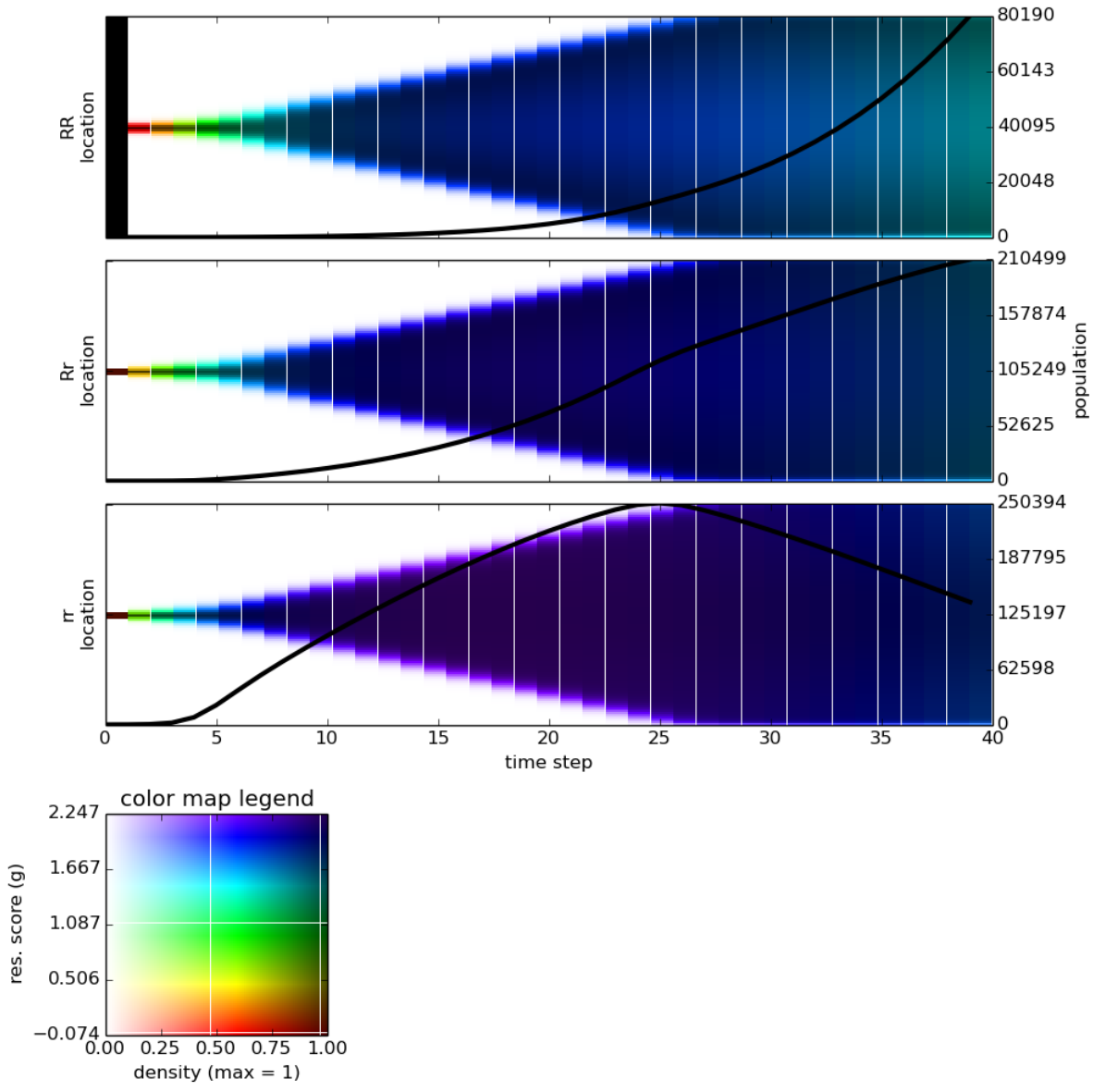


Integrated weed management

Integrated weed management as a combinatorial optimization problem

Actions:

crop choice = {Wheat, Alternative, Fallow}
herbicide = {Yes, No}
mech. cont. = {Yes, No}
plowing = {Yes, No}
planting density = {Standard, High}

