

# Population management in the face of evolution

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# Herbicide is great

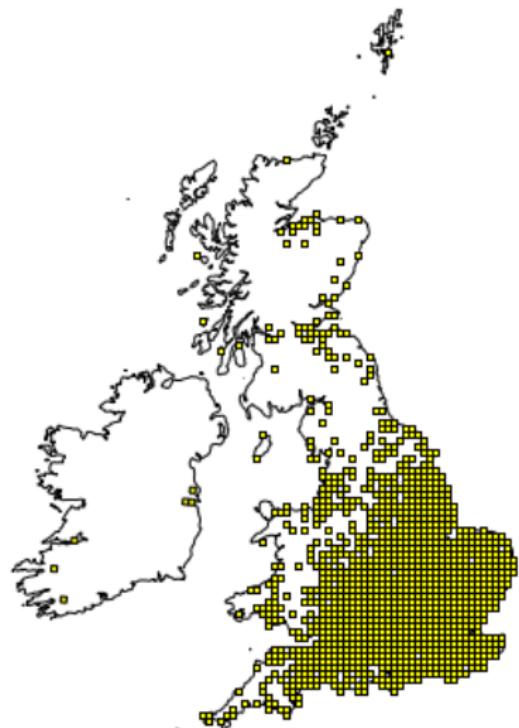
more weeds ⇒ less crops

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

crop rotations and fallow periods



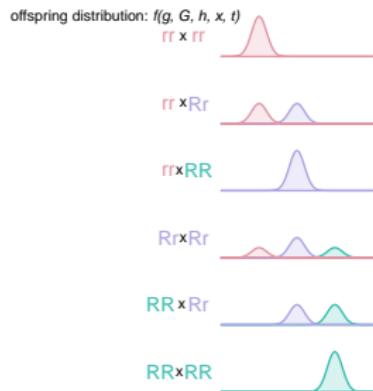
# Black grass (*Alopecurus myosuroides*)



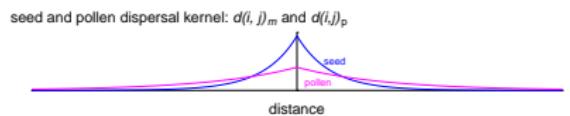
<https://data.nbn.org.uk>



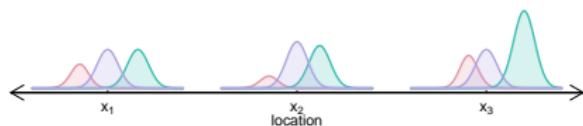
# herbicide resistance



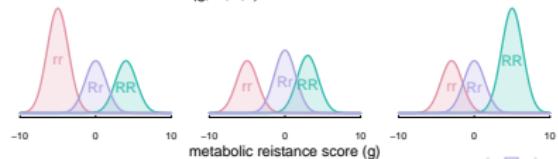
Offspring distributions of each genotype  $G$ , produced by each combination of parent genotypes  $G \times G$ .



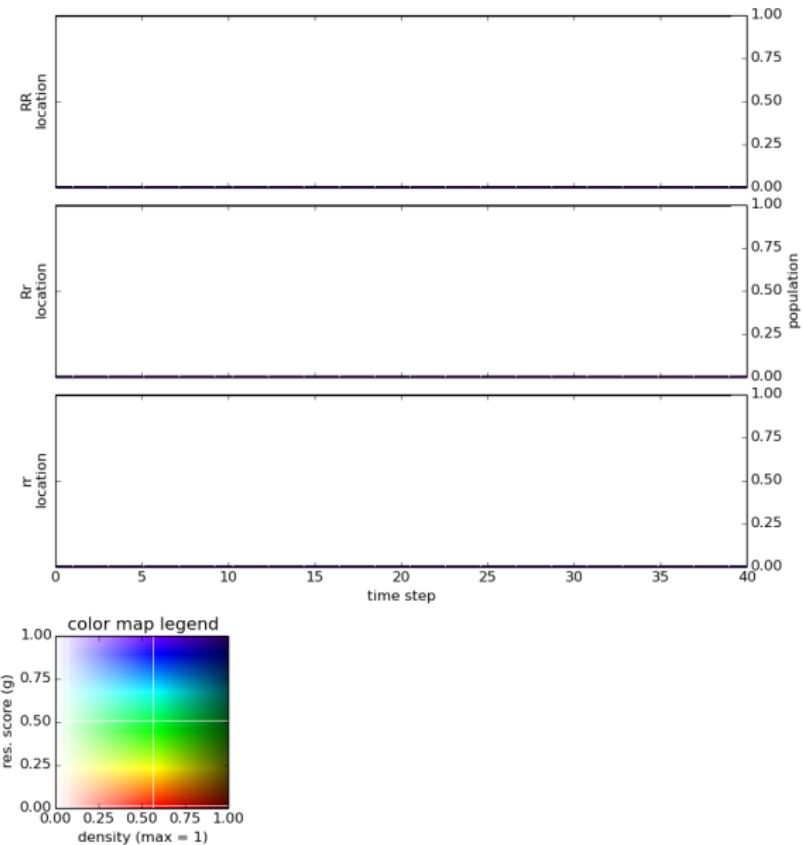
above ground population:  $n(g, G, x, t)s(g, G, x, h_x)$



