Quantifying ozone impacts on three ecosystem services in the UK

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& the participants of the Defra Ozone Umbrella consortium.

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Ecosystem services

Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuel/wood
- Fibre
- Biochemical
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease control
- Water regulation
- Water purification
- pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- *Spiritual and religious*
- *Aesthetic*
- *Inspirational*
- *Educational*
- *Sense of place*
- *Cultural heritage*

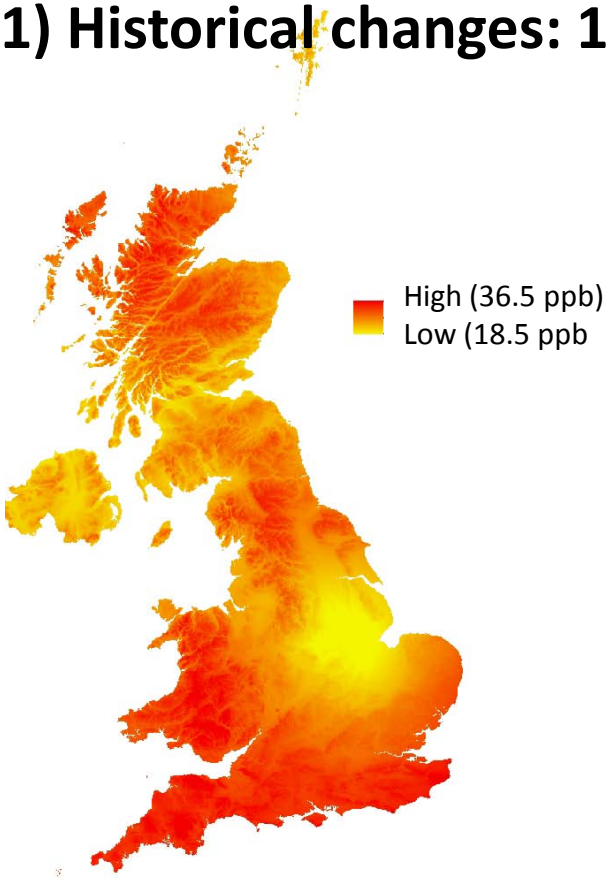
Supporting Services

Services necessary for the production of all other ecosystem services

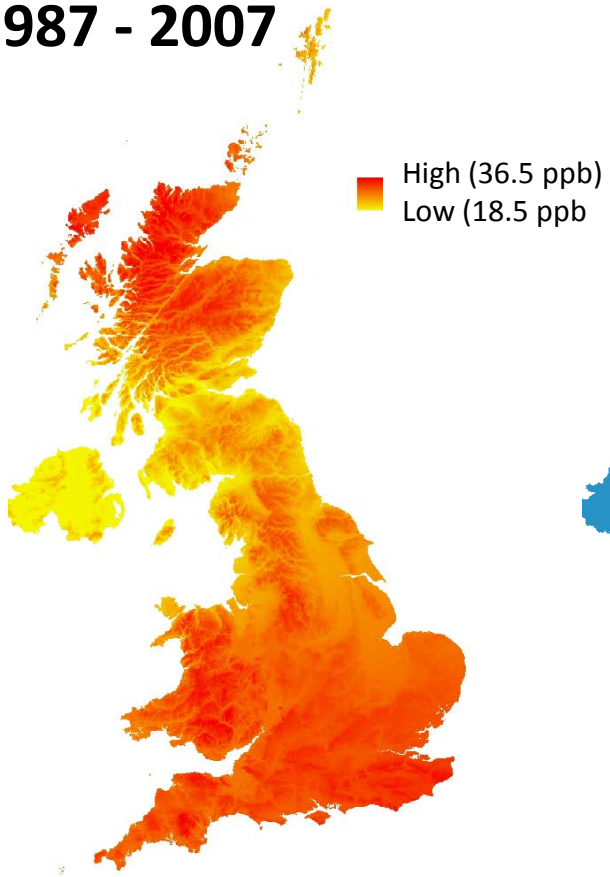
Soil formation *Nutrient cycling* *Primary production* *Water cycling*