Actions sequence:

Time	action combos
1	{Wheat, Herb, Mech, Std_dens}
2	{Wheat, Mech, Plow, Std_dens}
3	{Alt, Herb, Mech, Plow, Std_dens}
4	{Fallow}

Actions space:

action	action combos
1	{Wheat, Herb, Mech, Plow, Std_dens}
2	{Wheat, No_Herb, Mech, Plow, Std_dens}
.	.
.	.
.	.
25	{Fallow}

Integrated weed management as a combinatorial optimization problem

If $T = 20$ years there are number of actions^T possible actions sequences

Very BIG number
$25^{20} = 9.094947 \times 10^{27}$

Integrated weed management as a combinatorial optimization problem

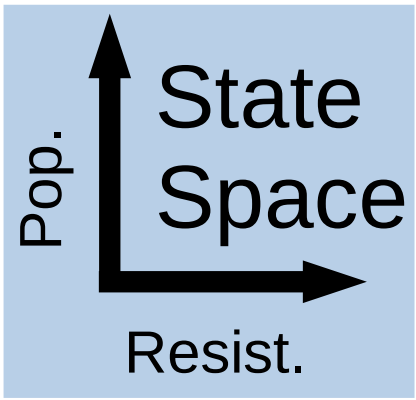
The goal is to find the sequence of actions over a given time horizon, T, that maximizes an objective function

Objective function: maximize discounted economic returns.

Other objective functions are possible that include a wider range of goals, such as social stigma or reducing resistance.

