



Modelling agricultural terrestrial ecosystems

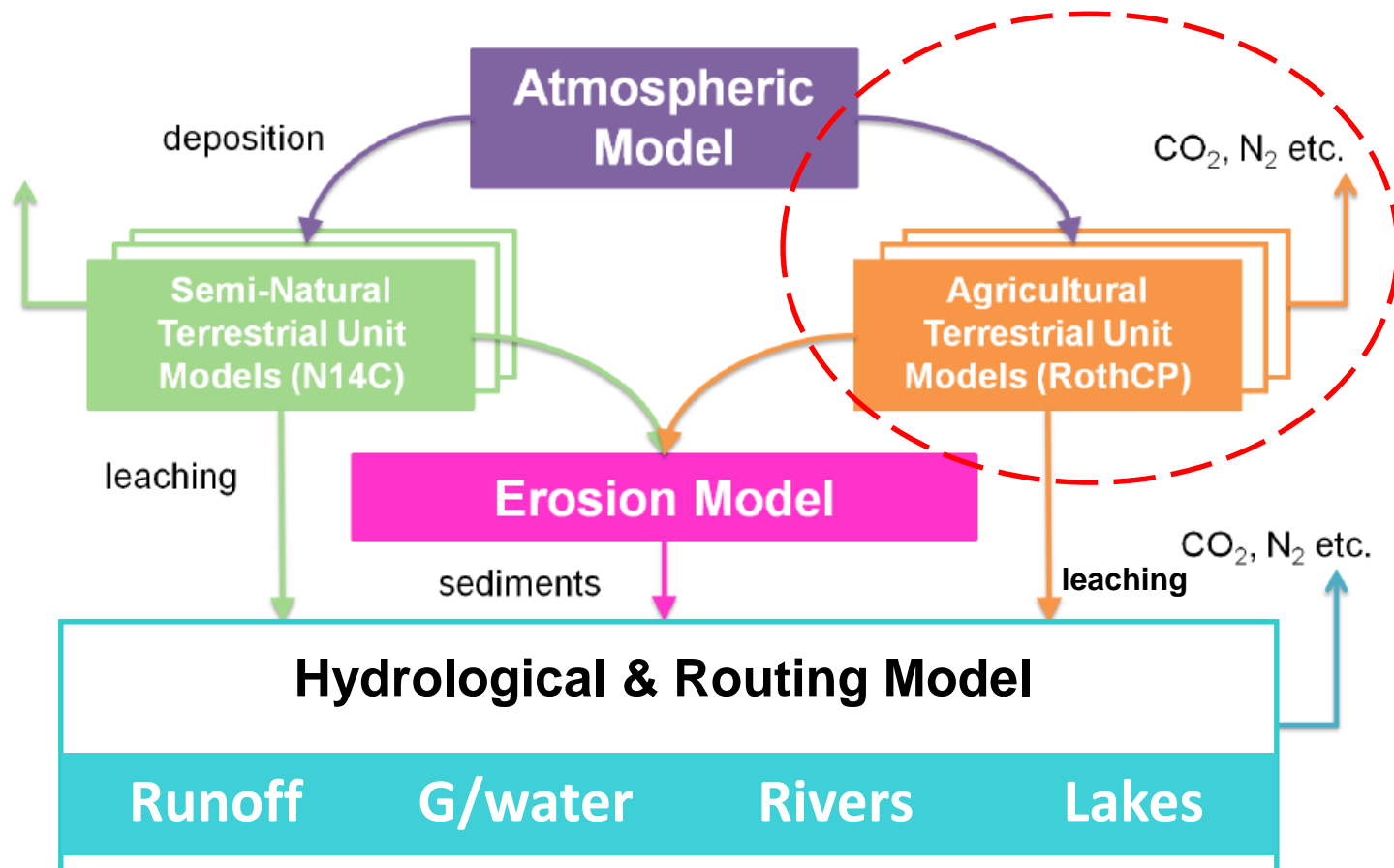
Shibu Muhammed, Kevin Coleman, Lianhai Wu, Andy Whitmore, Jess Davies, Vicky Bell, Edward Carnell, Tony Dore, Ulrike Dragosits, Pam Naden & Ed Tipping



Integrated Model (IM)



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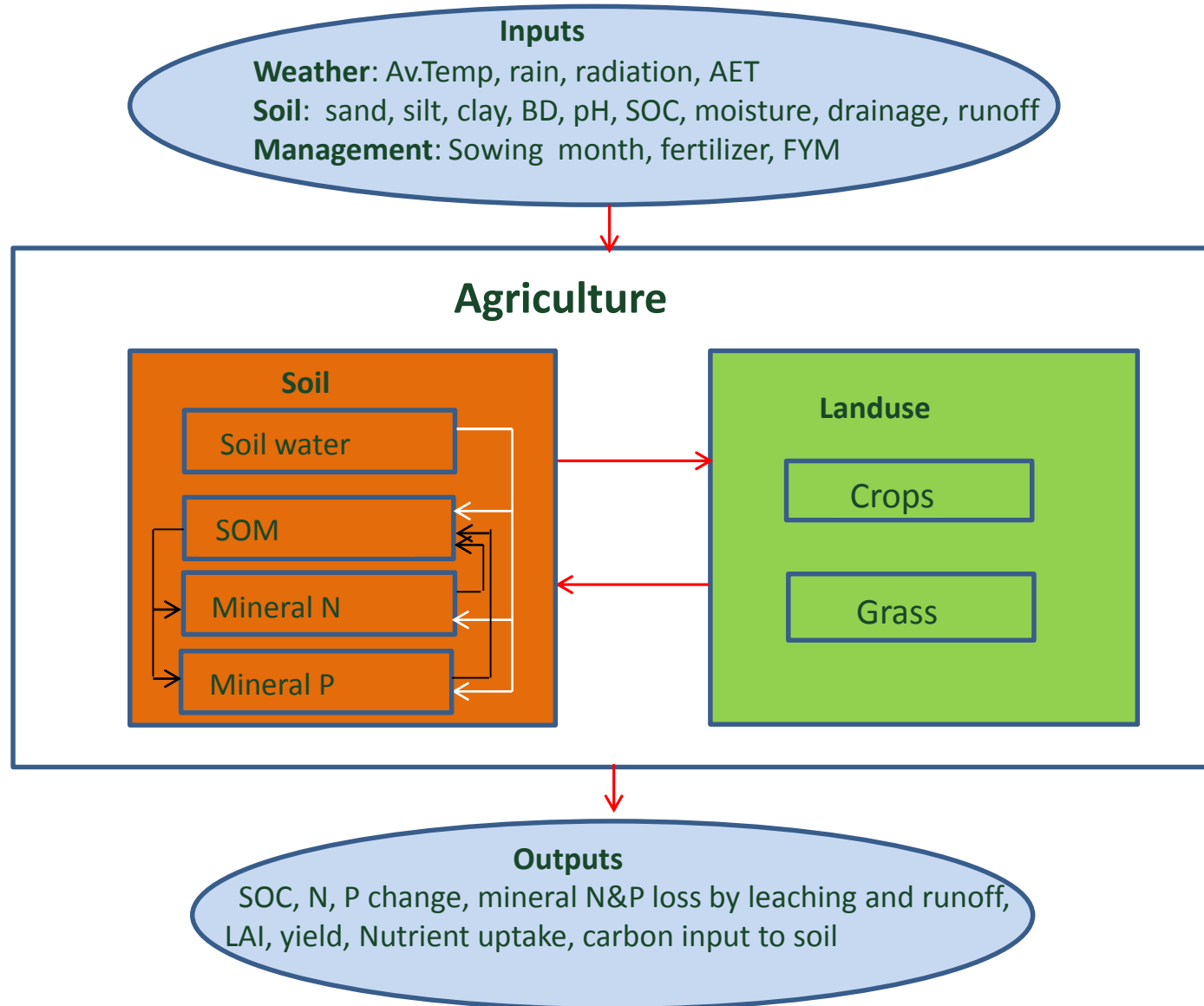