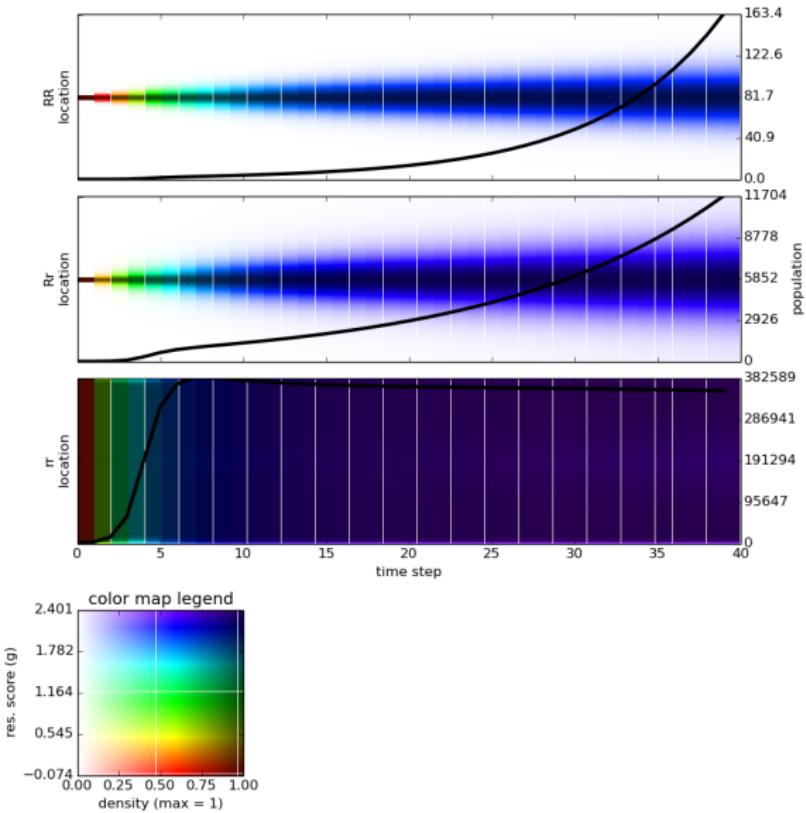
seed bank at each location:  $b(g, G, x, t)$



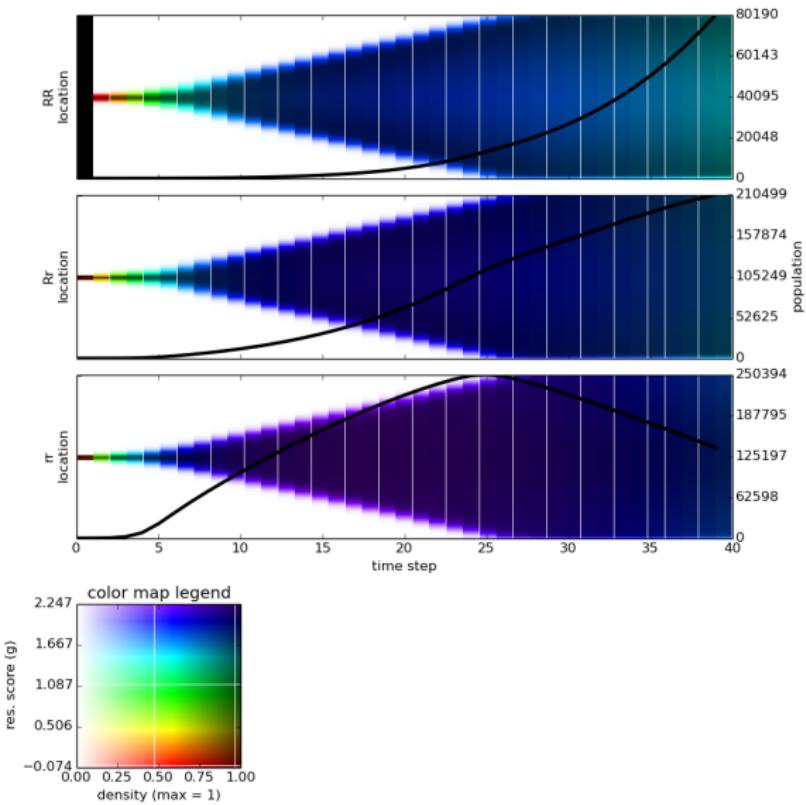
# If there are two ways to be resistant, why use both?