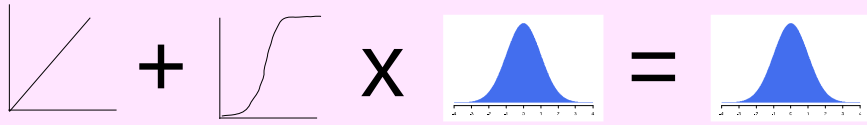
Dynamic programing

Starting at T go backwards in time



For every state

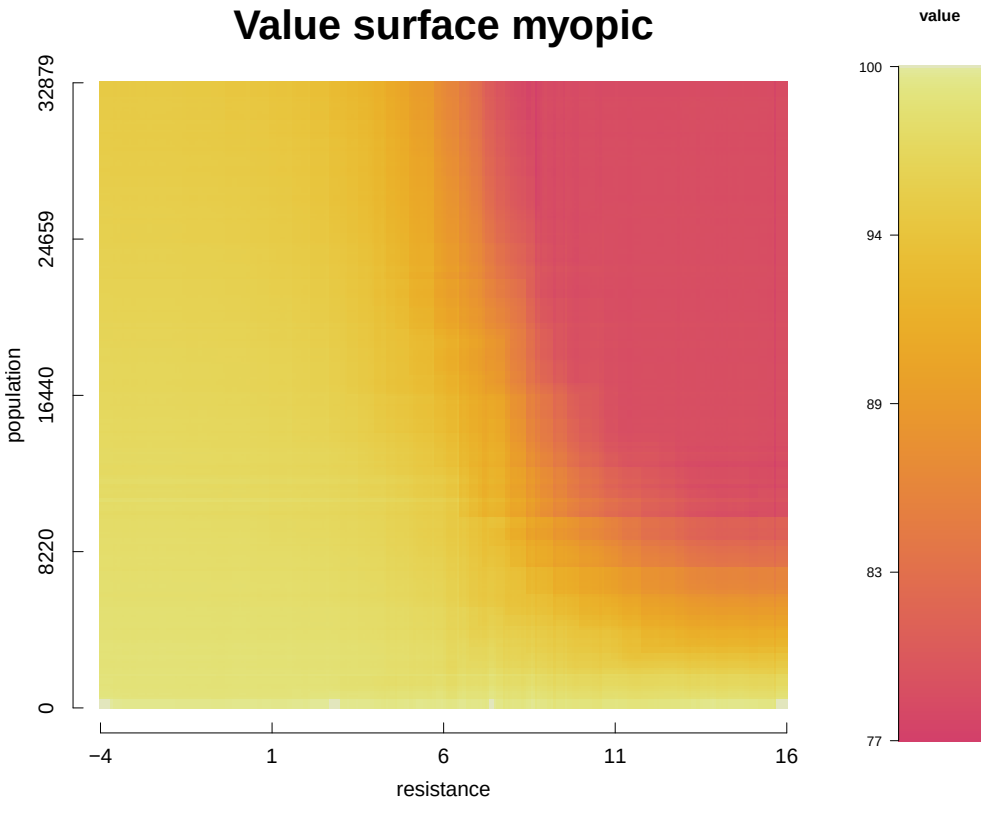
System model

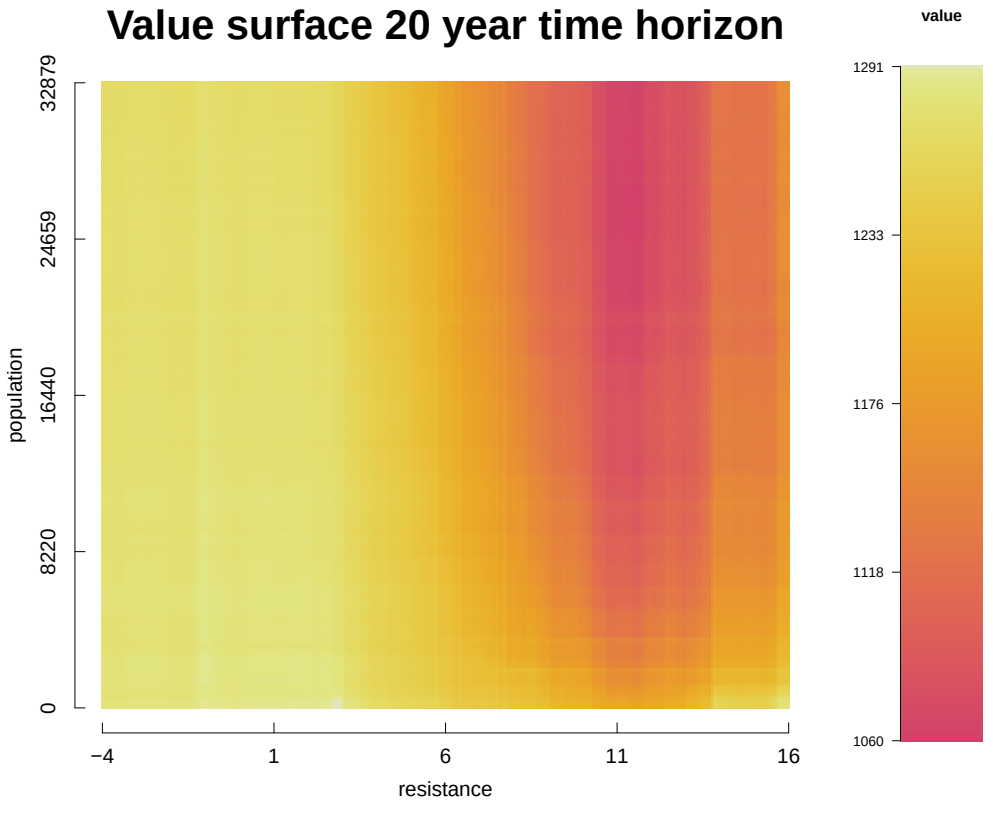


