Carbon footprinting of crop production

Jonathan Hillier[1], Alex Hilton[2], Stuart Wale[2], Cathy Hawes[3], Geoff Squire[3], Pete Smith[1]

1. School of Biological Sciences, Cruickshank Building, St Machar Drive, University of Aberdeen, AB24 3UU, UK
2. Scottish Agricultural College, Ferguson Building, Craibstone Estate, Aberdeen. AB21 9YA.
3. Scottish Crop Research Institute, Invergowrie, Dundee. DD2 5DA

UNIVERSITY OF ABERDEEN

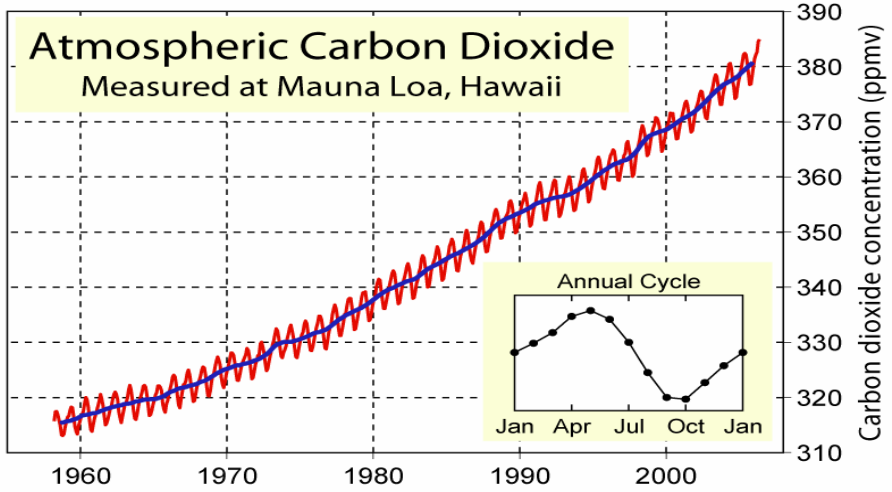
SAC

scri living technology

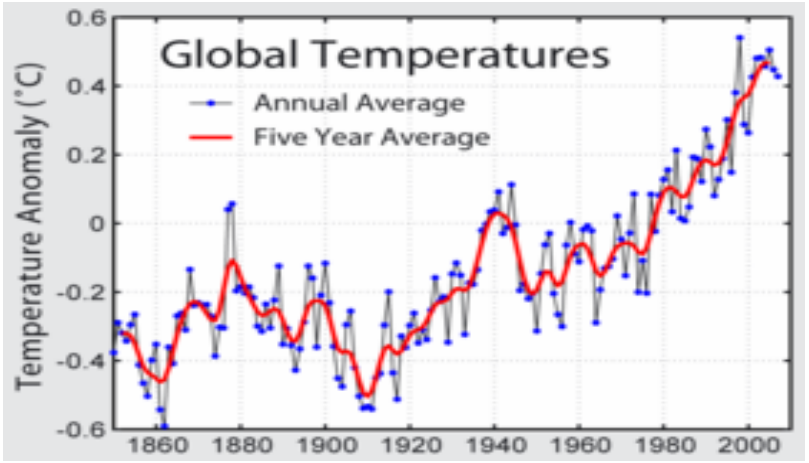
Plan

- Atmospheric CO_2 and global warming
- Bioenergy crops → potato
- Bioenergy crops (for methodology)
- Comparison of farm-gate C footprint of potato with other crops
  - 3 examples
  - are potatoes good or bad?
- Uncertainties
- Transport
- Scope for mitigation

Atmospheric CO_2 and global warming



http://en.wikipedia.org/wiki/Carbon_dioxide



http://en.wikipedia.org/wiki/Global_warming

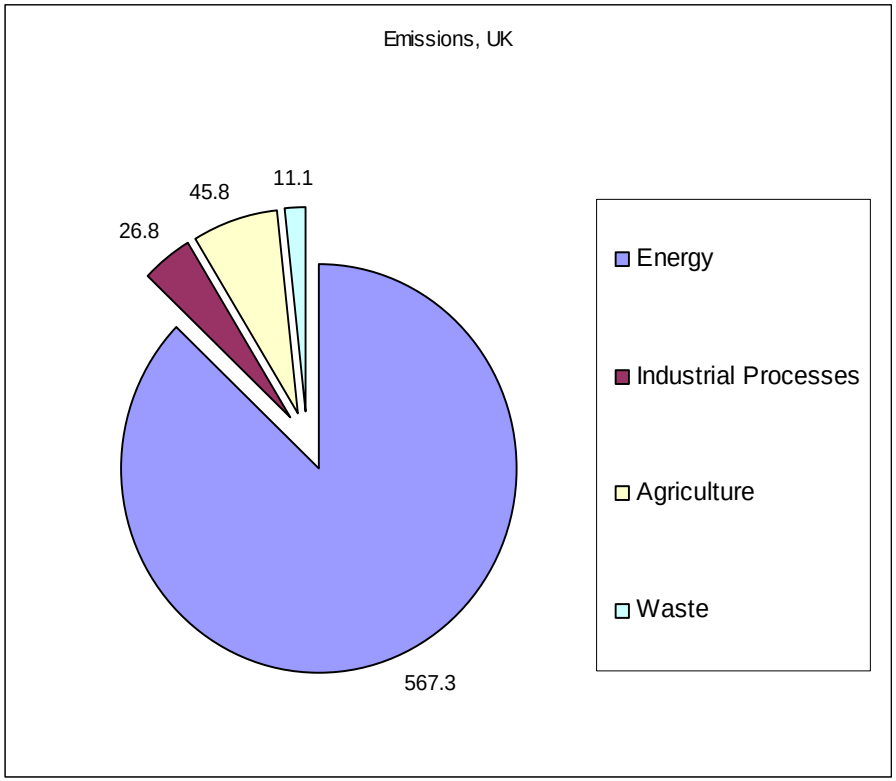
humans → CO_2 (IPCC – very likely)