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# Integrated weed management



# Integrated weed management as a combinatorial optimization problem

Five management options:

- ▶ **Crop choice:** winter wheat, alternative, fallow
- ▶ **Direct action:** herbicide, mechanical control, plowing to remove seeds from seed bank, planting wheat at high density to reduce black grass fecundity.

There are 25 different set of these management options which make logical sense.

each set is one action, e.g. {wheat, herbicide, no mechanical control, no plowing, standard planting density}

# 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

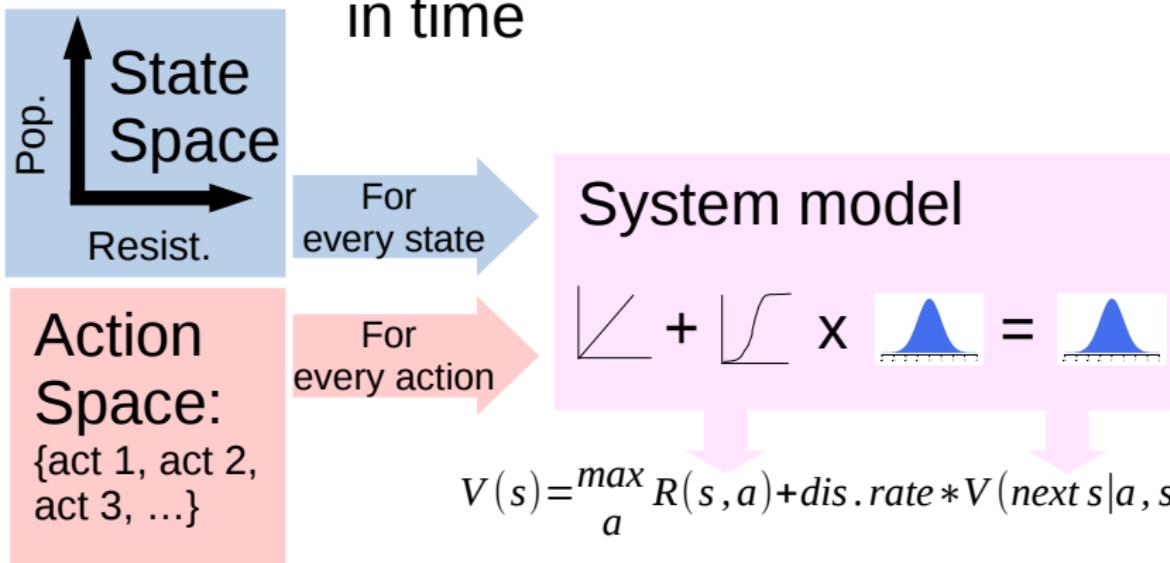
The goal is to find the sequence of actions over a given time horizon,  $T$ , that maximizes an objective function

Objective function: maximize discounted economic returns.

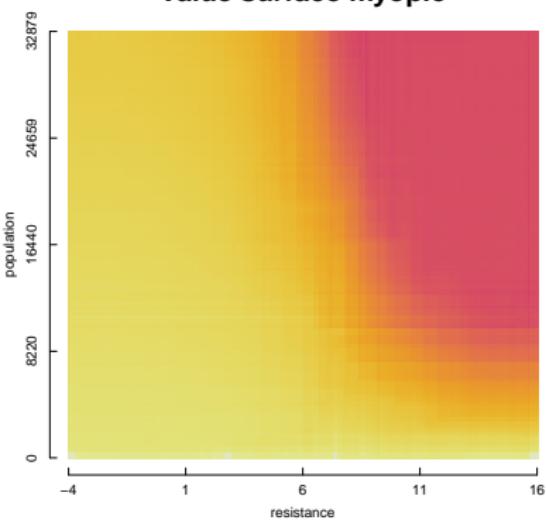
Other objective functions are possible that include a wider range of goals, such as social stigma or reducing resistance.

