Nature based solutions towards sustainable dairying: soil, forage and woodland

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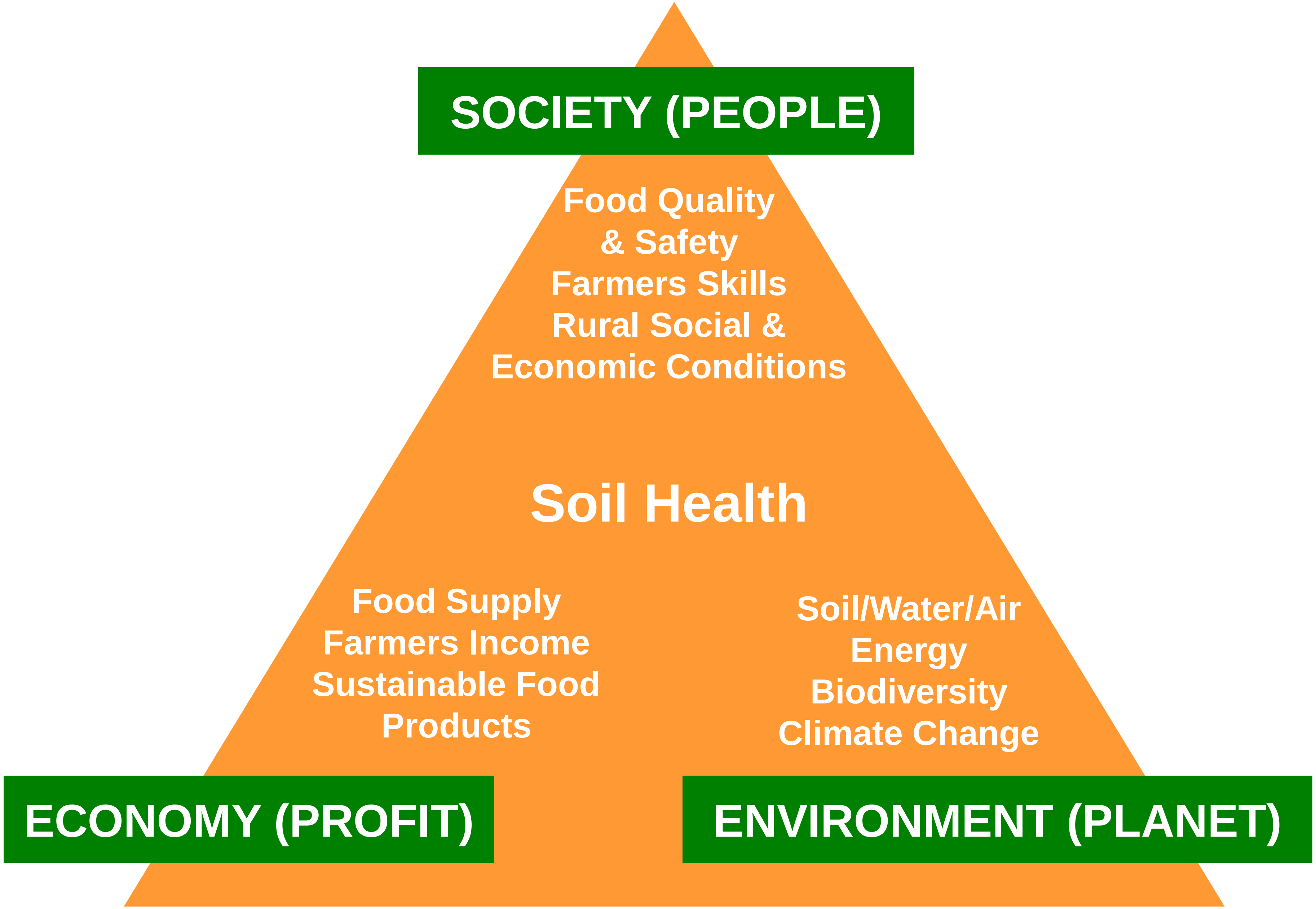
Sustainability – three equally important pillars

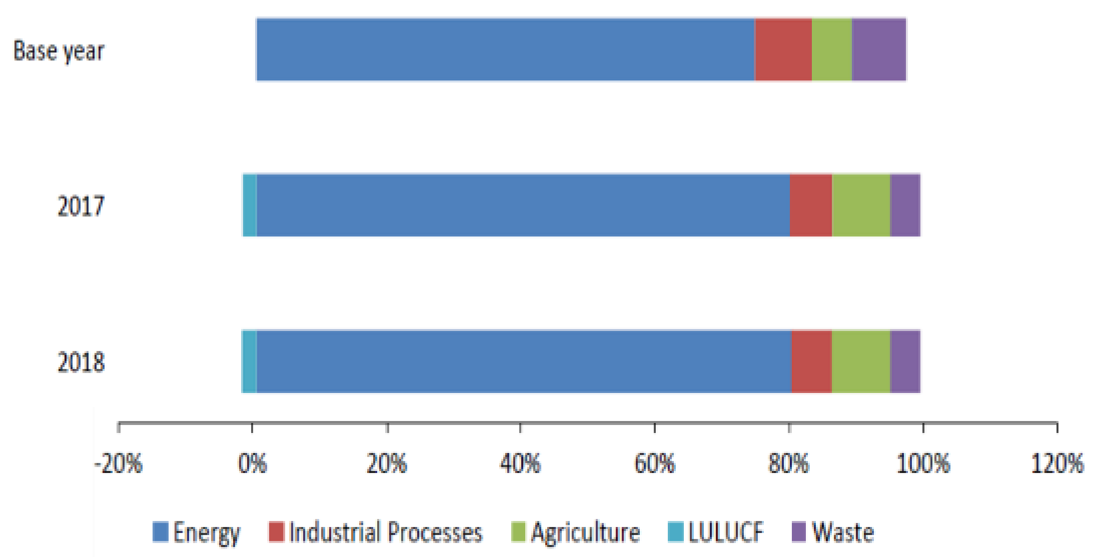


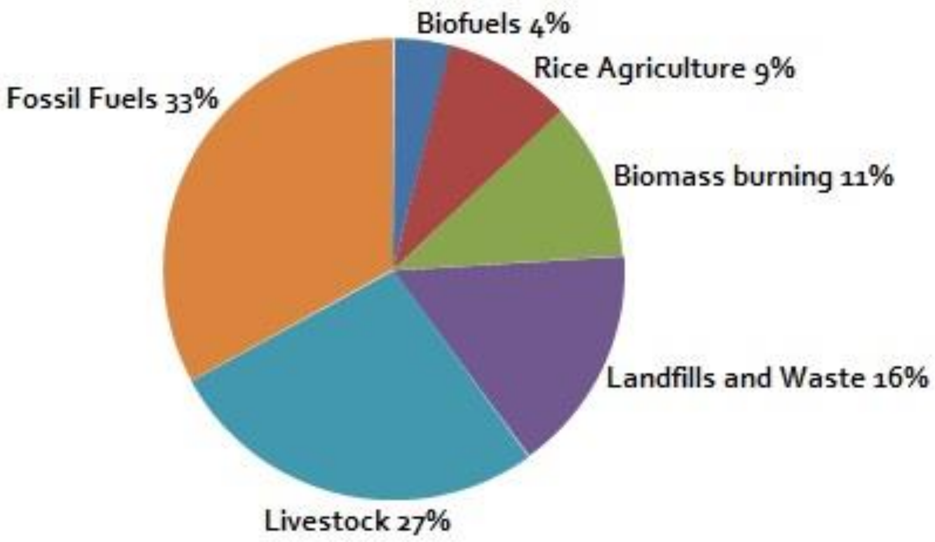
Trade – offs

Criteria	Measure	Units
Animal performance	Daily weight gain	Kg weight gain/day
Carrying capacity	Animals per hectare	Kg weight/ha
Nutritional quality	Nutrients per hectare (e.g. calories, protein, minerals)	Kg nutrient/ha
Nutrient and soil loss to water Soil Health	Losses per hectare per day SOC	Kg/ha/day %
Greenhouse gas emissions Sulphonation Eutrophication	CO_2 (or equivalent) per unit of animal product (S and P equivalents)	Kg CO_2eq/kg product (S and P equivalents)
Animal health	Costs of preventive veterinary care and treatment of diseases	Veterinary costs (£)
Animal Welfare	Negative and Positive assessment	Disease/EU Behaviour /time
Biodiversity	Range of wildlife and plant species	Species/ha
Inputs (fertiliser, machinery, labour)	Purchase cost	£
Outputs (beef cattle)	Sales value	£