Changing spatial pattern of ozone concentrations

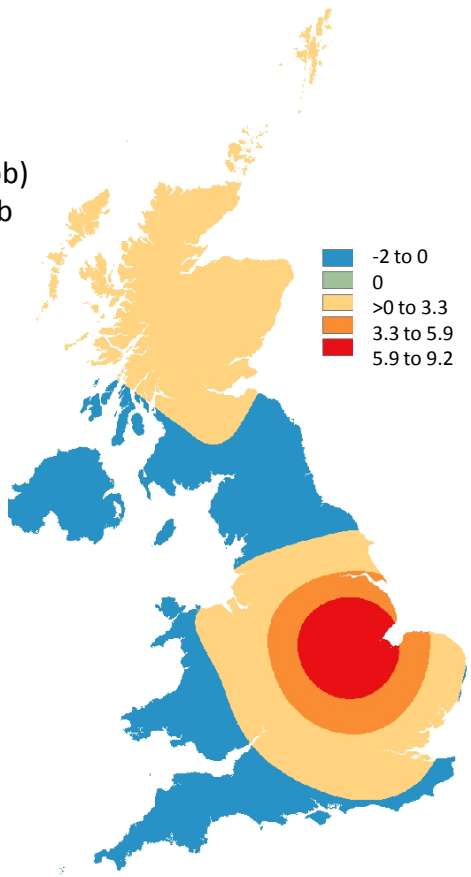
(1) Historical changes: 1987 - 2007



1987 – 1991, 24h mean, March - Sept



2002 – 2006, 24h mean, March - Sept



Difference in ppb

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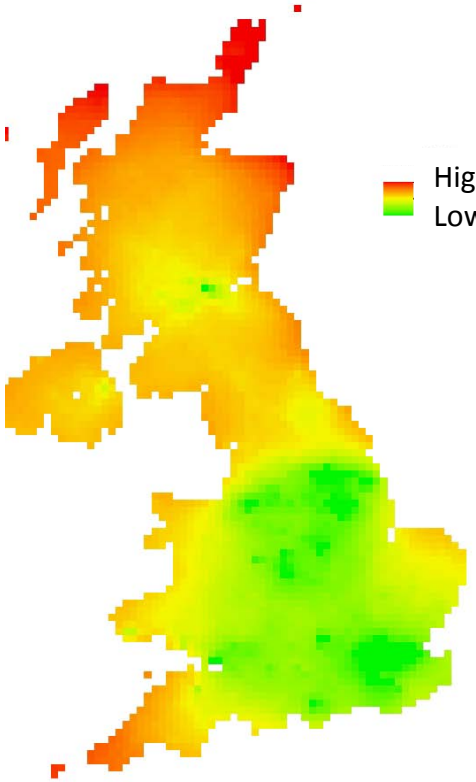
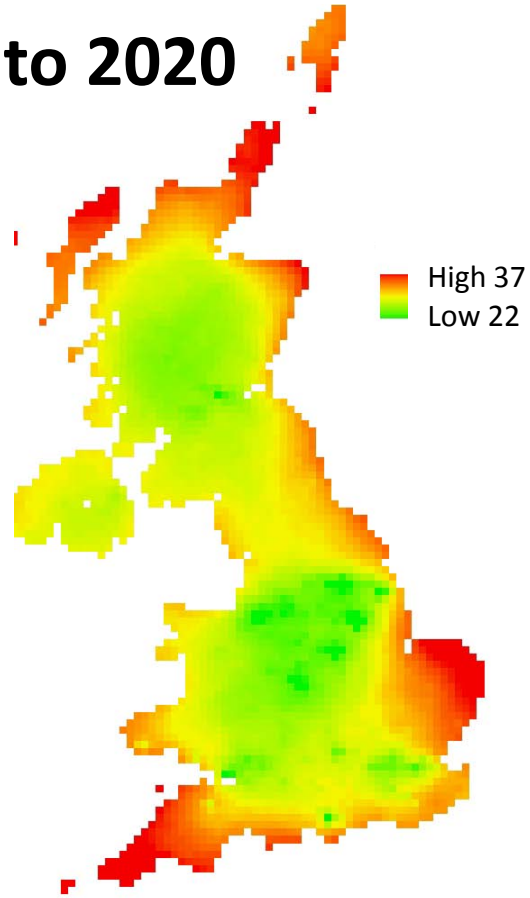
Maps provided by Mhairi Coyle

Changing spatial pattern of ozone concentrations

(2) Future predictions, 2007 to 2020



2007, 24h mean, March - Sept



2020, 24h mean, March - Sept

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Maps provided by AEA

Experiments within the ozone umbrella

Lancaster University

Grassland Species
+/- ozone

CEH Bangor

BAP Priority habitats:
Acid Grassland
Coastal and Flood Plain grazing meadow
8 ozone treatments

Newcastle University & York University

Mesotrophic grassland;
Sand-dunes;
spring bulbs
2 – 4 ozone treatments

Keenley All

Upland conservation hay meadow
Gradient of ozone treatments

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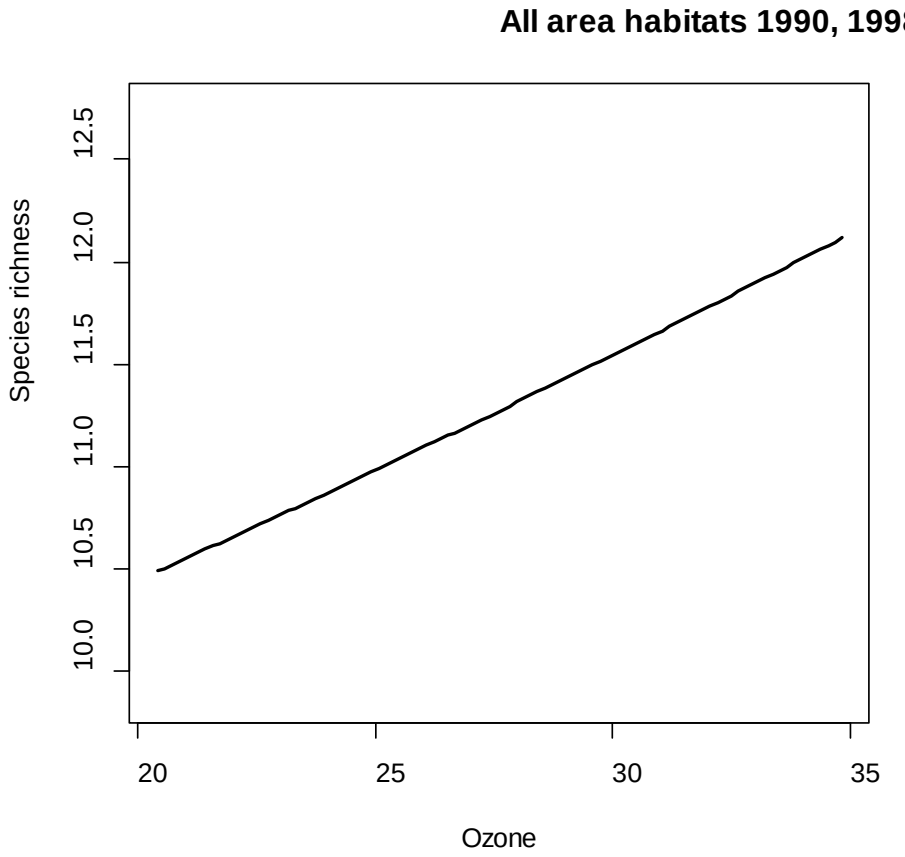
Appreciation of biodiversity

Appreciation of biodiversity (species richness)

- National-scale gradient analysis,
- 1 km data from Countryside Surveys from the years 1990, 1998 and 2007
- Analysis in R using General Additive Mixed models
- Includes: 24h O_3, min temp., max temp., Rain, NOy, NHx, change in SOx for 1990, 1998 and 2007
- Analysis by species richness and broad habitat type


Gradient analysis: all habitats



(model also includes temp, NOy, NHx, Rain, change in SOx)

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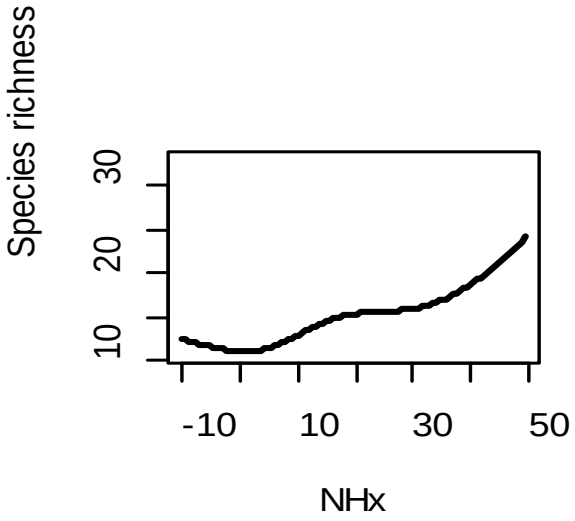
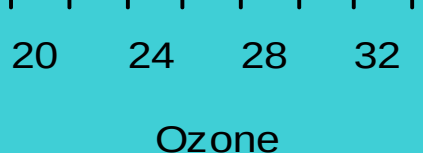

