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Are golf courses a source or sink of atmospheric CO_2: A modeling approach

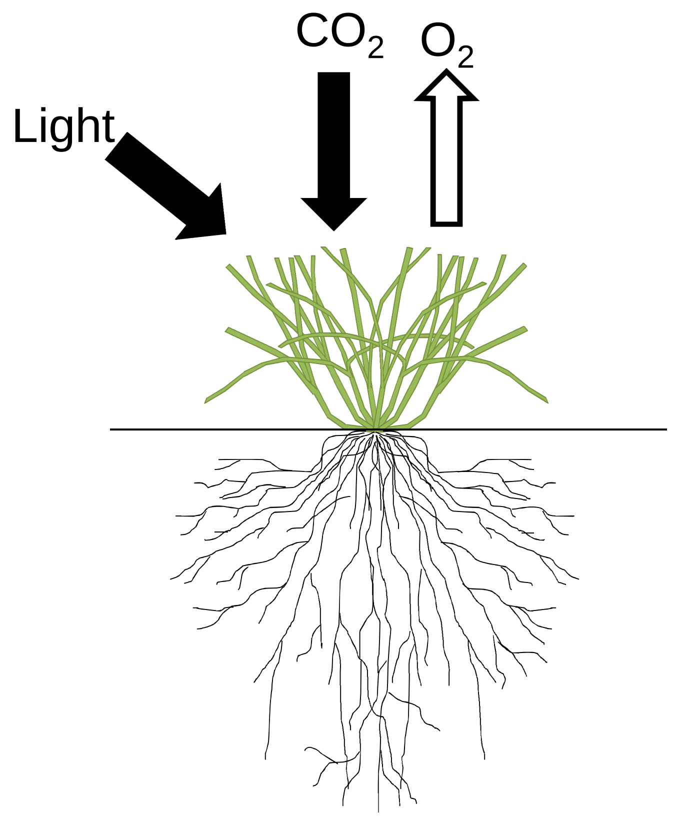
Co-author: I. James

The global carbon cycle

- Recent studies have shown that increased CO_2 concentrations in the atmosphere are resulting in changes to the global climate
- Anthropogenic CO_2 emissions have been strongly implicated in these changes and ambitious reduction targets have been established
- National and international governmental policies are driving increased accountability for every industry's contribution CO_2 emissions

Turf in the global carbon cycle

- Plants generate their energy from carbohydrates from atmospheric CO_2 and H_2O in photosynthesis
- Most of the carbohydrates produced are simple sugars and used by the plant to grow and develop
- Carbon is sequestered when it is locked in recalcitrant form, normally as soil organic matter
- Turfgrass is photosynthetic, so is capable of sequestering atmospheric CO_2



Emissions from modern pitches

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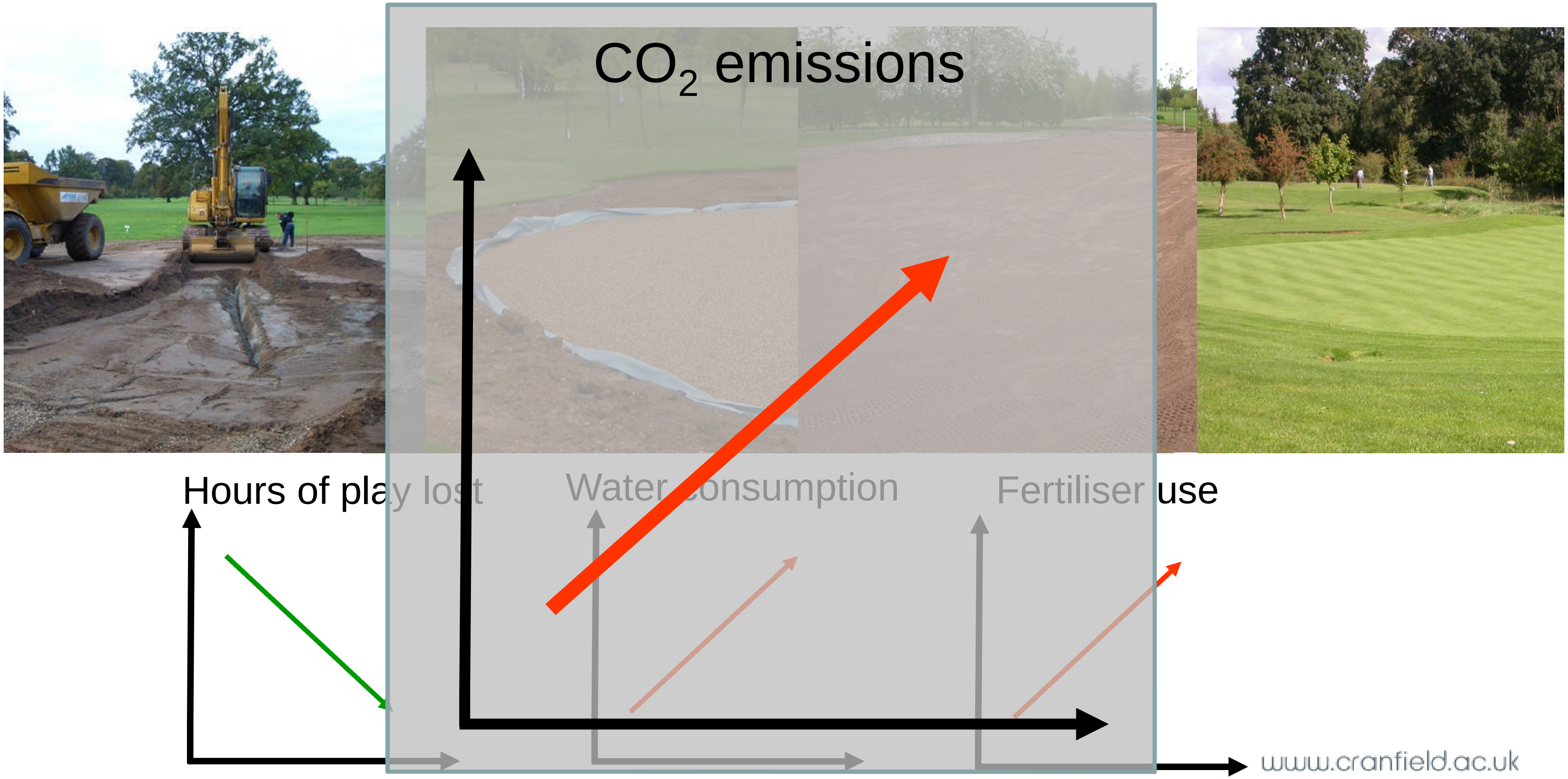
- The construction and management of fine turfgrass is resource intensive



Informing the sustainability debate

- Using a modelling approach (CranTurfC) this research addressed two questions:

1. What are the total direct annual CO_2 emissions for a golf course, and is a whole golf course a source or a sink for atmospheric CO_2?