Action Space:
{act 1, act 2, act 3, …}

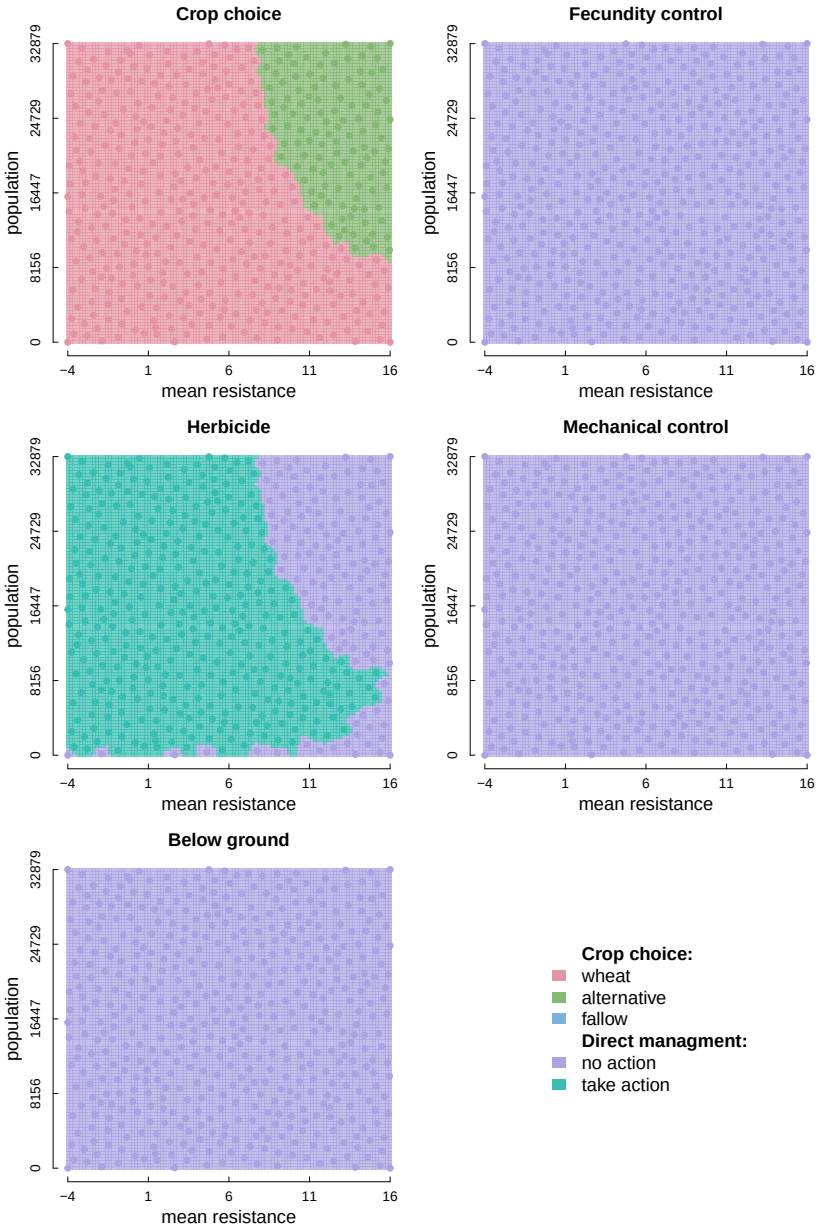
For every action

$$V(s) = \max_{a} R(s,a) + dis.rate * V(next\ s | a, s)$$

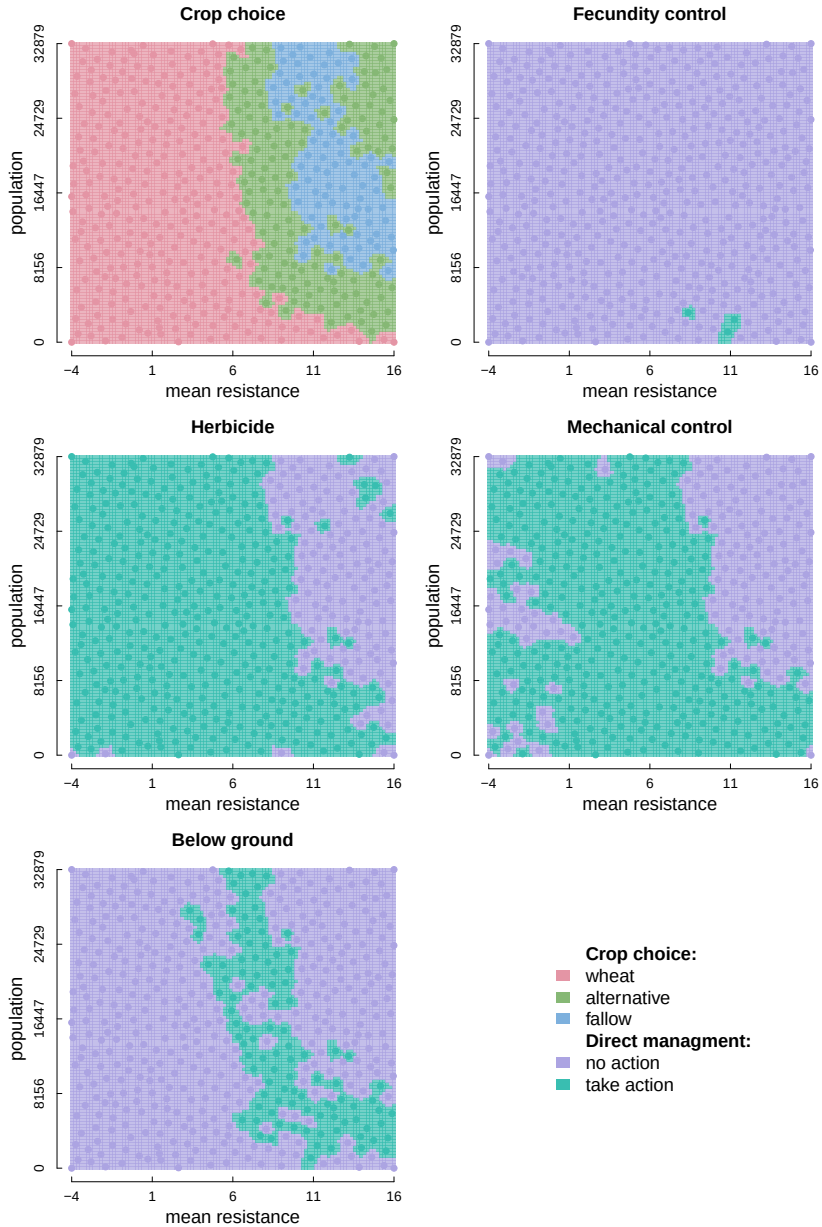

Value surface myopic
value
100
94
89
83
77
population
0
8220
16440
24659
32879
−4
1
6
11
16
resistance


Value surface 20 year time horizon
value
1291
1233
1176
1118
1060
population
0
8220
16440
24659
32879
−4
1
6
11
16
resistance

