Land Capability for Agriculture Research Platform

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10th February 2026

Agenda

- Re-cap on LCA
- Comparing original with new
- State of platform development – live demo
- Examples of outputs and analytical tools
- Challenges and solutions
- Dashboard: linking LCA to climatic water balance
- Next steps in LCA use for policy

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Class	Description	Climatic constraint*
Land suited to arable cropping		
1	Land capable of producing a very wide range of crops.	**None**
2	Land capable of producing a wide range of crops.	**Minor**
3.	Land capable of producing a moderate range of crops.	Moderate
3.1	Division 1 land is capable of producing consistently high yields of a narrow range of crops and /or moderate yields of a wider range.	
3.2	Division 2 land is capable of average production but high yields of some crops grass, barley and oats are often attained.	
4	Land capable of producing a narrow range of crops.	Moderately severe
4.1	Land in this division is suited to rotations	
4.2	Land is primarily grassland with some limited potential for other crops.	
Land suited only to improved grassland and rough grazing		
5	Land capable of use as improved grassland.	Severe
5.1	Land well suited to reclamation and to use as improved grassland.	
5.2	Land moderately suited to reclamation and use as improved grassland.	
5.3	Land marginally suited to reclamation and use as improved grassland.	
6	Land capable of use only as rough grazing.	Very Severe
6.1	High grazing value.	
6.2	Moderate grazing value	
6.3	Low grazing value.	
7	Land of very limited agricultural value.	Extremely severe

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Constraint*	Description
Climate:	Direct influence on land capability through influence on energy input and potential for soil moisture deficit.
Maximum potential soil moisture deficit (PSMD)	The theoretical deficit achievable under a short grass sward on which soil is assumed to have a large store of water and crop transpiration is unrestricted. The Deficit is the accumulation of the balance between rainfall and evapotranspiration calculated daily. It is the 30-year median maximum value of the deficit for any given soil.
Accumulated temperature (AT_0)	Thermal time accumulation over a base temperature of 0°C from the 1st of January to the end of June.
	PSMD and AT_0 are combined into a single classification constraint using the relationship shown in SMI Figure 1.
Gradient	Sets slope gradient limits per LCA class, based on the potential for cultivation through use of machinery. Note: values used are based on machinery capabilities in the 1980's and there can be large variation in practice depending on machinery configuration and type of operation.
Soil:	
Structure	This recognizes some soils may be vulnerable to slaking and or compaction. There are no specific thresholds set to determine constraints. Interpretation and adjustment to LCA was determined by field surveyors.
Shallowness	Soil depth limits per LCA class, i.e. Class 1 = >60cm, Class 4.2 = >20cm.
Stoniness	Constraints to land capability based on size and abundance of stones, modified by shape and lithology.
Droughtiness	A complex soil property, assessed by calculating the soil water reserves within depths likely to be exploited by crops (wheat, spring barley, potatoes) and subtracting the PSMD.
Wetness:	The principal effect is through workability and trafficability in the arable categories and trafficability and poaching in grassland, although physiological effects on the plant from waterlogging and the susceptibility of some sites to flooding are also important.
Workability, Trafficability, Poaching risk	Susceptibility of soils to structure damage by cultivations, traffic or stock, with consequent penalties for sustained crop production. Determined from: soil wetness, water retention and climate (mainly length of field capacity period). SM1 Table 2.
Flood risk	Survey based assessment using local knowledge on flooding frequency. This constraint was not utilised in the new framework.
Erosion	Categories of wind erosion risk (very slight, slight, moderate, severe).
Pattern	Uniformity and variation of good and bad physical conditions (% of area of a class) assessed by field surveyor.
Vegetation	Applied to land not suited for improvement by mechanical means, primarily in upland areas (Class 6). Assessed by surveyors using a rating of plant species and a Relative Grazing Value based on abundance of key plant species.
Rating of plant species	Plant species are given a rating on a scale of - 1 to 8 (10 point) which is basically an expression of their dry matter productivity, but which also includes an element relating to their sward-forming ability, regularity of production, coarseness, hairiness and palatability.
Relative grazing value	Relative Grazing Value is based on abundance of key plant species and may include relationships with soil types.