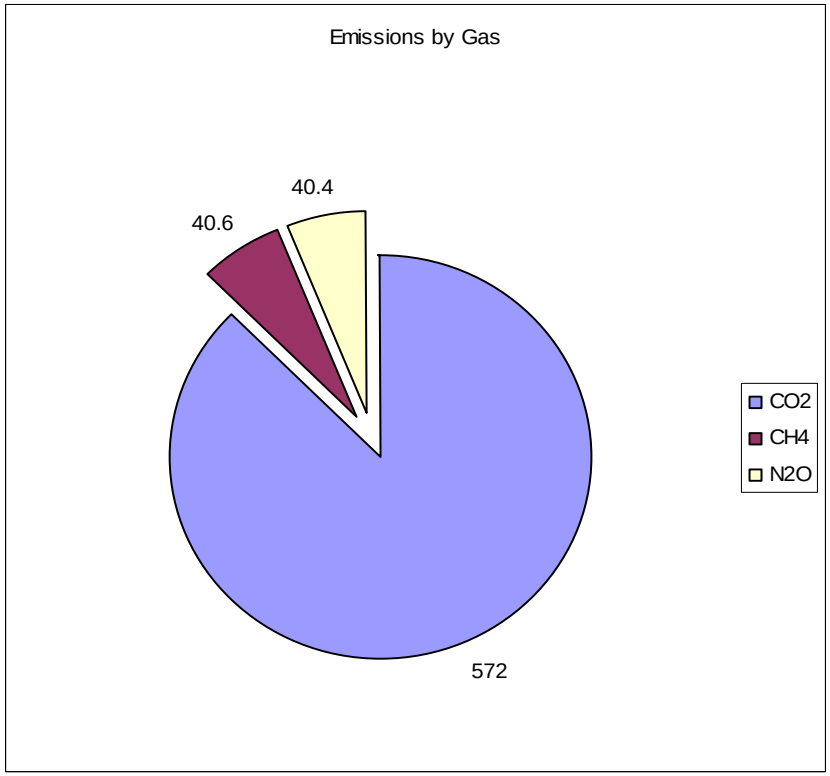
CO_2 → global warming (IPCC – unequivocal)

http://www.guardian.co.uk/environment/2008/jun/22/climatechange.carbonemissions

"The majority of the British public is still not convinced that climate change is caused by humans - and many others believe scientists are exaggerating the problem…"

Annual GHG emissions – sector and compound (Mt CO_2 eq)