(from Bell, CEH Wallingford)

Agricultural model (ROTH-CNP)



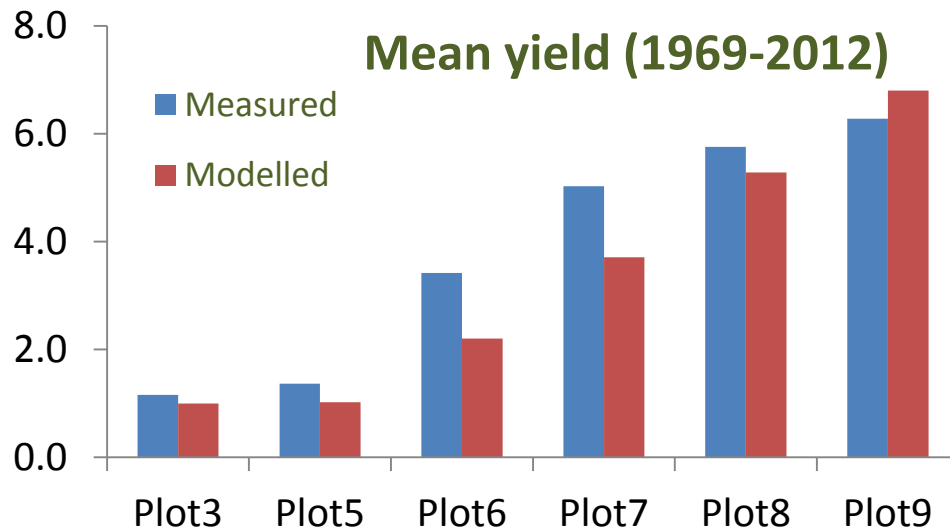
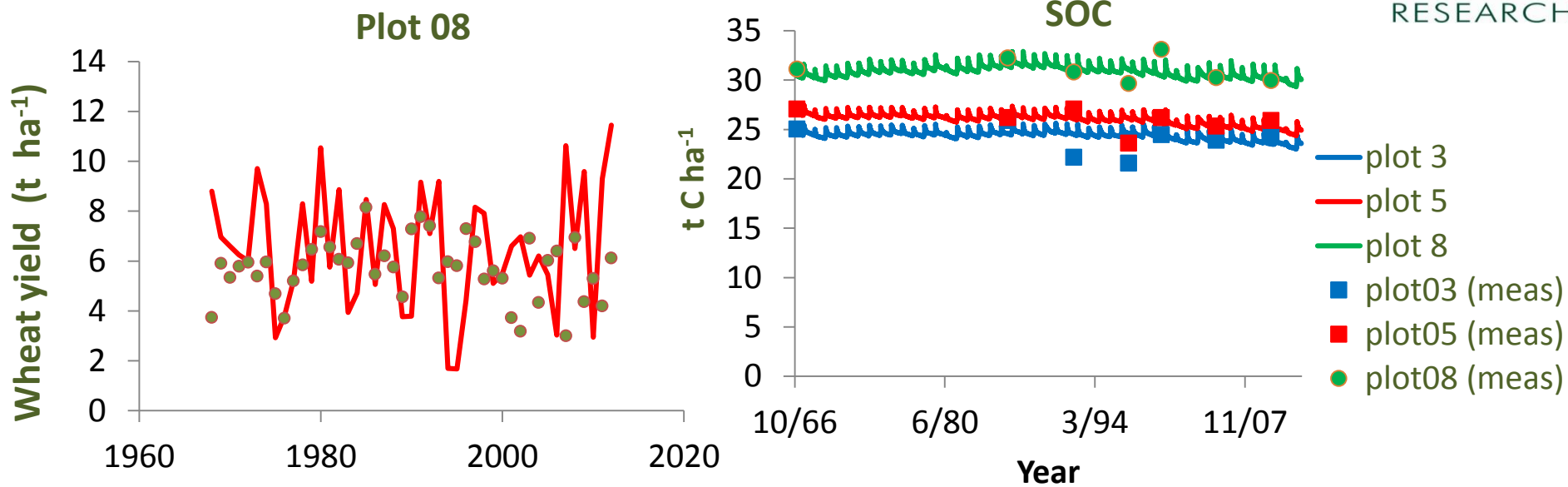
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Model testing - Broadbalk data



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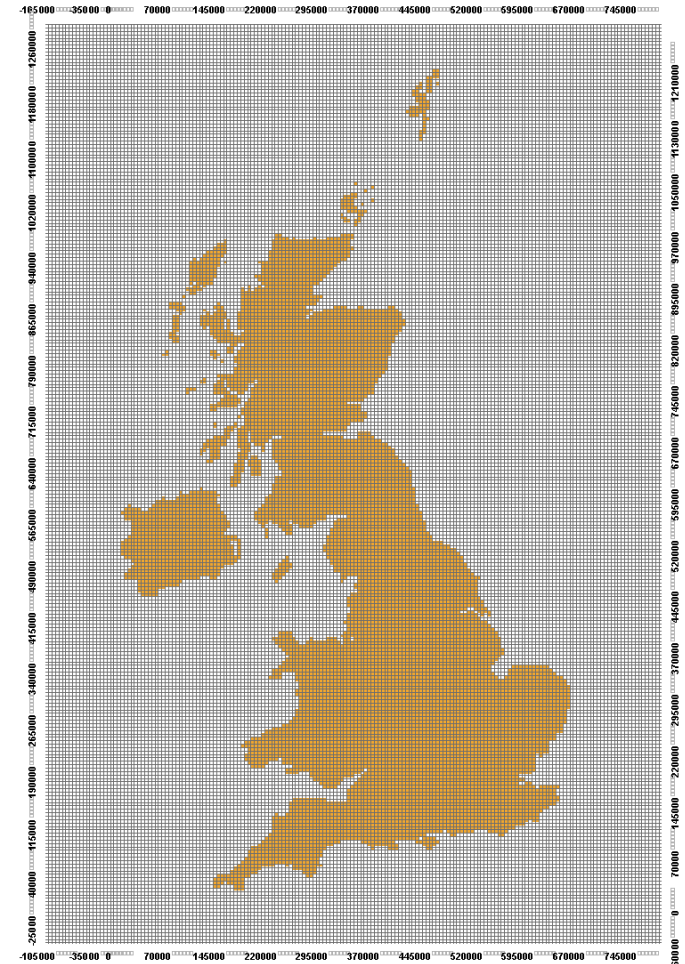
Plot3	Nil
Plot5	PK
Plot6	48N+PK
Plot7	96N+PK
Plot8	144N+PK
Plot9	192N+PK

