PLACING A VALUE ON OZONE EFFECTS ON ECOSYSTEM SERVICES: A CASE STUDY FOR THE UK

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* With contributions from the Defra Ozone Umbrella consortium, ICP Vegetation and EMEP participants

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Ecosystem services valued

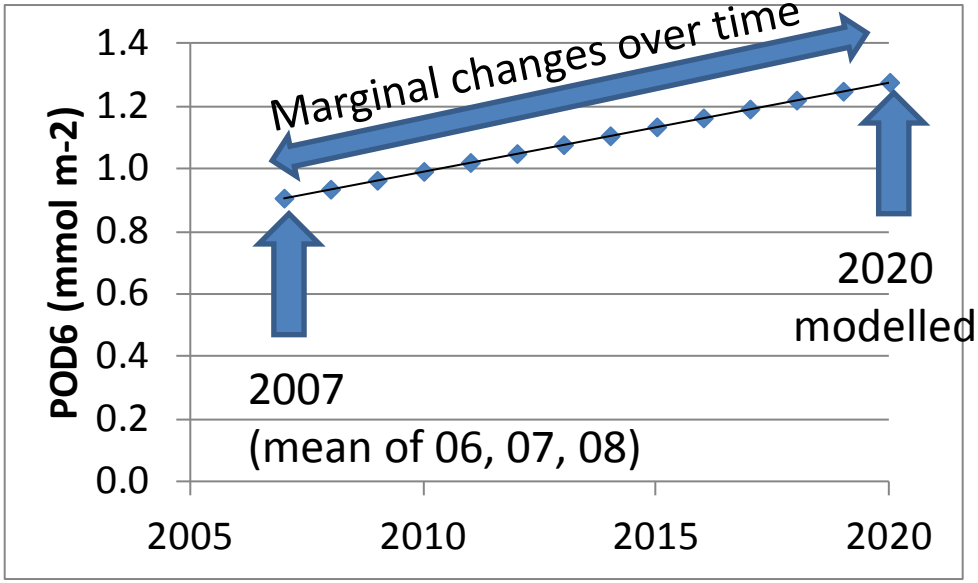
Funded by Defra*, we have **spatially analysed the marginal costs for the UK** of effects of ozone on:

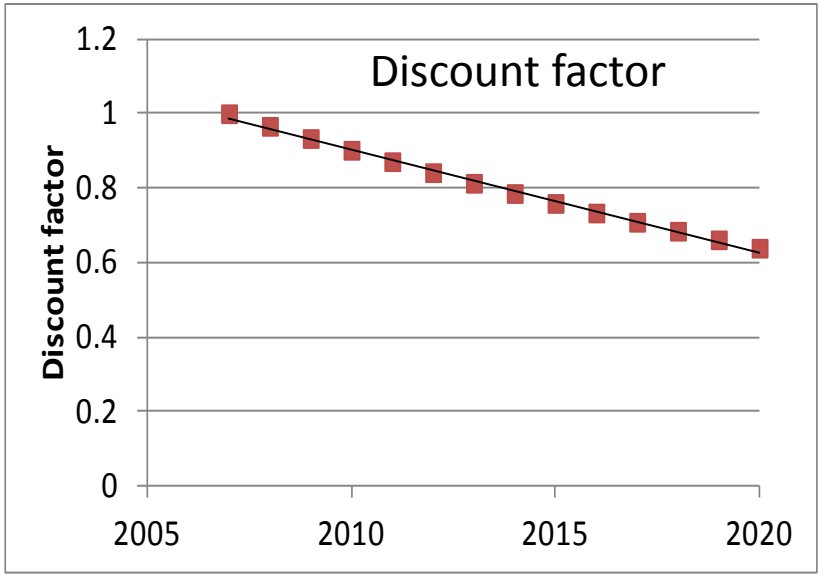
- Carbon sequestration by grasslands (regulating service)
- Lamb production via effects on pasture quality (provisioning service)
- Wheat production (provisioning service)

Although not yet taken through to valuation, we have also investigated effects on biodiversity

* Thank you!

Marginal costs: valuation method





Marginal costs approach, used for comparison of damage costs across impacts

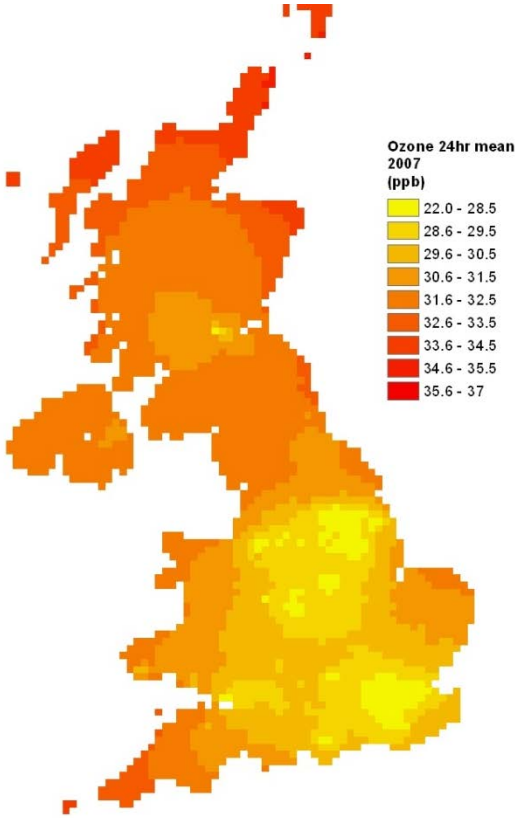
For each increasing year, for each 10 x 10 km square, calculate

Value per year = Change in yield in each year compared with reference year
x price of wheat (€126/tonne) x discount factor