2. How does the whole-system CO_2 efflux change in differently managed areas of a golf course?

Constructing CranTurfC

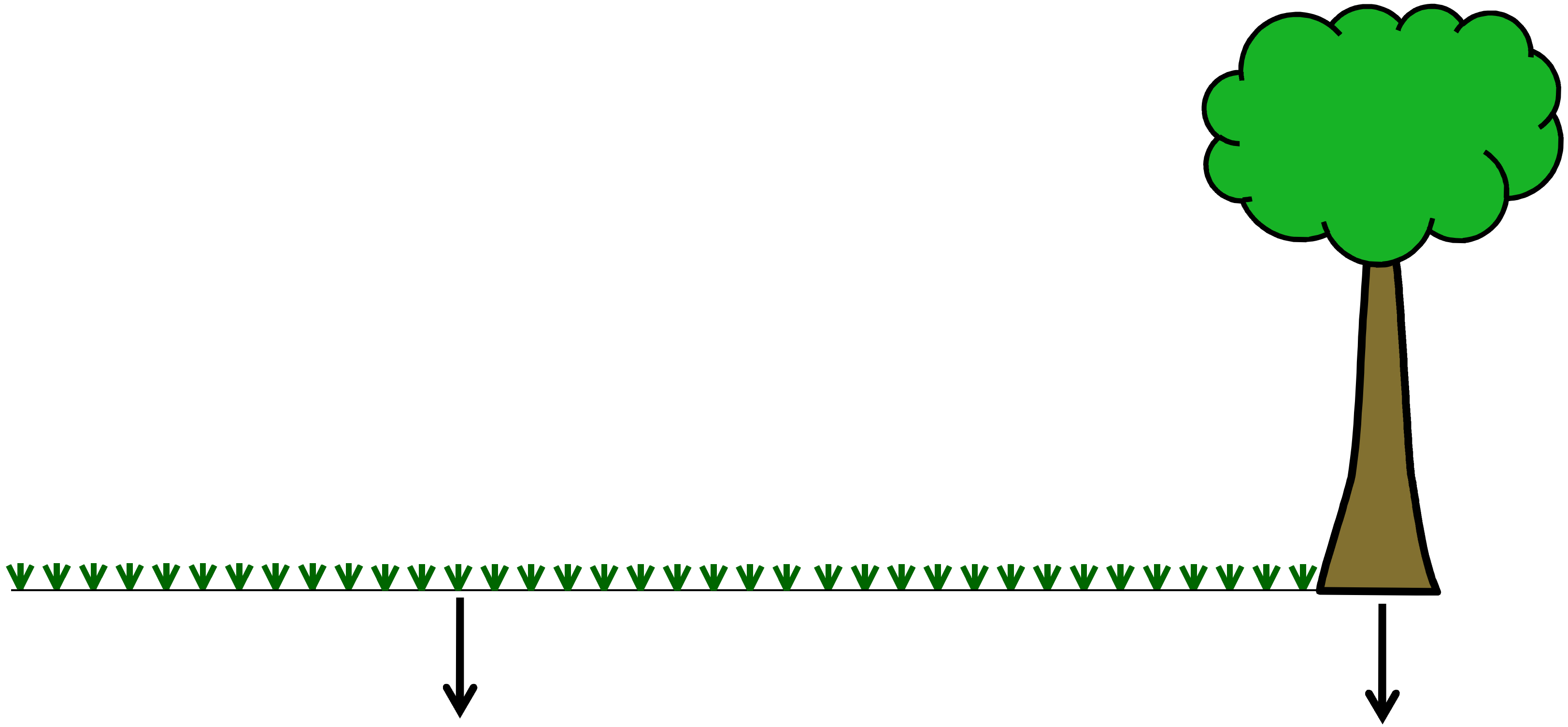
- A simple mass balance model

$$\chi = M - S$$

Where	χ	= CO_2 efflux for a whole golf course
	M	= Releases from maintenance
	S	= Sequestration on the golf course

Constructing CranTurfC

$$\chi = M - S$$



Sequestration: S = S_{turf} S_{trees}

Determining M

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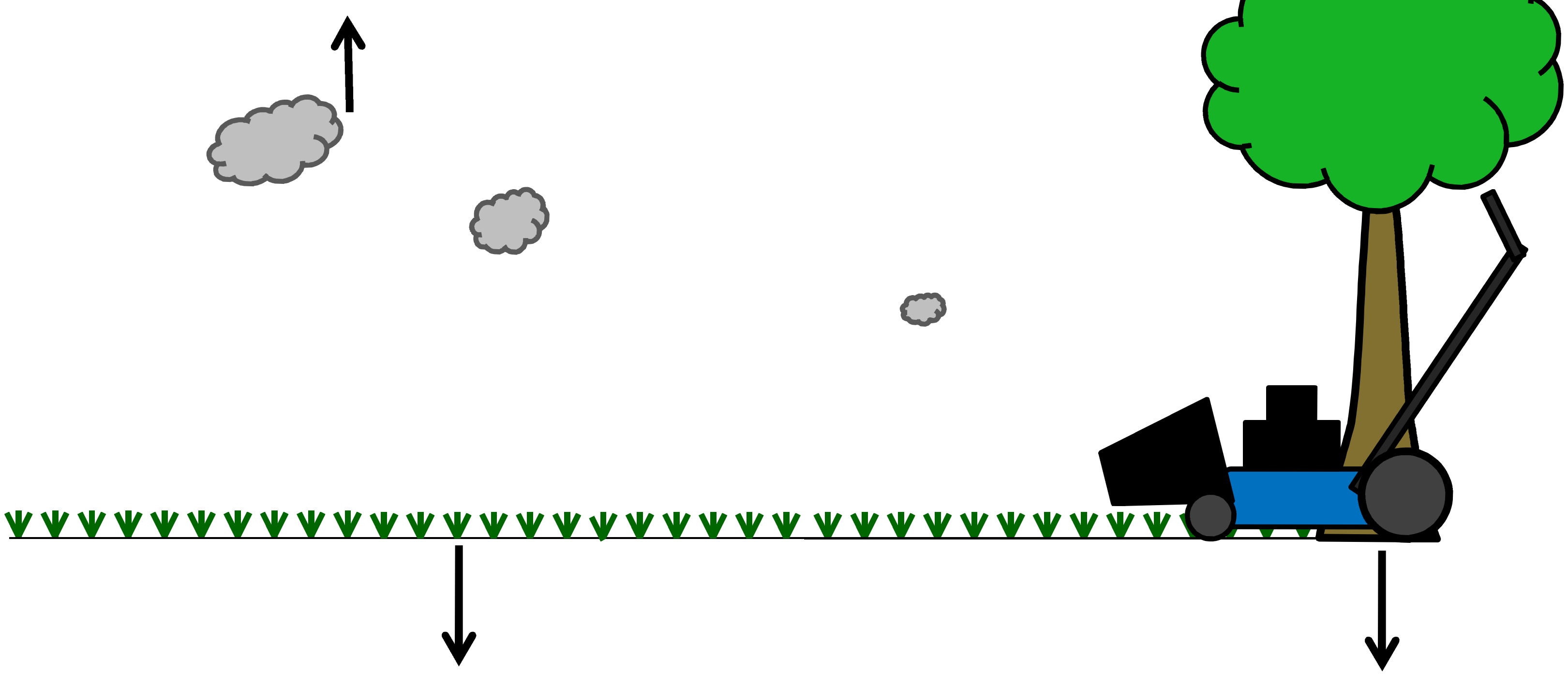
$\chi = M - S$