Species richness
10
20
30
-10
10
30
50
NHx



Species richness #1

Carbon Sequestration

Carbon sequestration: Input datasets

Site	ExptShortCode	ExptLongName
Bangor	U4_Com	U4 communities 2004 2005
Bangor	CG10_Com	CG10 communities 2005
Bangor	Heath_Com	Heath 2009 2010
Bangor	Viola_Com	Viola communities 2006
Bangor	Calc_Com	Calcareous 2009 2010
York	KF_York	KeenleyFell_York
Bangor	KF_Bang	KeenleyFell_Bangor
Newcastle	MG3b	MG3b mesocosms
Newcastle	SD9b	SD9b sand dune mesocosms

Mesocosms, complex species mixtures (>3 spp)

Field –based exposures

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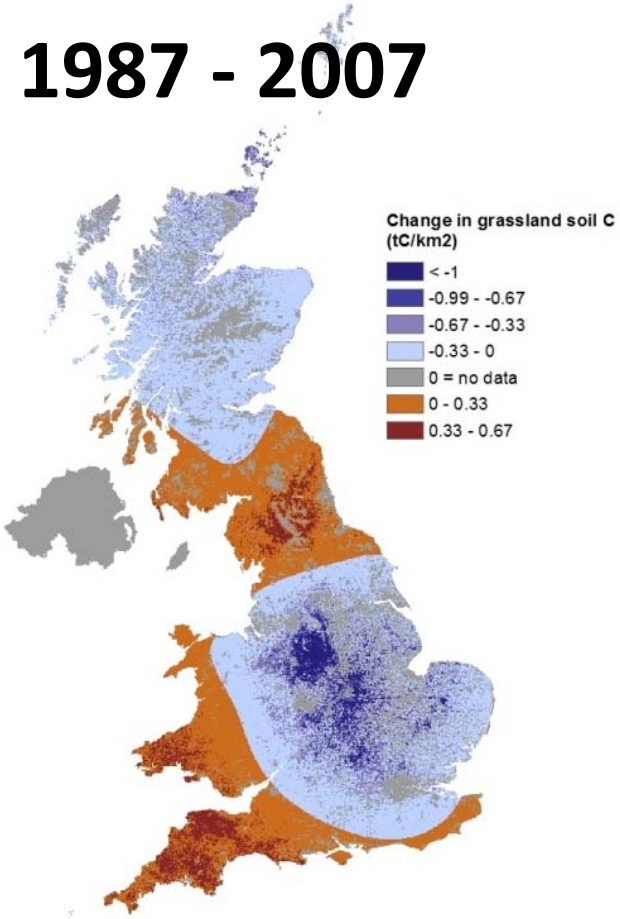
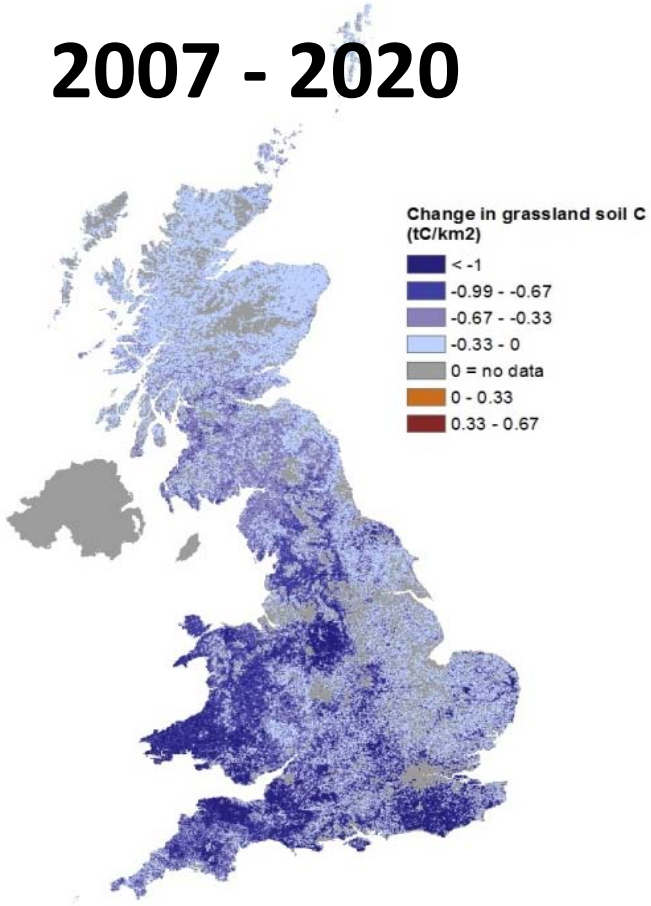
Change in C sequestration

1987 - 2007



2007 - 2020



Changes in carbon sequestration (tC/km^2) due to ozone*

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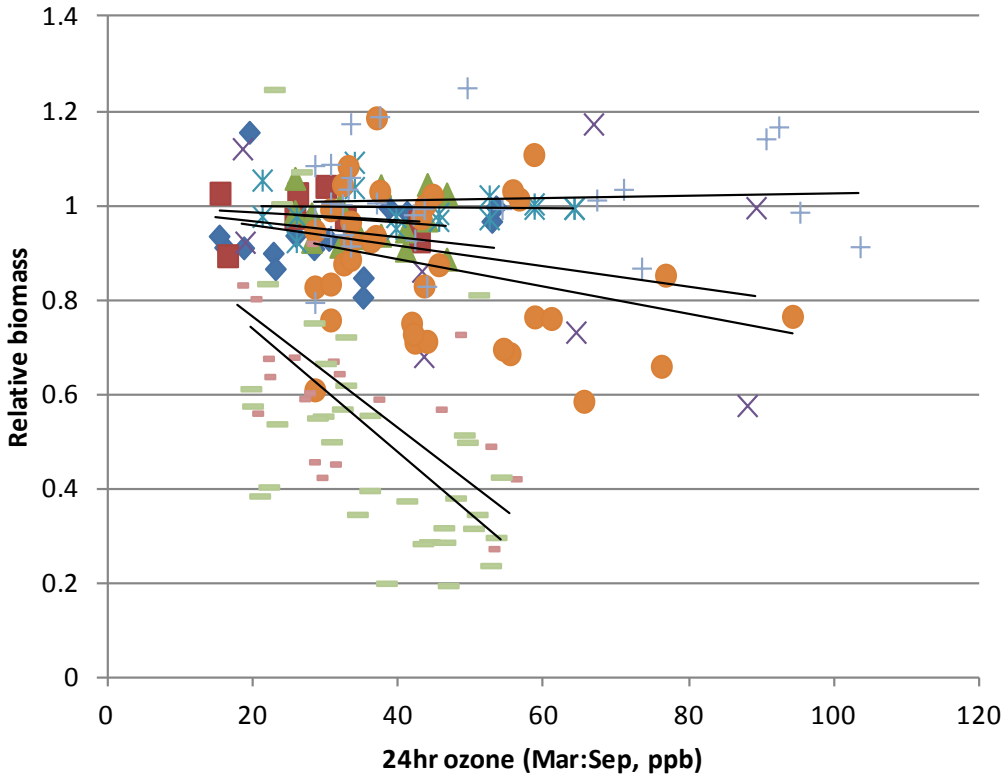
*** Latest data…**