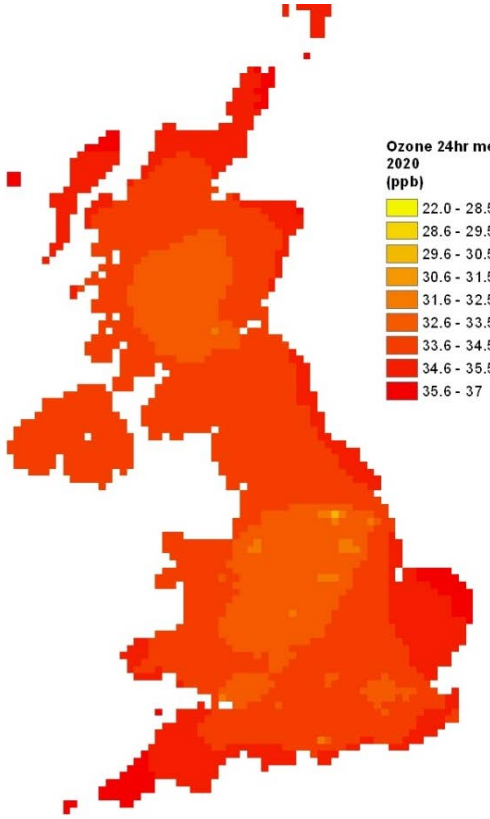
Equivalent Annual Net Value = sum of values for each year /annuity value

Damage cost = Equivalent annual net value/average change in O3 conc./flux over time

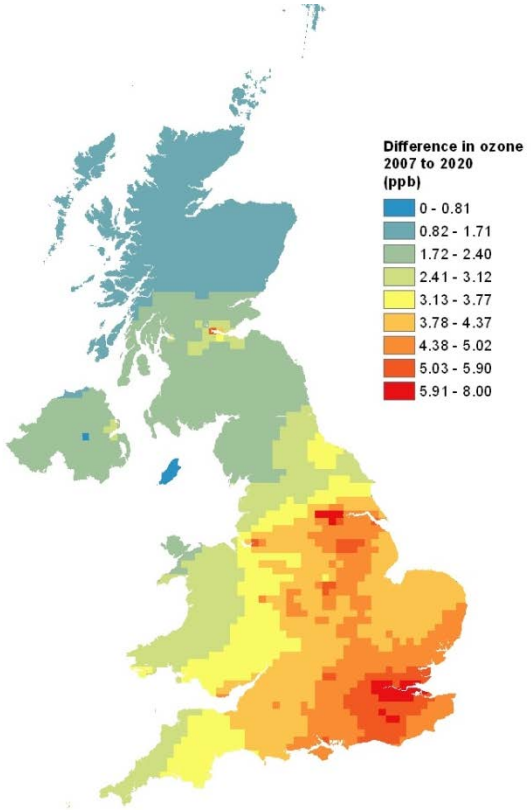
24h mean O_3 conc., 2007 to 2020



2007
(mean 30.9 ppb)



2020*
(mean 33.8 ppb)



Difference
(2020 – 2007)

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*OSRM model, based on 2007 met data, DECC UEP43 CCC energy projection and NAEI2008 emission spatial distribution maps, 7 month growing season

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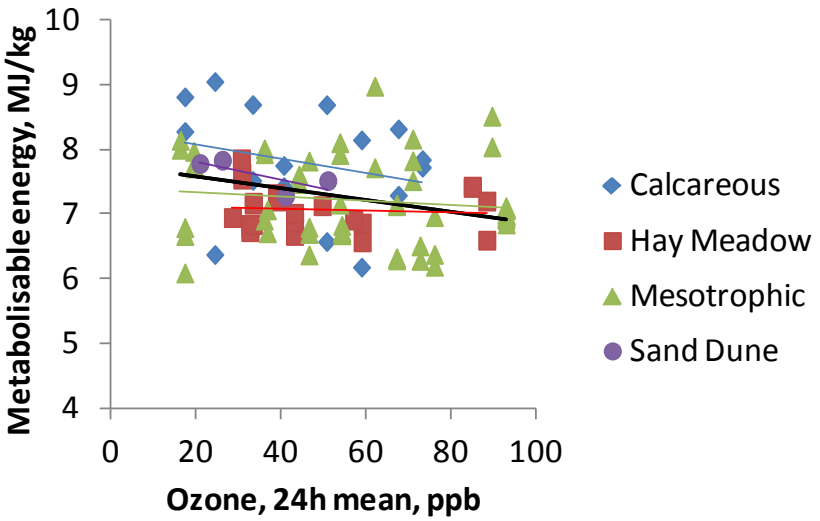
Impact pathway for pasture quality