http://www.ghgi.org.uk/sector.html

How I ended up working on potatoes

SAC

Alex Hilton *(Crop Services)*

Stuart Wale *(Crop Services)*

Aberdeen University

Soil C&N modelling & Climate change

Jon Hillier *(emissions/carbon footprint of bioenergy crops)*

Pete Smith

SCRI

Cathy Hawes *(Environment Plant Interactions, Farm surveys)*

Geoff Squire *(Environment Plant Interactions)*

How I ended up working on potatoes

SAC

Alex Hilton *(Crop Services)*

Stuart Wale *(Crop Services)*

Aberdeen University

Soil C&N modelling & Climate change

Jon Hillier *(emissions/carbon footprint of bioenergy crops)*

Pete Smith

SCRI

Cathy Hawes *(Environment Plant Interactions, Farm surveys)*

Geoff Squire *(Environment Plant Interactions)*

How I ended up working on potatoes

SAC

Alex Hilton *(Crop Services)*

Stuart Wale *(Crop Services)*

Aberdeen University

Soil C&N modelling & Climate change

Jon Hillier *(emissions/carbon footprint of bioenergy crops)*

Pete Smith

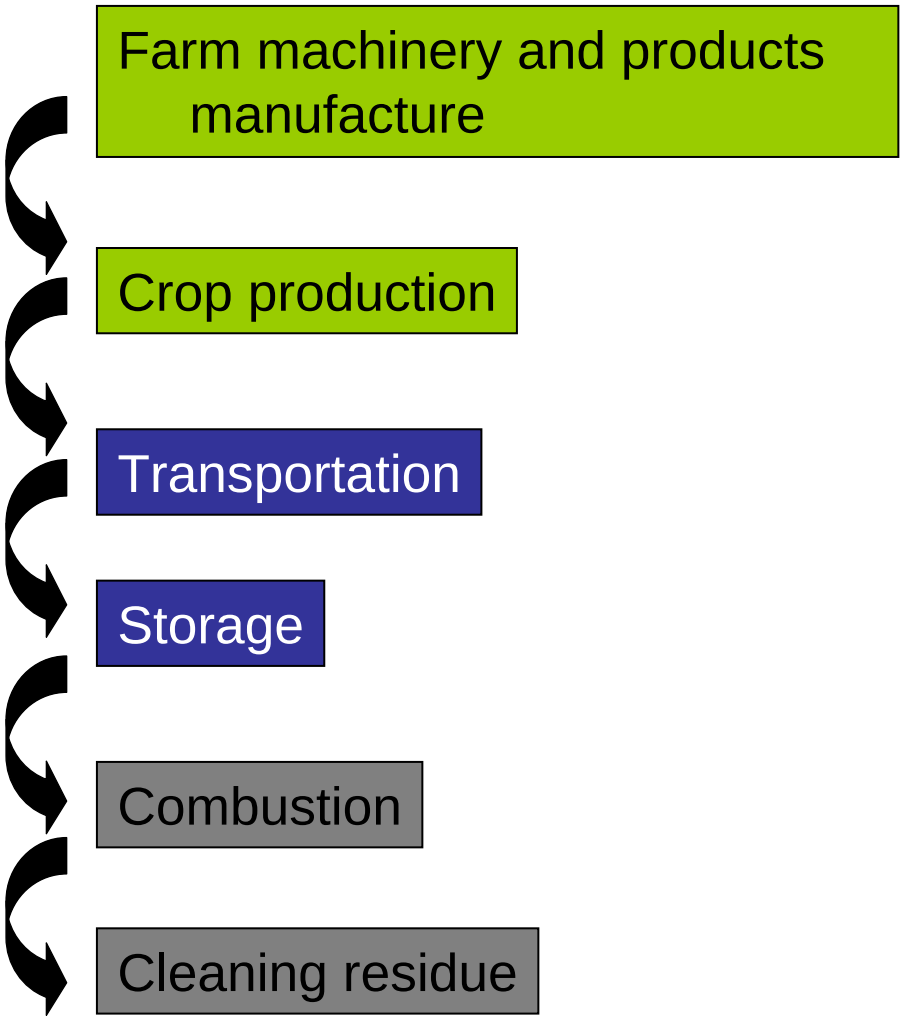
SCRI

Cathy Hawes *(Environment Plant Interactions, Farm surveys)*

Geoff Squire *(Environment Plant Interactions)*

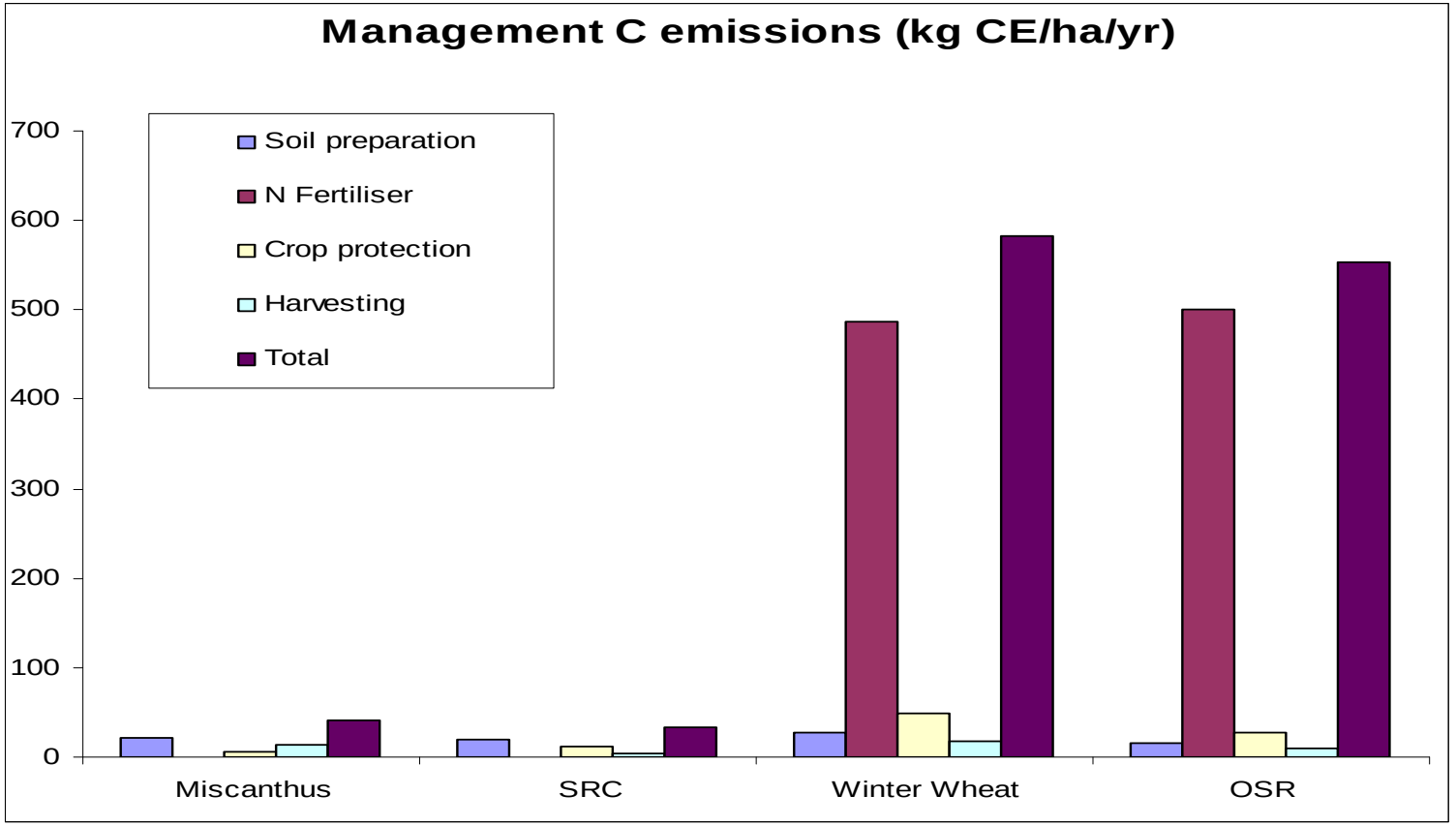
Bioenergy Crops – Full Life Cycle Analysis. C footprint.

- C emissions for whole of life cycle from planting to combustion and waste disposal
  - farm gate
    - machinery manufacture (e.g. tractors)
    - product manufacture (e.g. fertilisers)
    - mechanical operations (e.g. ploughing, planting, harvesting, spraying)
  - beyond farm gate
    - transportation
    - storage
    - combustion
    - cleaning
  - etc…



Farm gate emissions - method

- Need to know
  - what is done to the field (management)
  - emissions for each operation/unit of product applied
- Growers guides
- Data for emissions mostly obtained from Lal 2004, Carbon emissions from farm operations. *Environment International* 30: 981-990.
  - product (fertiliser, herbicides, insecticides, fungicides) manufacture & storage)
  - emissions from diesel used in mechanical operations



	Miscanthus	SRC	Winter Wheat	OSR
Soil preparation (e.g.ploughing, drilling, discing, etc)	21.674	19.094	28.2	16.3
Fertiliser (N,P,K)	0	0.72	487.16	500.584
Crop protection (pesticide, herbicide, etc)	6.08	10.9	49.45	26.85
Harvesting	13.3	3.3333	17.95	10
Total	**41.054**	**34.0473**	**582.76**	**553.734**

N is BAD!

- For every 100kg N applied 1.25 kg N is emitted as N_2O (IPCC – Bouwman *et al**).
- N_2O is a BAD greenhouse-gas!
  - global warming potential (GWP) of 310
  - 1 kg of N_2O is equivalent to 310 kg of CO_2.
- (from molecular weights) every 1 kg N applied gives emissions equivalent of 6.08 kg CO2.
- Or 1.66 kg C
- Add production cost (Lal 2004), of 1.3 kg C/kg to get 2.96 kg C/kg N produced
- e.g. 200 kg of N fertiliser adds 0.6 tonnes C to the C footprint