Carbon sequestration: Dose response



Overall function

Y = -0.0041 X + 1

- U4_Com
- CG10_Com
- Heath_Com
- Viola_Com
- Calc_Com
- KF_York
- KF_Bang
- MG3b
- SD9

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Carbon sequestration: Calculations

Applying calculations spatially:

Dose response used to predict total NPP at predicted ozone concentrations (MODIS data)

Filtered for squares where > 25% grassland (LCM 2007)

10% of NPP goes to long-term soil C allocation in grasslands

Convert to tCO2e

Use non-traded shadow price of C (2010 price = £51.70 /tCO2) & discounting procedures to calculate value of changing ozone on C in each year

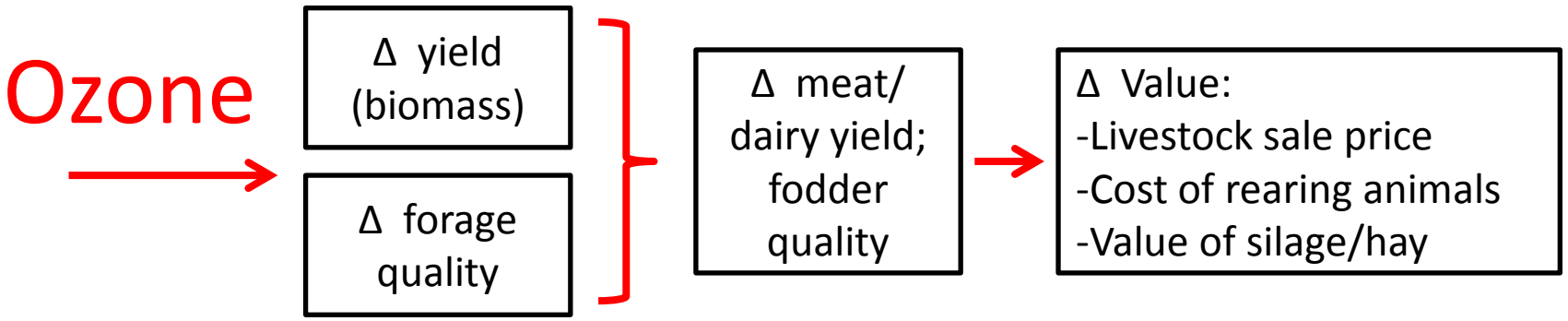
Calculate Net Present Value & Annual Equivalent Value

Cost of ozone impacts on grassland C allocation

	Historical - Comparison of 1987 with 2007	Future to 2020 (based on UEP30 scenario) - Comparison of 2007 with 2020
Total loss in C sequestered (tons)	188,000	623,000
Total losses (£)	£22.1 million	£94.4 million
Equivalent Annual Net loss (£)	**£1.6 million**	**£9.2 million**

Pasture Quality

Impact pathway: Pasture quality



	2012 number	Range 2005 – 2012
Beef cattle > 2 years old	1.7 million	1.7 – 1.8 million
Dairy cattle > 2 years old	1.8 million	1.8 – 2.0 million
Sheep + lambs*	32 million*	31 – 32 million

* Value £1.1 billion

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Datasets used

Site	Experiment	Sub-treatments
CEH-Bangor	Calcareous grassland	Well-watered, drought
CEH-Bangor	*Dactylis glomerata-Ranunculus acris*	Drought, well-watered, wet
CEH-Bangor	*Leontodon hispidus – Anthoxanthum oderatum*	
CEH-Bangor	*Leontodon hispidus-Dactylis glomerata*	
CEH-Bangor	*Dactylis glomerata-Ranunculus acris*	Drought, well watered
CEH-Bangor	Keenley	+/- N(all un-grazed), 2009, 2010 and 2011
Newcastle Uni	Sand dunes	
York University	Keenley	2010, 2011 (all grazed)

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Sample preparation

Stored samples from previous ‘grassland’ experiments
All had different ozone treatments
Different years and different sub-treatments

Samples were recombined (after previous sorting per species…), cut with shears and thoroughly mixed
Each ‘sample’ was 100g+
> 200 samples were sent for forage quality analysis

Approx. 1/3 of samples from CEH Bangor

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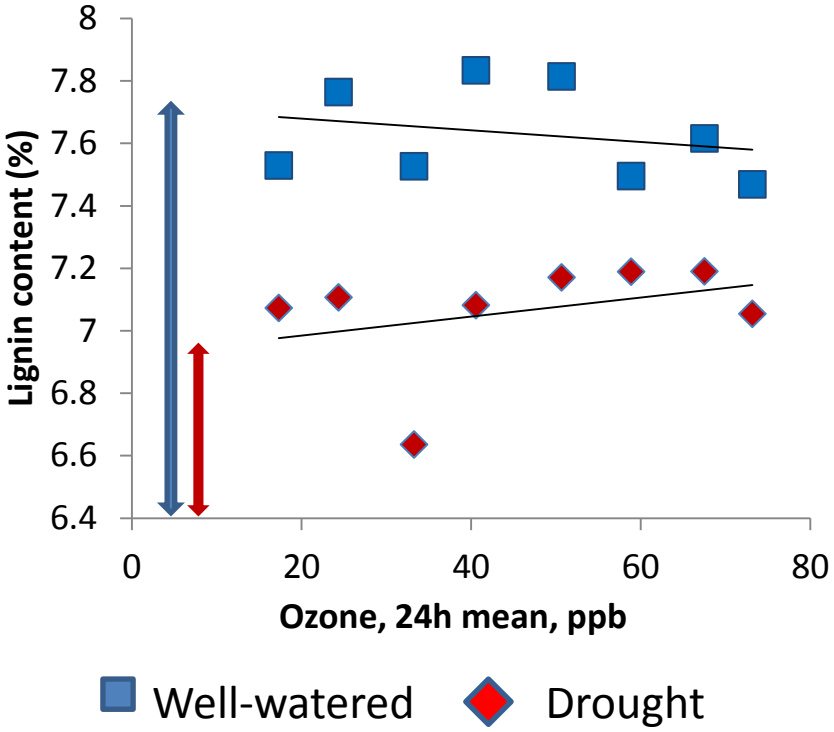
Standardisation of data