Agriculture is a Significant Source of Emissions

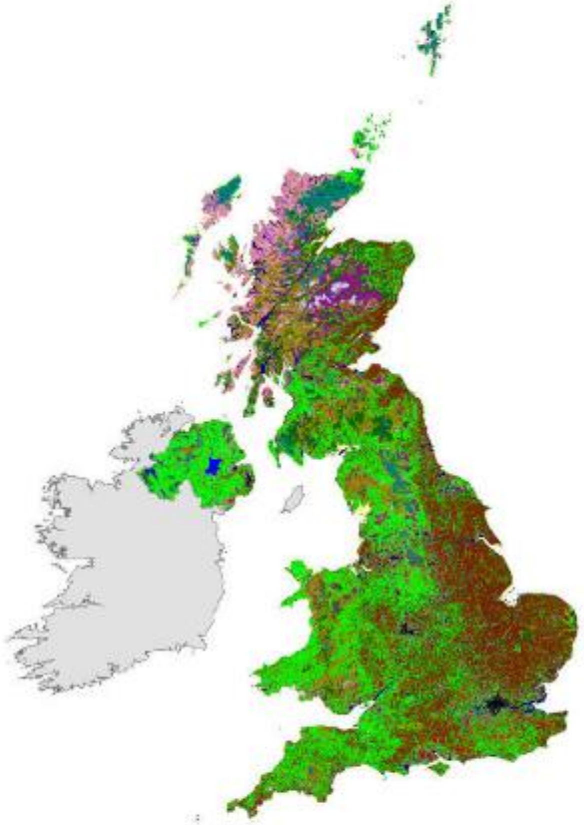
- Agriculture contributes ~10% of UK annual greenhouse gas emissions
- Livestock are responsible for two thirds of agriculture's emissions
- Mainly methane from livestock & nitrous oxide from soils
- Livestock account for ca. 27% anthropogenic methane
- COP26 – 30% reduction in methane

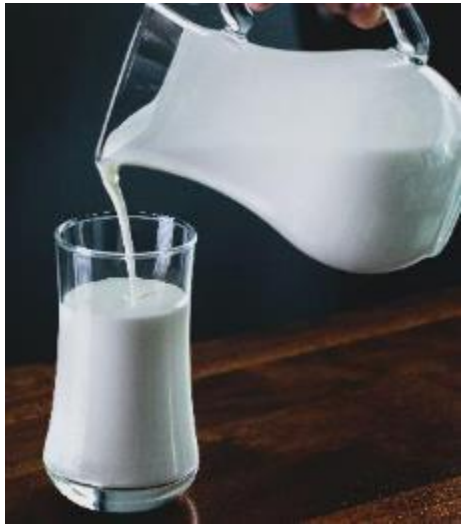




Ruminant Livestock are Important to UK

- Livestock foods are important for human nutrition, supplying high quality protein
- UK is 60-70% self-sufficient in meat, milk & eggs
- Livestock convert low quality forage to high quality protein, on land not suited to cropping
- Farmgate products are worth £12bn
- Rural communities are grassland based





UK Livestock Carbon Footprints

- Comparisons of carbon footprints for the UK's major livestock products from two of the most commonly used sources of national environmental impact data

	Defra	Poore & Nemecek
	Global warming potential	Global warming potential
Unit	kg CO_2-eq/kg carcass weight	kg CO_2-eq/kg edible product
Beef (dairy herd)	10.7	25.9
Beef (beef herd)	25.3	48.4
Chicken (meat)	4.6	9.8
Chicken (eggs)	5.5	4.2
Lamb	17.4	37.4
Milk	1.1	2.3
Pork	6.4	11.9

CIEL, 2020

Dairy Footprint (Product level)

Carbon footprints of three conventional dairy systems

	Unit	C1	C2	C3
Grazing access	*days/year*	*270*	*180*	*0*
Milk yield (energy corrected)	*kg/cow/year*	*5,500*	*7,800*	*9,200*
Feed carbon footprint (minus N application)	**kg CO_2-eq/kg milk**	0.30	0.37	0.35
Enteric methane	*ditto*	0.69	0.47	0.44
Manure management methane	*ditto*	0.08	0.10	0.13
Nitrous oxide	*ditto*	0.17	0.12	0.09
Total carbon footprint (beef + dairy)	*ditto*	**1.24**	**1.06**	**1.01**
Burdens allocated to beef	*ditto*	0.11	0.06	0.05

C1 = grazing most of year
C2 = grazing half of year
C3 = fully housed

Dairy Footprint (Farm level)

Agriculture cannot de-carbonise like other sectors

<u>Main agricultural emissions</u>

- Carbon dioxide (CO_2) – burning fossil fuels
- Methane (CH_4) – enteric fermentation
- Nitrous oxide (N_2O) – Soil and manures

<u>Challenge and opportunities</u>

- Farms are complex biological systems
- Farms emit and sequester
- Set boundaries

<u>The Carbon Calculation</u>

Two main elements

1. A database or model that contains standard figures for emissions and sequestration rates associated with an individual item or process
2. Farm specific data i.e. cattle numbers, crop yields, slurry usage. This is largely based on a financial year though cropping cuts across years.
3. Many models none are perfect

Approaches to Farm Net Zero – 4 steps

1. Animal – Genetics and Health (Performance)

2. Feed – Nutrition and supplements

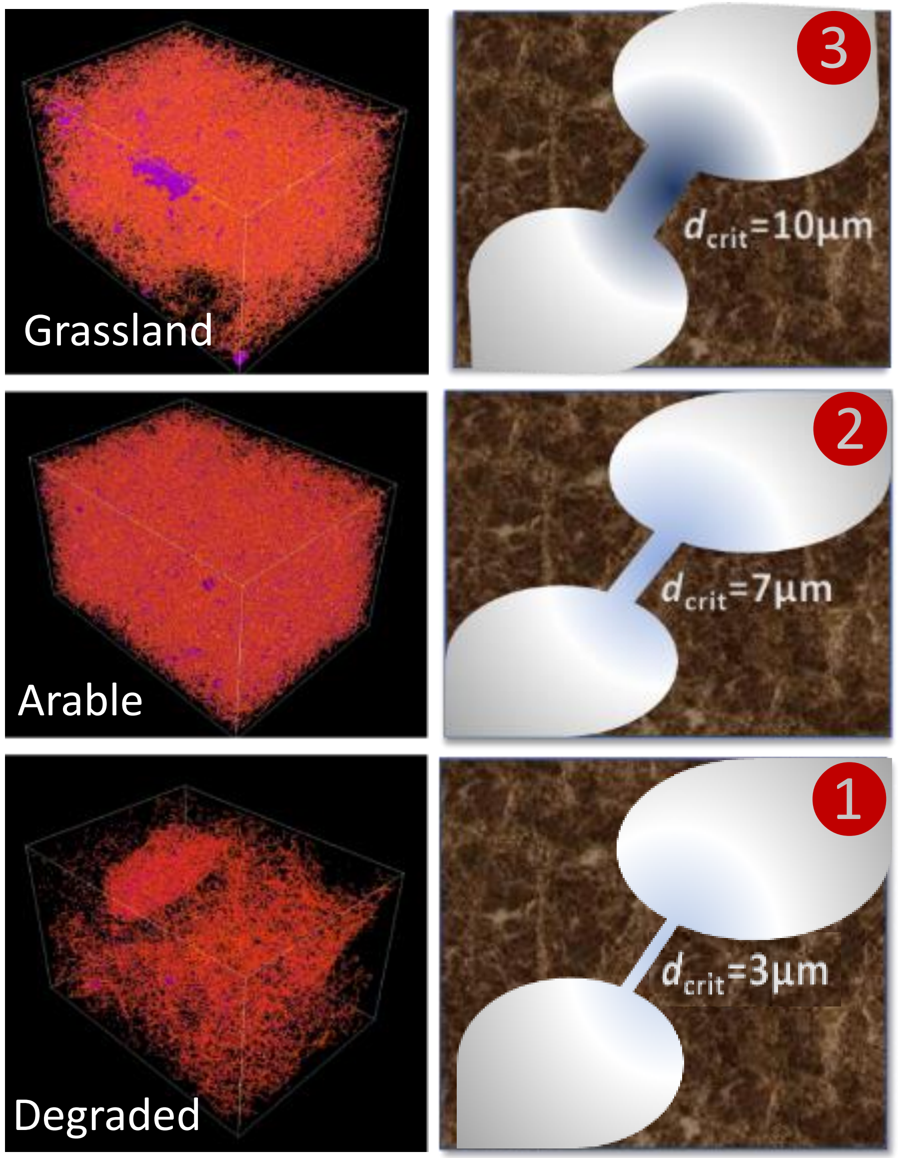
3. Land – Nature Based solution (soil, forage, woodland)