Emissions: $M = \quad \Sigma m$



Sequestration: $S = \quad S_{turf} \quad S_{trees}$

Determining M

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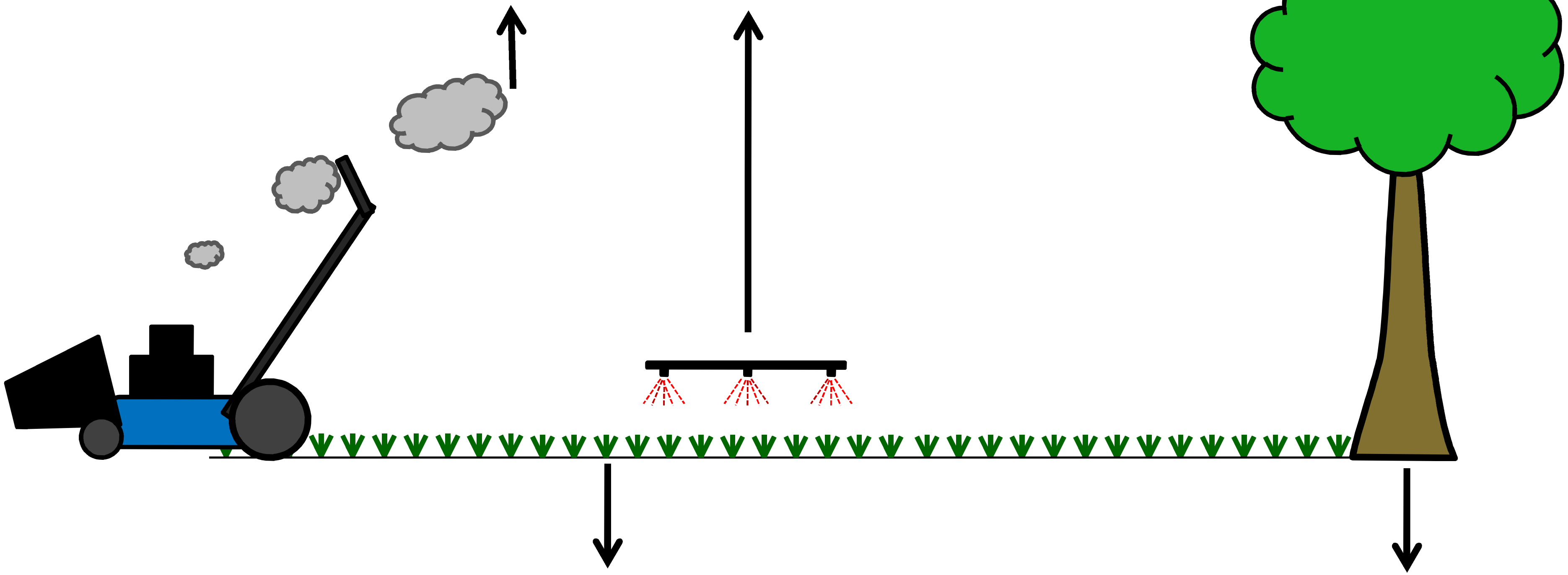
$\chi = M - S$