# Dynamic programming

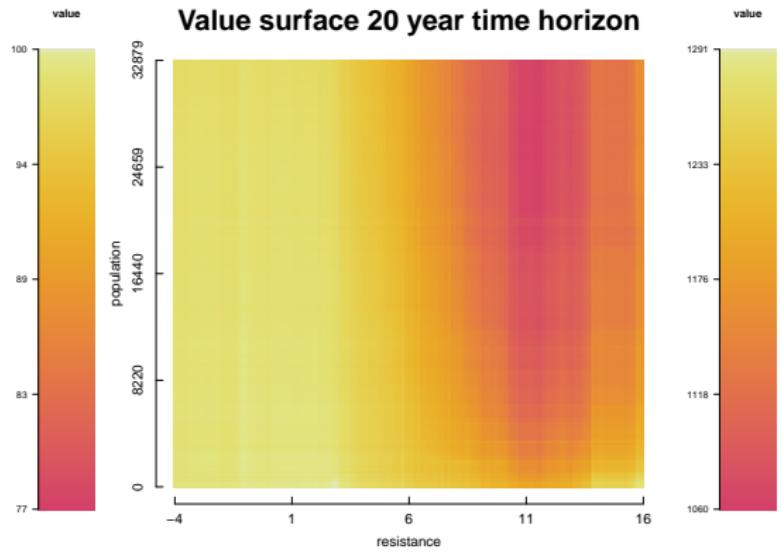
Starting at  $T$  go backwards  
in time