e.g. Calcareous grassland - solardomes

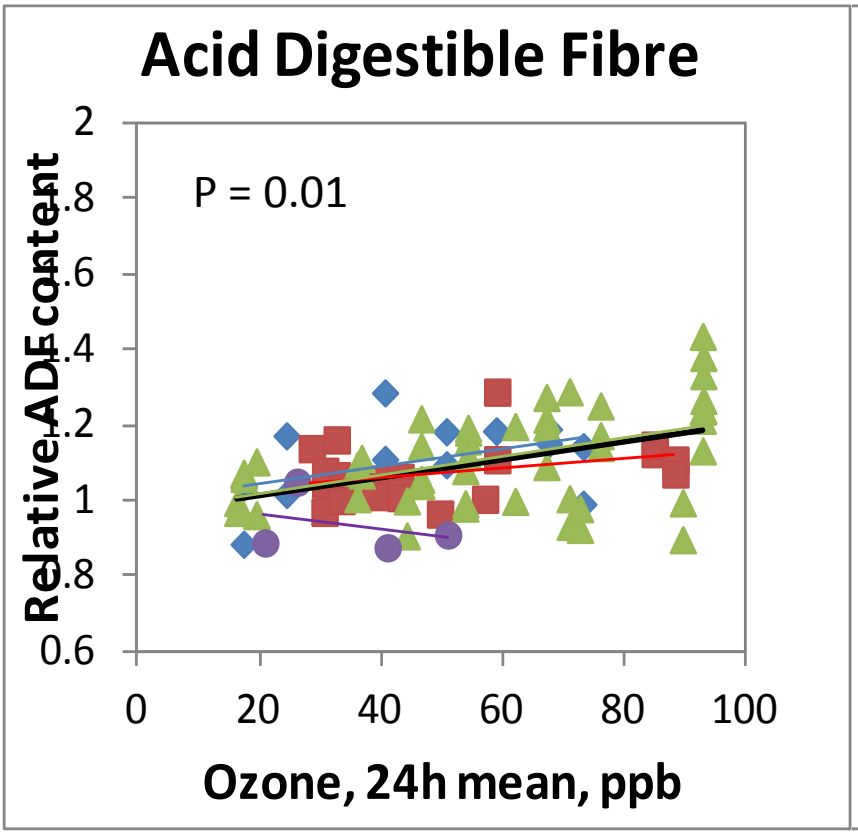
Quality parameters

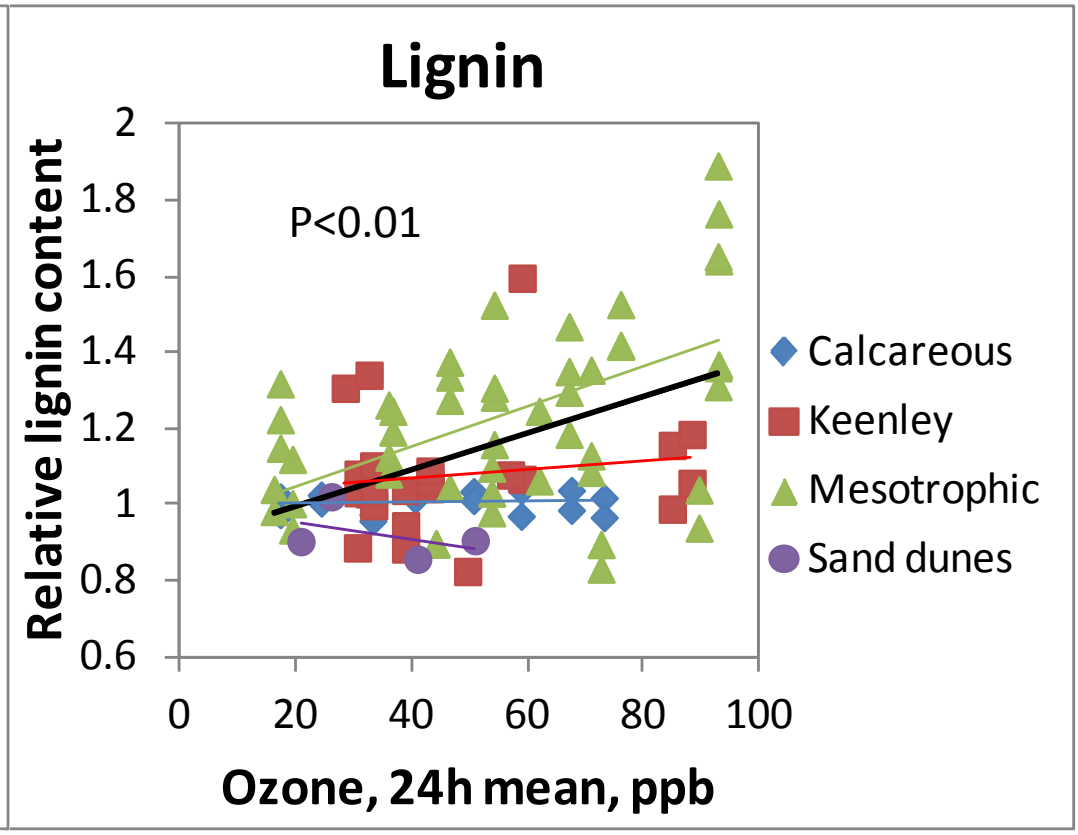
All datasets were standardised by calculating the value at 0 ppb (by regression), and expressing the measured values relative to this.

'Yield' calculated (e.g. for protein)

This is a combination of % in the sample, and above-ground biomass.