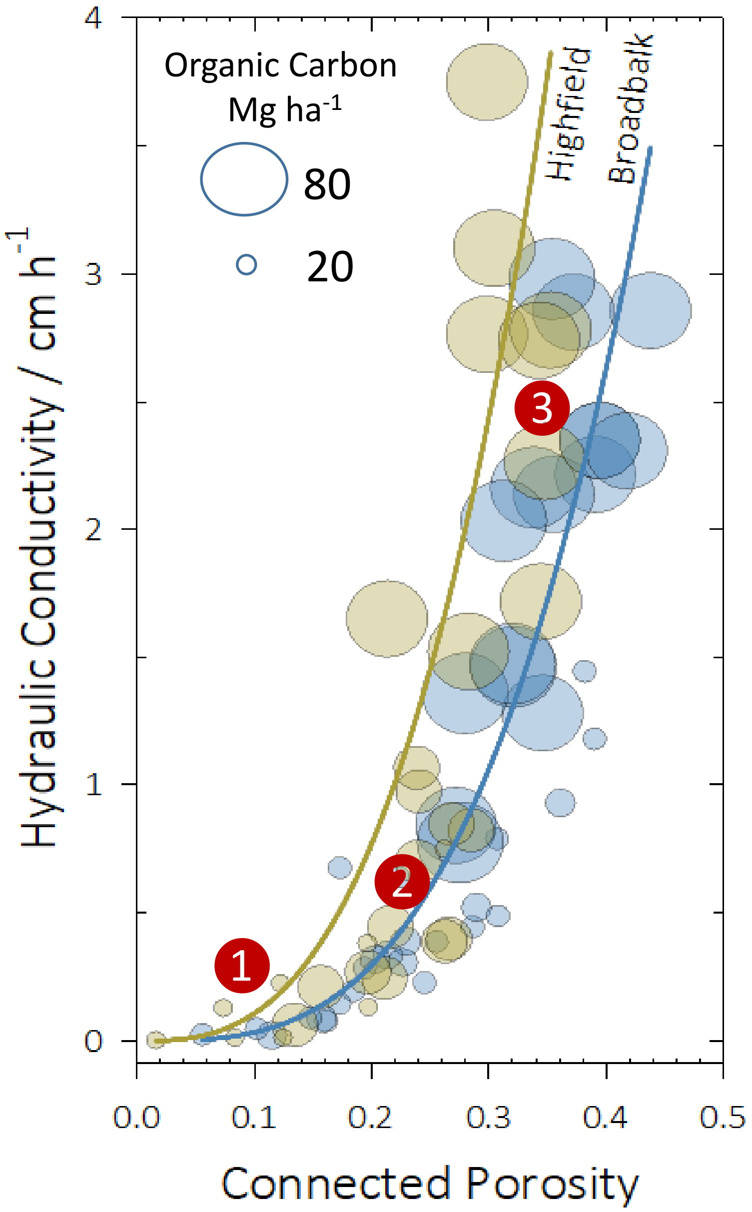
4. Energy – Reduce fossil fuels – produce green energy

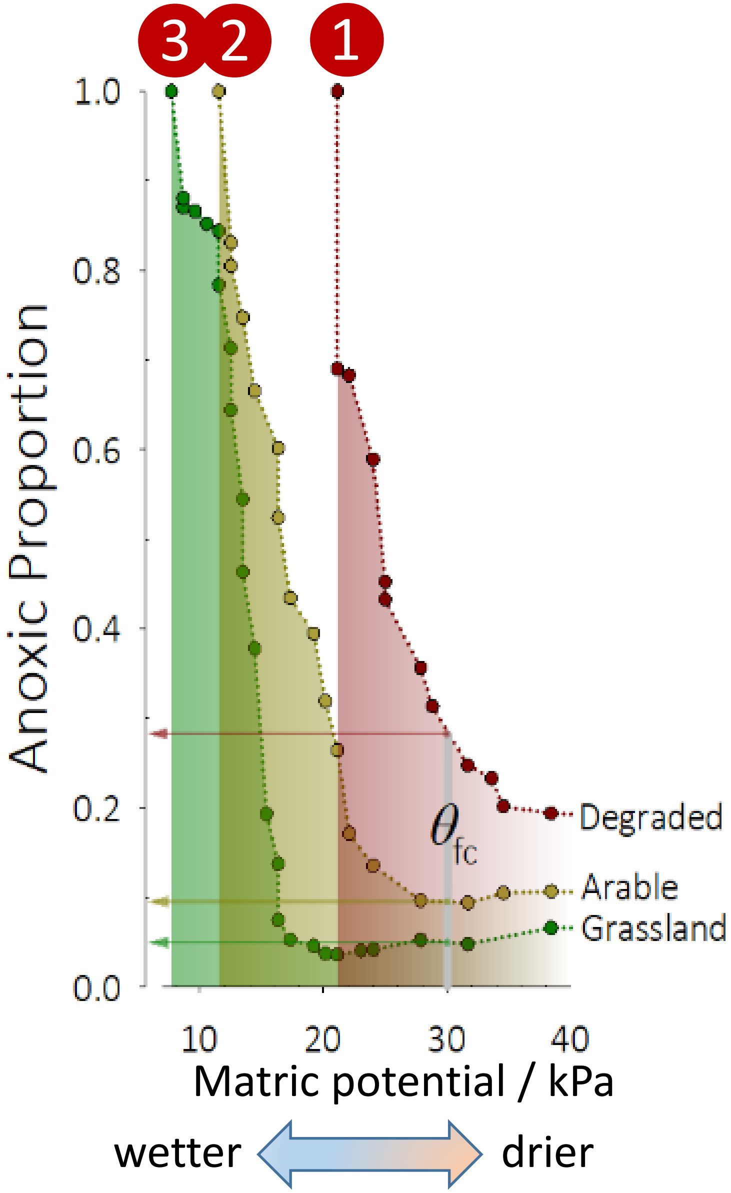
Soil health (Prof Andy Neal)