Agricultural system simulation



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- Run the model for (5 x 5 km) grids
- Run the model for **historical to current** (1800-2010) and **future** (2010-2100)
- Landcover maps available from 1800 - 2007
- Landuse (crops and livestock) information from 1900-1990
- Soil maps from HWSD, Outputs from semi-natural system
- Hydrology data from the IM model outputs
- Gridded monthly met data:
 - 1900-1970 (WATCH EU project)
 - 1971-2010 (Met office)
 - 2011-2100 (WATCH EU project)

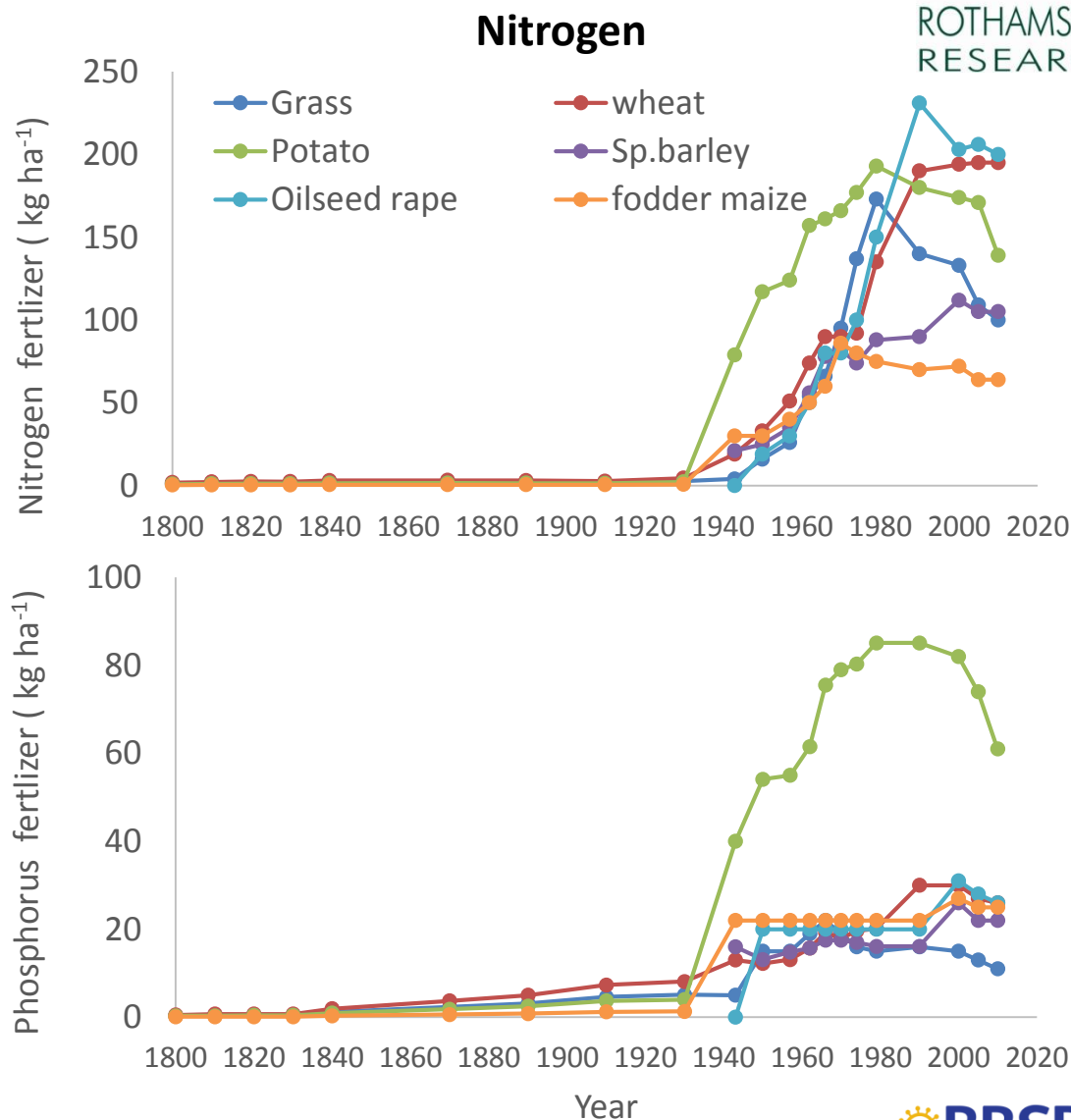


Crop, grass and soil management



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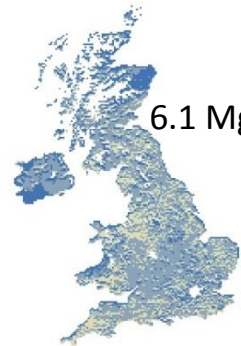
- Five major crops (winter wheat, Sp.barley, potato, OSR, and fodder maize) are grown in rotations
- Grass management: dairy, beef, sheep and silage systems
- Slurry and manures are applied in spring
- Fertilizer rates and timing were based on DEFRA reports/other sources



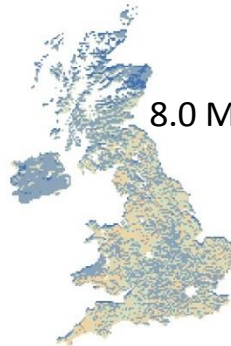
Yield

Improved grass

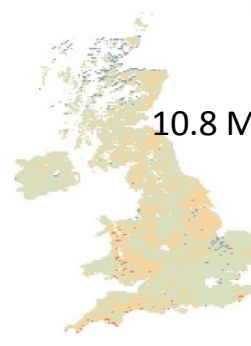
1800-1850



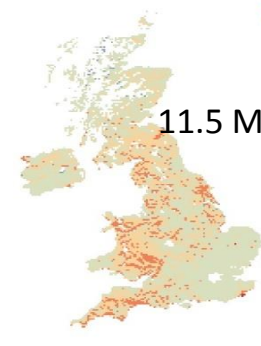
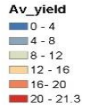
1900-1950



1950-1970



1990-2010



Arable

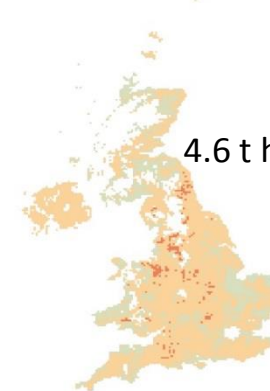
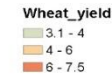
1800-1850