Forage Quality





No significant effects on “desirable” characteristics

“Undesirable” pasture characteristics increase with increasing ozone

- Pattern is repeatable across grassland types

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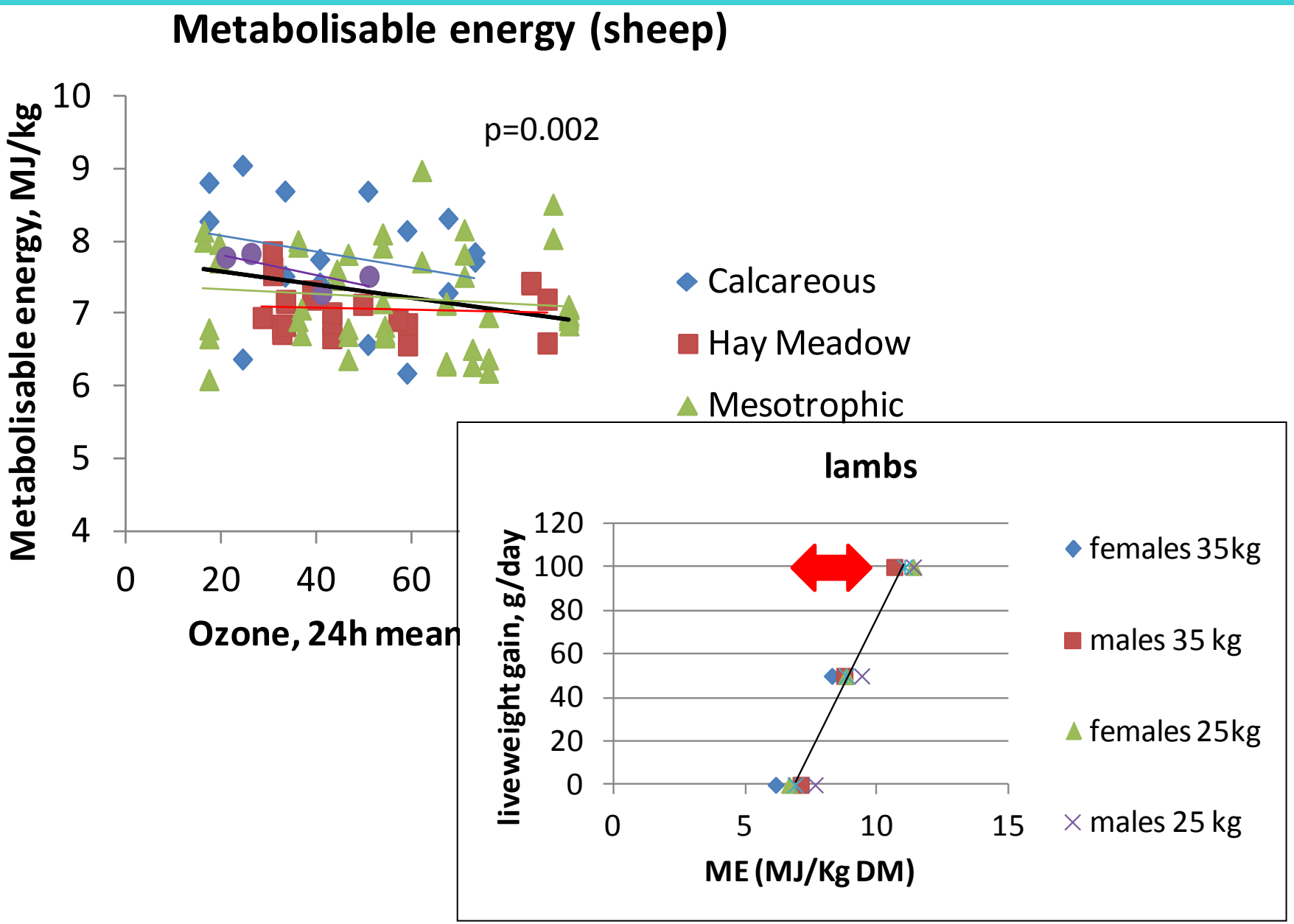
Forage quality



Ozone impacts on liveweight gain

From 2007 to 2020

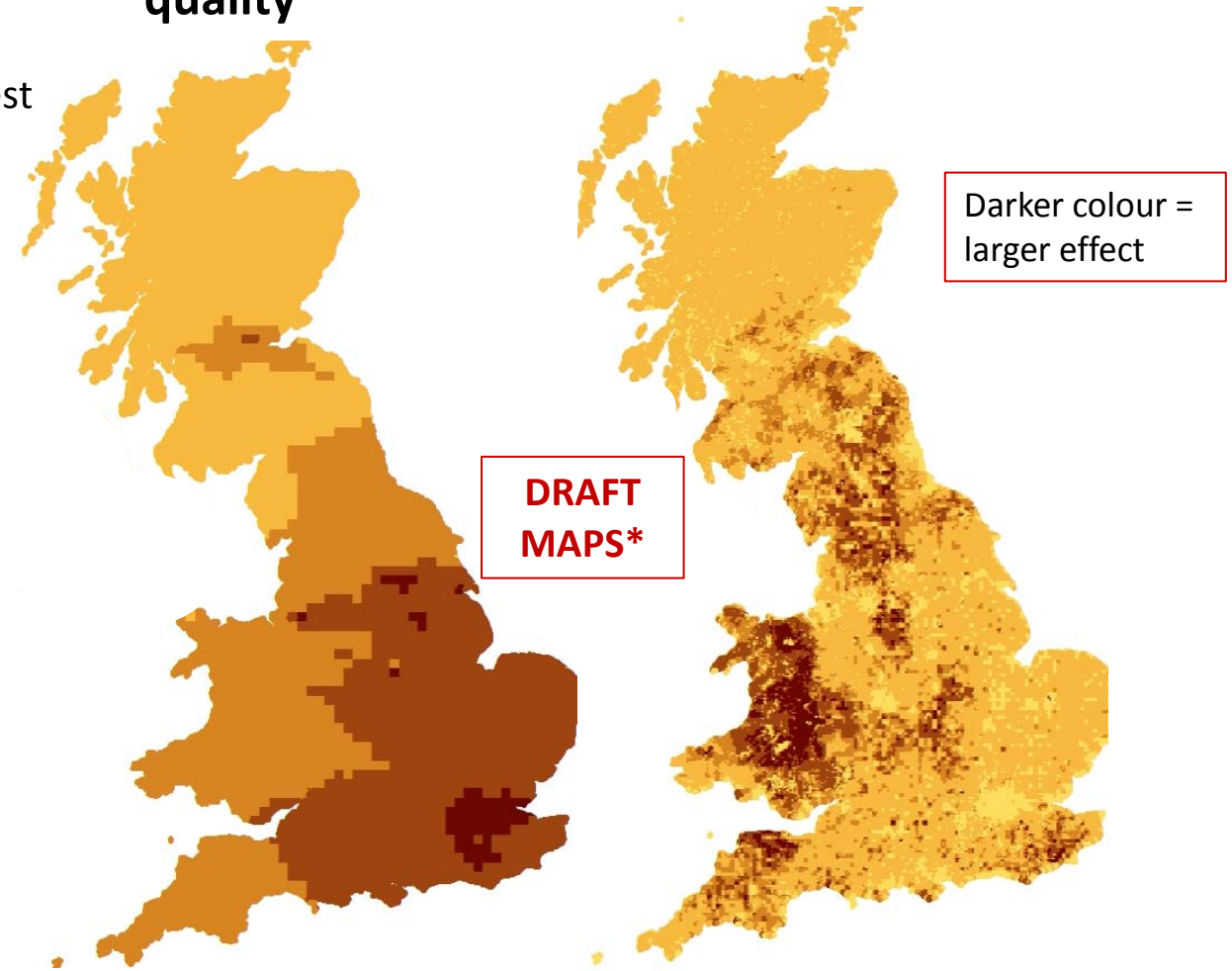
In the UK the effects are largest where the ozone increase is moderate but there are many lambs