Biotechnology and Biological Sciences Research Council

ROTHAMSTED RESEARCH





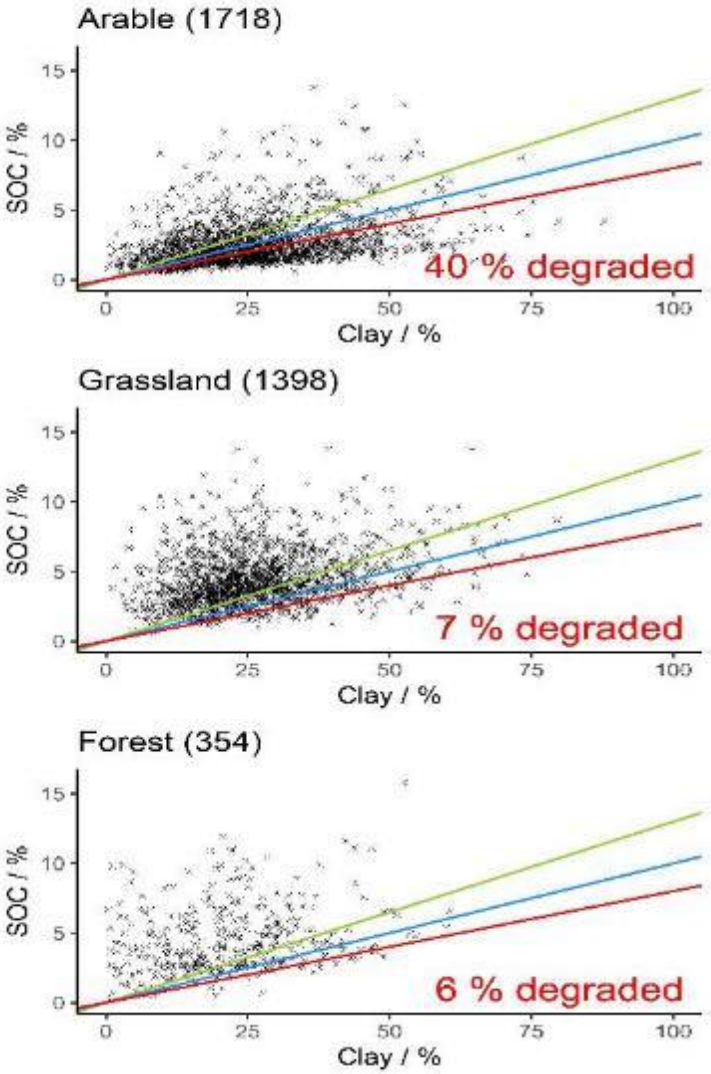


Soil health needs organic matter returns

Biotechnology and Biological Sciences Research Council

ROTHAMSTED RESEARCH

Data Mining England and Wales Soils



SOCC

1:8

1:10

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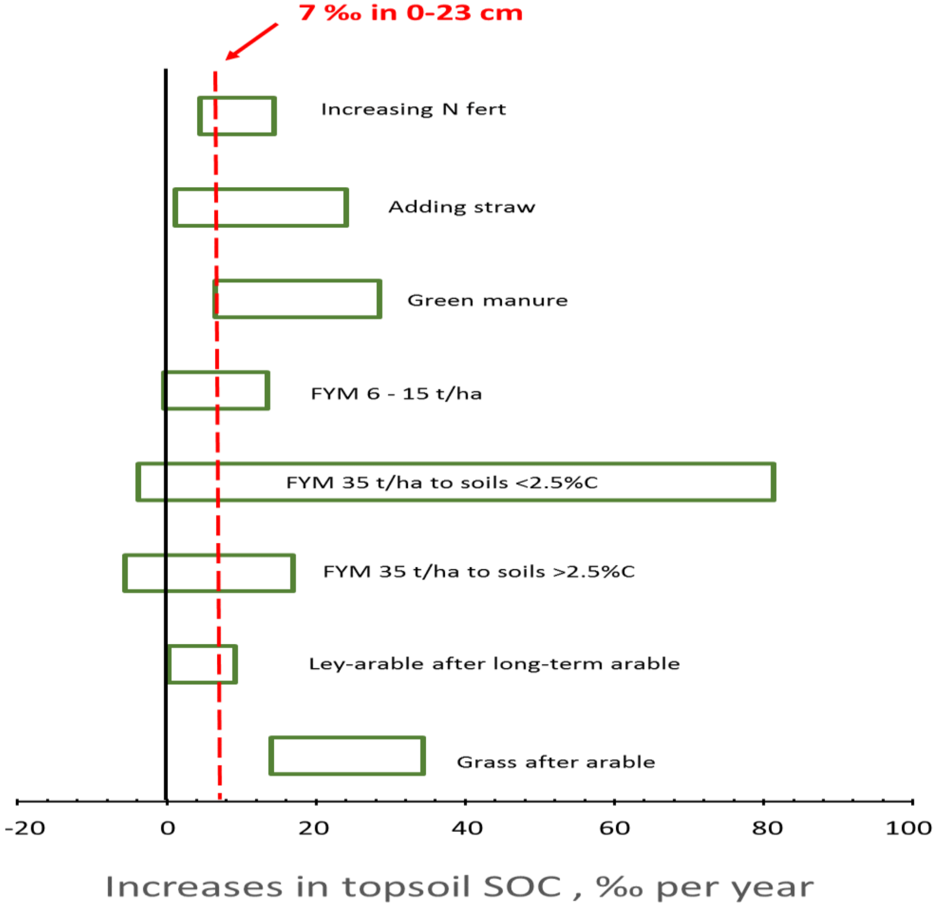
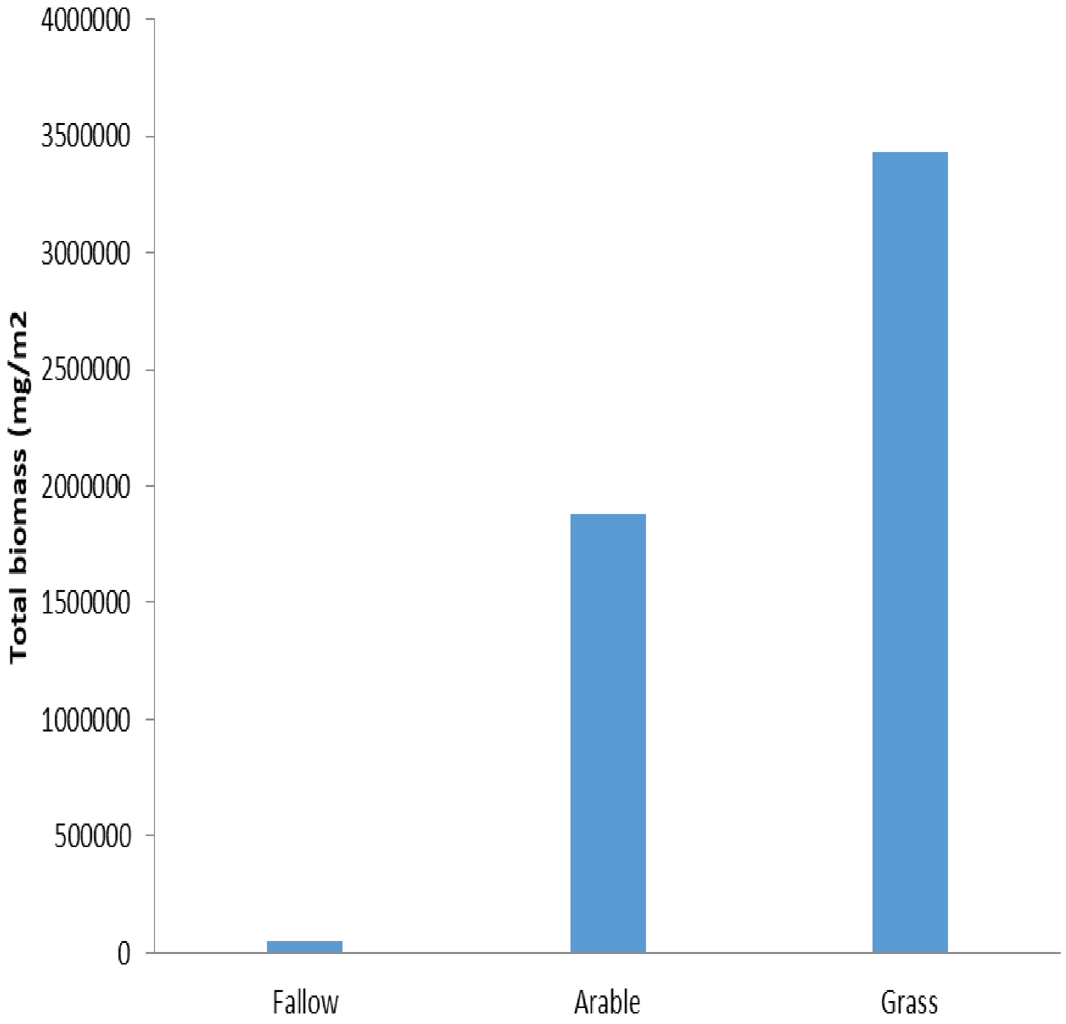
Interventions to increase soil organic carbon (power of Long term experiments)

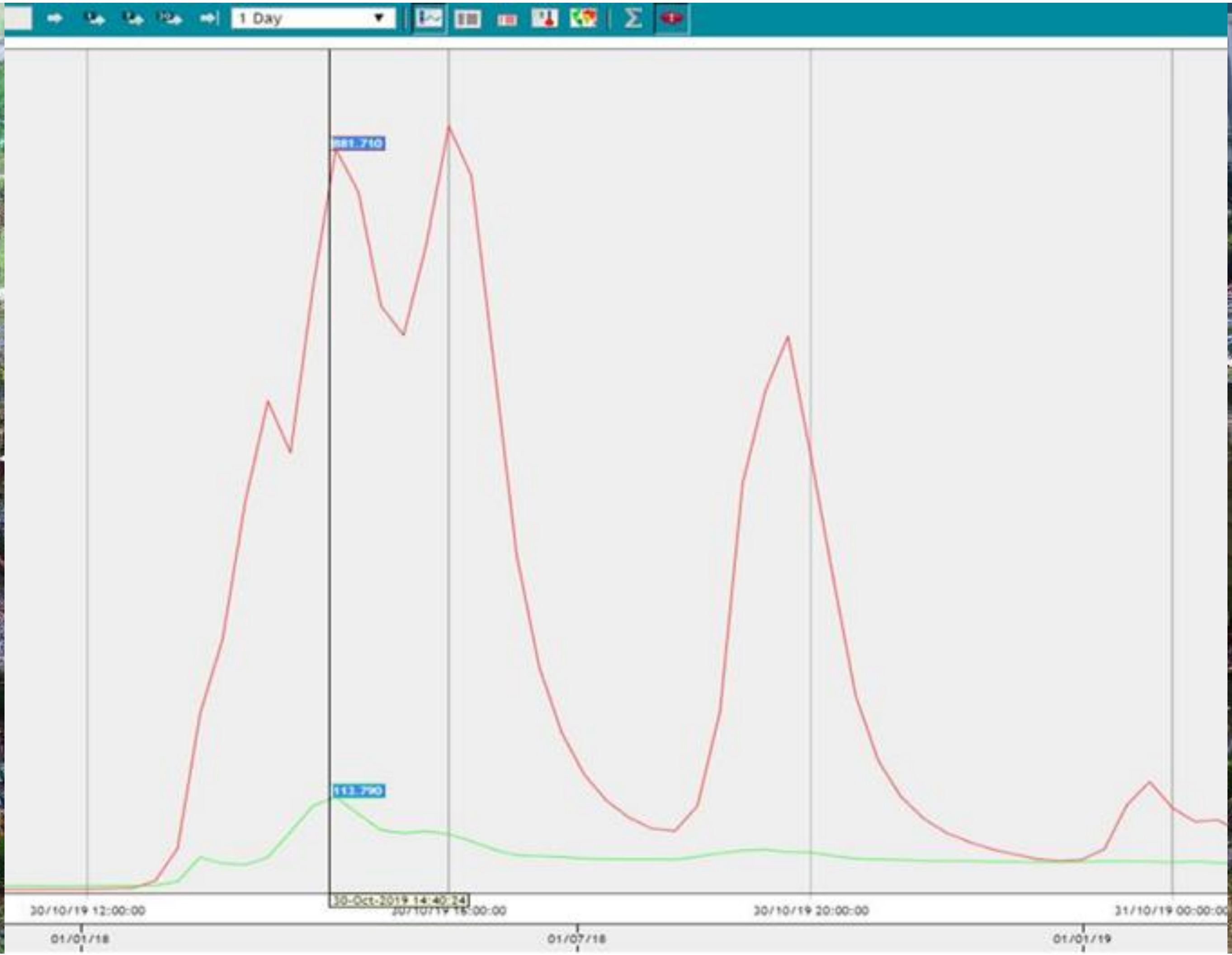


Poulton et al., 2018

Soil – Organic Matter - Carbon and Biodiversity



Soil loss from arable system versus grassland soil North Wyke Farm Platform (systems based experiment)