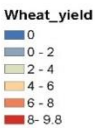
1900-1950



1950-1970



1990-2010

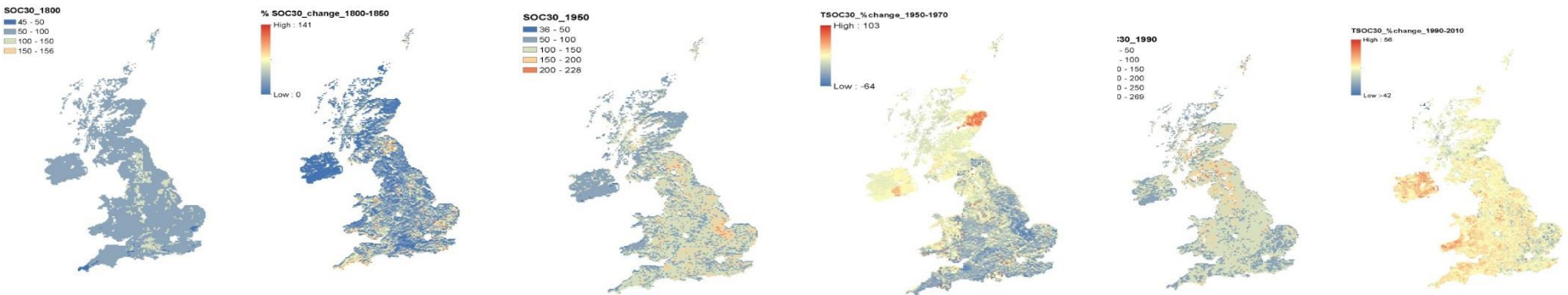


- Overall mean annual grass yield increased by 32% and wheat yield by 36% during 1900-1950 compared to 1800-1850

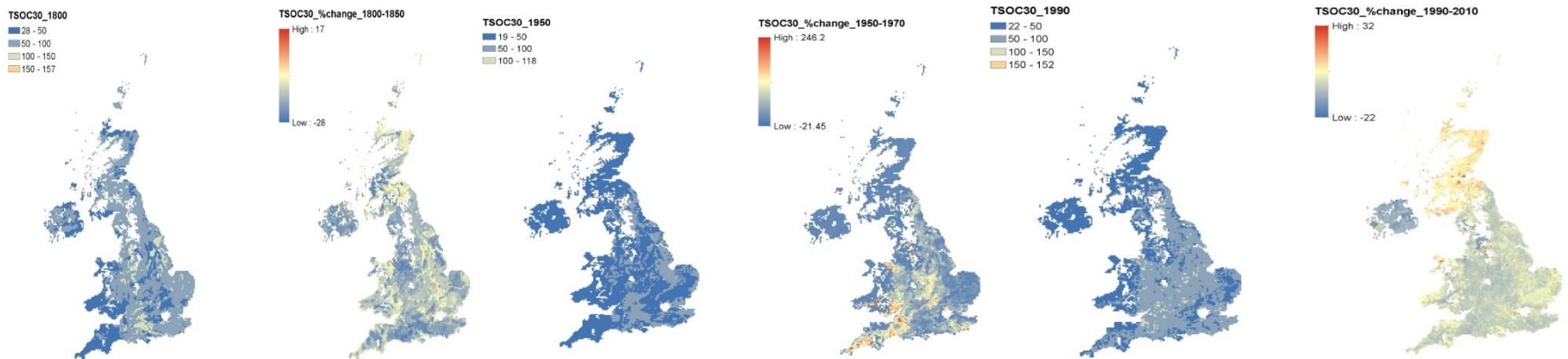
- During 1990-2010, overall mean annual grass yield increased by 7% and wheat yield increased by >80% compared to 1950-1970

Soil organic carbon stock/changes (30 cm)

Improved grass



Arable



- SOC continued to increase in grass (7%) with a marginal loss in arable (-0.8%) during 1990-2010
- During 1950-1970, overall mean SOC increased in both grassland and arable by 16% and 30%
- SOC continued to increase in grass (7%) with a marginal loss in arable (-0.8%) during 1990-2010

Inorganic N-loss

- Overall mean average annual N loss is greater in grass than arable during 1800-1850
- During 1990-2010 mean average annual N loss is greater in arable compared to grass
- Mean average annual N loss increased by 36% in grass and 76% in arable during 1990-2010 compared to 1950-1970

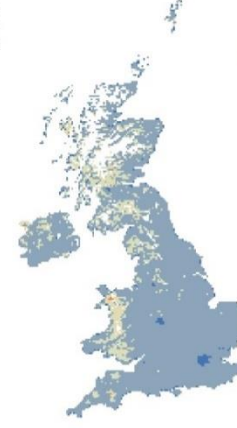
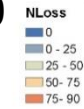
Improved grass

1800-1850



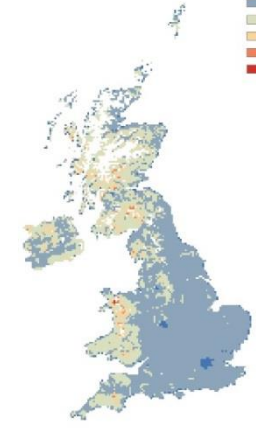
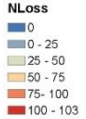
11 kg N ha⁻¹y⁻¹