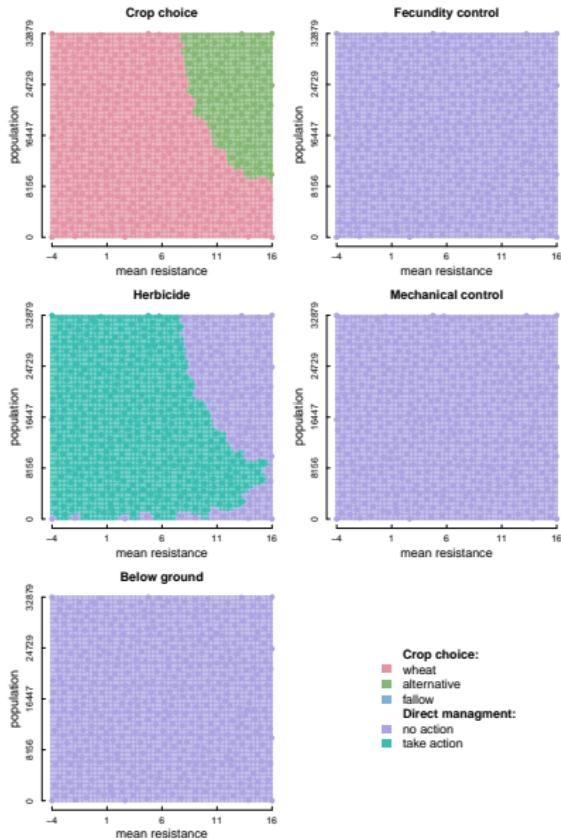
### Value surface myopic



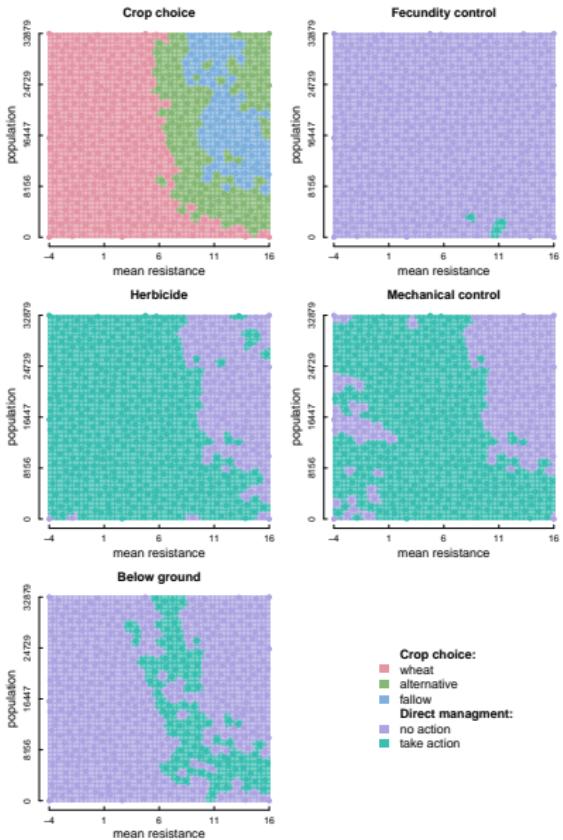
### Value surface 20 year time horizon



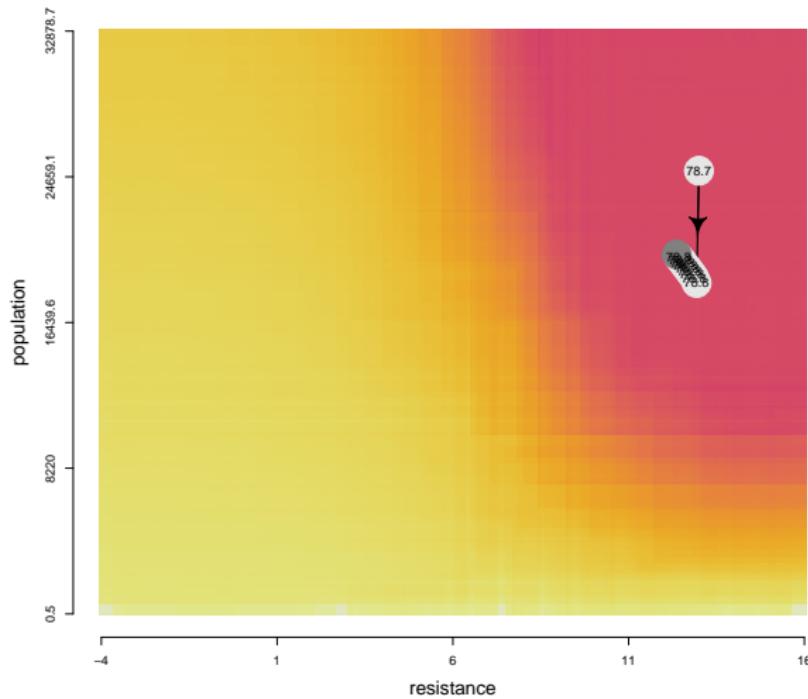
## Myopic policy



T = 20 policy

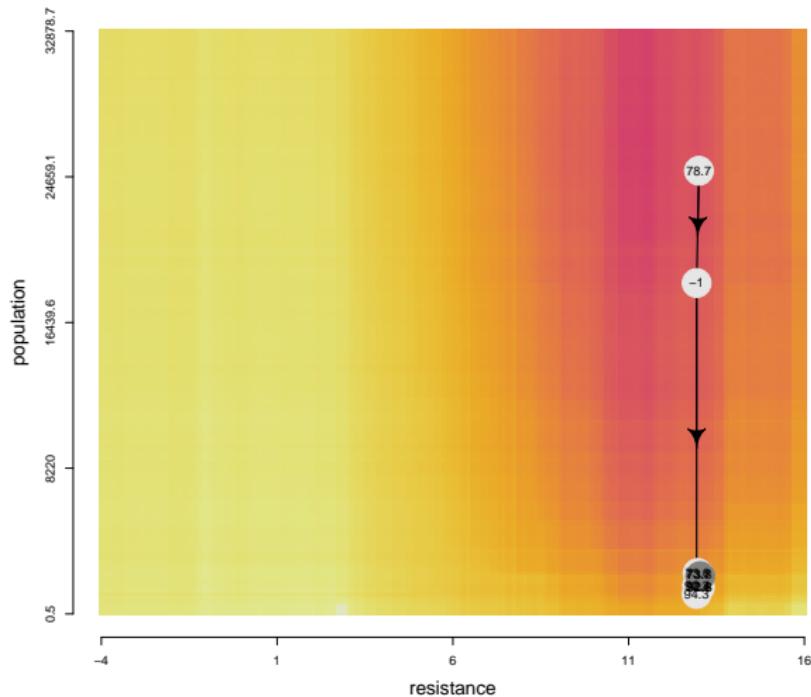


# Action over time: Myopic



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 differences translate into different optimal actions.