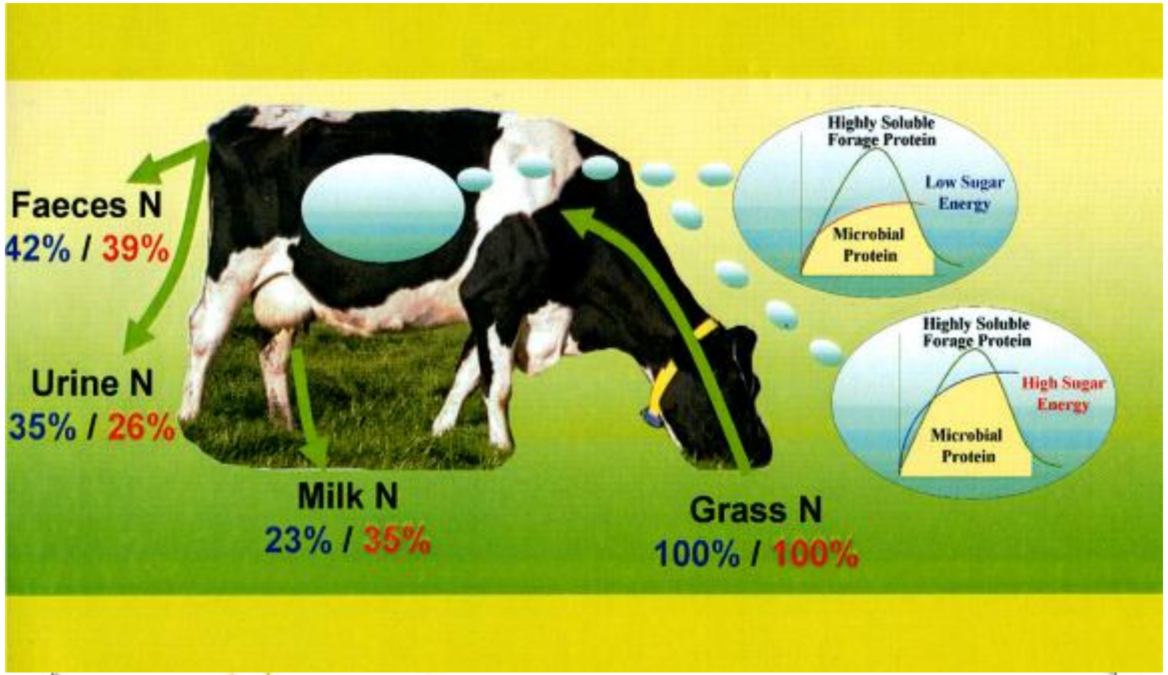


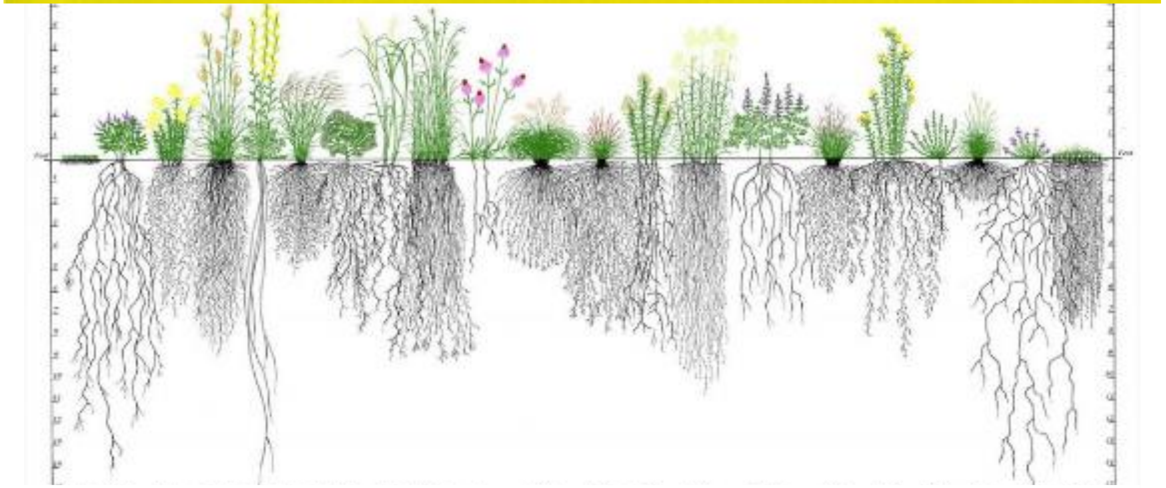
Forage – direct and indirect C reduction

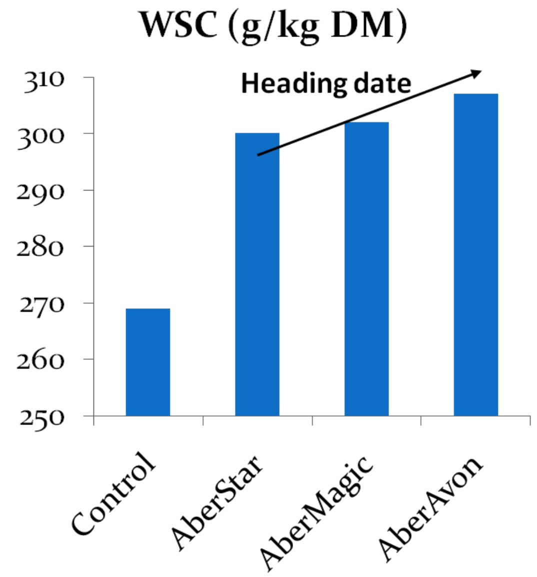
Home grown feed reduces processing and shipping C and legumes reduce fertiliser use
(1 mol of N in fertiliser = 6 mols of C to the atmosphere)

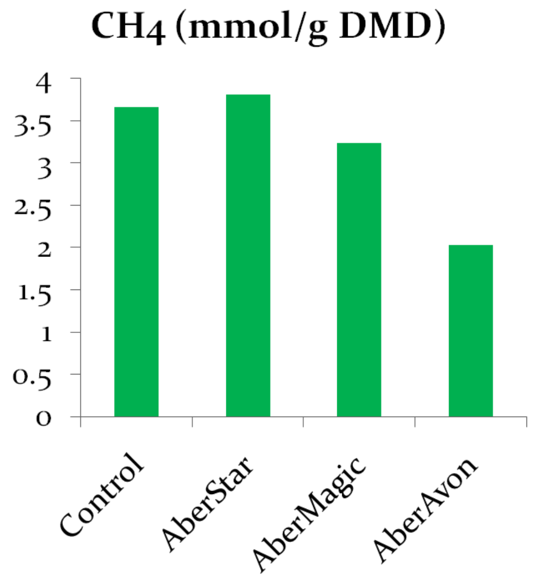
White clover in sward has been shown to reduce nitrous oxide emissions through influencing soil structure as well as reducing inorganic inputs (McAuliffe et al., 2020)

Forage – direct and indirect C reduction and NUE









Plant breeding and multifunctional swards can reduce emissions through improving nutritional value and soil structure reducing emissions of methane and nitrous oxide, respectively

Hedgerow and tree management

Table 5. Carbon storage for different types of UK plantations.