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Importance of the LCA Climatic guidelines:

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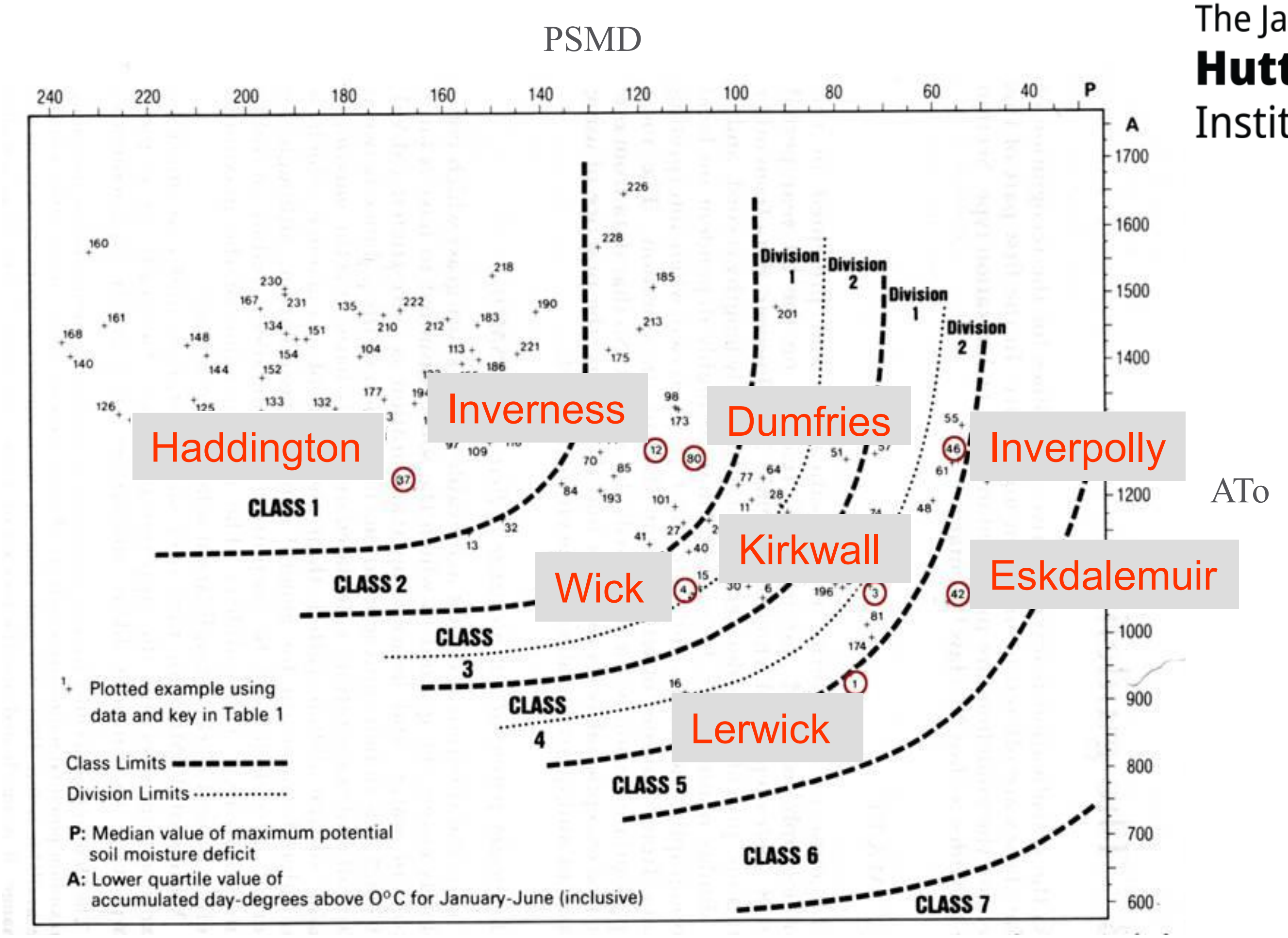
Climate data used to estimate soil wetness, field capacity days plus two climatic constraints:

- **Accumulated temperature (ATo)** in °C days
  - Lower quartile of accumulated temperature above 0°C over first six months
- **Maximum potential soil moisture deficit (PSMD)** in mm
  - Accumulated daily difference between precipitation and evapotranspiration
  - LCA uses the Median of the maximum PSMD value from all years



Soil Wetness

Wetness class	General properties of the soil profile
1	Profile normally lacks gley features within 70 cm or an impermeable horizon within 80 cm depth. Many strongly gleyed, permeable soils, with efficient drainage systems also occur in this class.
2	Profile normally lacks gleyed features within 40 cm or an impermeable horizon within 60 cm depth.
3	Profile normally lacks gleyed features within 40 cm or an impermeable horizon within 40 cm depth.
4	Profile normally has gleyed features and an impermeable horizon within a 40cm depth, but lacks a humose or peaty topsoil greater than 20 cm thick.
5	Profile normally has prominent gleyed features within 40 cm depth and is usually wet within 70 cm depth. Commonly the topsoil is humose or peaty and the natural vegetation has numerous hydrophilous species.
6	Profile normally has a peaty topsoil, a prominently gleyed mineral subsoil and is usually wet within 40 cm depth. The natural vegetation consists of hydrophilous species.

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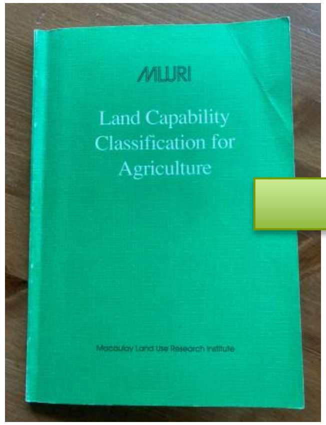
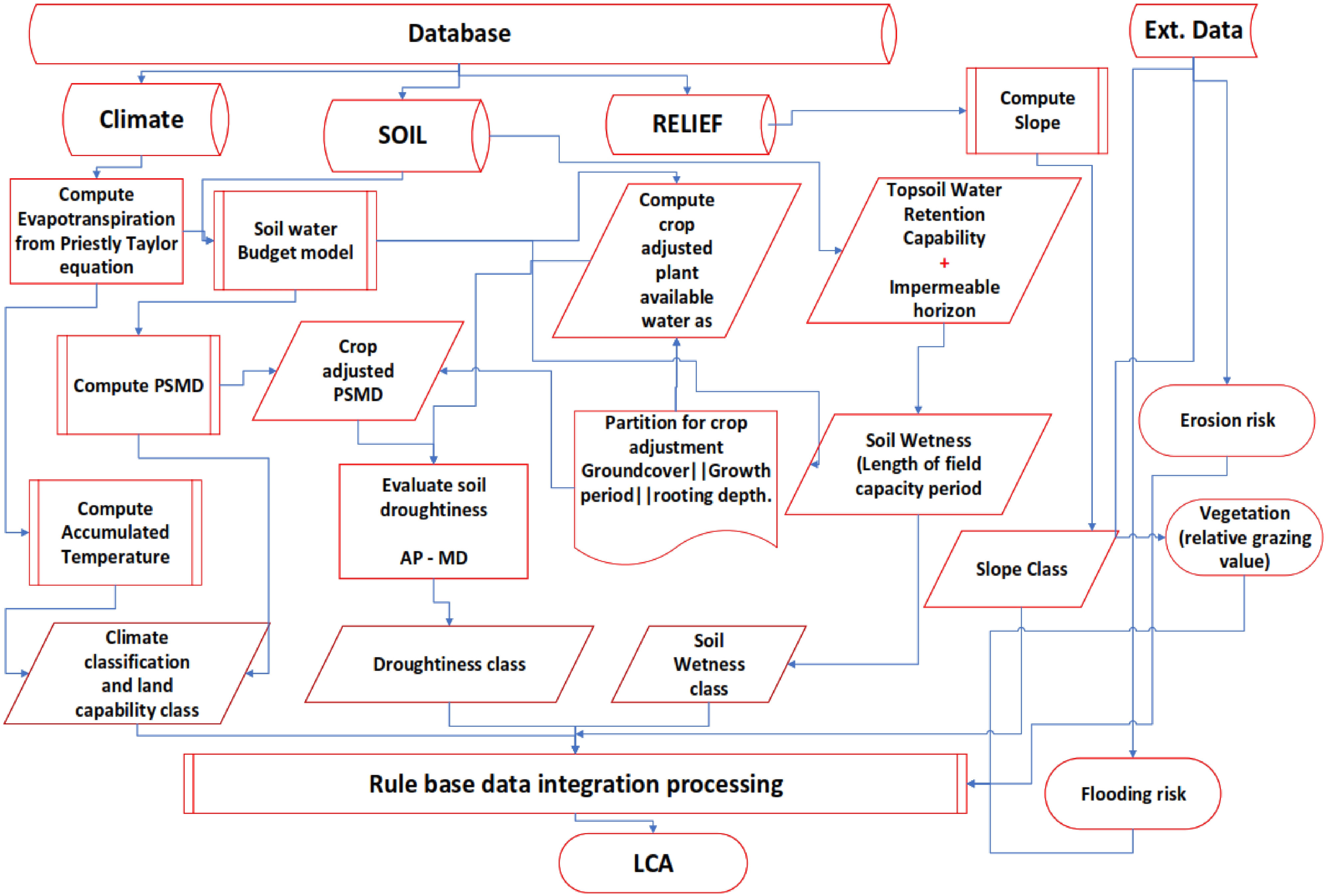
Creating a computing platform