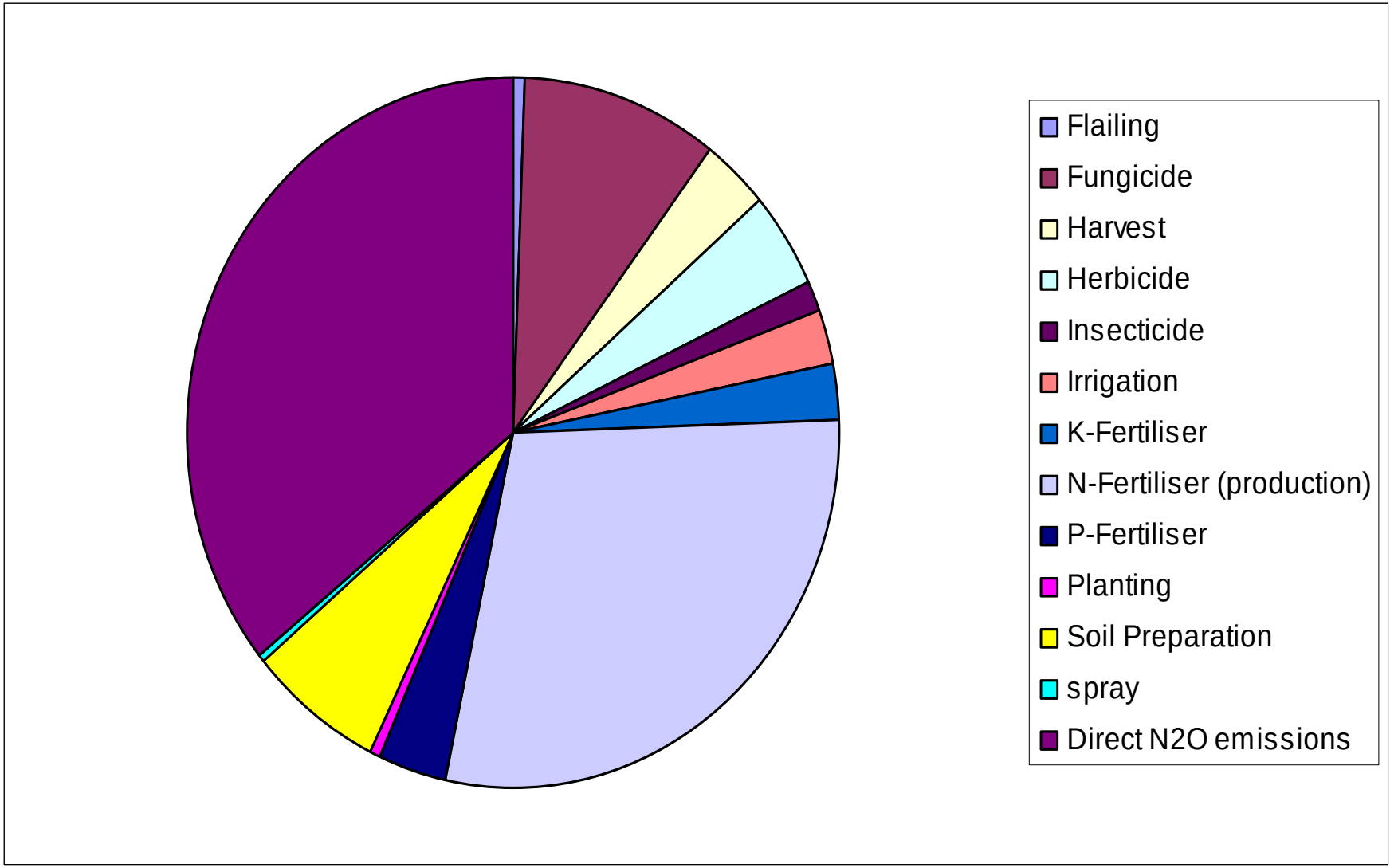
Bouwman *et al* 2002, Emissions of N_2O and NO from fertilised fields: Summary of available data, Global Biogeochemical Cycles, 16(4): 1058.

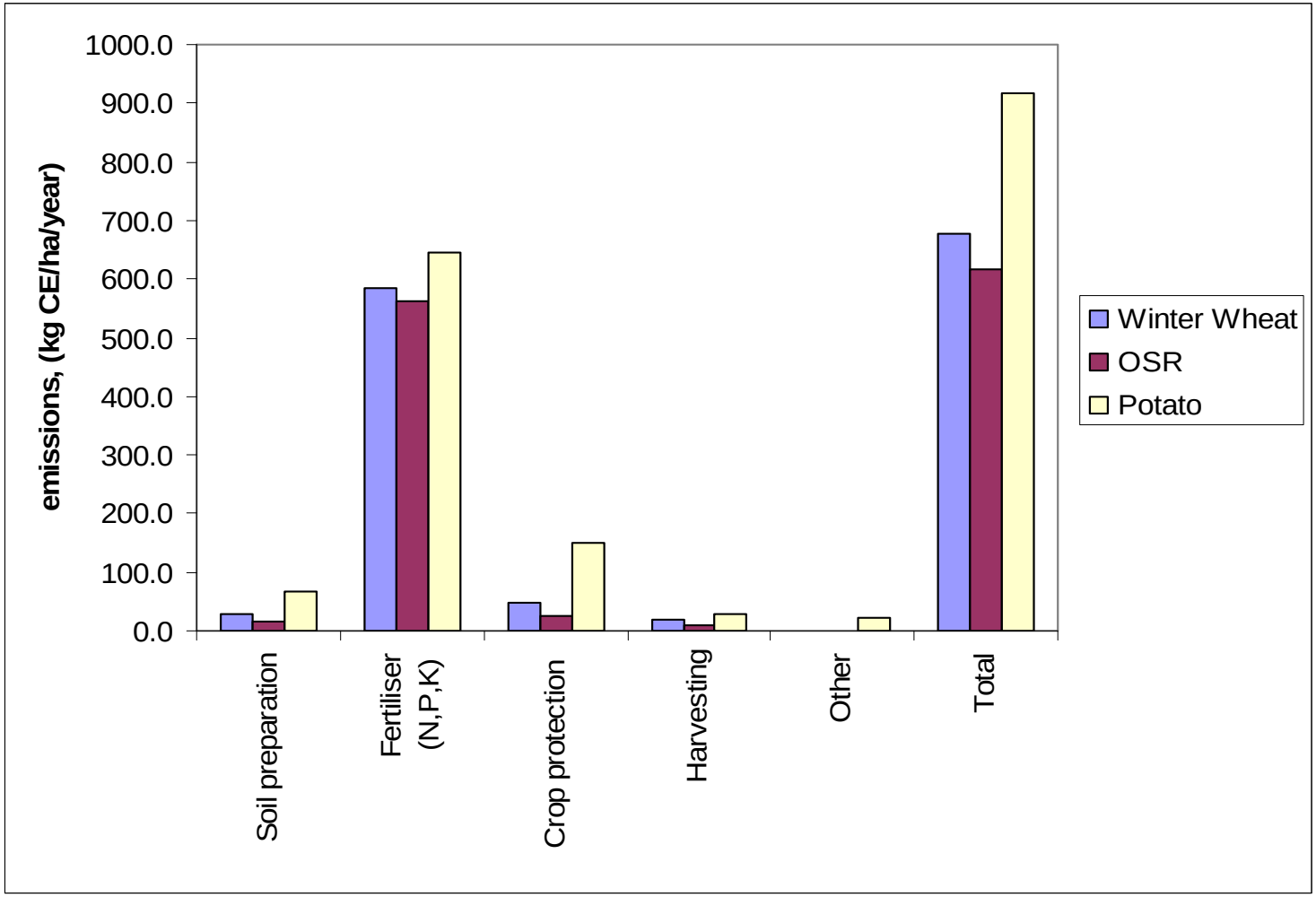
Potato, Winter Wheat, Oilseed Rape

	Winter Wheat	Oilseed Rape	Potato
Soil preparation/planting (mechanical)	3	4	6
Fertiliser N	197	190	200
Crop protection	7	6	10
Harvest	2	2	3
Other			irrigation
	Koga et al (Eco & Env 2003, 99:213-9)	HGCA growers guide, DEFRA fertiliser recommendations	SAC, Alex Hilton

Potato footprint - approximately 924 kg CE/ha/year

(SAC potato newsletter)