Emissions: $M =$ Σm Σa

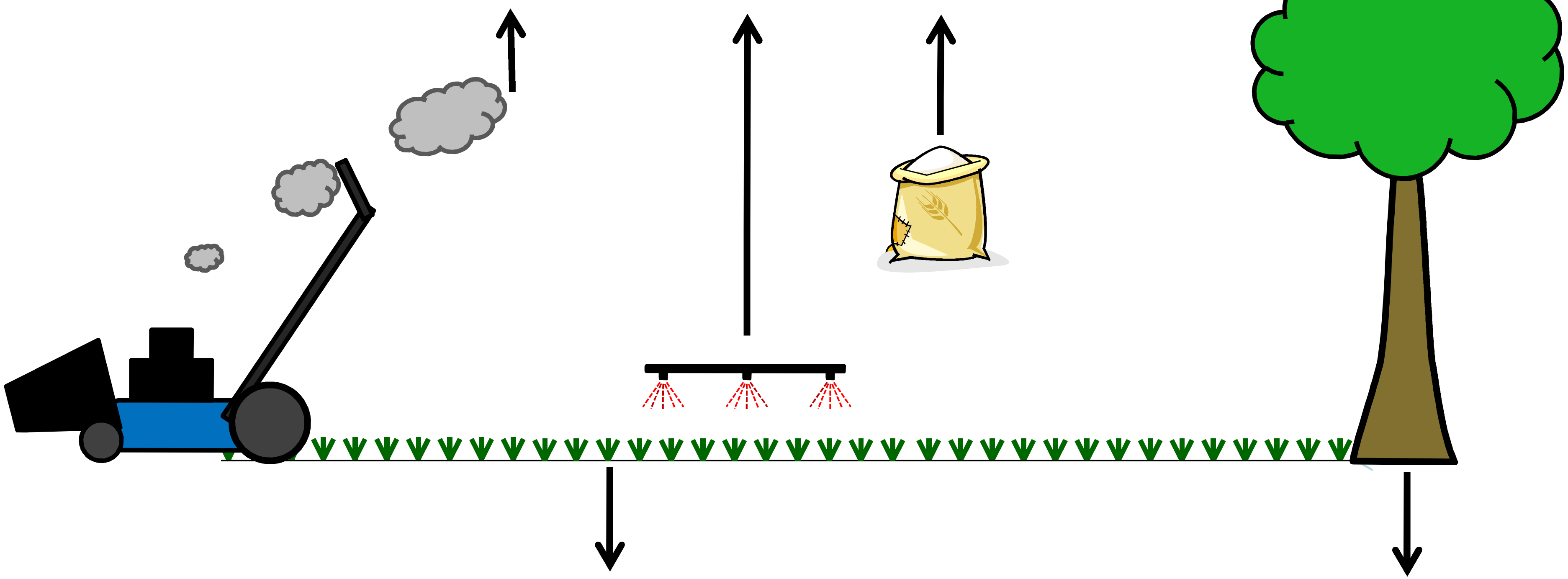


Sequestration: $S =$ S_{turf} S_{trees}

Determining M

$\chi = M - S$

Emissions: M = Σm Σa Σf



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Determining M

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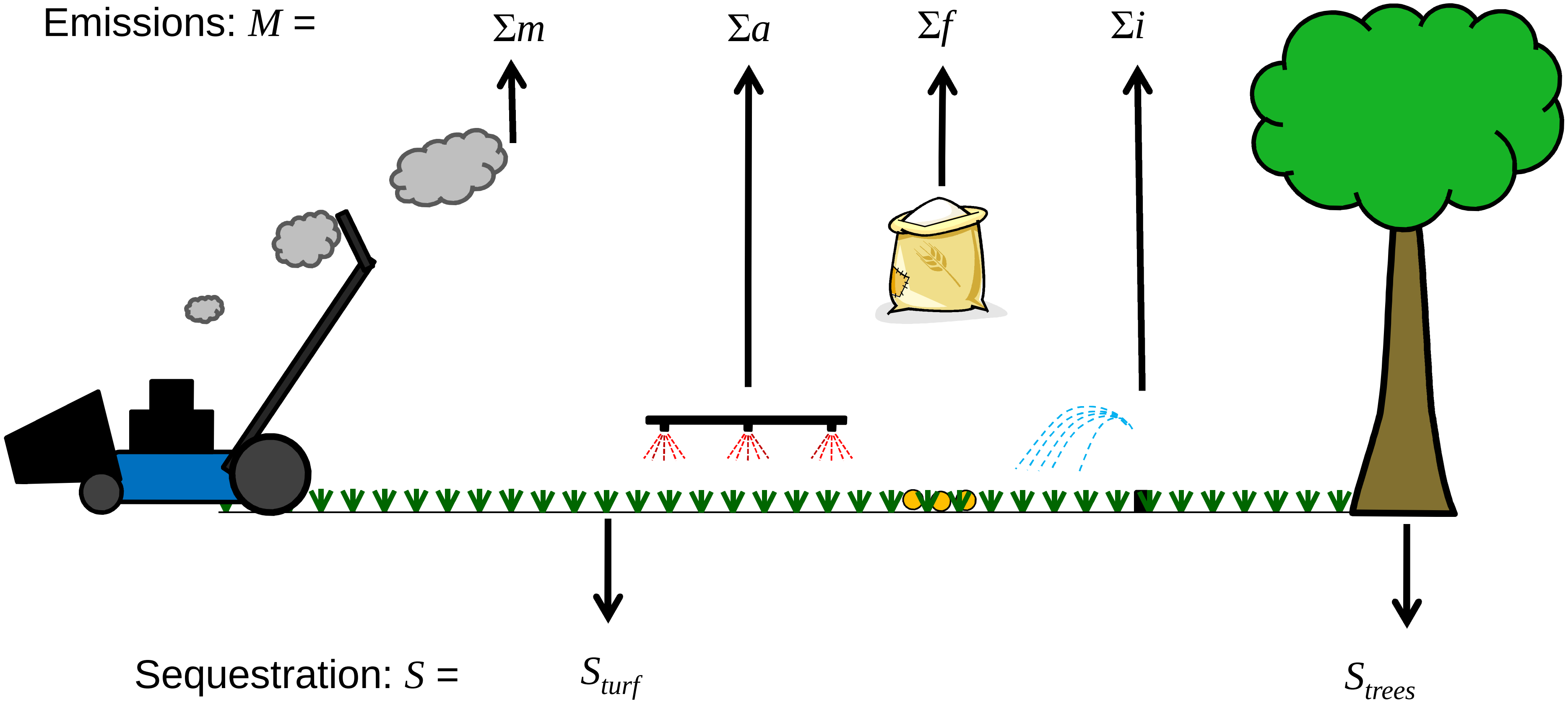

Determining M

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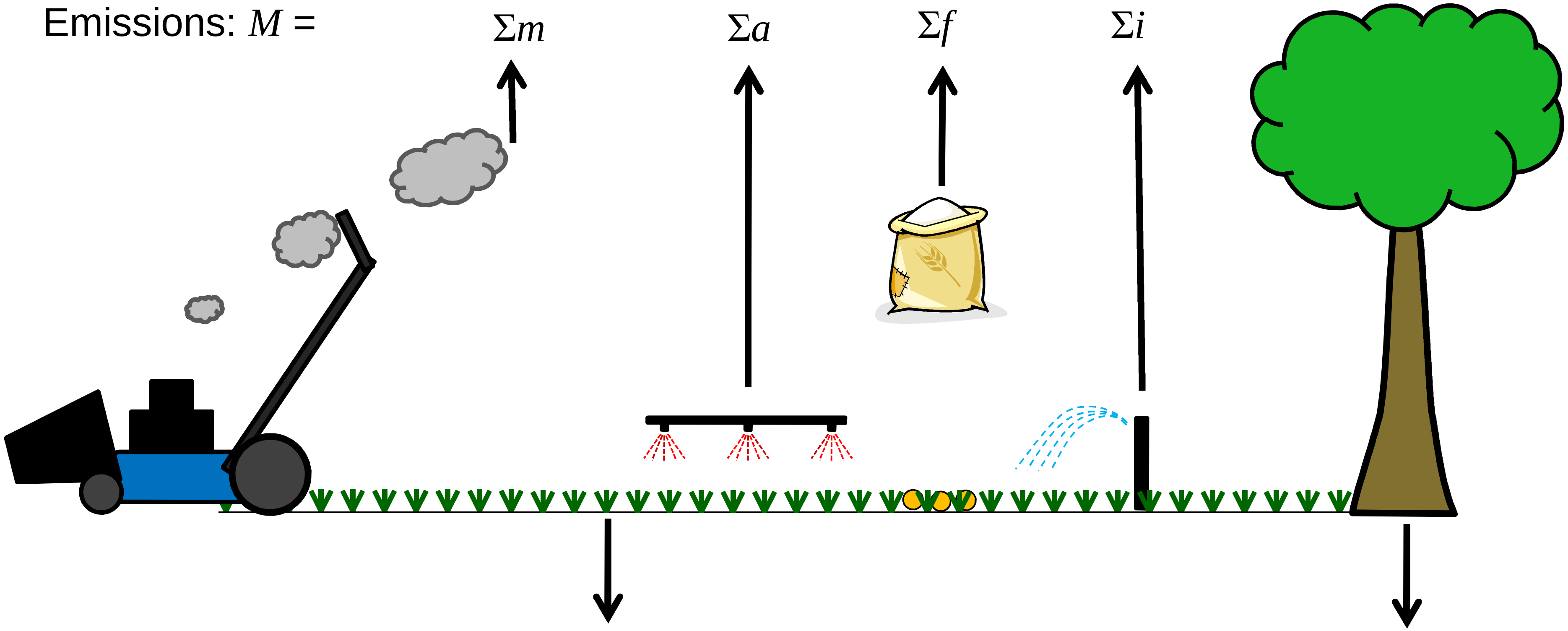
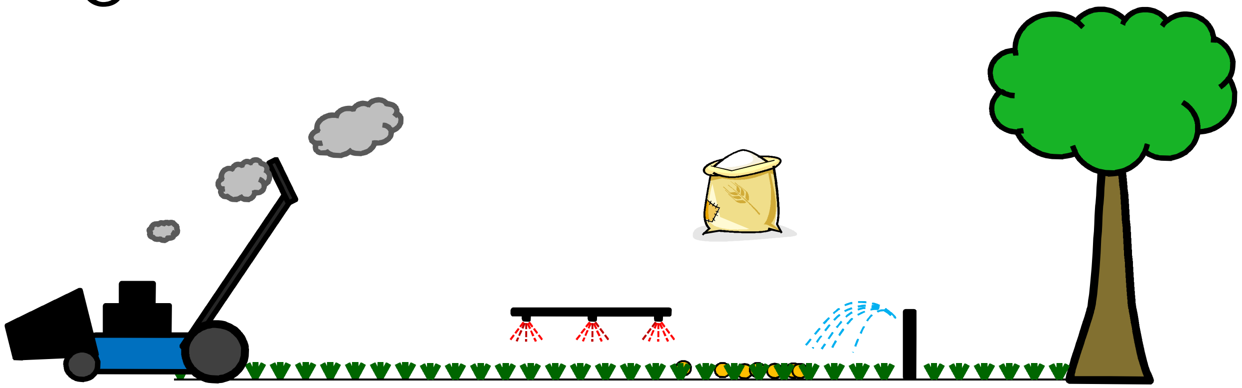
$\chi = M - S$