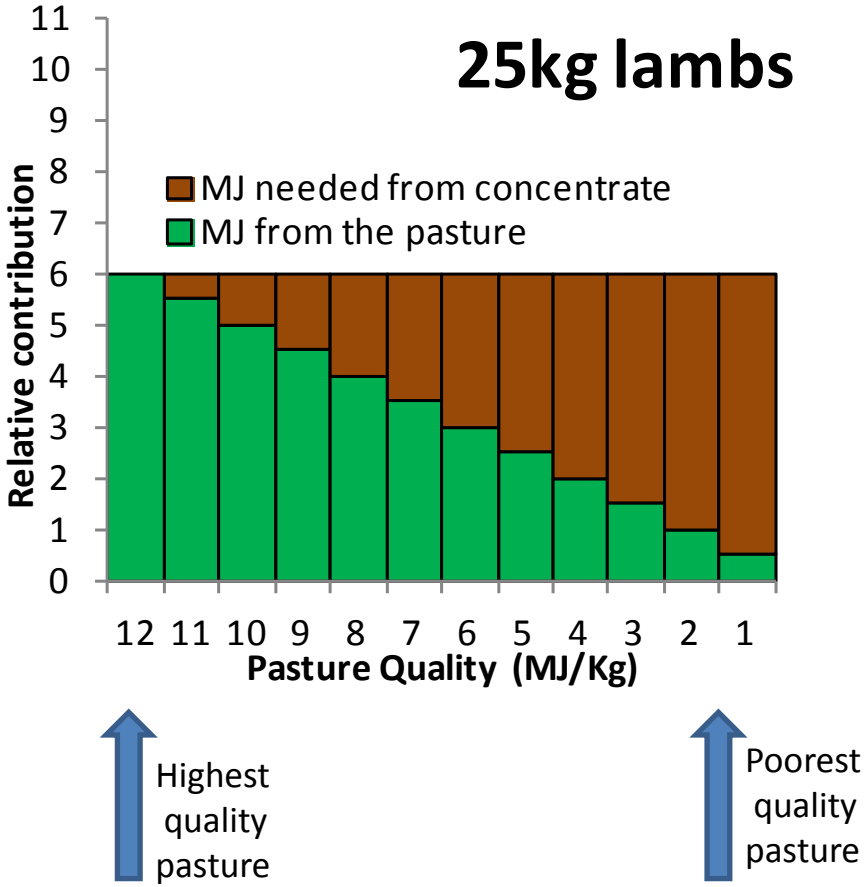
Δ ozone conc. → Δ yield (biomass); Δ forage quality → Δ meat/ dairy yield; fodder quality → Δ Value:
-Livestock sale price
-Cost of rearing animals
-Value of silage/hay

In 2012 there were 32million sheep and lambs in the UK, of total value £1.1 billion (€ 1.3billion)

Pasture quality vs supplementary feed

Ozone effects on metabolisable energy (a measure of pasture quality)





❑ Increasing ozone pollution reduces the energy available from pasture, reducing lamb growth unless supplementary feed is provided

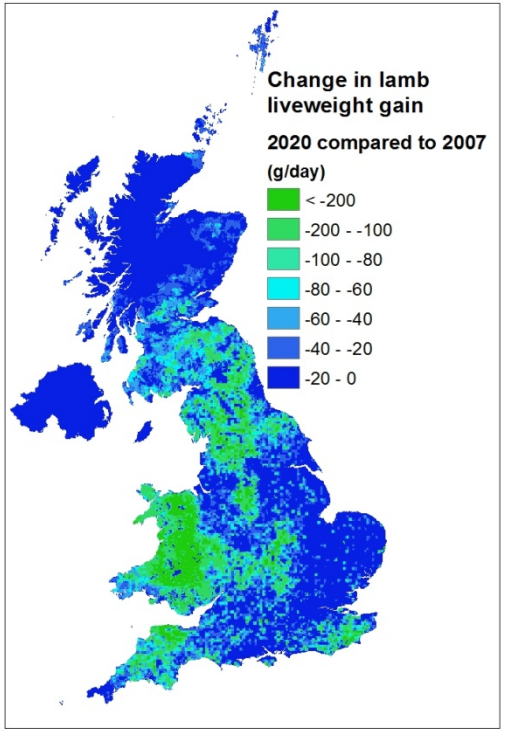
* Relationships varies by lamb size

Ozone impacts on lamb liveweight gain

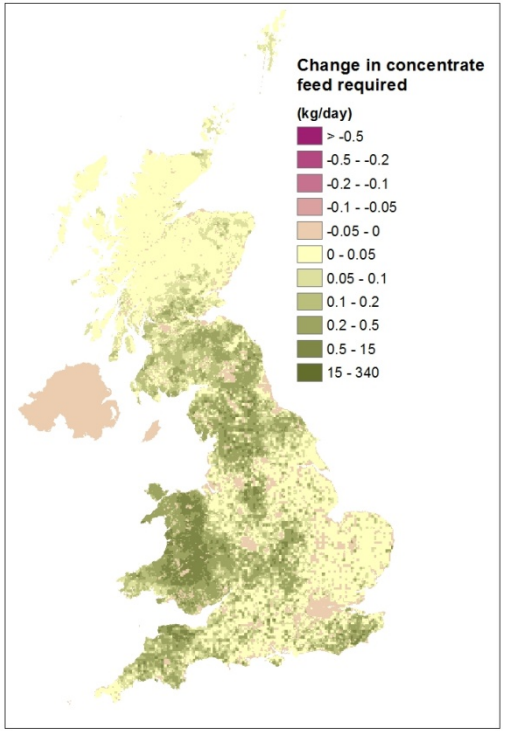
From 2007 to 2020

- 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

Change in Liveweight gain per square



Change in concentrate required to reach target sale weight of lambs



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Marginal costs of ozone impacts on lamb production

Based on change in concentrate needed to get lambs to target weight	**From 2007 to 2020**	**Range (95% CI)**
Total Value accumulated (2007 to 2020)	-€295k	-€1.9k to -€571k
Equivalent Annual Net Value (£)	-€227k	-€91k to -€367k
The damage cost per unit increase in growing season 24 hr mean ozone (ppb)	-€147k	-€57k to -€229k

* Includes separate calculations for upland and lowland lambs

Quantified sources of uncertainty: spatially variable ozone concentration, regression equation, predicting liveweight gain per lamb from pasture quality, distribution of lambs