	Winter Wheat	OSR	Potato
Soil preparation	28	16	75
Fertiliser (N,P,K)	583	562	644
Crop protection	49	26	153
Harvesting	18	10.0	29
Other	0.0	0.0	23
Total (kg CE/ha/year)	679	616	925

Farm surveys

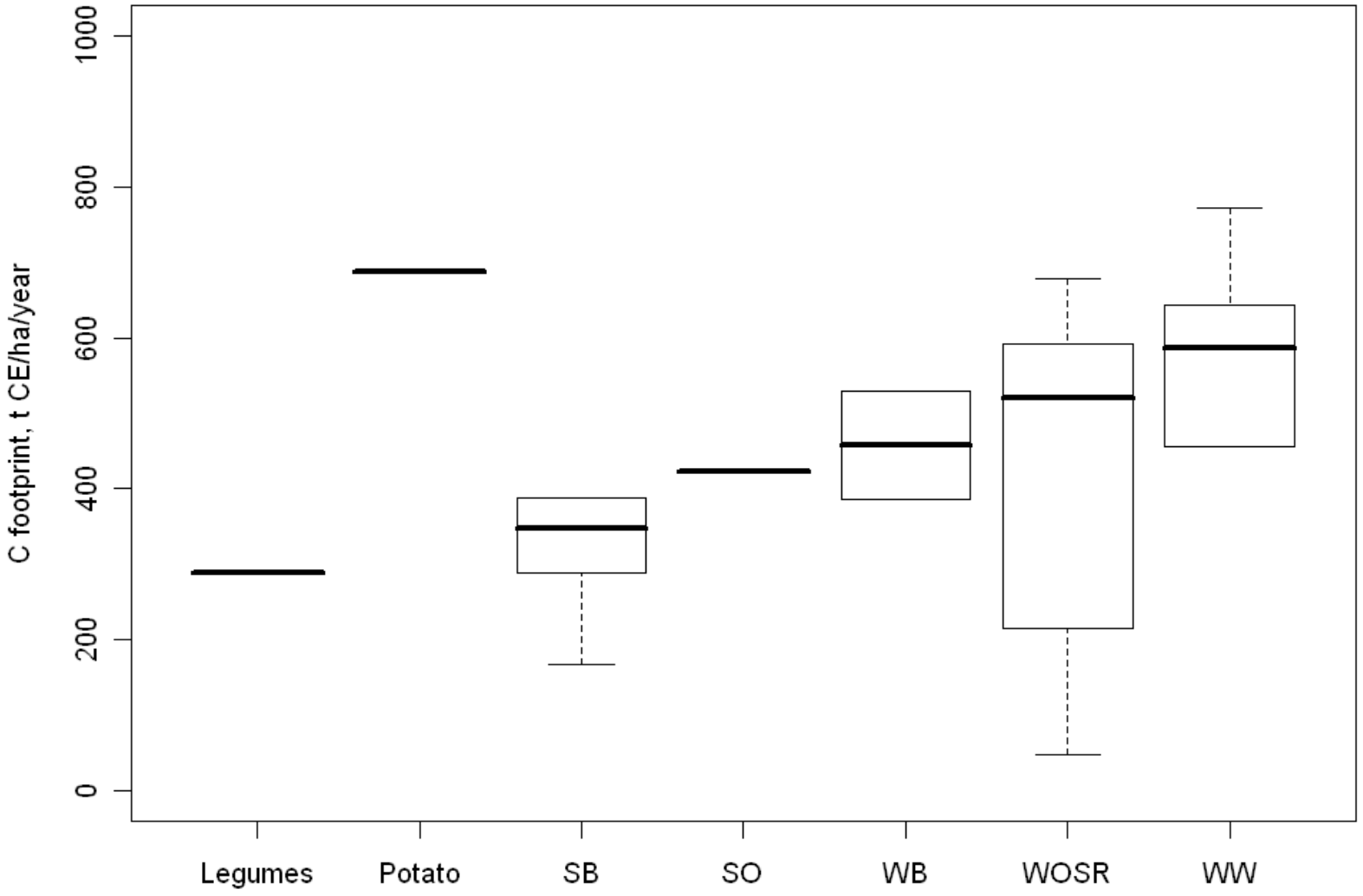
- Conducted by SCRI and SAC (part of the Scottish Government funded work programme)

- actually conducted for studying biodiversity and soil resilience but the farm management component is useful to us

- 57 farms in Scotland
- range of crops
- organic, LEAF, and “conventional” farming
- only “conventional” is considered here (sadly only 1 potato crop in this group)

Mechanical operations		C cost (kg CE/ha)	Winter wheat	Totals
Soil preparation	Ploughing	15.2	1	15.2
	Harrowing	1.7	1	1.7
	Discing	5.8		0
	Direct drill	3.2		0
	Combo Drilling	3.2	1	3.2
	Other sowing/planting	6.4		0
	Rolling	1.7	1	1.7
	Subsoiling	11.3	1	11.3
	Potato planter	6.9		0
Product Application	Fertiliser spraying	0.9	3	2.7
	Herbicide spraying	1.4	4	5.6
Removal		C cost (kg CE/hour)		
Harvesting	Combining	33.3	0.3	9.99
	Carting	1.44	0.5	0.72
	Baling	19.3	0.3	5.79
Additions		C cost per kg applied (kg CE/kg AI)		
		Quantity		
Fertiliser	N	2.39	215	513.85
	P	0.2	142	28.4
	K	0.15	194	29.1
	FYM	0.071		0
	Lime	0.16		0
	Amendments	0.16		0
Crop protection	Herbicide	6.3	1	6.3
	Insecticide	0.36	1	0.36
	Fungicide/nematicide	3.16	2	6.32
			Total footprint kg CE/ha	642.23

Farm surveys



Quality v consistency

- Two different estimates – from using:

1. “typical” management or growers guides – different levels of detail
2. farm surveys - consistent methodology but less detailed model