Differences between original and new

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Inputs	Original LCA	Computing platform
Climate data	**Limited number of meteorological stations with 20-year records for precipitation, temperature (1958-78) and wind (1965-73), whilst wetness classes based on 1941-71.**	**1km resolution daily spatially interpolated observed precipitation, maximum and minimum temperature (1960-2019), solar radiation (derived from satellite observations for 1994-2019, and estimated using Machine Learning from 1960-1994), wind (MORECS covering 1960-2017). There have been detectable changes in the climate since the 1958-78 original period.**
Estimation of climatic constraints	**Accumulated temperature (ATo) and maximum potential soil moisture based on limited climatic data. Soil wetness class was generally based on field observations.**	ATo and maximum PSMD estimated using a daily time step soil water balance model and 1km resolution daily time-step climate data. Soil wetness classes estimated from multiple methods run using soil database details.
Potential soil moisture deficit (PSMD)	**This was a climatic constraint only and used an 'ideal' soil (loamy, free draining, no limitation to water) and had simplistic 'bucket' approach to calculate evaporation.**	**1km resolution precipitation and Reference Evapotranspiration used to estimate Climatic Water Balance on a daily basis, to determine the maximum PSMD.**
Soils data	1:250,000 soil series maps	National Soils Inventory / SSKIB database, based on original 1:250,000 soil series, updated through resampling and generation of additional properties through pedotransfer functions.
Topography	Ordnance Survey relief maps (50m contours)	OSTerrain5 Digital Elevation Model resampled at 100m resolution for gradient analysis.
Guideline application	**Based on surveyors skillfully applying the guidelines** in an objective way (hence standardisation between surveyors).	**Guidelines implemented within computer code**, but it has not been possible to factor in the human 'on-site checking' element. Some text descriptions and structures of the assessment of the physical factors cannot be directly converted to computer code.

Mis-match between original LCA and soil series

- Challenge: Original LCA boundaries do not align with the soil series boundaries = “slithers”
- New LCA uses soils database hence series boundaries
- Makes comparison between original and new LCA difficult