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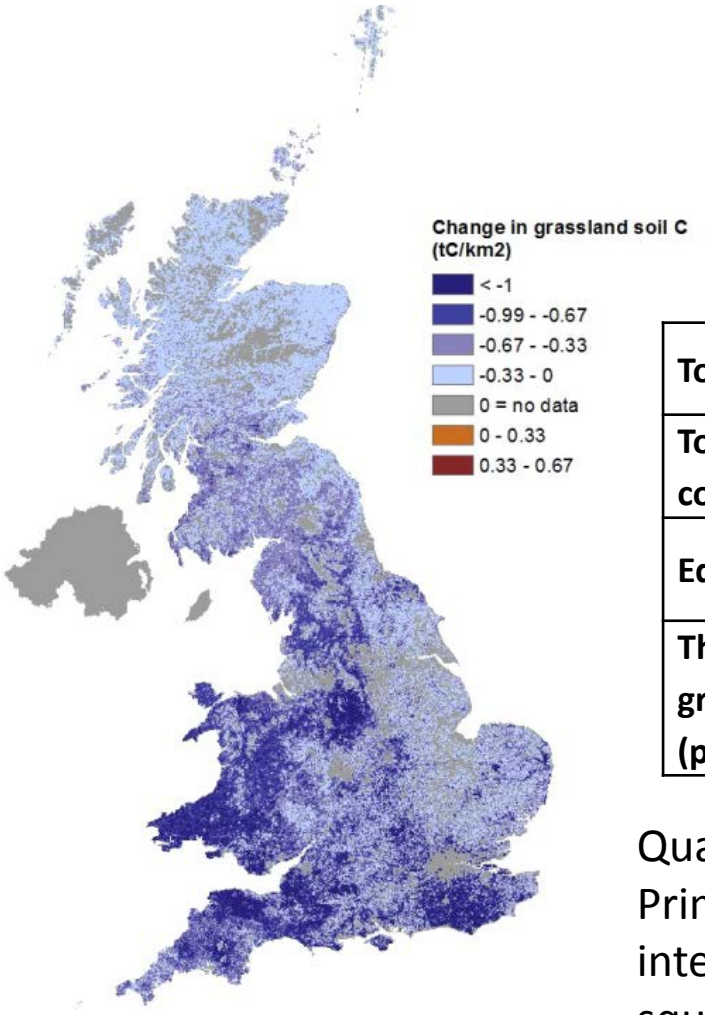
Impact pathway: Carbon sequestration

Δ ozone conc. → Δ biomass (NPP) → Δ C long-term allocation below ground → Δ Value: non-traded shadow price of C (2010 price = £51.70 /tCO2)

Marginal costs of ozone impacts on grassland C allocation



	From 2007 to 2020	Range (95% CI)
Total change in C sequestered (tons)	-619,000	
Total accumulated value of marginal costs (2007 – 2020)	-€111 million	-€76 million to -€155million
Equivalent Annual Net Value	-€10.9 million	-€7.3 million to -€15million
The damage cost per unit increase in growing season 24 hr mean ozone (ppb)	-€6.7million	-€4.6 million to -€9.3million

Quantified uncertainty: Spatial variability of ozone; Primary Productivity data; response function slope and intercept; NPP allocated to soil C; % grassland in 1 km square

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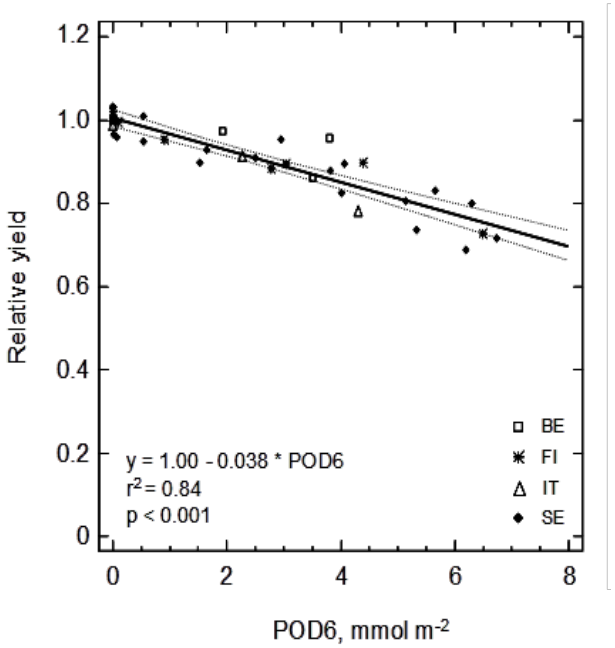
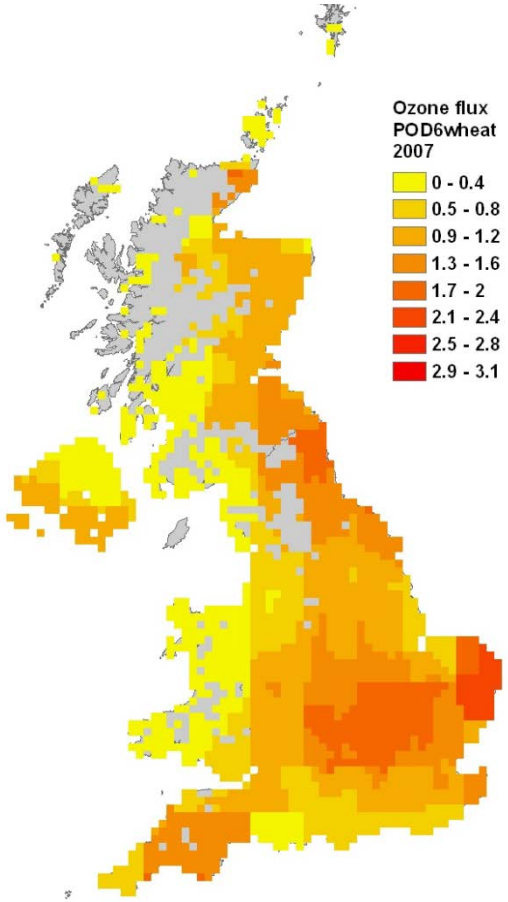
Impact pathway for wheat production