Emissions: M = Σm Σa Σf Σi



Sequestration: S = S_{turf} S_{trees}

Unpacking the model further



$$\chi = \left(\sum m + \sum a + \sum f + \sum i\right) - \left(S_{turf} + S_{trees}\right)$$

How often is the mower used?
How much fuel is used each time?
How often is the oil changed?

Landscape units of a golf course

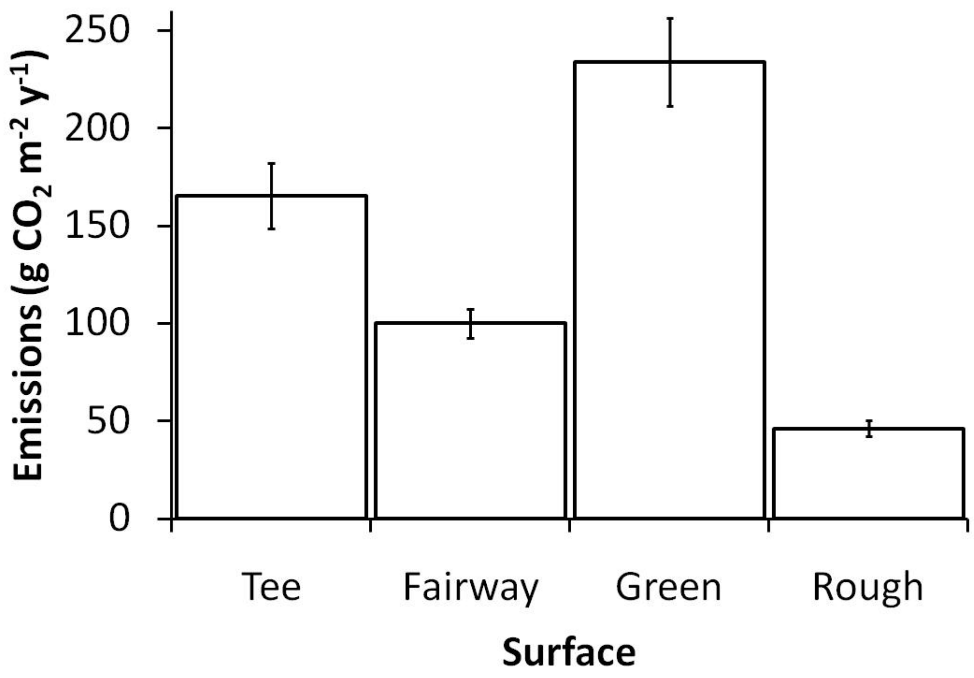
Input parameters

- Different types of sports surfaces have varied maintenance inputs (per m^2 per y)

Input parameter	Tee	Fairway	Green	Rough
Mowing frequency (n)	104	48	135	29
Volume of irrigation water (L)	20500	0	26000	0
Insecticide applications (n)	4	1	4	0
Herbicide applications (n)	2	0	6	0
Fungicide applications (n)	2	1	4	0
Fertiliser applications (n)	10	3	13	1
Nitrogen fertiliser (kg)	2.07	0.45	2.91	0.24
Phosphorous fertiliser (kg)	0.15	0.01	0.82	0.00
Potassium fertiliser (kg)	1.38	0.27	1.85	0.14

Model output, on an equal area basis

- The management of fine turfgrass on this (typical) golf course results in a net release of CO_2



- The magnitude of annual emissions is directly related to management intensity

Whiskers show standard deviation of 100 model iterations

Managing player expectations

- Mowing isn't just about keeping the grass short

Managing player expectations

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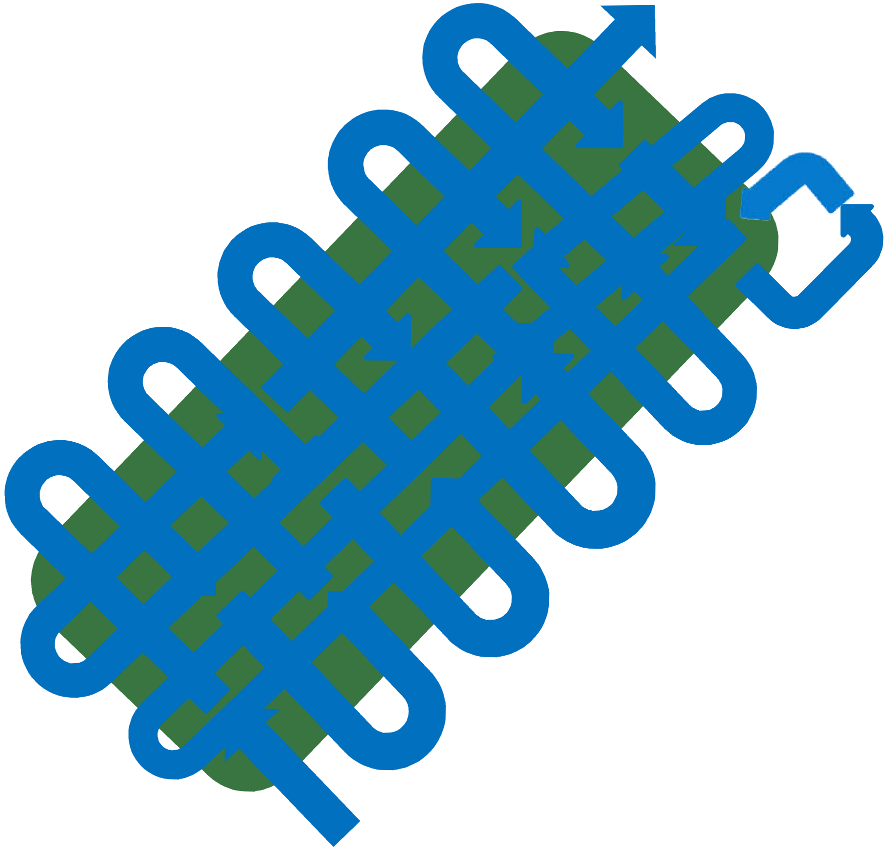