1950-1970



14 kg N ha⁻¹y⁻¹

1990-2010



23 kg N ha⁻¹y⁻¹

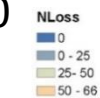
Arable

1800-1850



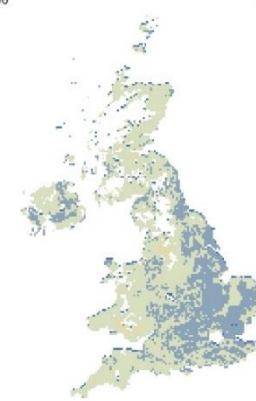
4 kg N ha⁻¹y⁻¹

1950-1970



13 kg N ha⁻¹y⁻¹

1990-2010

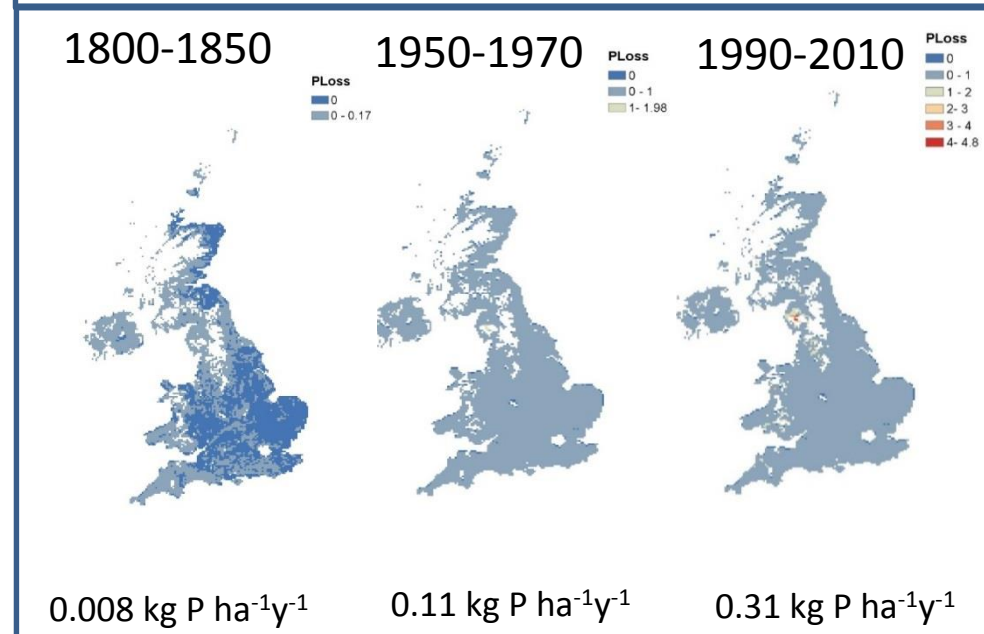
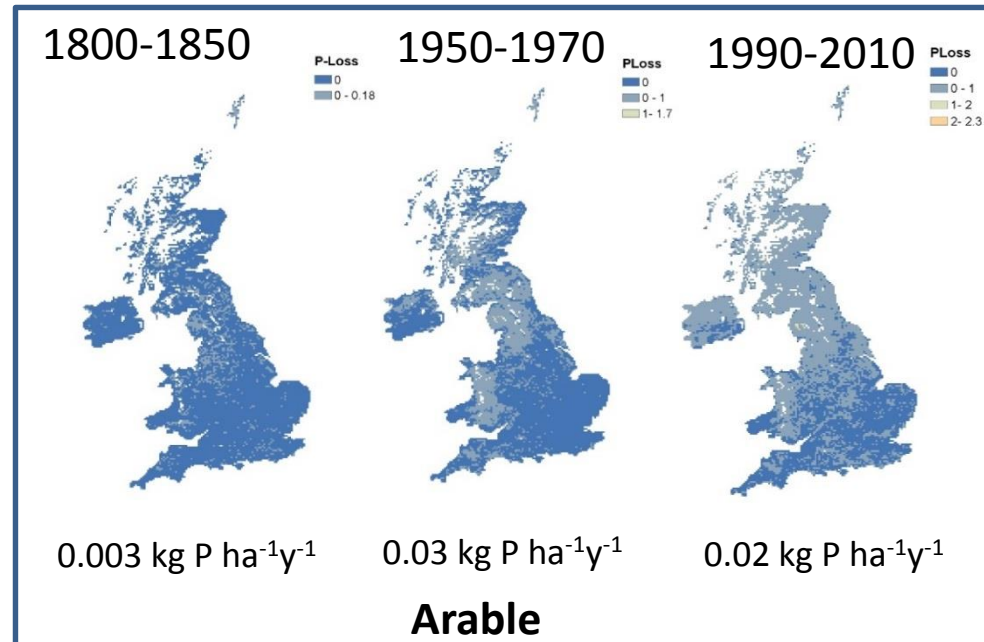


29 kg N ha⁻¹y⁻¹

Inorganic P loss

- Average annual P loss is negligibly small under both grass and arable during 1800-1850
- During 1950-1970, P loss increase by more than 10 times compared to 1800-1850
- During 1990-2010, mean annual P loss increase by about 3 times under arable system compared to 1950-1970

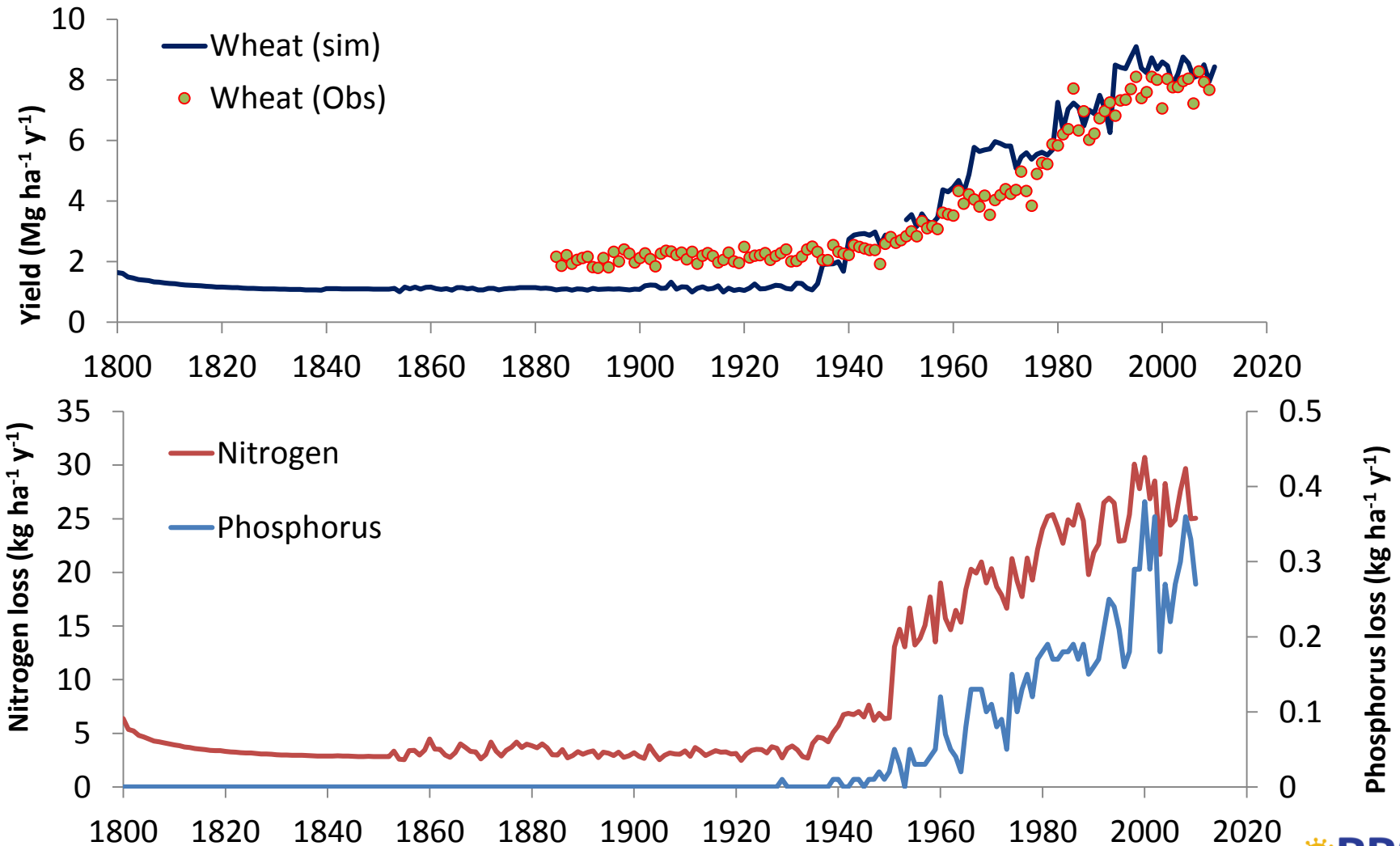
Improved grass



Historical to current trend in arable: crop yield and nutrient loss (whole UK)



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Scenarios of agricultural Intensification



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Main scenario: A2 climate change (2001-2100)
Atmospheric deposition scenario (2010-2100)

Arable:

RA1:

Improved crop varieties

+

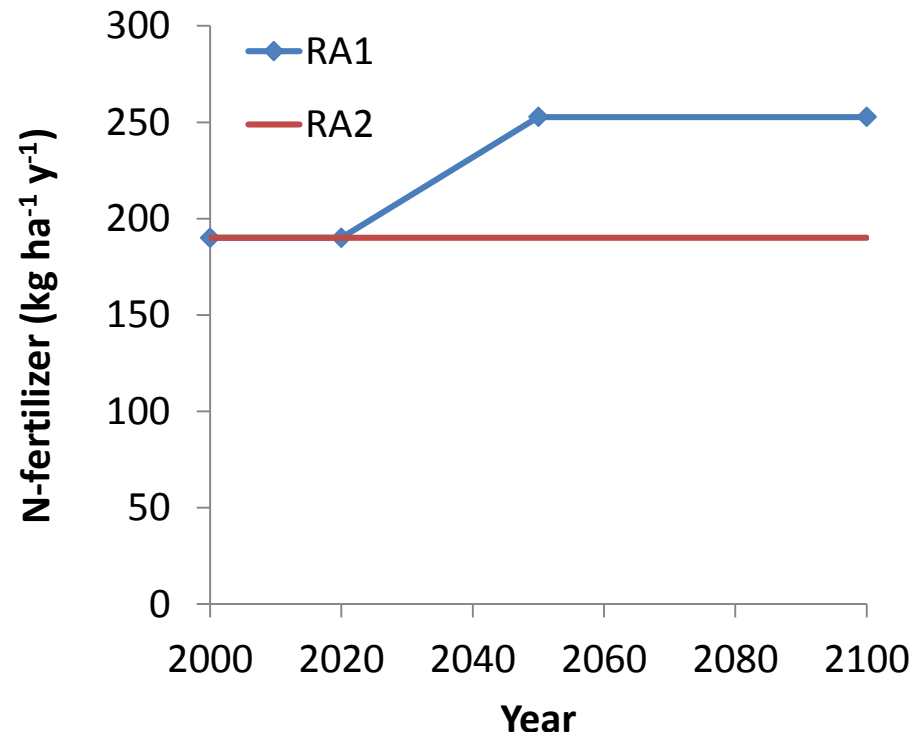
increase in N-fertilizer
application rate (by 1/3rd)

RA2:

Improved crop varieties only

RG1:

no further intensification

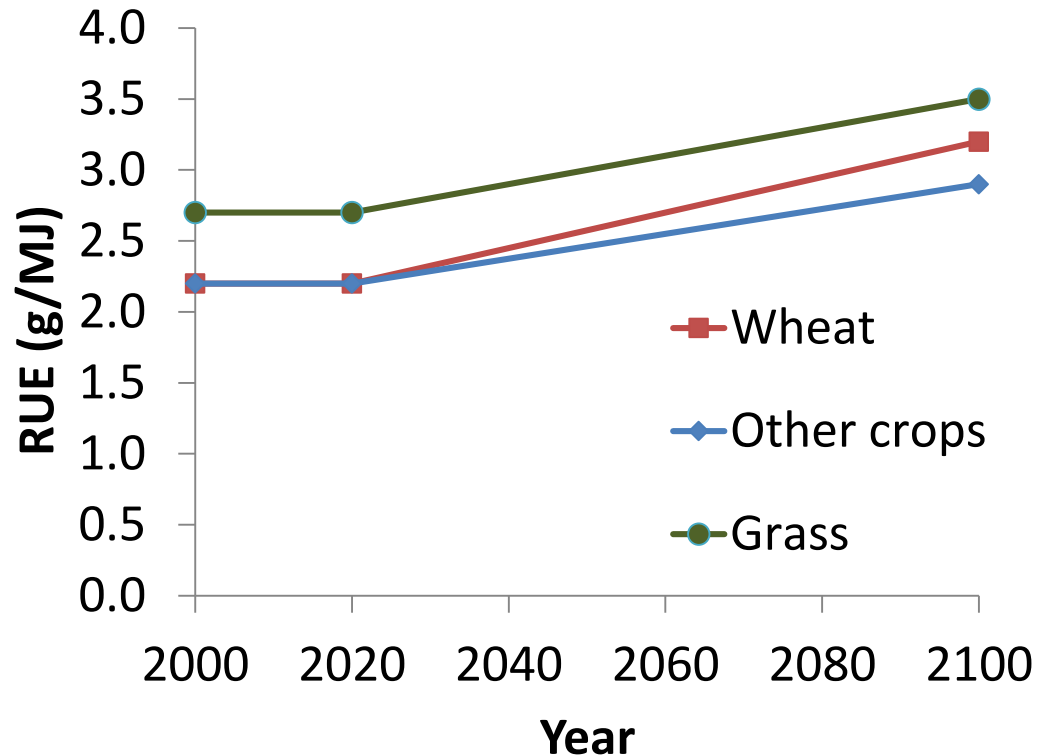


Crop (model) adaptation for Climate Change



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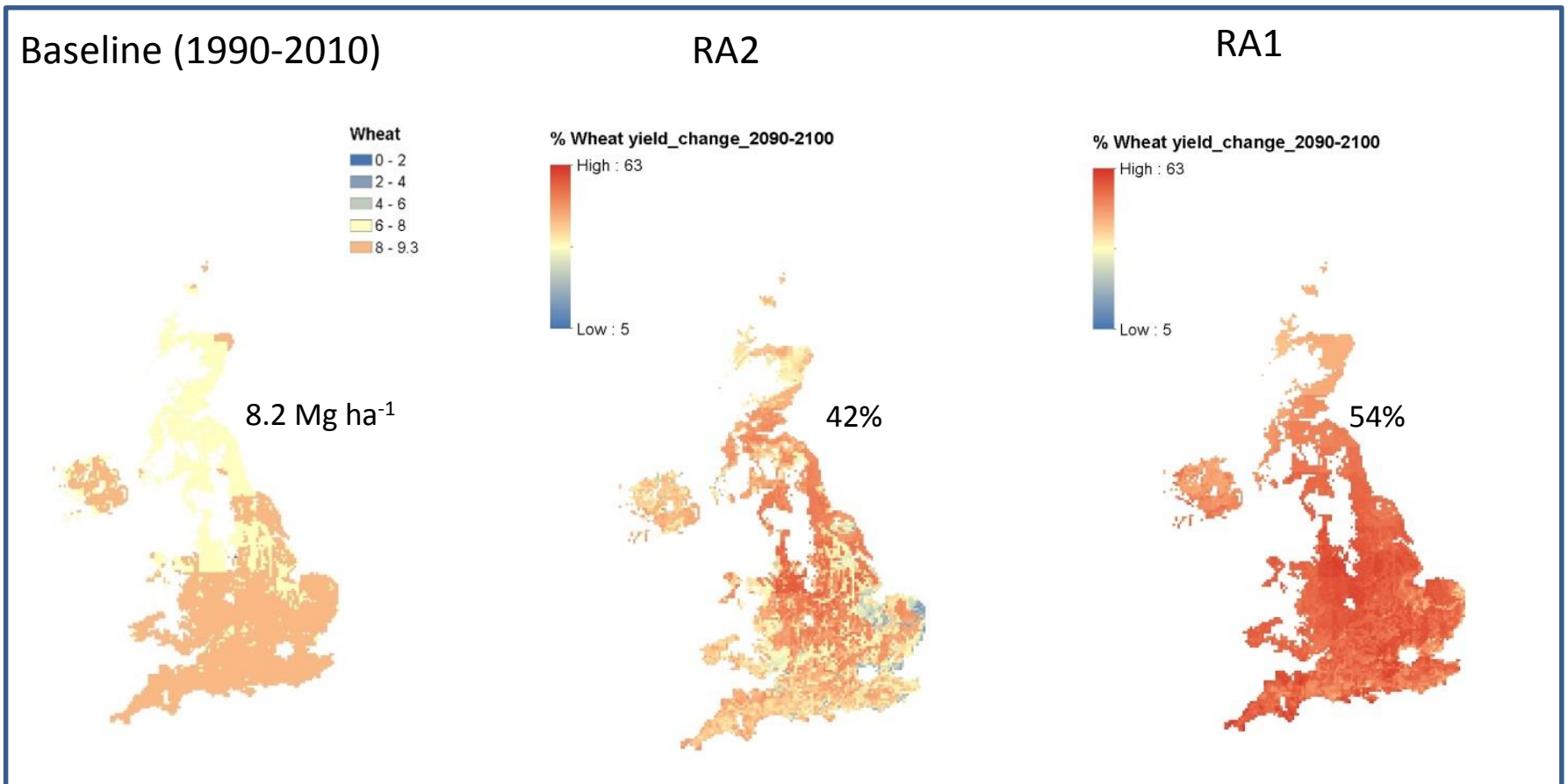
- Doubling in CO₂ by 2100 increase RUE by 30%
- Extended duration in grain filling
- Healthy green area index ('stay green')
- Drought tolerance