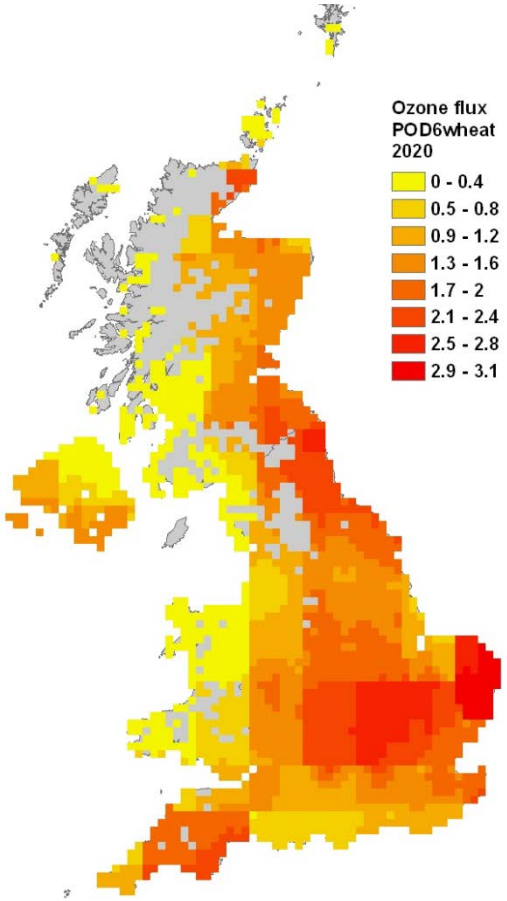
Δ ozone conc. → Δ yield → Δ value



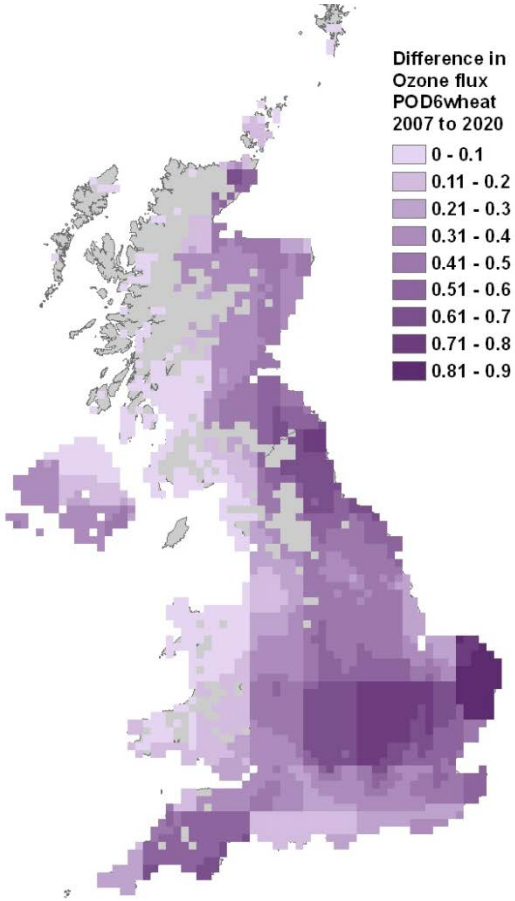
Ozone flux (POD_6) in 2007 and 2020



2007
(mean of 2006, 07 and 08)