Issues and solutions

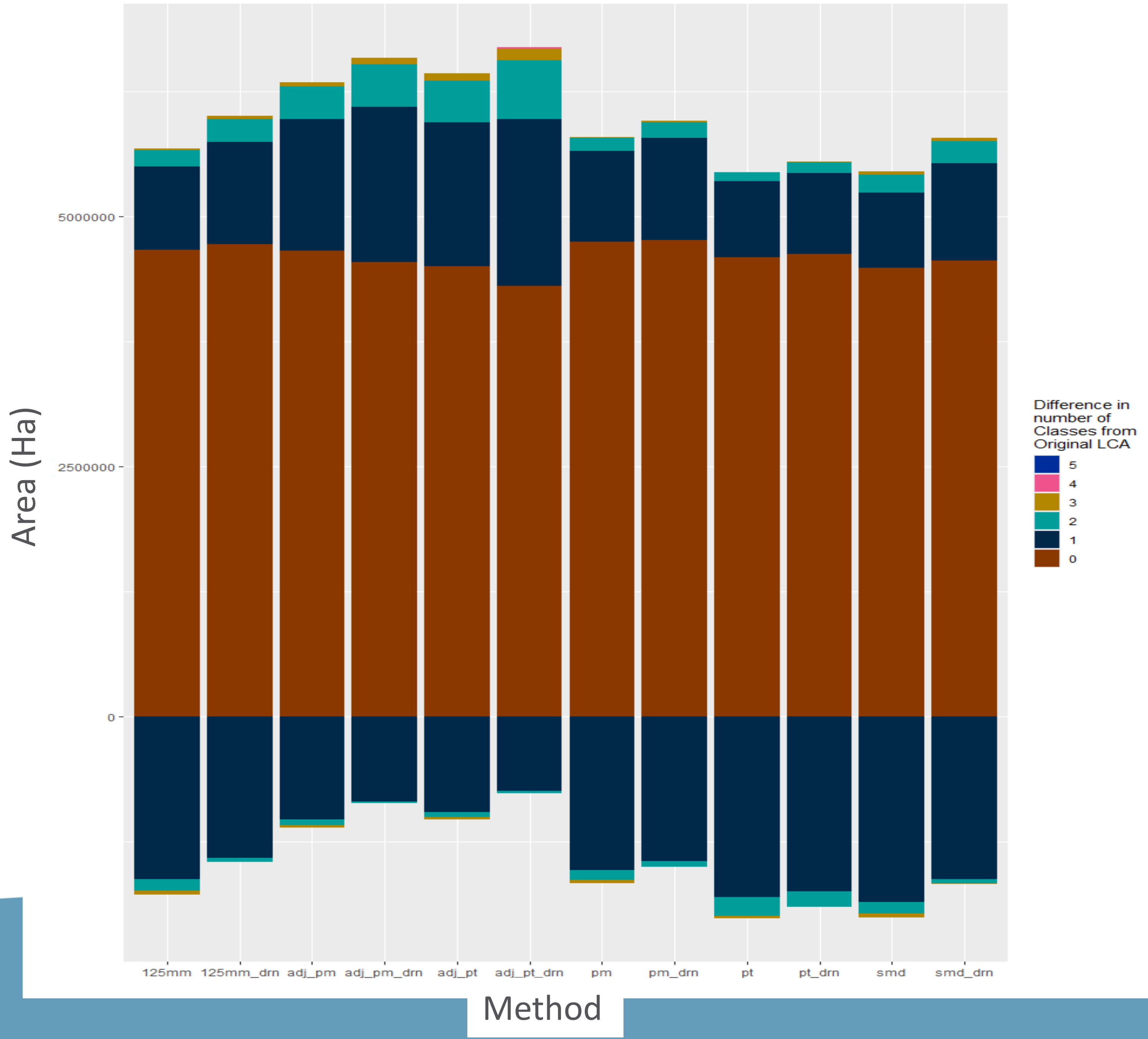
- Polygon may have multiple soil series: which one to use?
  - LCA run on each series present then assess with land use and original LCA
  - May help serve as data to indicate what the actual series is
- Class 6 divisions and Relative Grazing Value
  - Use original LCA map
  - However, no climate change impact on RGV included
  - Potential for improved habitat maps, NVC and use of Ellenberg Indicators approach to assess climate impacts on species distributions (D1.1, D5-2) (https://www.hutton.ac.uk/wp-content/uploads/2023/12/D5-2-2d-Identifying-habitats-at-risk-of-species-loss-due-to-envirnmental-change.pdf)
- Drainage (may have been undertaken after original survey)
  - Example: Kilmarnock soil series = platform estimates Class 6 based on soils data, land use indicates Class 3.2
  - Use of HOST and drainage mapping (Zisis Gagkas)
  - Assess land use and revert to original LCA if land use indicates actual capability
- Original indicated potential LCA with management, new uses actual land use to inform where class estimate requires assessment