A simpler model to compare crops

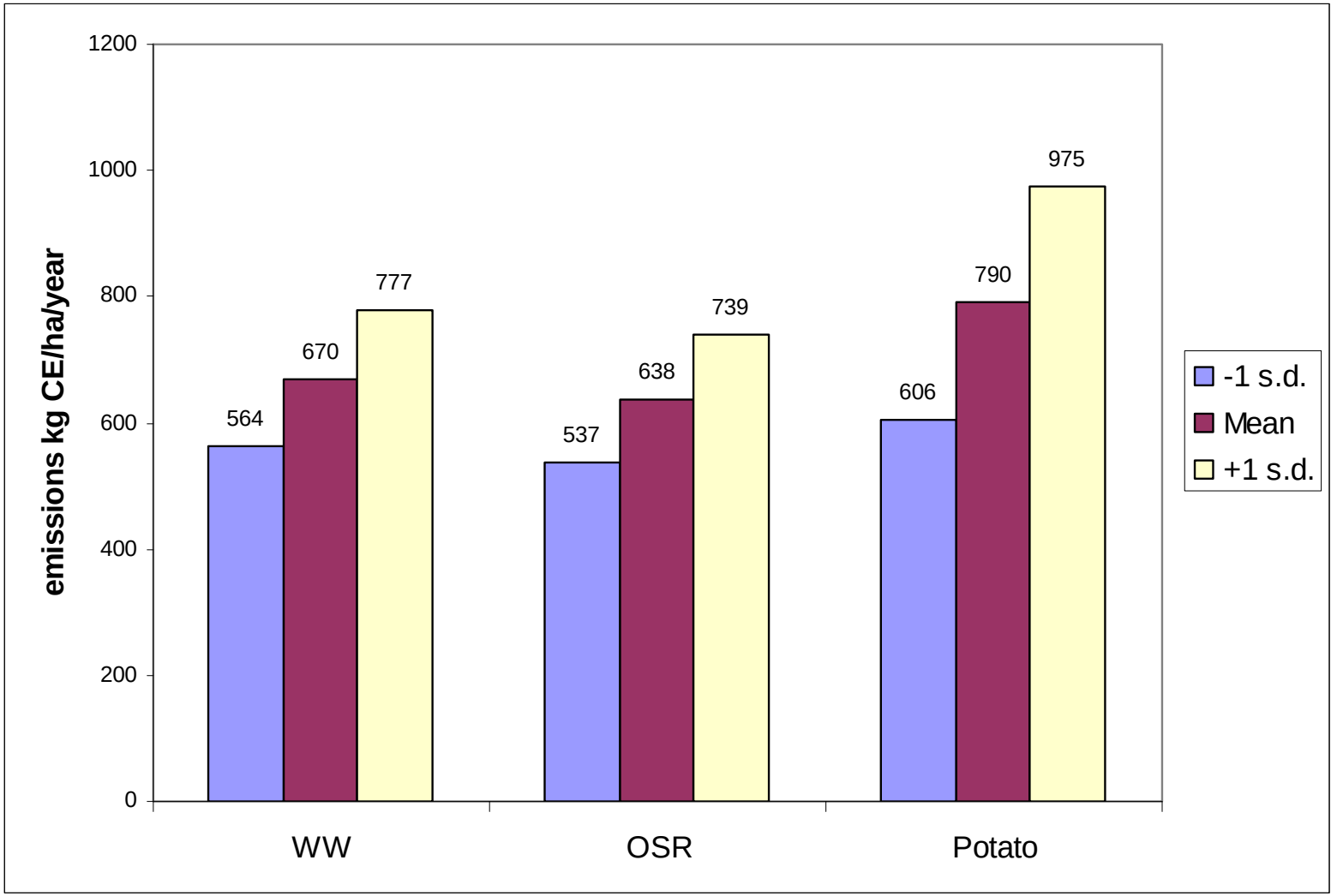
- “Best” estimates for management
- Equivalent level of detail
- Variation in management from emissions included

From Lal 2003

	-1 sd	mean	+1 sd
Soil preparation/planting (mechanical)	1.60	6.16	10.71
Fertiliser N	2.66	2.96	3.26
Fertiliser P	0.14	0.20	0.26
Fertiliser K	0.09	0.15	0.21
Crop protection	1.96	4.83	7.70
Harvest	2.96	7.13	11.29
Irrigation	1.35	39.31	77.27

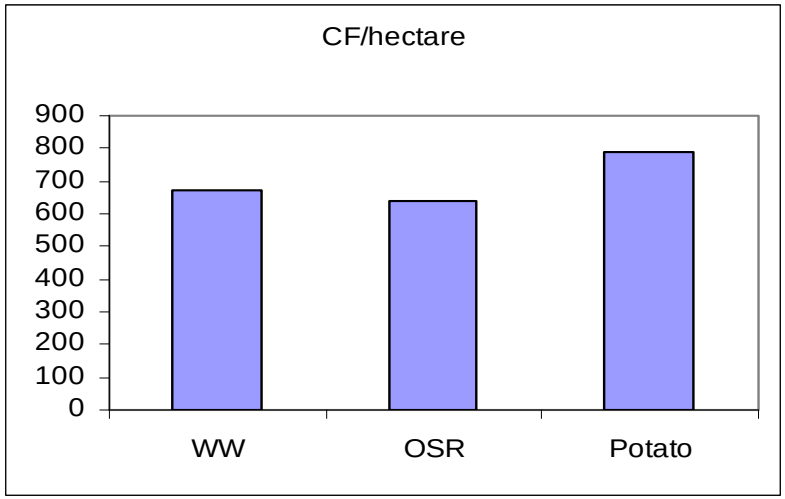
Combining growers guides and farm survey*

	Winter Wheat	Oilseed Rape	Potato
Soil preparation/planting (mechanical)	3	4	6
Fertiliser N	197	190	200
Fertiliser P	66*	42*	150
Fertiliser K	98*	76*	150
Crop protection	7	5	10
Harvest	1	1	3
Irrigation	0	0	1

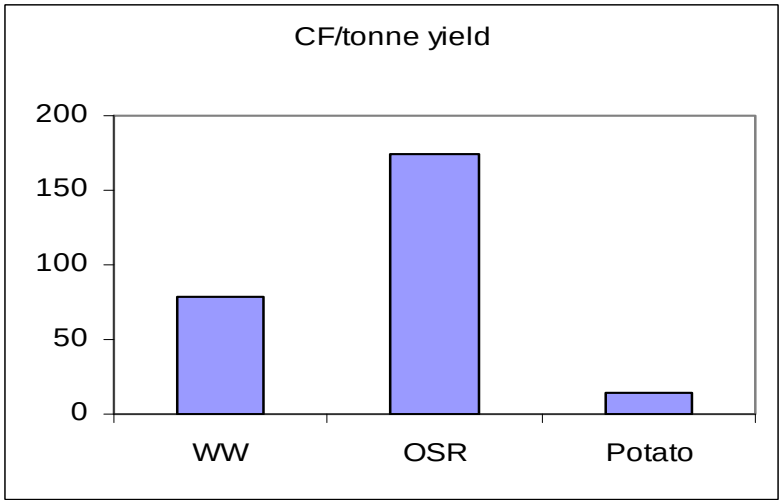


	WW	OSR	Potato
Original – growers guide or typical management	582	549	924
Farm survey	520	518	688
Simple model	670+/-107	638+/-101	790+/-184