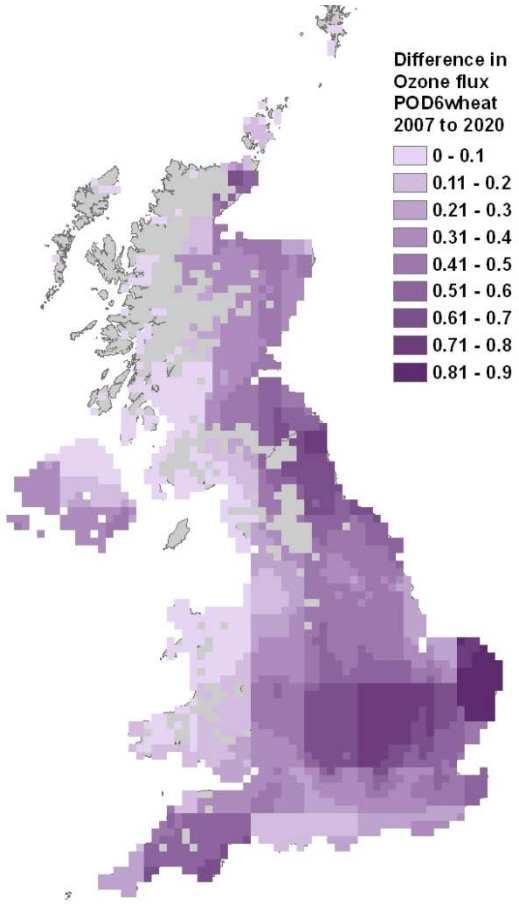
2020



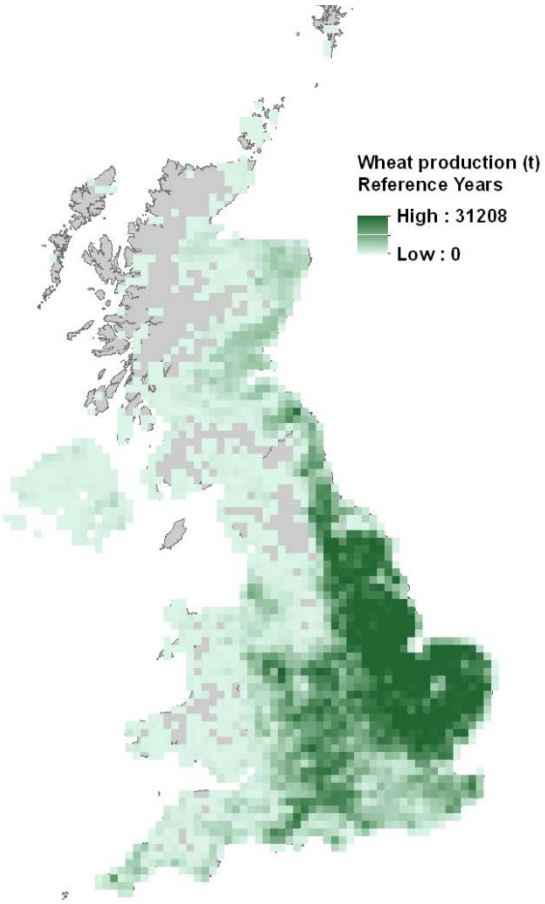
Difference

Spatial pattern of ozone flux (POD_6 wheat, mmol m^{-2}) in wheat growing areas

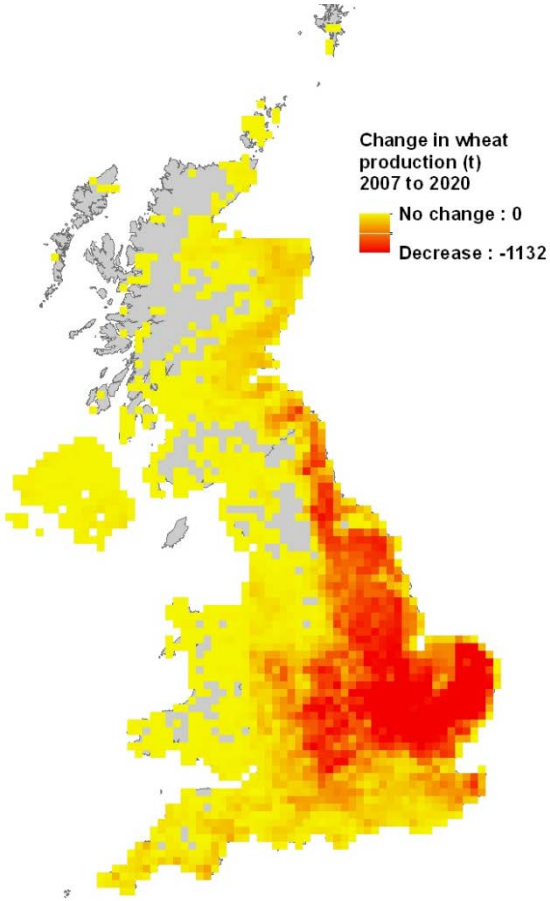
Change in wheat production, 2007 to 2020



Difference in ozone
(POD_6, mmol m^{-2}
2020 – 2007)



Wheat production
(mean of 2006 and 2008)

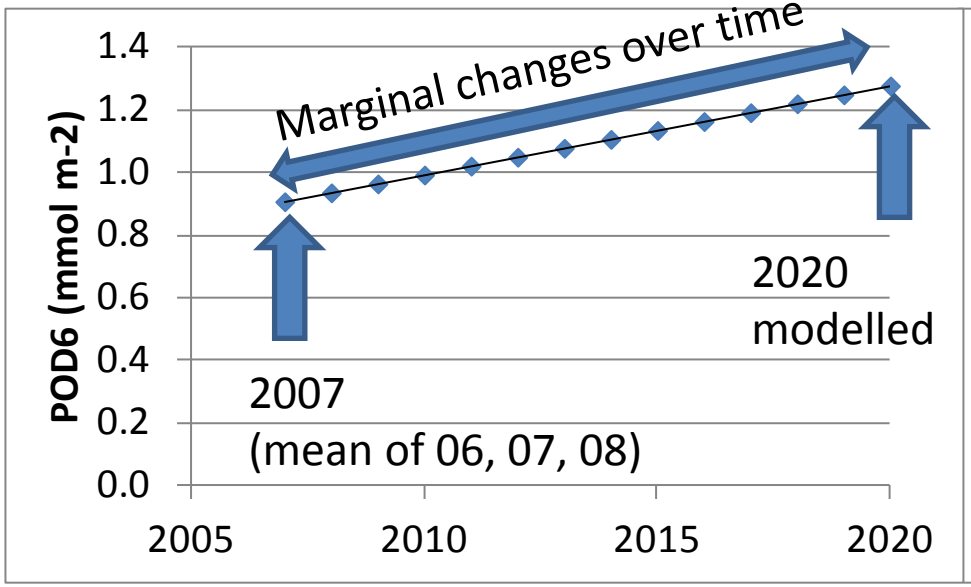


Change in wheat production 2007 to 2020
(t per 10 x 10km square)

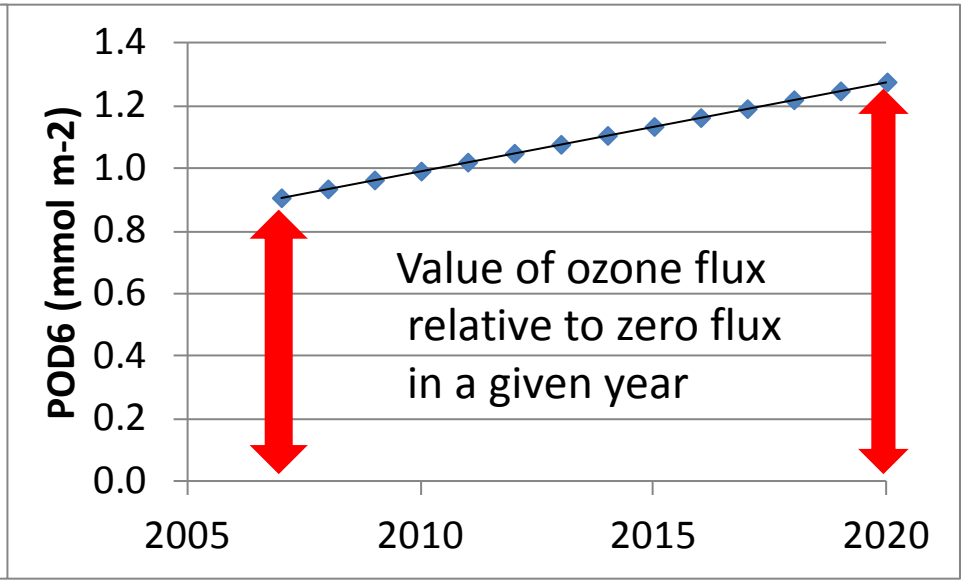
Marginal costs of effects of O_3 on wheat