(Semenov *et al.*, 2014)

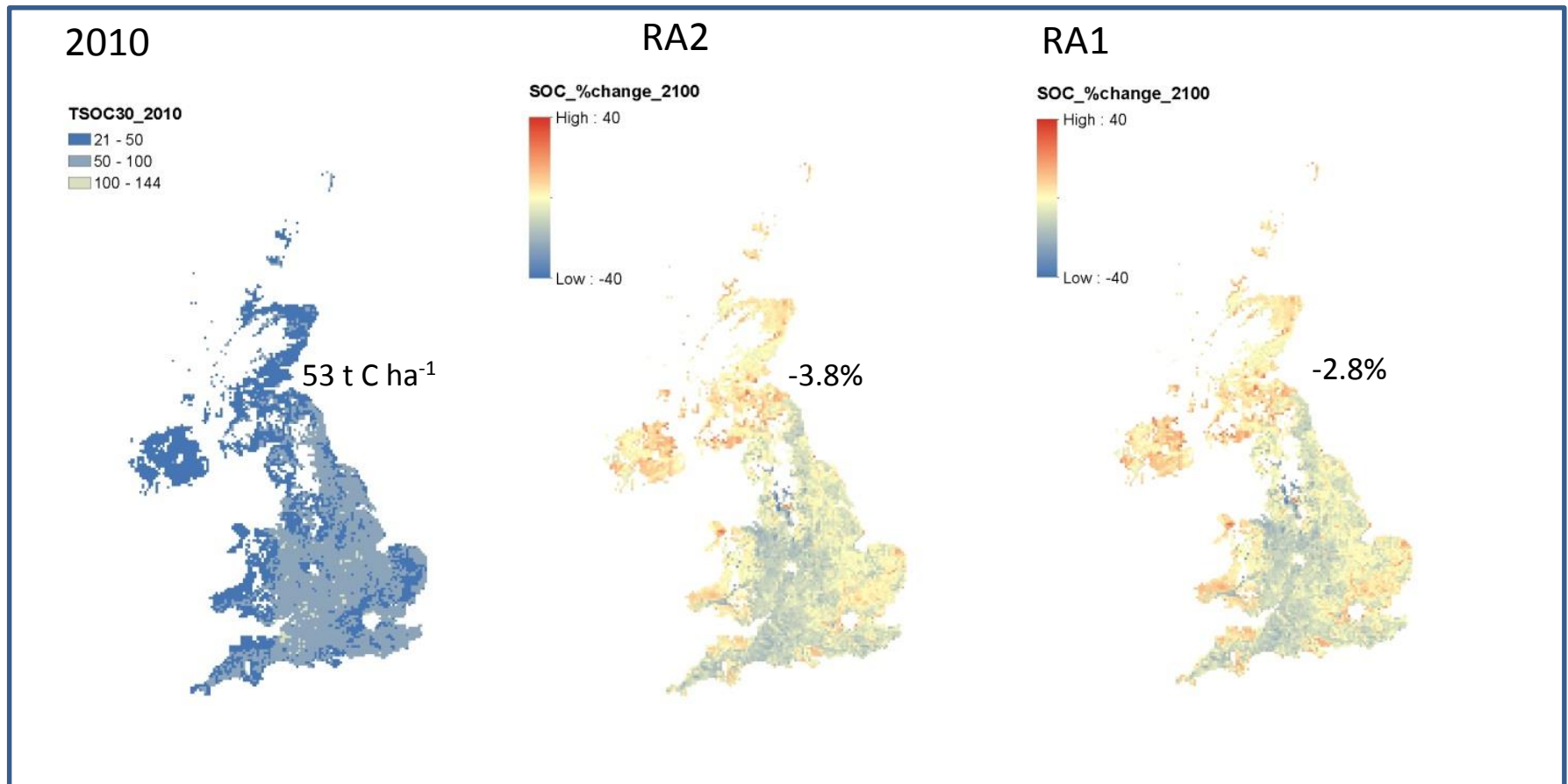
(for wheat, 10% increase in RUE by crop improvement also)

Arable: Crop yields (Wheat)