Managing player expectations

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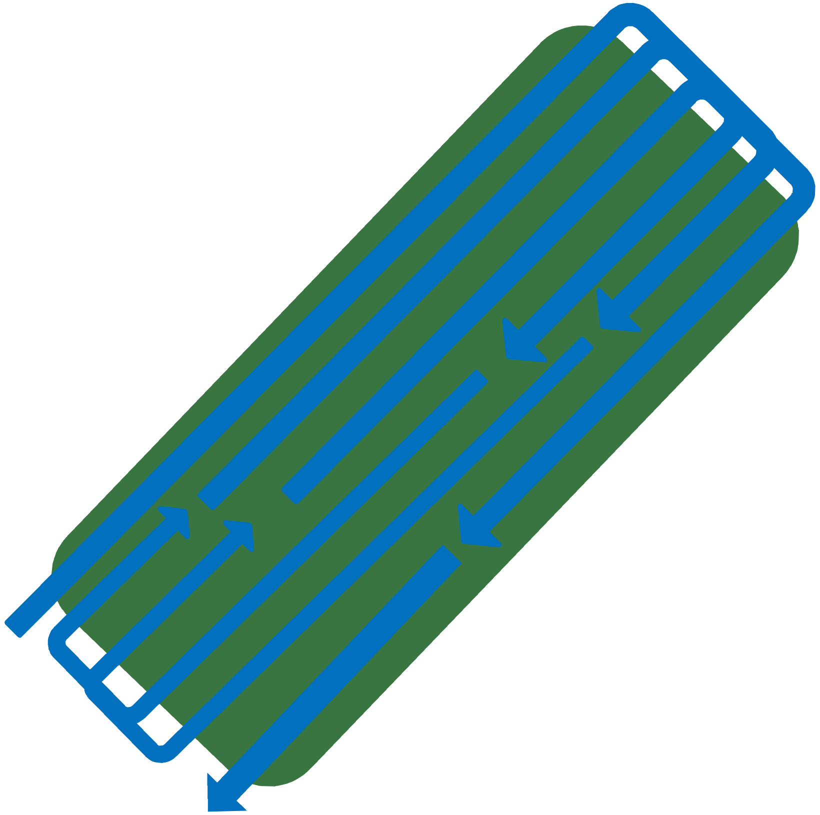

Managing player expectations

- Mowing isn't just about keeping the grass short

Scaling up: A UK parkland golf course

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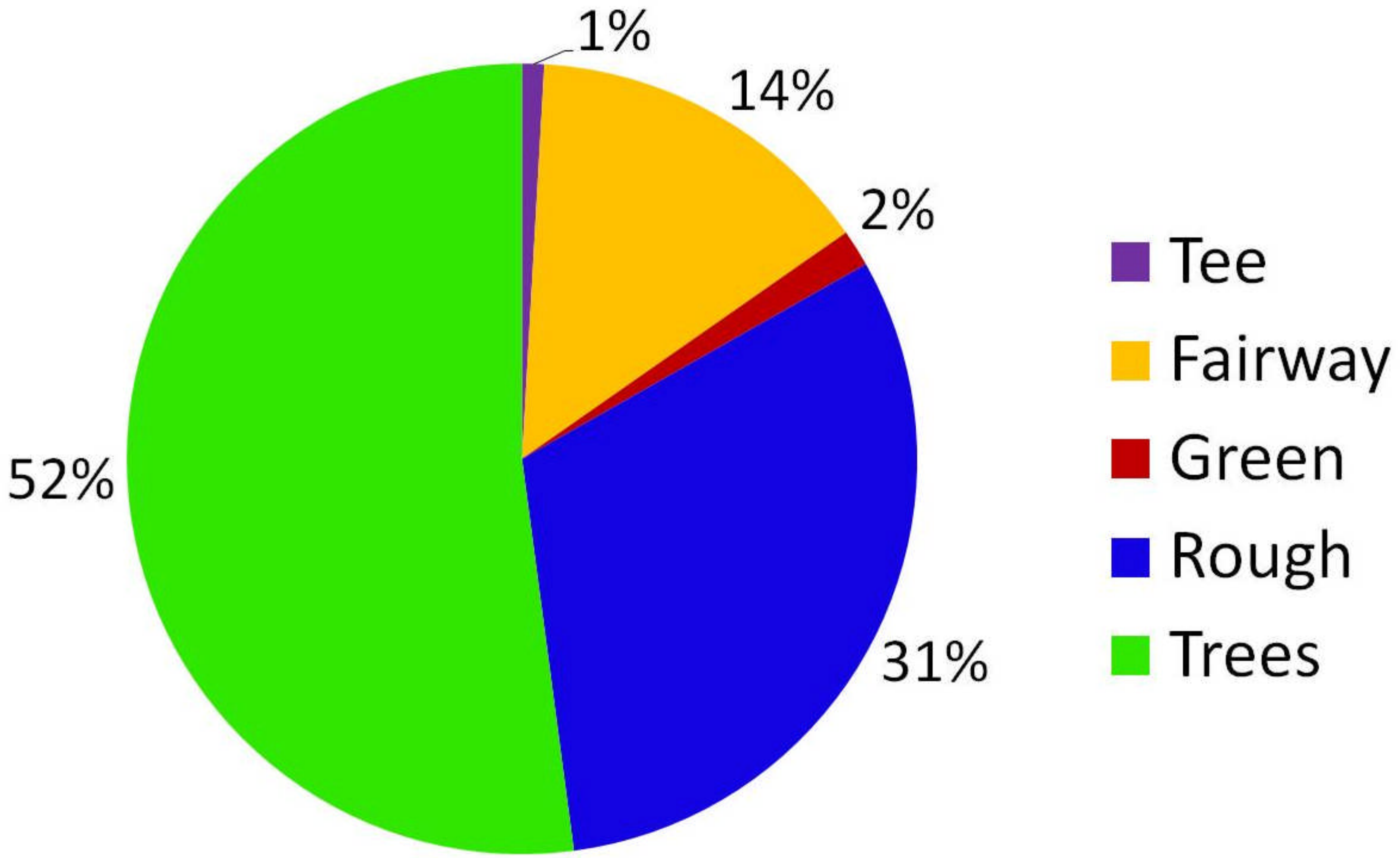
Golf course analysis