	2007 to 2020	Range (95% Confidence interval)
Total Value of marginal costs (2007 to 2020)	-€226 million	-€187 million to - €268 million
Equivalent Annual Net value	-€21.9 million	-€18.2 million to -€26.0 million
The damage cost per unit increase in growing season POD6	-€118.7million	-€98.4 million to -€144.4 million

Marginal costs



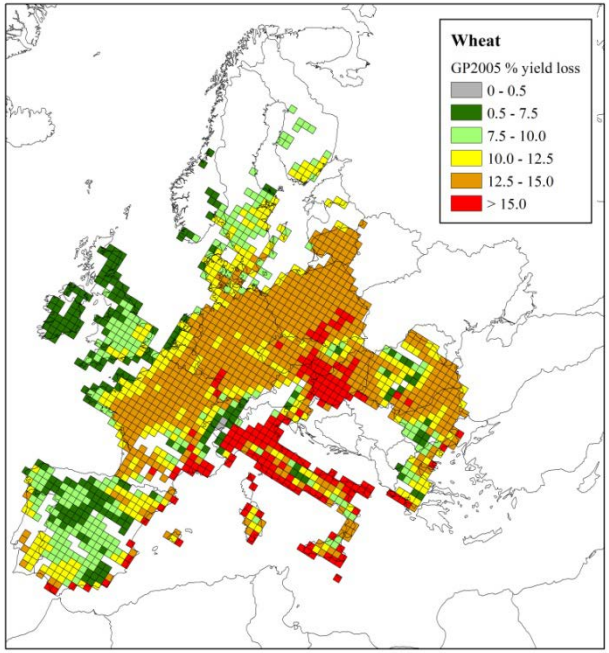
Magnitude of effects



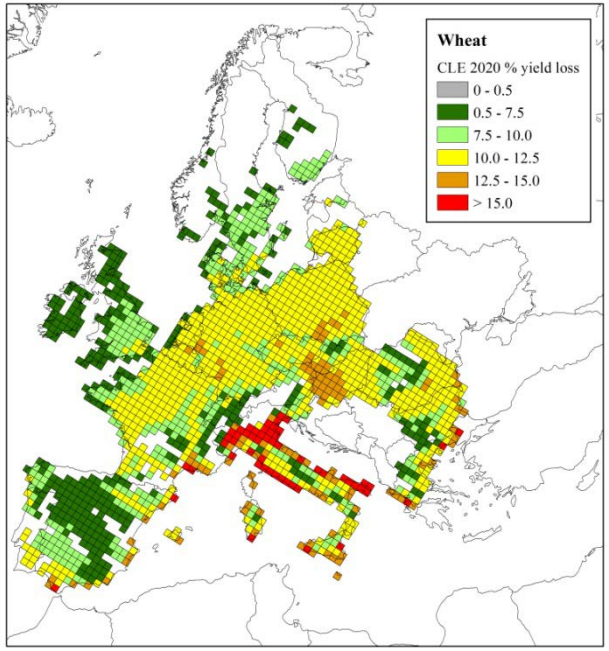
* Used to quantify economic effects of ozone for the revised Gothenburg Protocol scenarios

European crop loss calculations: GP scenarios

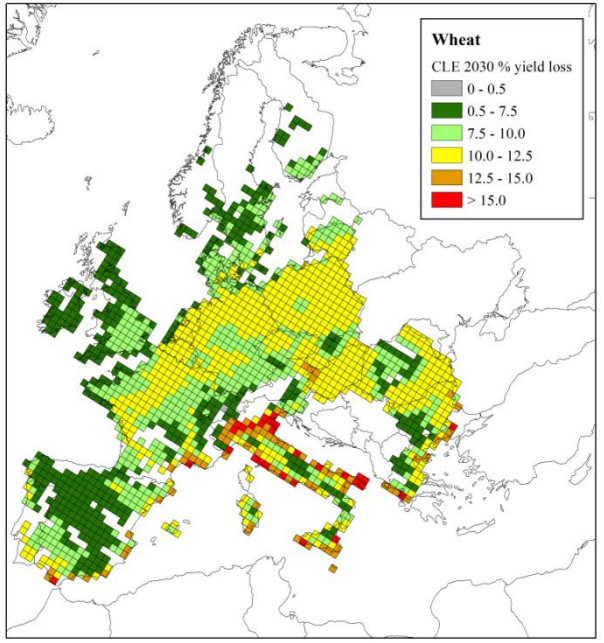
GP2005



GP CLE 2020



GP CLE2030



Percentage yield loss – calculated using a new response relationship for the generic crop flux model (POD_3IAM)[1]