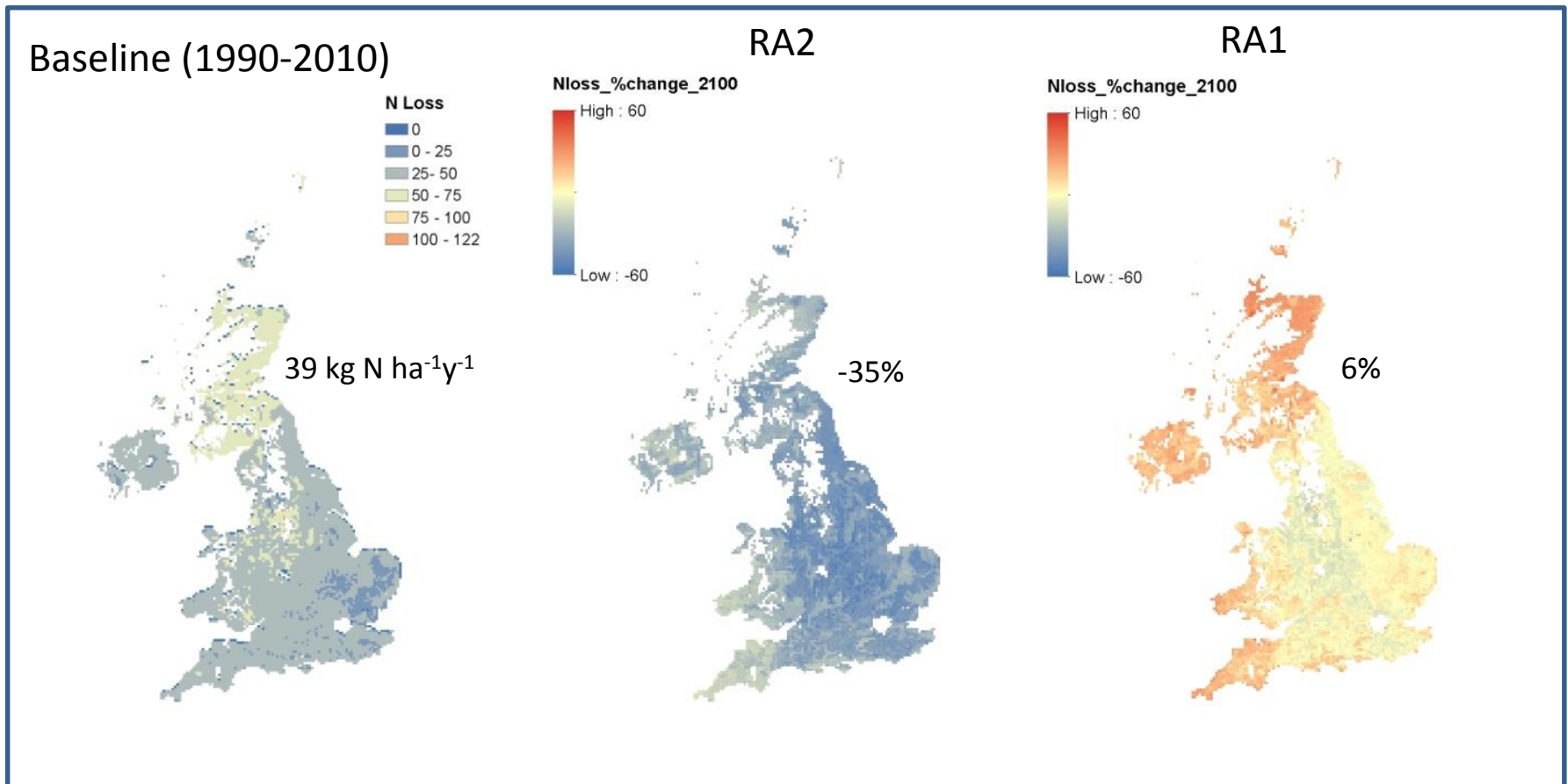
- Wheat yield increase under both RA2 and RA1
- Overall mean average yield is higher in RA1 (12.6 t/ha) compared to RA2 (11.6 t/ha)

Arable: Soil organic carbon stock/changes



- A small decline in SOC stock under both RA1 and RA2 at 2100 compared to 2010
- SOC loss is less in RA1 compared to RA2

Arable: N-loss (Leaching+ runoff)



- Overall mean average annual N loss decrease (by 35%) under RA2 and increase (by 6%) under RA1 compared to baseline period

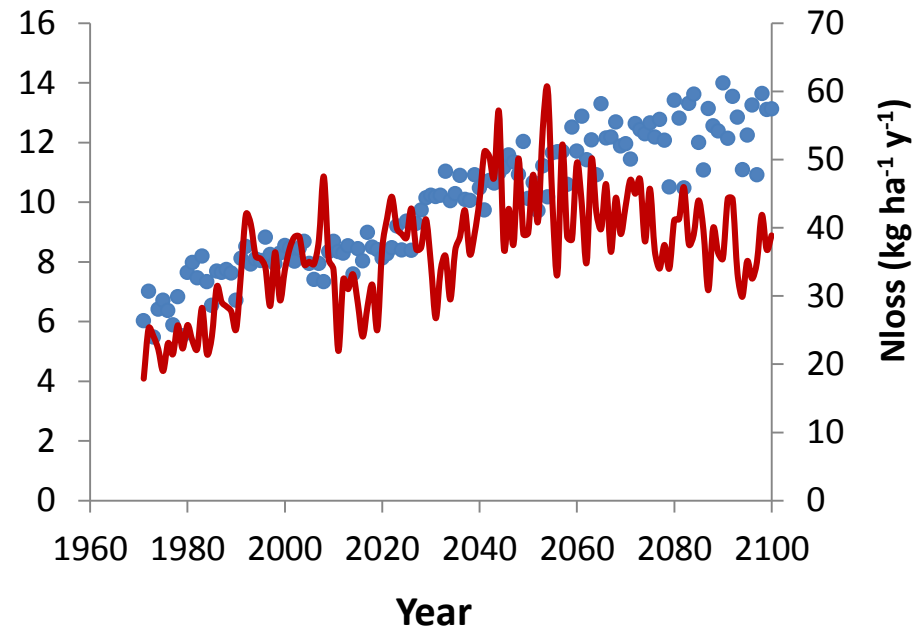
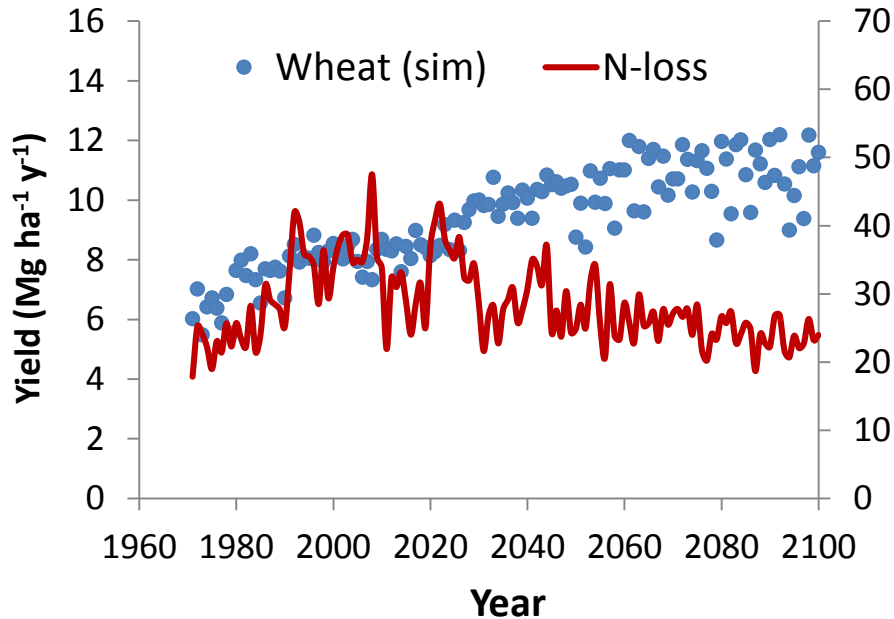
Current-to-future trend (whole UK)



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RA2

RA1



- Average wheat yield increases up to 12 and 14 t ha^{-1} in RA2 and RA1 by 2100
- In RA2, N loss reduced from 35 $\text{kg N ha}^{-1} \text{y}^{-1}$ in 2020 to 25 $\text{kg N ha}^{-1} \text{y}^{-1}$ in 2100.
- In RA1, N loss increased to 40 $\text{kg ha}^{-1} \text{y}^{-1}$ in 2100

Summary and conclusions



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Historical to current:

- SOC builds up under improved grass and loss under arable land
- Simulated crop yields and N loss increase under both grass and arable systems
- Simulated P loss increase under arable land

Current to future:

- Crop yield increase by 40% in RA2 and more than >50% in RA1 by 2100
- N loss decrease by 35% in RA2 and increase by 6% in RA1 by 2100
- Crop adaptation to climate change may increase the NUE of the crops and there by N losses



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Thank you!