State of platform development

- Working platform running on Hutton HPC
- Multiple methods for constraint estimation
  - ET x2 methods
  - Soil Water balance model
  - Climatic Water balance
  - "125mm" - comparable to original, representing a uniform ‘loamy soil’ – used for comparison purposes only
- Inclusion of assessment of drainage
- Assessing temperature lapse rates with elevation.
- Not yet included: flood risk
- Prototype Dashboard for analyses
- Tools for comparing with original and assessing utility

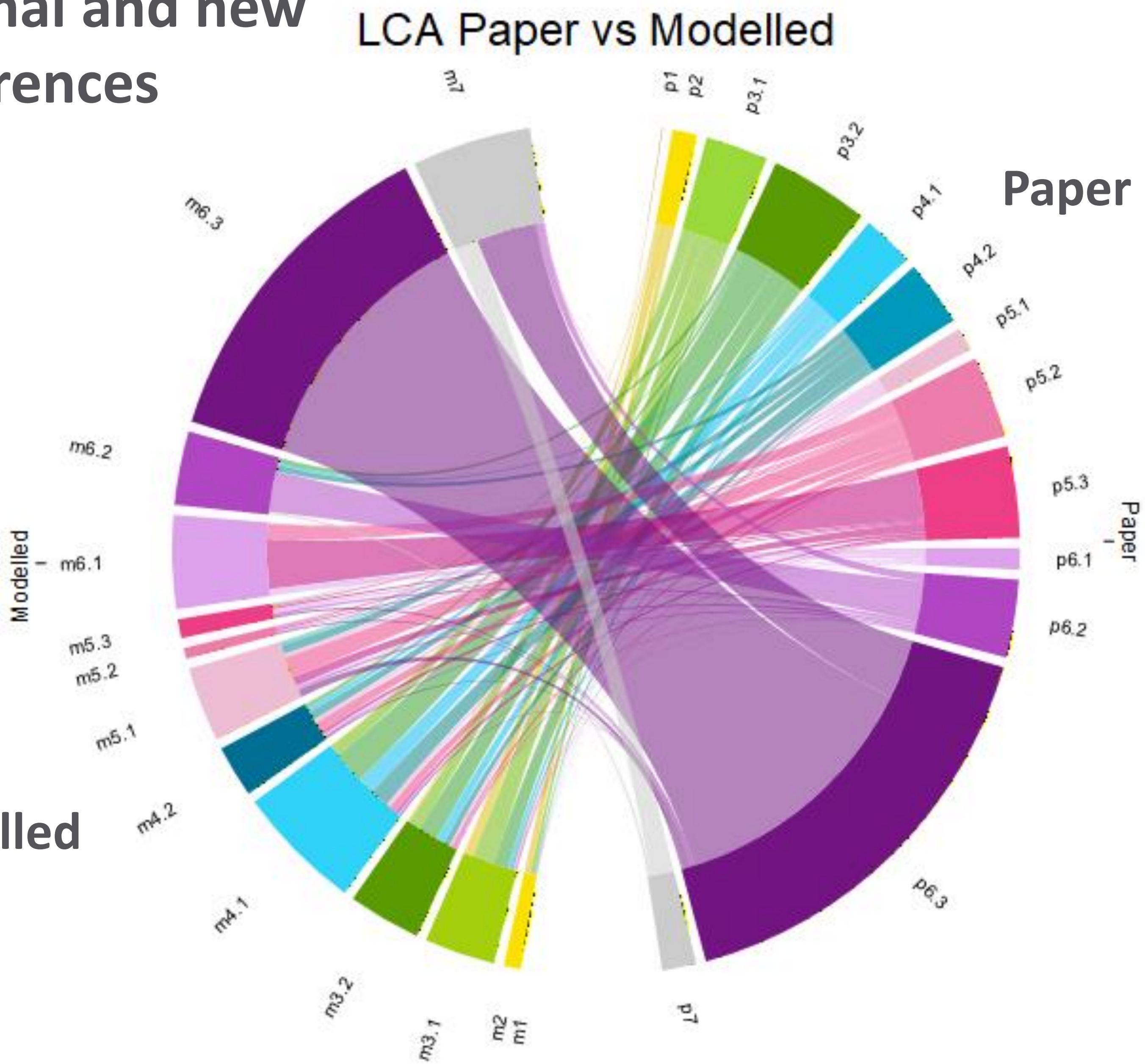
Tools for assessing original and new differences