[1] assumes soil water is not limiting

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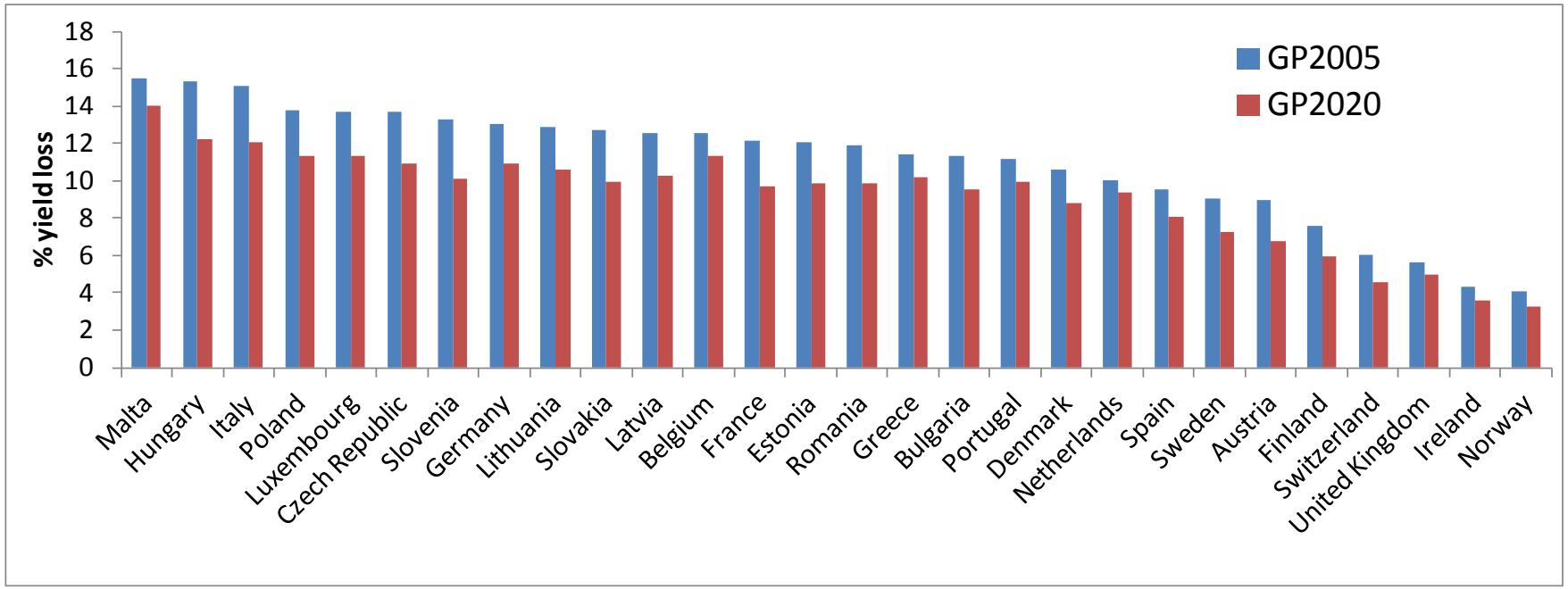
Wheat yield loss – Revised GP scenarios

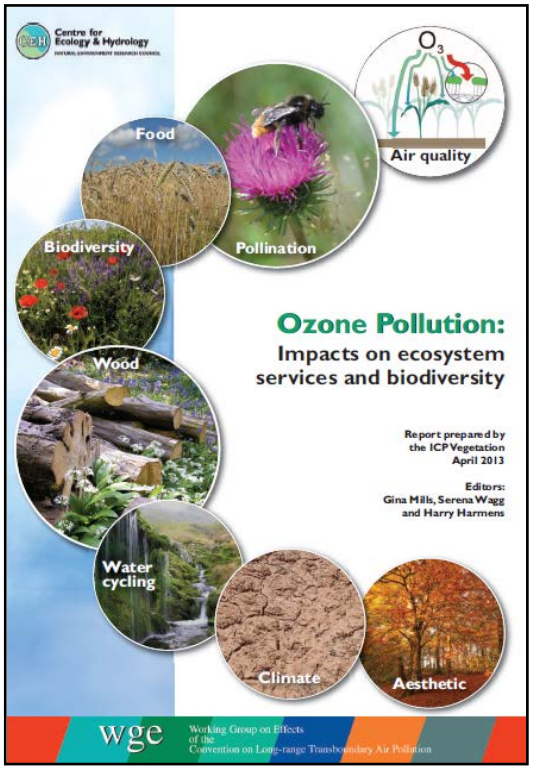
See informal document no. 4 ('Guidance document')



Mean % yield loss* for EU27: 12.4% for GP2005
10.3% for GP CLE2020

* assumes soil water is not limiting

ICP Vegetation State of Knowledge Report



http:/icpvegetation.ceh.ac.uk

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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Conclusions

- **Marginal costs** quantified for UK for O_3 effects on three ecosystem services, for the period 2007 to 2020; allows comparison with other air quality impacts e.g. health

- **Equivalent Annual Net Value** was largest for wheat yield (€21.9 million), less for C sequestration (£10.9 million) and quite small for lamb production (€0.23 million).

- We **quantified uncertainty** associated with these figures, providing 95% confidence intervals for effects on each service

- At the **European scale**, the magnitude of effects of ozone in a given "year" were calculated relative to zero ozone flux (approx pre-industrial ozone), with mean yield losses calculated for EU27+CH+NO was 12.4% for GP2005 and 10.3% for GPCLE2020

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SPARES

Quantification of uncertainty

Quantification of the range of values for each stage in analysis

- Statement of what the range represents
- Distribution of values within the range. The following were considered:
  - Uniform, where all values within the range are equally likely.
  - Triangular, where values towards the centre are more likely than those closer to the extremes.
  - Normal, similar to triangular in effect, but used where it is possible to base the range on statistical evidence.
- Whether uncertainties in parameters are independent of each other.

Monte Carlo simulation to propagate the uncertainty in the parameters and variables through the model, thereby calculating the uncertainty in the estimated impacts of ozone.

Using @Risk software, running simulation for 10000 iterations