Species	Yield Class (m^3 ha^{-1} $year^{-1}$)	Rate of storage[1] (Mg C ha^{-1} $year^{-1}$)	Equilibrium carbon storage[2] (Mg C ha^{-1})				
			Trees	Wood products[3]	Litter	Soil	Total
P. sitchensis[4] (unthinned)	24	5.6	90	42	34	89	254
	22	5.3	88	41	32	90	251
	20	5.1	86	40	30	92	249
	18	4.7	83	39	28	87	237
	16	4.5	79	37	26	87	229
	14	4.1	74	34	24	83	215
	12	3.7	68	32	21	77	198
	10	3.4	62	30	18	79	189
	8	2.9	54	27	15	72	169
	6	2.5	45	22	12	72	152
P. sitchensis[4] (thinned)	24	4.4	67	31	29	84	211
	22	4.3	67	31	29	87	214
	20	4.1	65	29	26	88	208
	18	3.8	62	28	25	83	198
	16	3.6	59	27	23	84	192
	14	3.3	54	26	21	80	181
	12	3.0	50	24	19	75	167
	10	2.8	46	22	17	77	162
	8	2.4	41	20	14	71	146
	6	2.1	36	16	11	71	134
Populus	12	7.3	66	36	23	87	212
Salix	–	5.9	13	9	6	65	93
Nothofagus	16	4.6	40	17	27	96	179
P. sitchensis[5]	12	3.0	52	24	19	75	170
P. sylvestris	10	2.7	53	26	19	81	178
P. contorta	8	2.5	44	19	15	78	155
F. sylvatica	6	2.4	60	26	27	87	200
Quercus	4	1.8	48	19	20	68	154

[1] Initial rate of increase in total carbon storage, calculated as total C storage at end of first rotation divided by rotation length. [2] Time-averaged storage of carbon at equilibrium. [3] In the case of thinned stands, contributions to the wood product pool from stem thinnings are calculated assuming a 5-year lifetime. [4] 2.0 m initial spacing. [5] 1.8 m initial spacing.

North Wyke modelling (Dr Taro Takahashi)

20 ha

1.5LU/ha

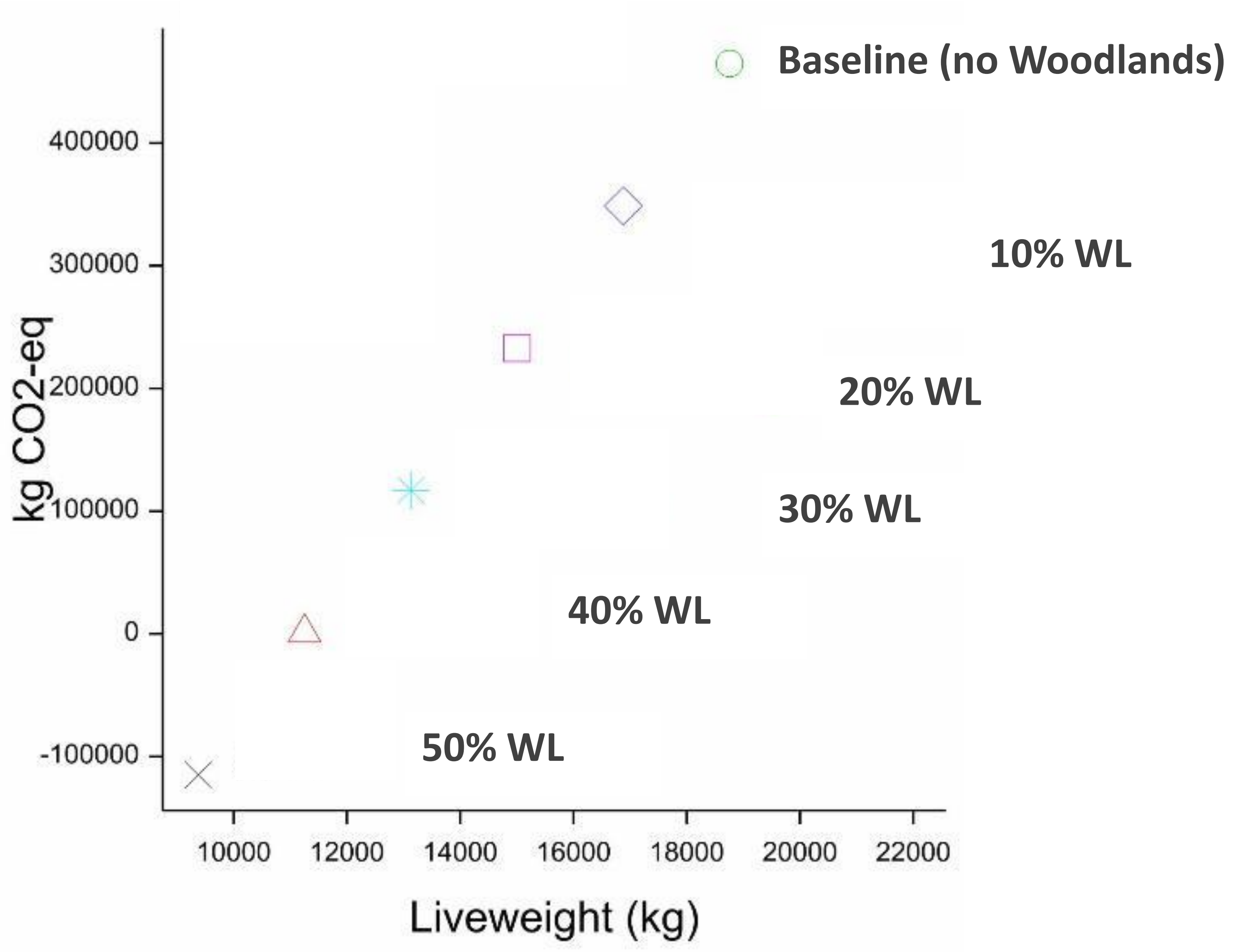
30 finishing suckler cattle

Finishing 600 kg/LW

15t CO_2e/animal

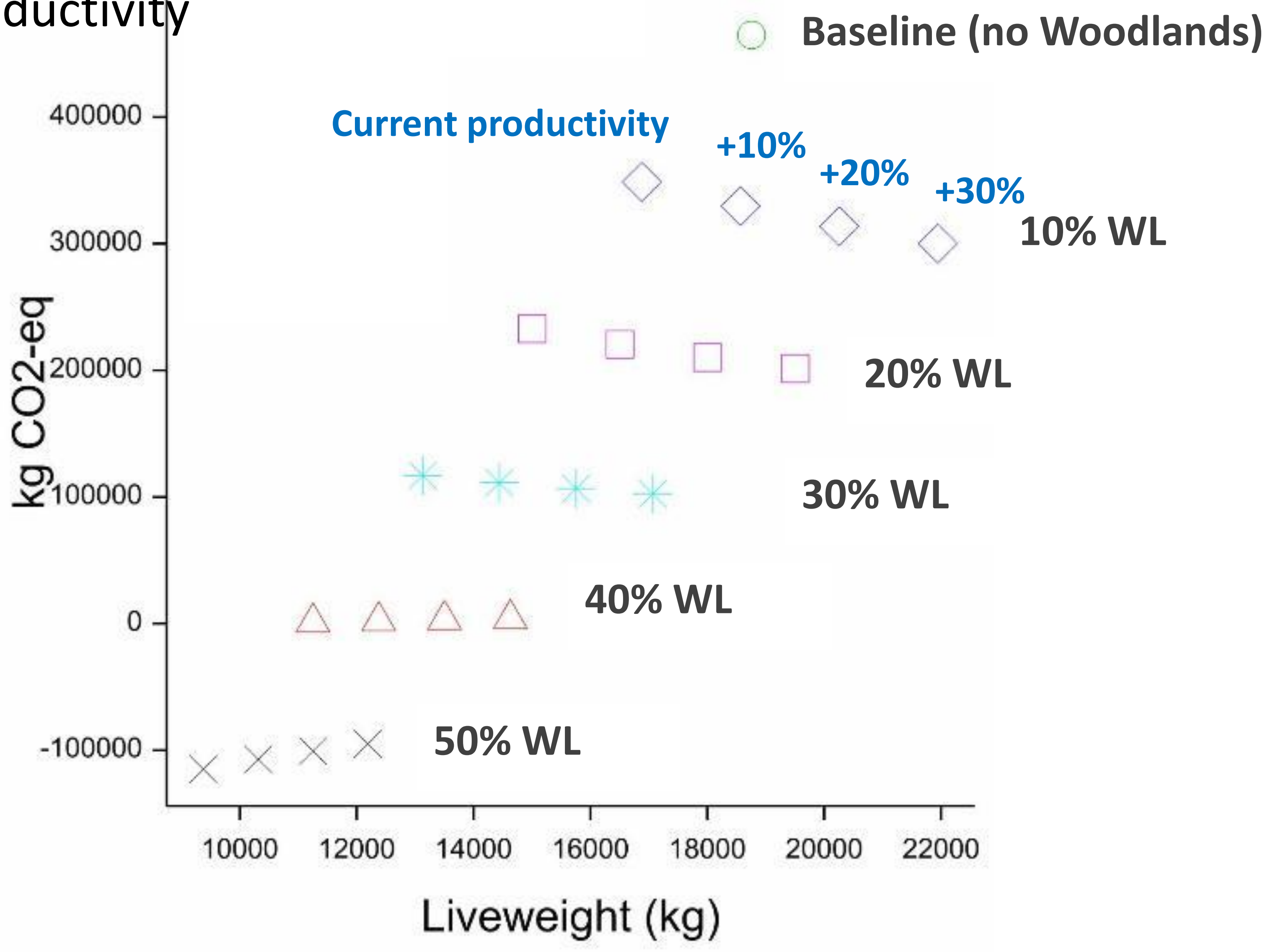
How much trees to offset?