- Analysis of each landscape unit with aerial photo identification



Percentages are proportions of golf course by area

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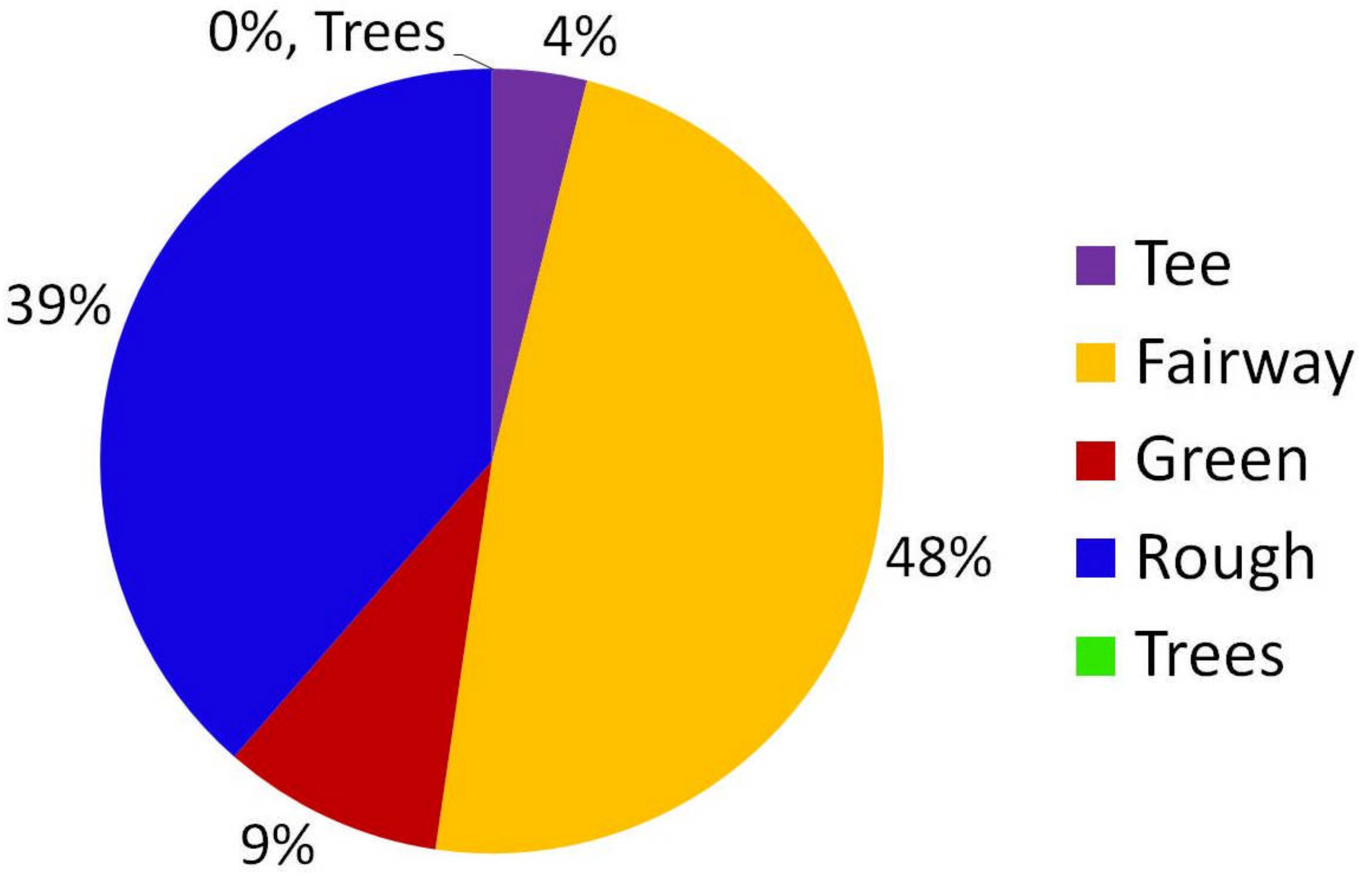
Golf course analysis

- Whole course contributions vary between landscape units



Whole system balance

- The trees on the golf course are a net sink for atmospheric CO_2 and there emissions from maintenance are negligible: - 172 g CO_2 m^{-2} y^{-1}
- Taking it back to the original mass balance equation for the whole course area, in Mg CO_2 y^{-1}

$$\chi = M - S$$

$$\chi = + 33.8 - 82.7$$

$$\therefore \chi = - 48.9 \text{ Mg } CO_2 \text{ } y^{-1}$$

$$\equiv - 0.53 \text{ Mg } CO_2 \text{ } ha^{-1} \text{ } y^{-1}$$

Values are the mean of 100 iterations

Using and adapting CranTurfC

- Relatively little data available to populate the model
    - Simplifications made about mowing equipment
    - Chemical and fertilizer synthesis
    - Some maintenance operations are outside the system boundary