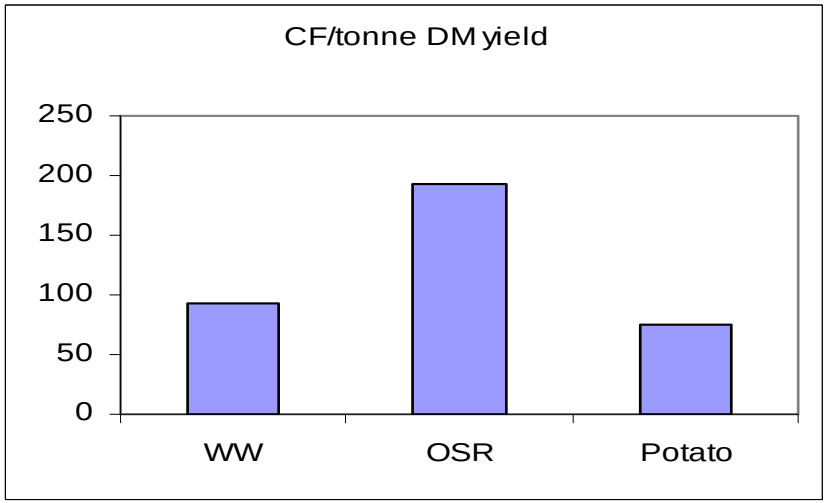
Per ha, potatoes are bad



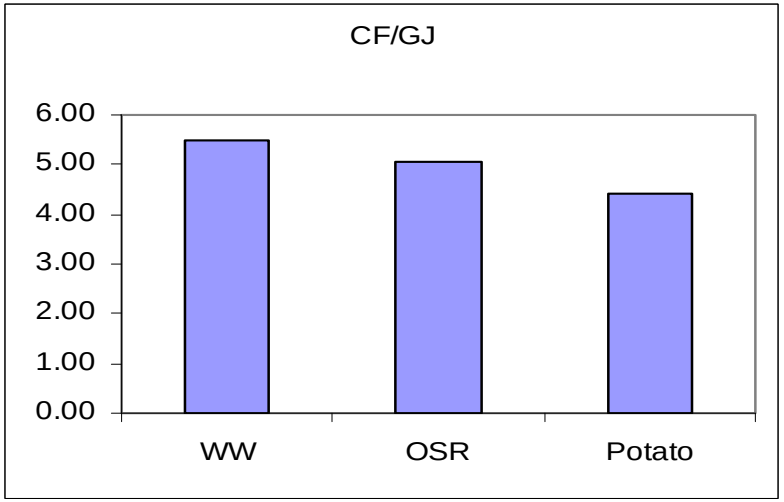
Per tonne yield, potatoes are good!



Per tonne DM yield
(Pot 20%, WW 85%, OSR 91%)



Per GJ (food)



Uncertainties? (almost everywhere!)

- Fuel usage
  - Lal's data goes back to the 70s - improved efficiency over last 30 years
  - soil properties
- N emissions
  - production emissions
  - soil properties
  - simulation models – validation via experiment
- Crop protection
  - huge range of products
  - some information may be commercially sensitive

Beyond the farm gate
Transport costs

- 44 tonne truck
  - Smith & Smith et al*
    - ~ 0.013 kg C per km-tonne
  - Carly Whittaker, Plant Science, ICL
    - ~ 0.019 – 0.038 kg C per km-tonne
- Average is 0.022 kg C per km-tonne

Smith & Smith (2000), Transport carbon costs do not negate the benefits of agricultural carbon mitigation options. *Ecology Letters* 3:379-381.

Approximate potato C footprint model (kg CE/ha)

CF =

103

+ 6.16 * SP

+ 2.96 * N (kg)

+ 4.83 * CP (kg a.i.)

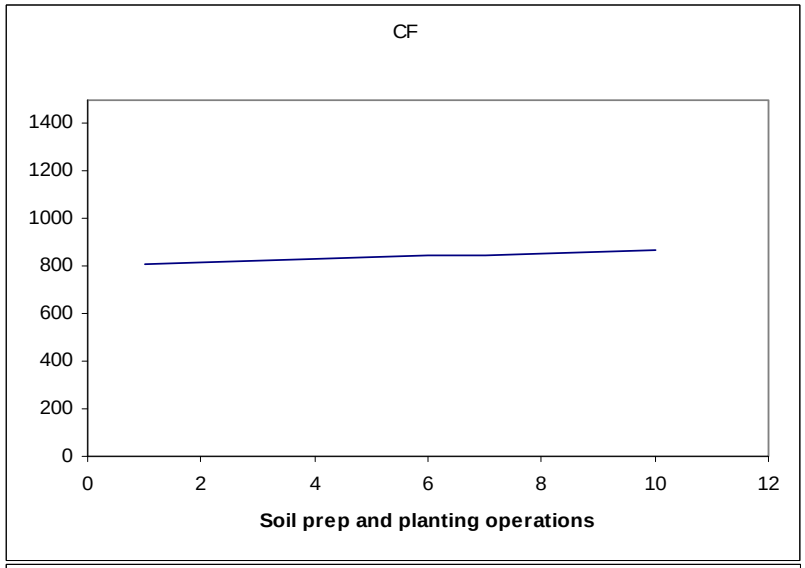
+ 0.022 * distance (km) * yield (t)