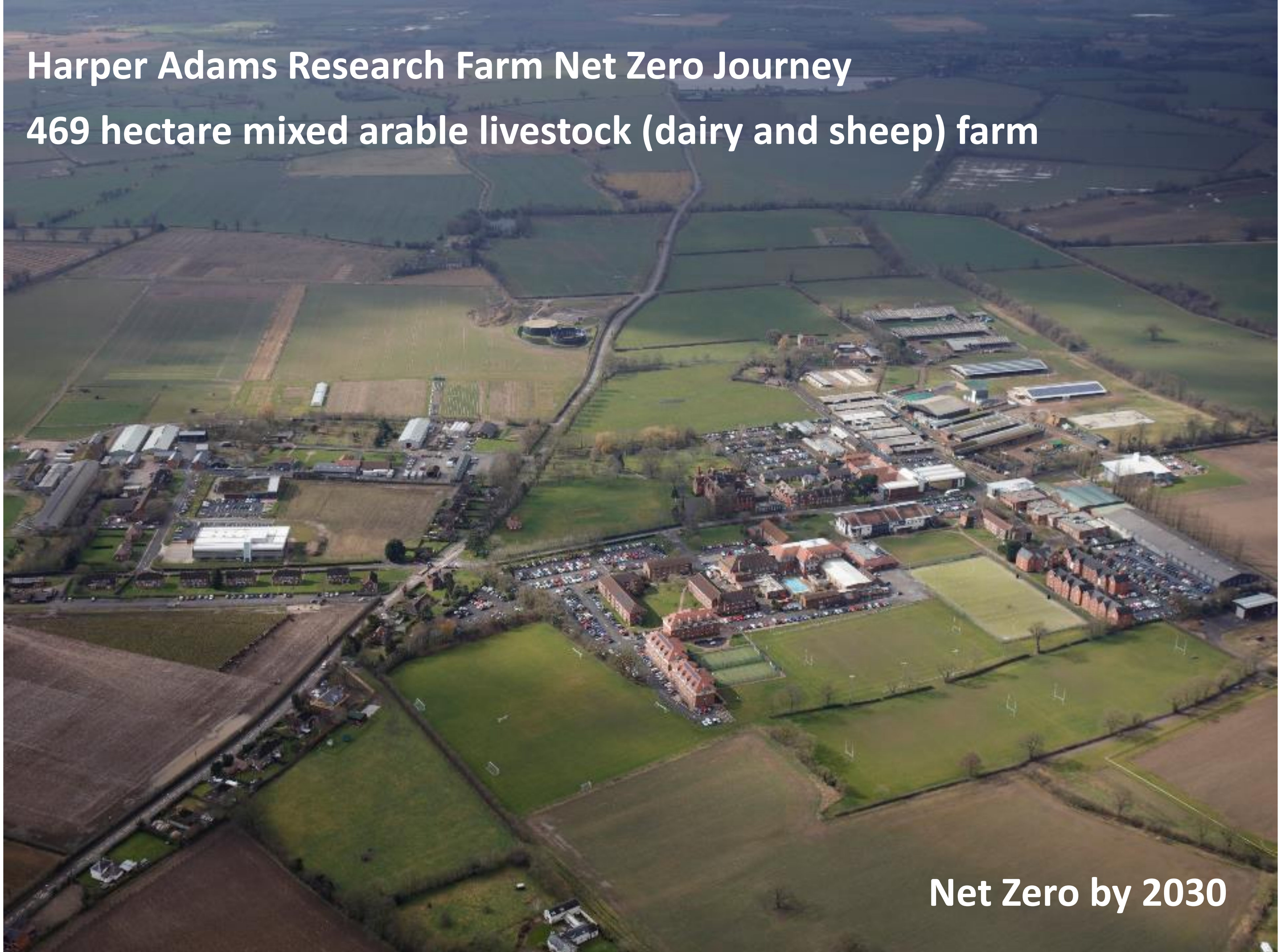
Emission off-setting vs. Productivity



Sweet-spot

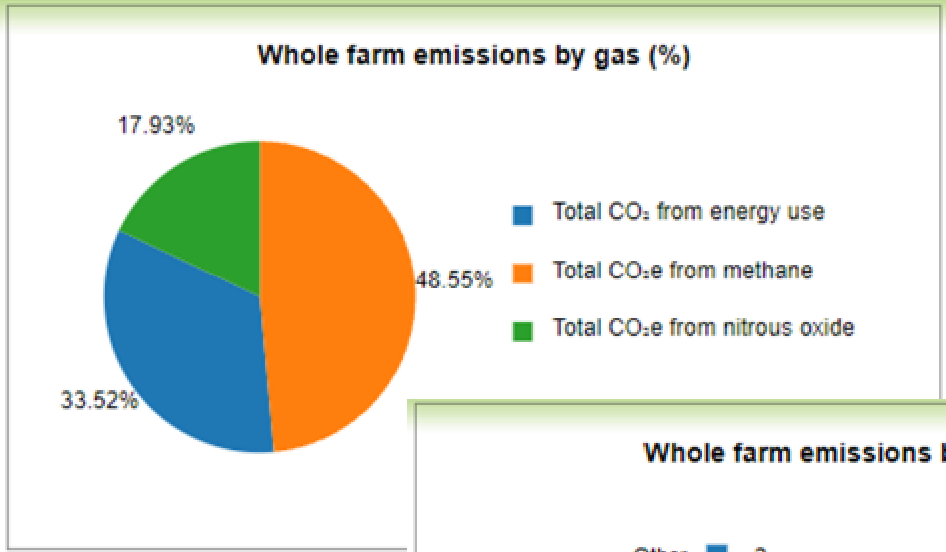
Productivity improvement (20%) and woodland (20% cover) may result in 70% reduction in GHG with 96% productivity

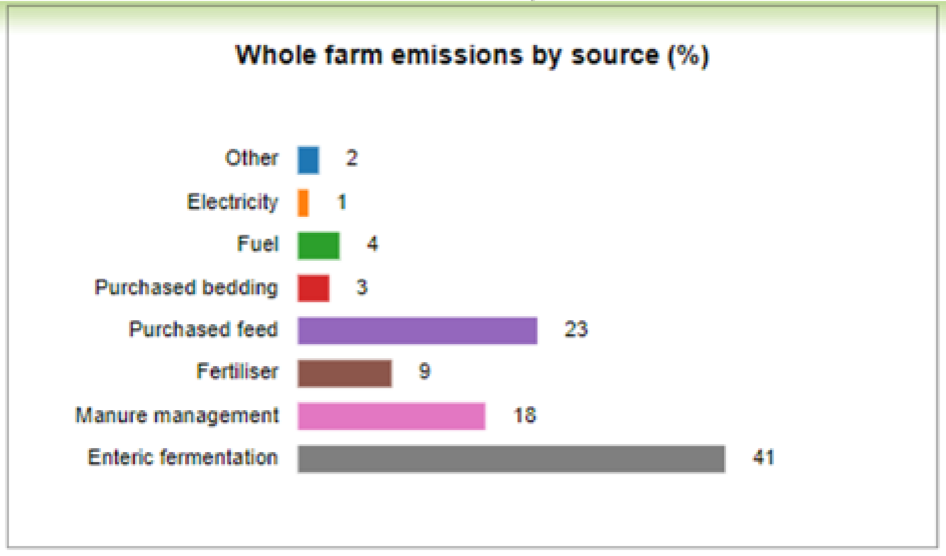



Harper Adams Research Farm Net Zero Journey
469 hectare mixed arable livestock (dairy and sheep) farm
Net Zero by 2030

Agrecalc

A leading agricultural resource efficiency and greenhouse gas emissions calculator developed by SAC Consulting and SRUC.





ams University Farm 2020)