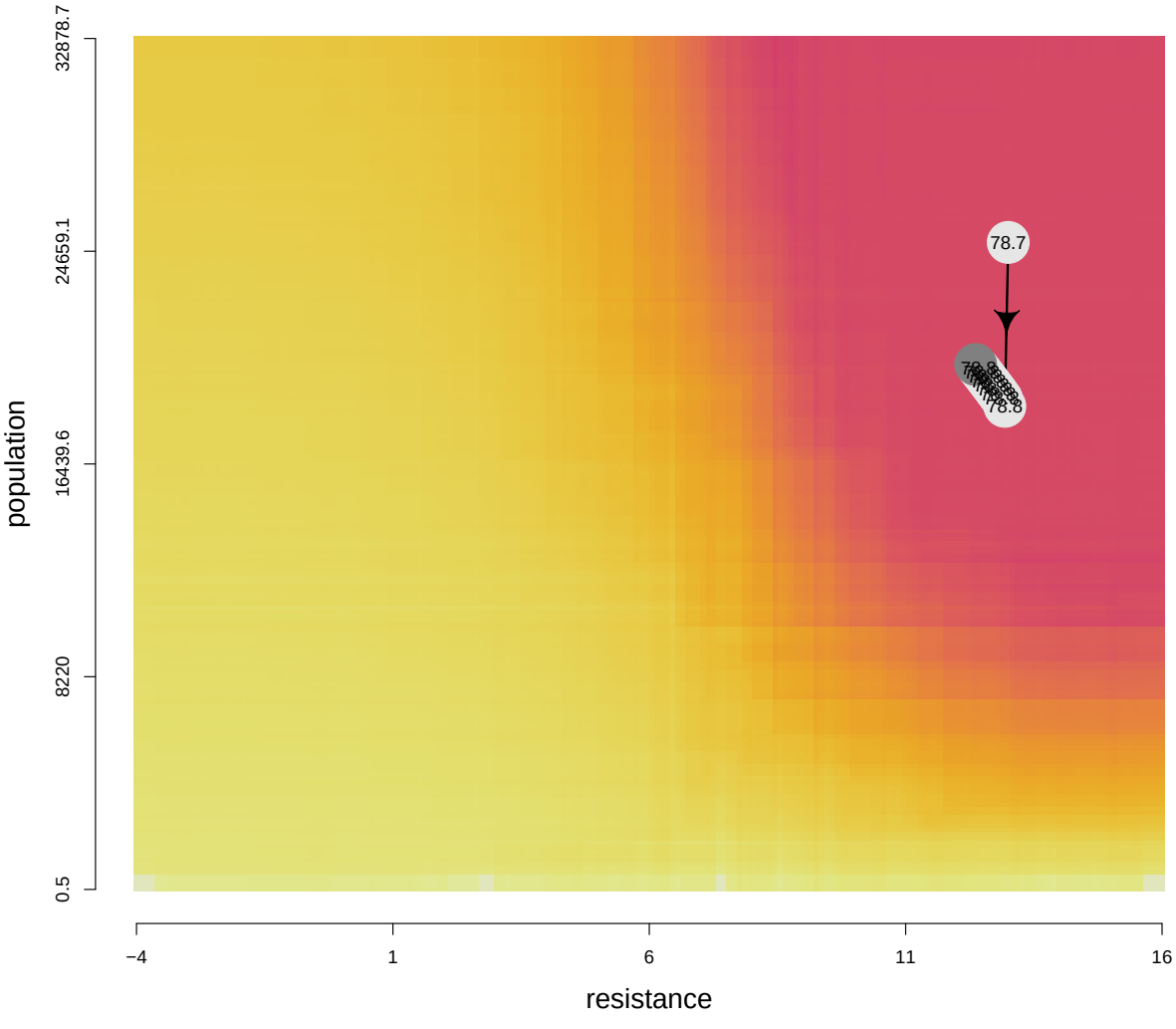
Myopic policy



T = 20 policy

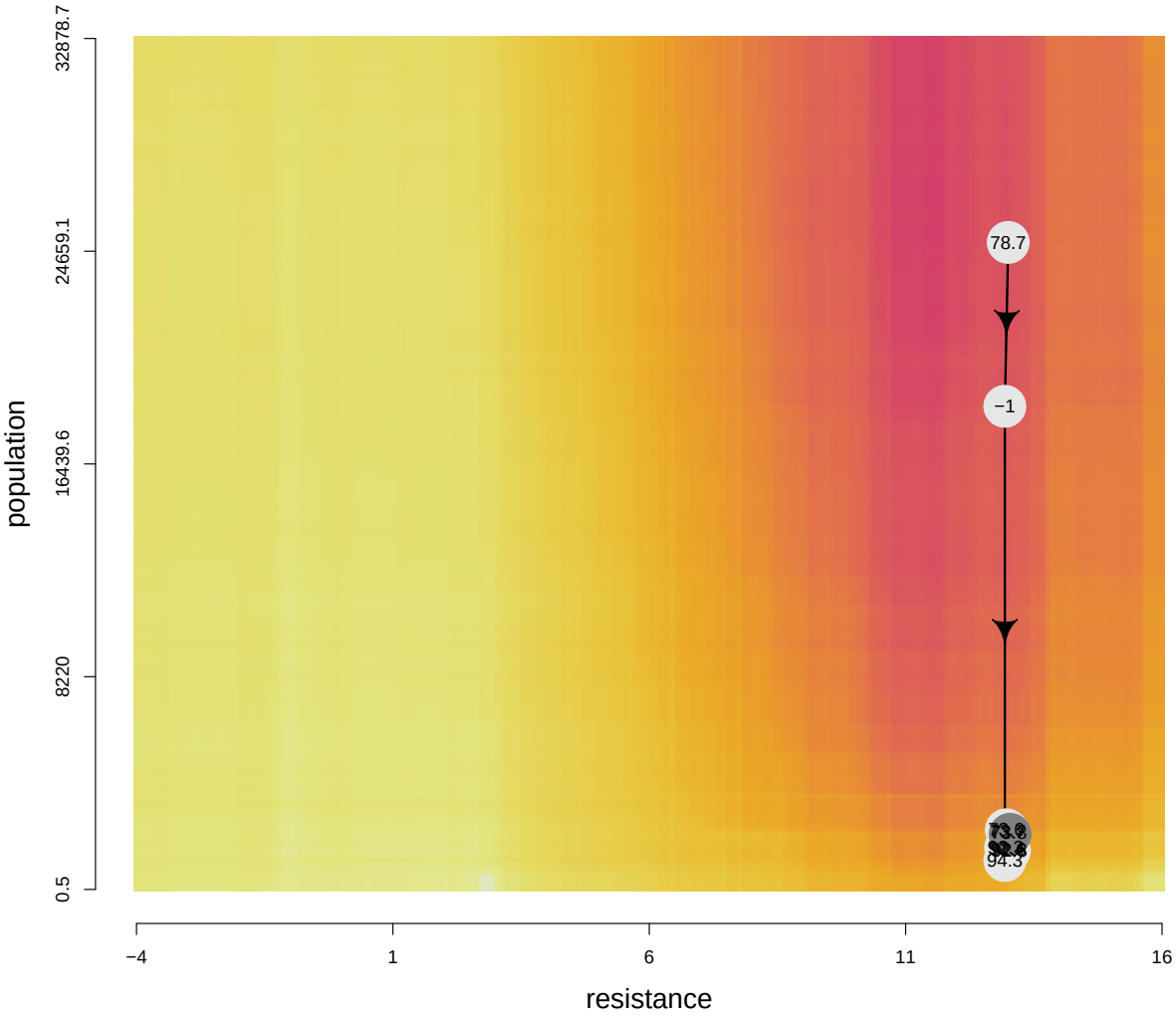


Action over time: Myopic



time	crop	herb.	mech.	plow	dens.
1	A				
2	A				
3	A				
4	A				
5	A				
6	A				
7	A				
8	A				
9	A				
10	A				

Action over time: Long term



time	crop	herb.	mech.	plow	dens.
1	A				
2	F				
3	W	●	●		
4	W	●	●		
5	A	●	●		
6	W	●	●		
7	A	●	●		
8	W	●	●		
9	A	●	●		
10	W	●	●		

Wrap up

To get both metabolic resistance and target site resistance in the same population nascent foci ahead of the invasion front are likely to be important.

For myopic decision makers both population size AND how resistant that population affect value

For forward looking decision makers population resistance affects value much more than population size

These difference translate in to different optimal actions.