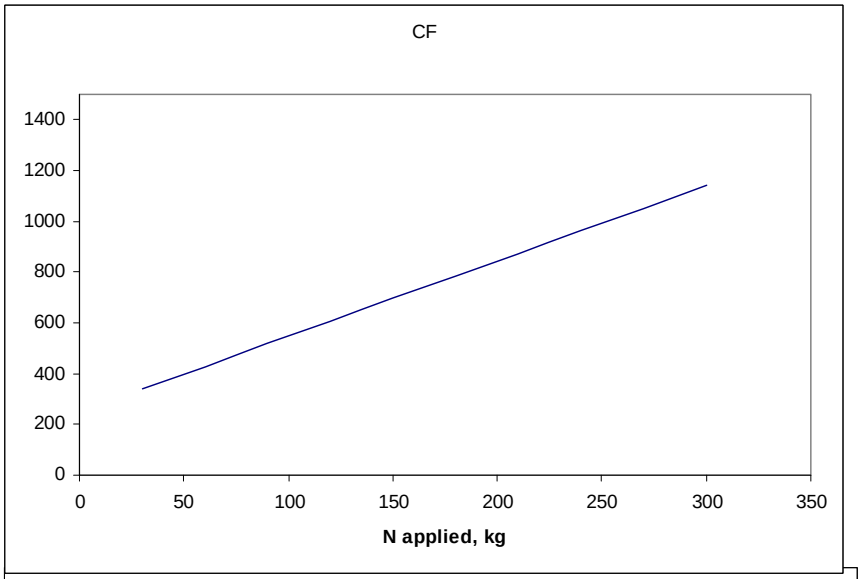
SP: soil preparation and planting

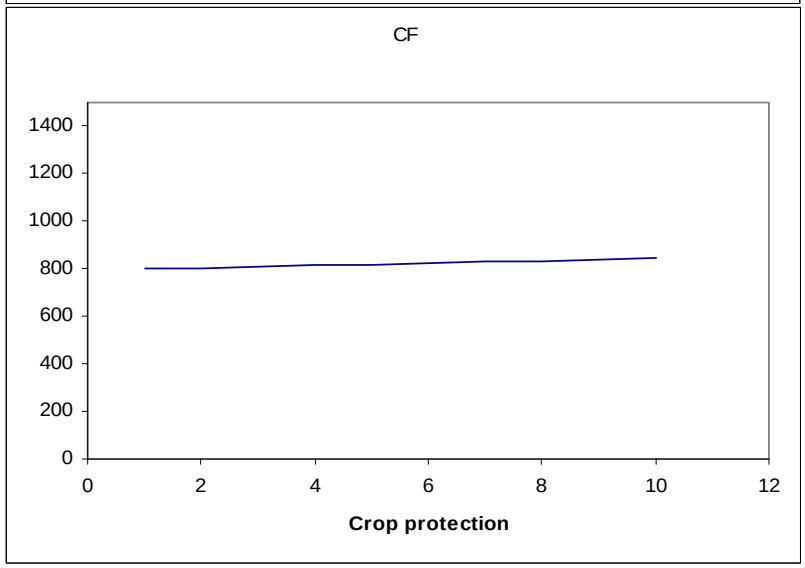
CP: crop protection

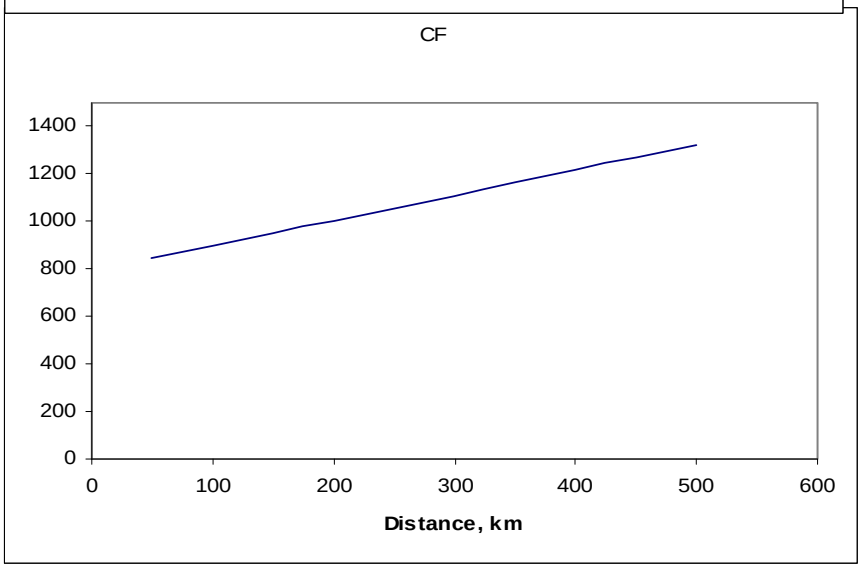
Following slide - sensitivity around assumed baseline

- 48 tonnes transported 50 km





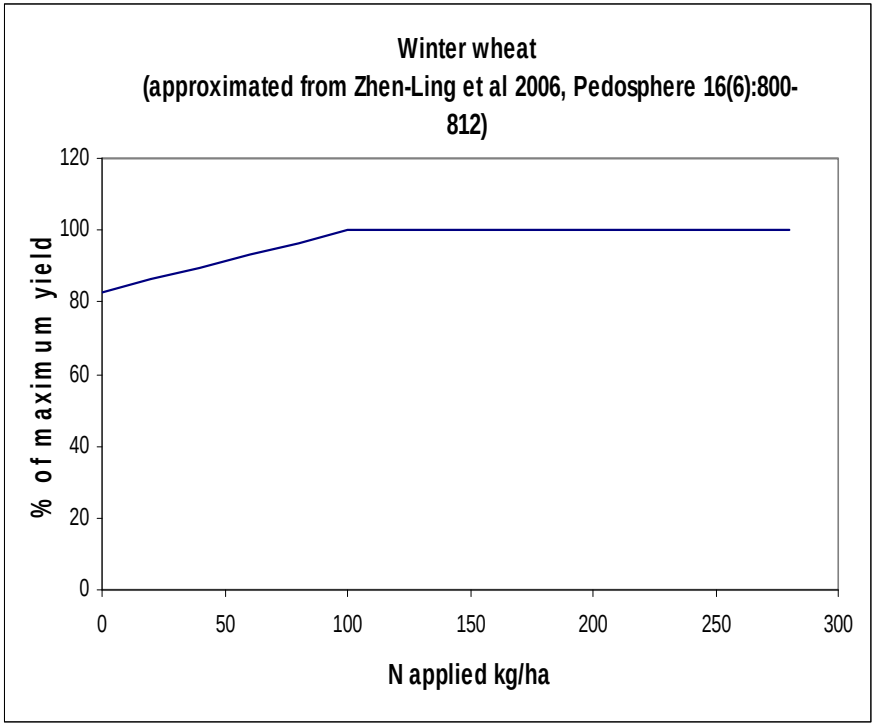




- N is the most important factor
- Distance transported is quite significant

Can we reduce the footprint?
Mitigation options – farm gate

- N
  - It's expensive! Due to fossil fuel use in production
  - So probably already optimised (in UK) and can't be reduced whilst maintaining yield
- Tillage – reduces CO2 emissions from soil
- Grow more legumes!
- SCRI-SAC (long term sustainability expts) to come



Look elsewhere?

Transport

- 50 tonnes (1 ha), 500 km adds 50% to the C footprint

- Can be reduced by
  - transporting less
  - by using greener transport

- Whose problem is transport ?
  - transport sector
  - agriculture sector
  - potato industry

Conclusions

- Potato footprint per hectare around 20-30% higher than WW or OSR
- Potato footprint per tonne yield much lower than WW or OSR
- N application is by far the most important arable farming emission source (for these crops)
- Transport emissions can be very significant beyond the farm gate adding ~50% per 500 km for potato
- Storage/packaging/processing emissions?

This could be refined - can you help?

- Contact me

  j.hillier@abdn.ac.uk

- Farmers or growers:
  - Tell us how YOU grow potatoes (or other crops)

- Beyond the farm gate
  - let’s talk

Thank you to my funders – NERC (NE/C516279/1)

The organisers for the invite…

…and to everyone else for listening

j.hillier@abdn.ac.uk