View detailed results

		Whole Farm	Sheep	Dairy	Hay & graze	Feed wheat	Oilseed rape
		kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e
		251,518	24,743	164,952	1,184.44	39,812	20,787
		1,545,798	61,952	1,405,479	0	24,765	52,364
&		1,797,316	86,696	1,570,471	1,184.44	64,577	73,150
ne		2,603,785	425,709	2,178,077	0	0	0
oxide		961,555	157,253	602,733	539.11	151,723	47,944
Total CO_{2e} emissions from farming		5,362,660	669,657	4,351,280	1,723.55	216,300	121,094
Sequestration by forestry	(kg CO_{2e})	412,404					
Net emissions from land use		4,950,255					
Whole farm CO_2e emissions per kg of farm output	($KgCO_2e$/kg output) [2]	1.06					
Product CO_2e emissions							
Meat	Total $KgCO_2e$		650,426	164,752			
	($KgCO_2e$/kg lwt)		7.92	2.32			
	($KgCO_2e$/kg dwt)		17.59	4.37			
Wool	Total $KgCO_2e$		19,231				
	($KgCO_2e$/kg wool)		6.92				
Milk	Total $KgCO_2e$			4,186,529			
	($KgCO_2e$/kg FPC milk) [3]			1.10			
Eggs	Total $KgCO_2e$						
	($KgCO_2e$/kg eggs)						
Forage, grain, seeds, roots	Total $KgCO_2e$				1,723.55	190,518	106,660
	($KgCO_2e$/kg crop)				0.02	0.30	0.98
Straw	Total $KgCO_2e$					25,782	14,434
	($KgCO_2e$/kg straw)					0.13	0.24
Emissions per LU equivalent	($KgCO_2e$/LU)	0	4,832	8,002			
Emissions per hectare	($KgCO_2e$/ha)	10,506	4,202	14,146	123.02	2,421	3,016
Farm and enterprise output	(Kg)	5,041,058	39,748	3,842,409	82,580.00	840,580	168,600

Focus on NPP

- 38 hectare of woodland
- 18 km hedgerows restored
- 4.5 km new hedgerows
- 0.80 km planned this winter
- 413 tCO_2e sequestered

Focus on Fossil fuels (Fertiliser)

Quick glance enterprise emissions

	* kg CO_2e/ kg grain	Opportunity Level	Comparison
Manure and fertiliser	0.21	Low	0.29
Pesticides	0.000	Low	0.000
Lime	0	Low	0.02
Fuel	0.05	Low	0.06
Electricity	0.01	Medium	0.00
Crop residues	0.03	Low	0.03
Other	0	Low	0.00
Total emissions **	0.30	Low	0.41

Other: transport, waste

Physical performance of enterprise

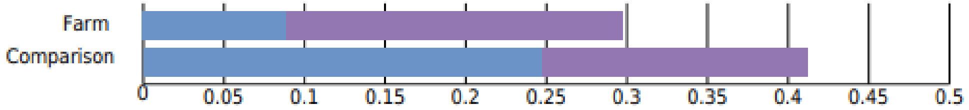
	Value	Comparison
Area of feed wheat sold (ha)	72.54	65.62
Grain yield (t/ha)	8.86	8.84
Straw yield (t/ha)	3.50	3.39
Fertiliser use (t per t grain)	0.04	0.09
Fertiliser use (t per ha)	0.35	0.77
Electricity use (kWh per t grain)	59.04	18.74
Red diesel use (l per t grain)	18.65	18.98
Red diesel use (l per ha)	165.32	159.47

Whole farm sustainability indicators

Nitrogen Use	37.62	kg/ha	**Water use**	41,326,020.00	litres
Phosphate Use	12.01	kg/ha	**Stocking density**	1.34	LU/ha
Potash Use	5.59	kg/ha	**Sequestration**	412.40	tCO_2e
Waste	9,705.00	kg	**Renewable energy used**	144,175.00	kWh

Emissions by gas and benchmark comparison

CO_2 : 0.09 kg CO_2e/unit output
CH_4 : 0 kg CO_2e/unit output
N_2O : 0.21 kg CO_2e/unit output



Focus on Soil

Direct drilling - less than £100/ha

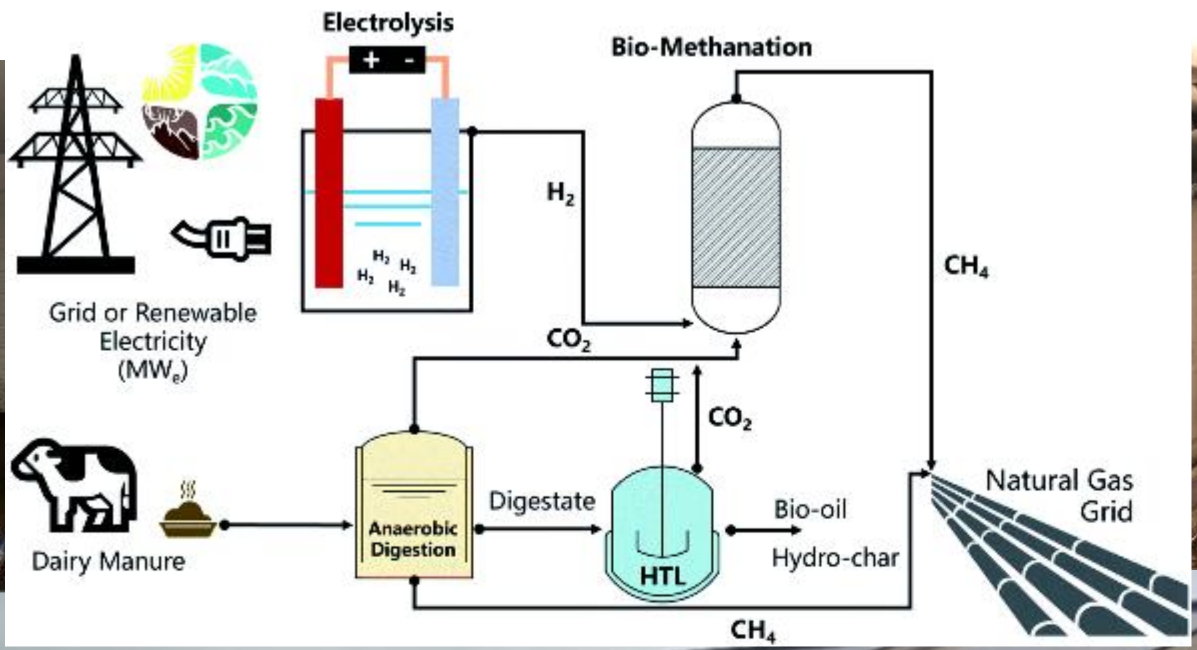
Worth a reduction of 1,074 tCO_2e

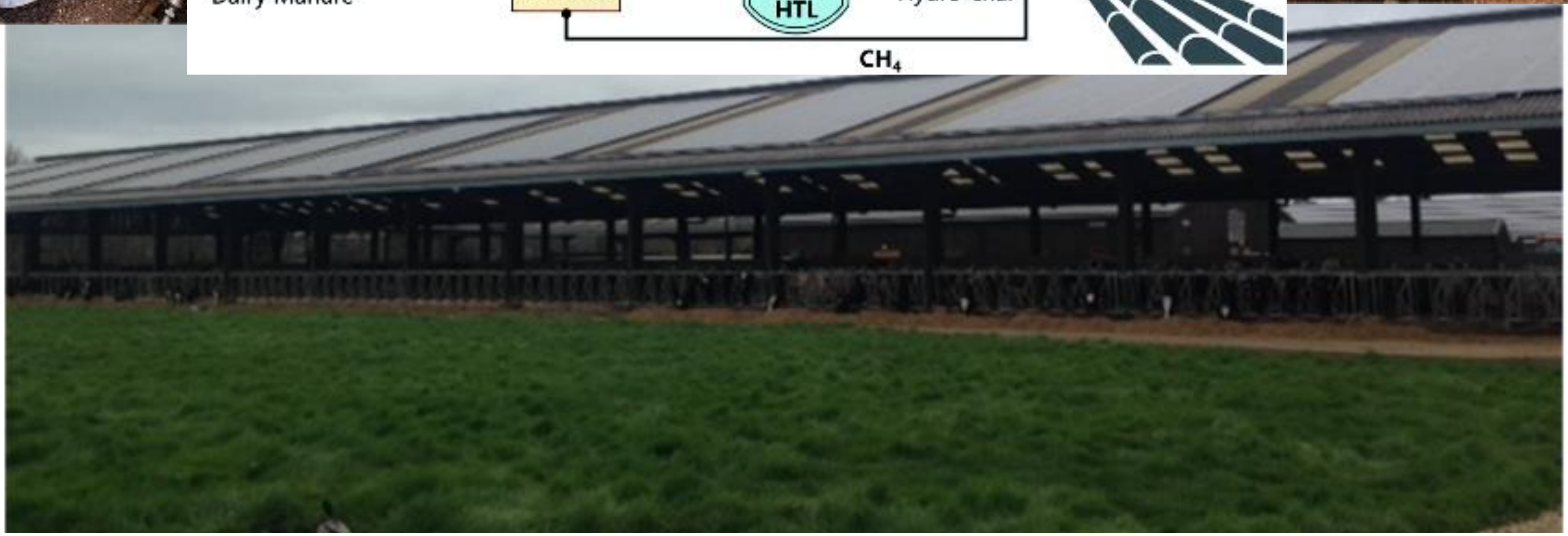
Focus on Integration (Soil, crops and Livestock)

Focus on integration (Soil, crops and livestock)

Focus on Forage

Focus on Green Energy





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OUR VISION

Educating, Inspiring and Empowering current and future farmers to achieve net zero within a sustainable farming and food system.

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http://harper.ac.uk/SSFF

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