- CranTurfC is sensitivity to uncertainty all input parameters

Using and adapting CranTurfC

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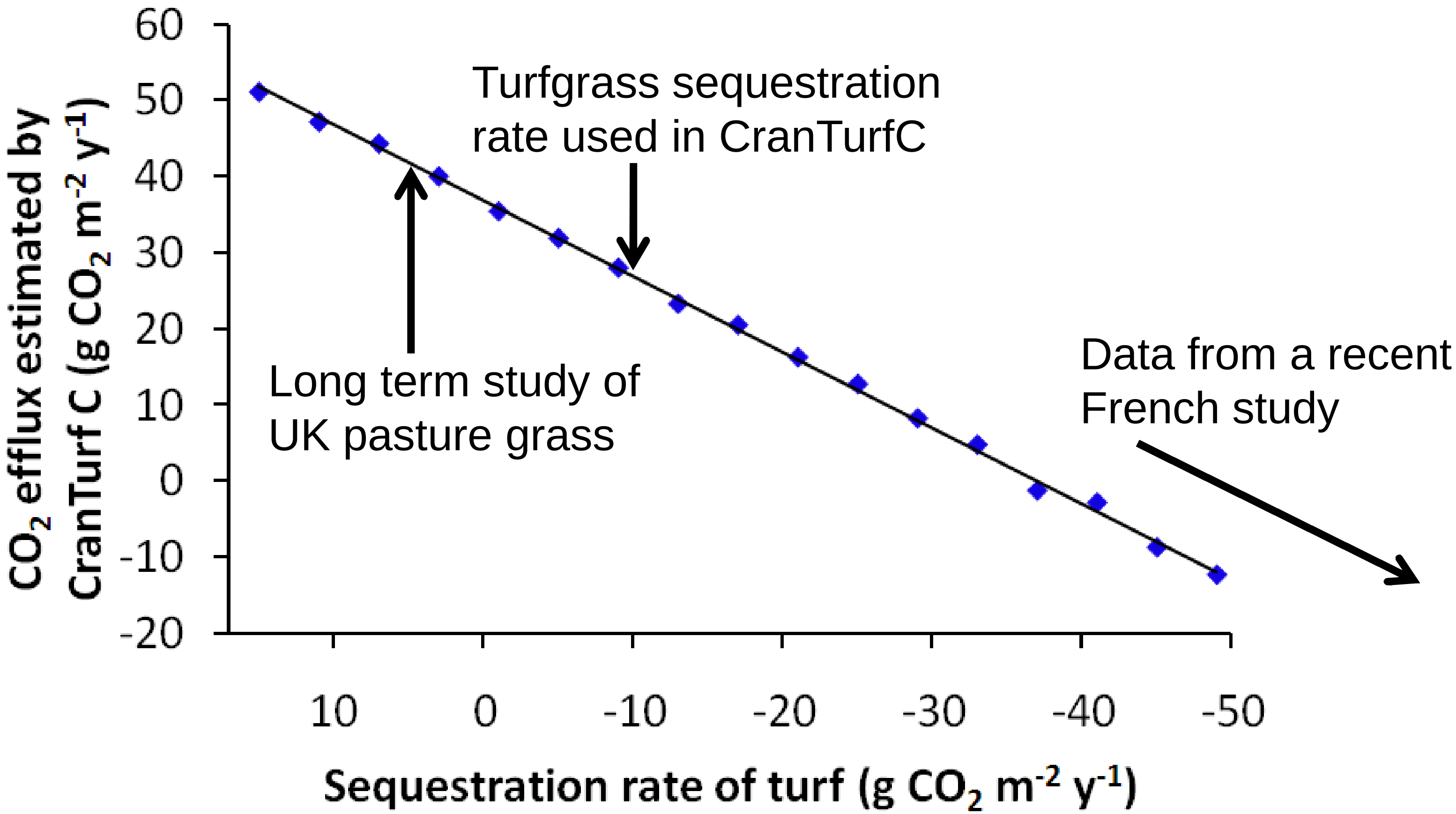
- An instrumented model was used to test sensitivity to sequestration



CranTurfC output for golf course rough

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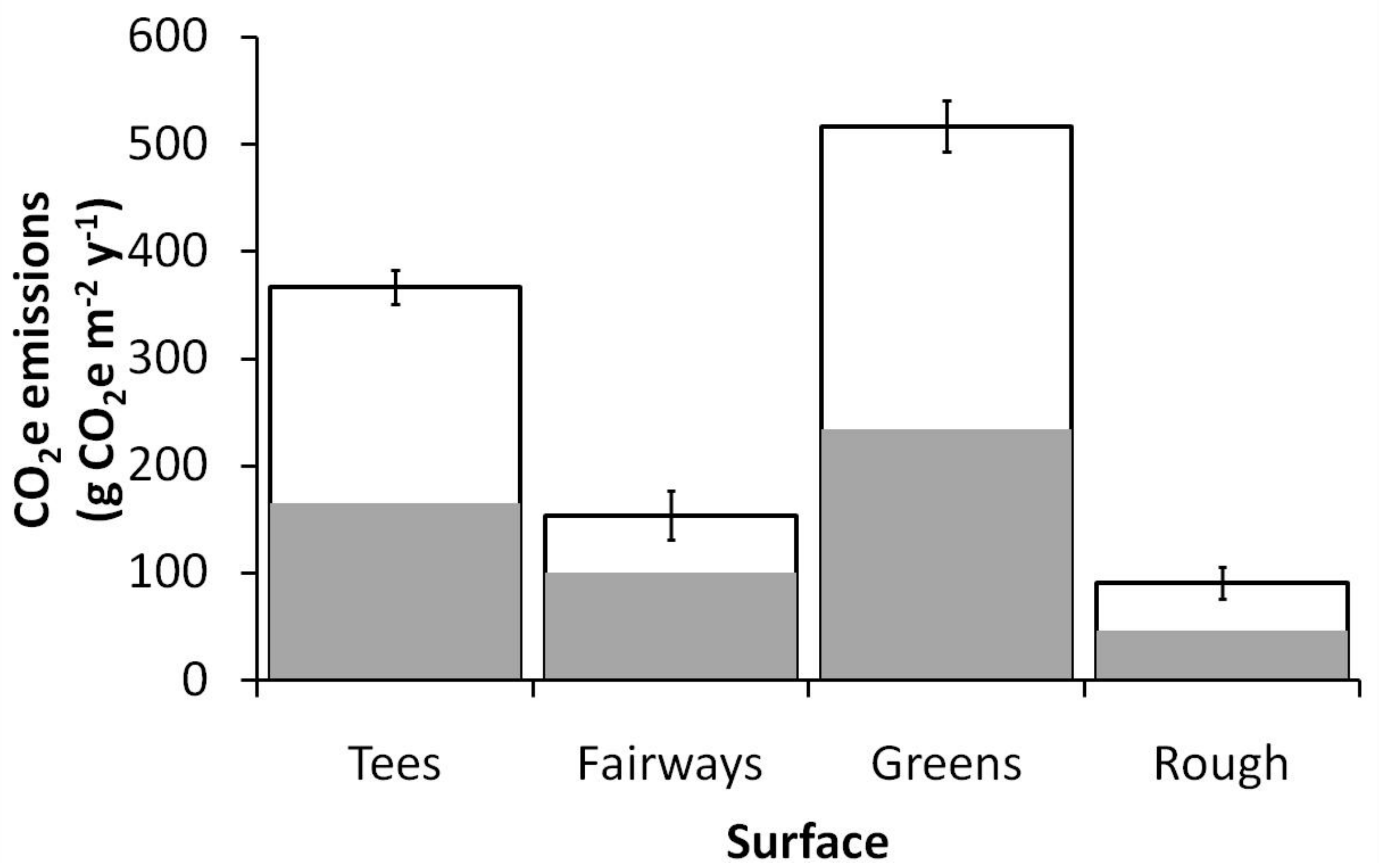
Latest adaptations of CranTurfC

- CranTurfC now accounts for all greenhouse gas emissions from turfgrass management as CO_2e



Bartlett and James (2010). A model of greenhouse gas emissions from the management of turf on two golf courses. Submitted.

Conclusions

The headlines from this research

- Management of fine turfgrass results in the net emission of CO_2 and the scale of these emissions are dependant on the intensity of management
- This model is applicable to all types of amenity and managed turfgrass (and with modification could be applied to synthetic turf)
- Further research and field trials are required to externally validate these findings

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