Total liveweight gain of lambs per day is predicted to be decreased by 4% in 2020 compared to 2007

Flock management information is needed to translate this into a monetary impact

Decrease in pasture quality

Liveweight gain per square

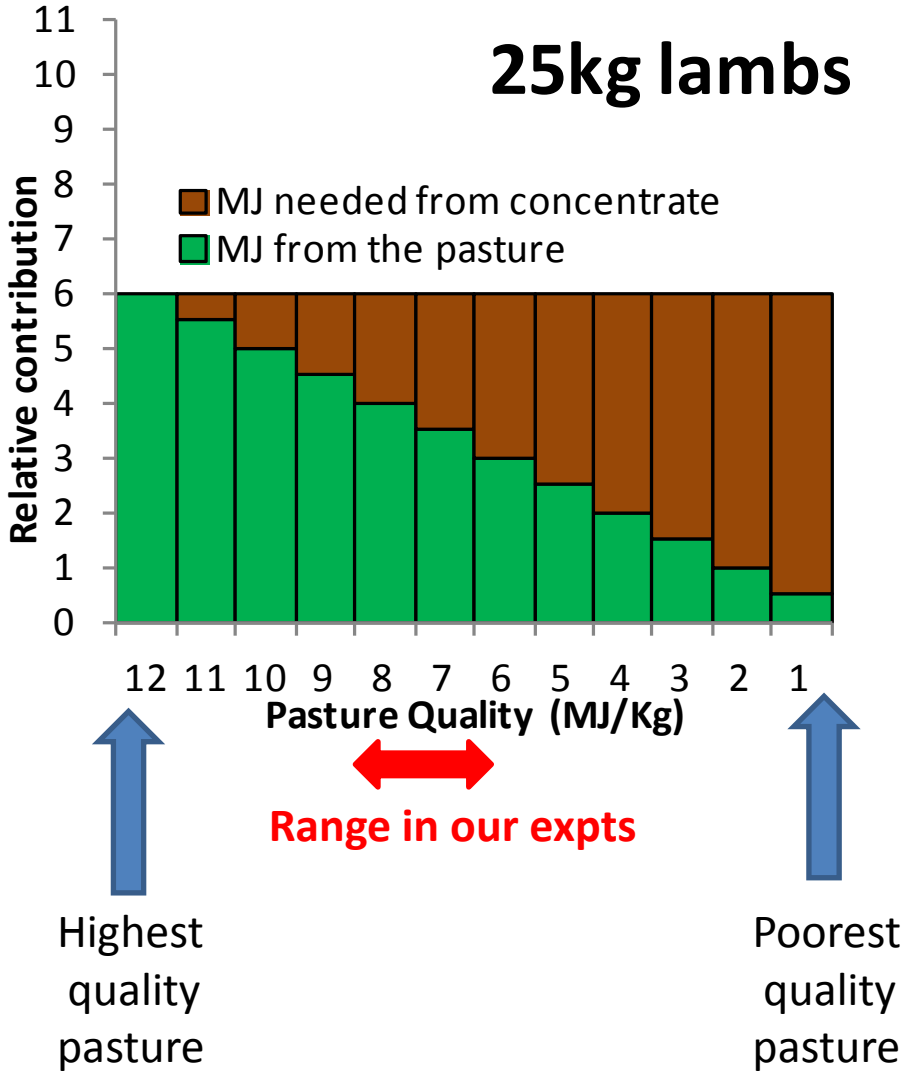


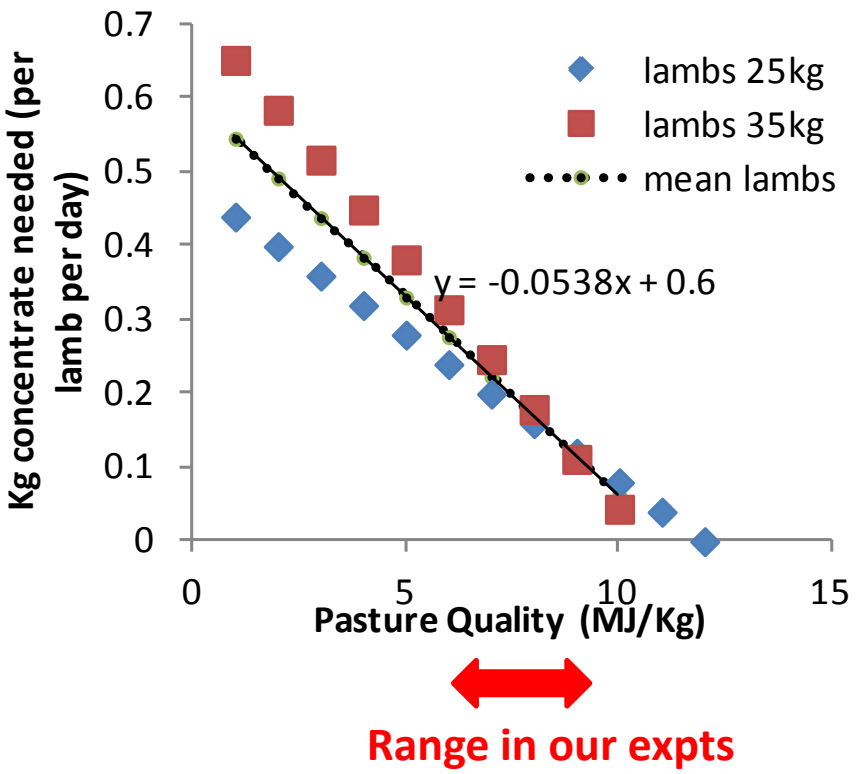
Darker colour = larger effect

DRAFT MAPS*

* To be corrected for pasture location

Pasture quality vs supplementary feed





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* Relationships varies by lamb size

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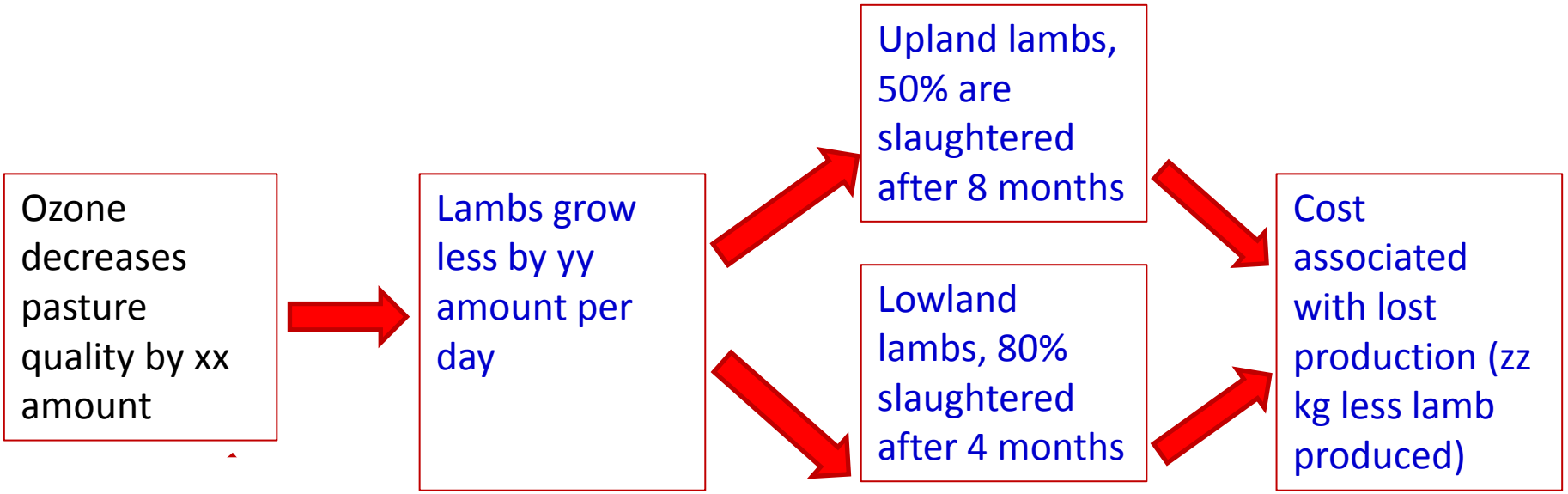
Calculation Pathway



Economic valuation

		Loss in live weight gain		Additional feed needed	
		1987 - 2007	**2007 - 2020**	**1987 - 2007**	**2007 - 2020**
upland	%	0.7	3.5	0.1	0.6
lowland	%	0.4	4.2	0.1	0.7
Total change in annual net loss*	£million	89.1	86.2	57.3	59.4

UK 1.1 billion for sheep and lambs , 2011 production value
£3.46 per kg deadweight (Dec 2012 price)

*Mean change in value per year , calc from kg of sheep in UK that are eaten (50% upland, 80% lowland) x discount factor x price/kg, added for upland and lowland

New Defra contract (thank you!)

Assessment of the Impacts of Air Pollution on Ecosystem Services: Gap Filling and Research Recommendations

Work Package 1 – summarise evidence gaps

- Critical review of impact pathways to identify evidence gaps
- Evaluating knowledge gaps and the feasibility of addressing them

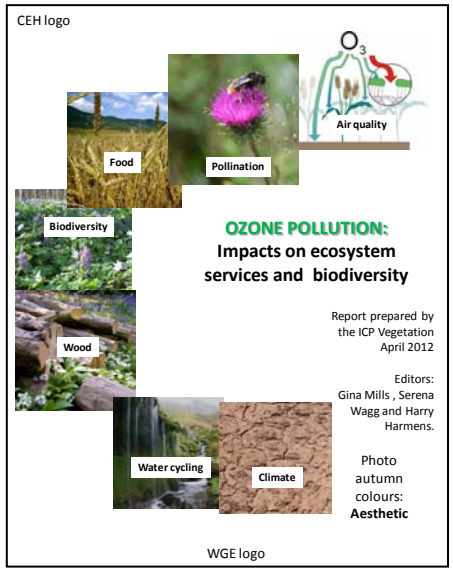
Work Package 2 – develop the assessment for selected ecosystem services

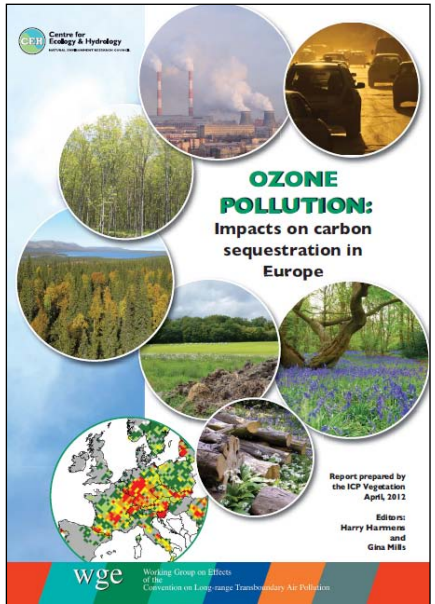
For example:

- Spatially explicit calculation of nitrogen impacts on biodiversity, and subsequent valuation
- Ozone impacts on crops

Work Package 3 – identify and prioritise further research requirements

ICP Vegetation State of Knowledge Report





Ozone Pollution: Impacts on Ecosystem Services and Biodiversity

1. Introduction
2. Ecological processes and supporting services
3. Provisioning services
4. Regulating Services
5. Cultural services
6. Placing an economic value on effects
7. Conclusions and recommendations
8. Annex 1 : Contributions from participants
9. Annex 2: O_3 and stomatal conductance

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Ecosystem Services Summary (1)

Biodiversity:

Route to valuation not yet clear

Dose-response relationships with species richness are not consistent; closely follow temperature gradient

Carbon sequestration:

For grassland soil, £1.6 and £9.2 million annual equivalent losses due to lost C sequestration (provisional data)

Where services can be taken through to valuation, we will estimate*Uncertainty* & calculate *Damage cost* figures per unit 7mo. 24hr mean ozone.

Ecosystem Services Summary (2)

Pasture quality

Overall, there was a decline in forage quality in terms of metabolisable energy value and therefore animal production

Differences in farming practices make attributing a monetary value difficult, but losses have been calculated of ~£90 million per year based on reduction in liveweight gain , which could be offset by ~£60 million per year for more feed

To do:

Finalise maps
Uncertainty analysis
Finalise C sequestration in grasslands
Complete report (by end of April).

Thank you to Defra for supporting this study

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Valuation based on liveweight gain

Liveweight Gain	Historical (1987 – 2007)	Future (2007-2020)
Upland		
Total Weight Reduction	0.7%	3.5%
Equivalent Annual Net Benefit	£26,708,916	£25,877,895
Lowland		
Total Weight Reduction	0.4%	4.2%
Equivalent Annual Net Benefit	£62,359,768	£60,338,956
Total change in Annual Net Benefit (all lambs)	£89,068,684	£86,216,851

Valuation based on supplementary feed

Additional Concentrate Feed Required	Historical (1987 – 2007)	Future (2007-2020)
Upland		
Additional Concentrate Required	0.1%	0.6%
Equivalent Annual Net Benefit	£18,304,901	£18,9447,561
Lowland		
Total Weight Reduction	0.1%	0.7%
Equivalent Annual Net Benefit	£39,022,697	£40,404,075
Total change in Annual Net Benefit (all lambs)	£57,327,598	£59,351,636