- Majority have same LCA class
- Most differences are of 1 class
- Analysis of polygon attributes enables assessment of why a class difference
- **Note:** data includes polygons of mis-match due to non-alignment of soil series with original
- This explains some of the large class differences

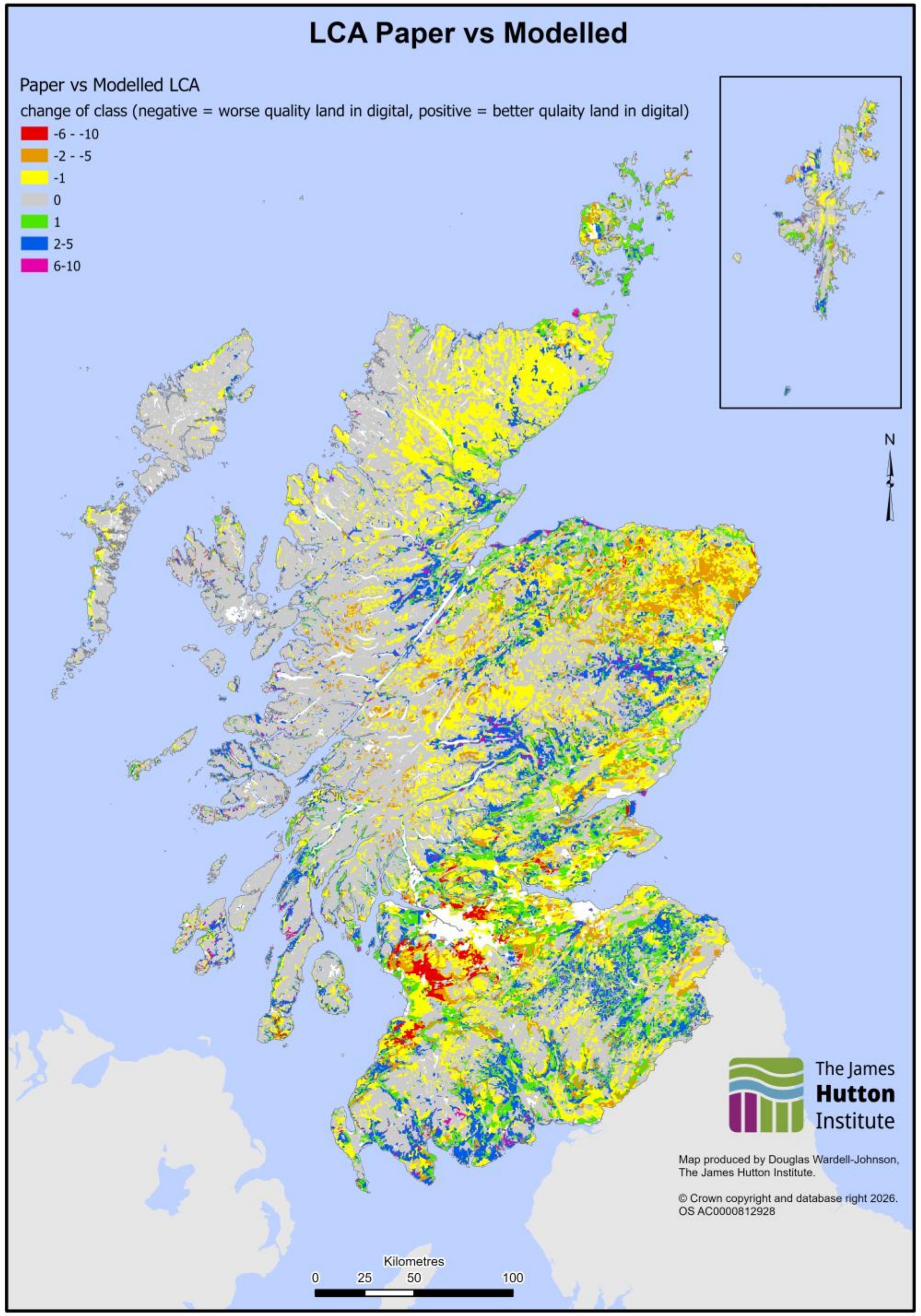


Tools for assessing original and new differences

Paper

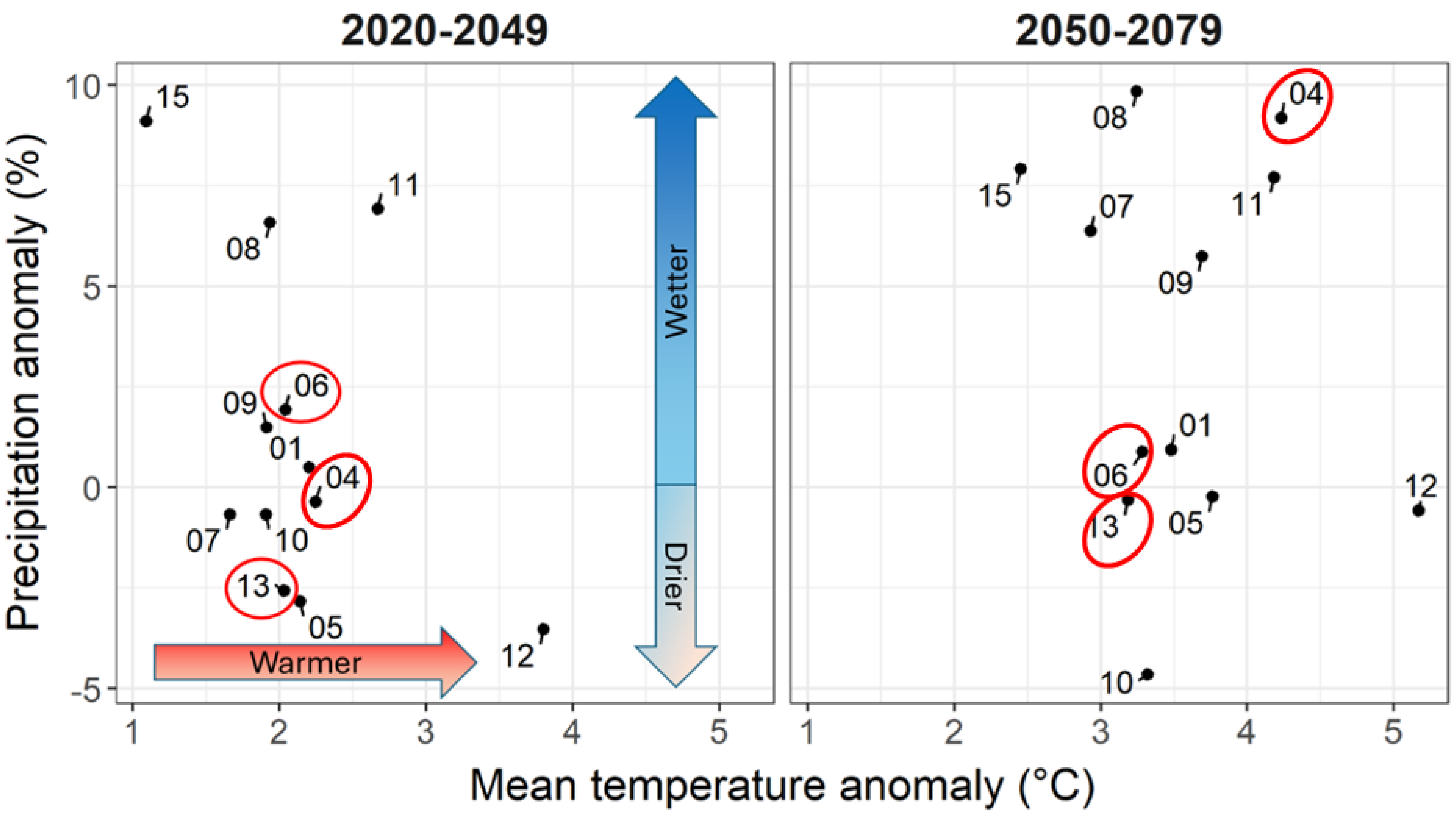


Modelled

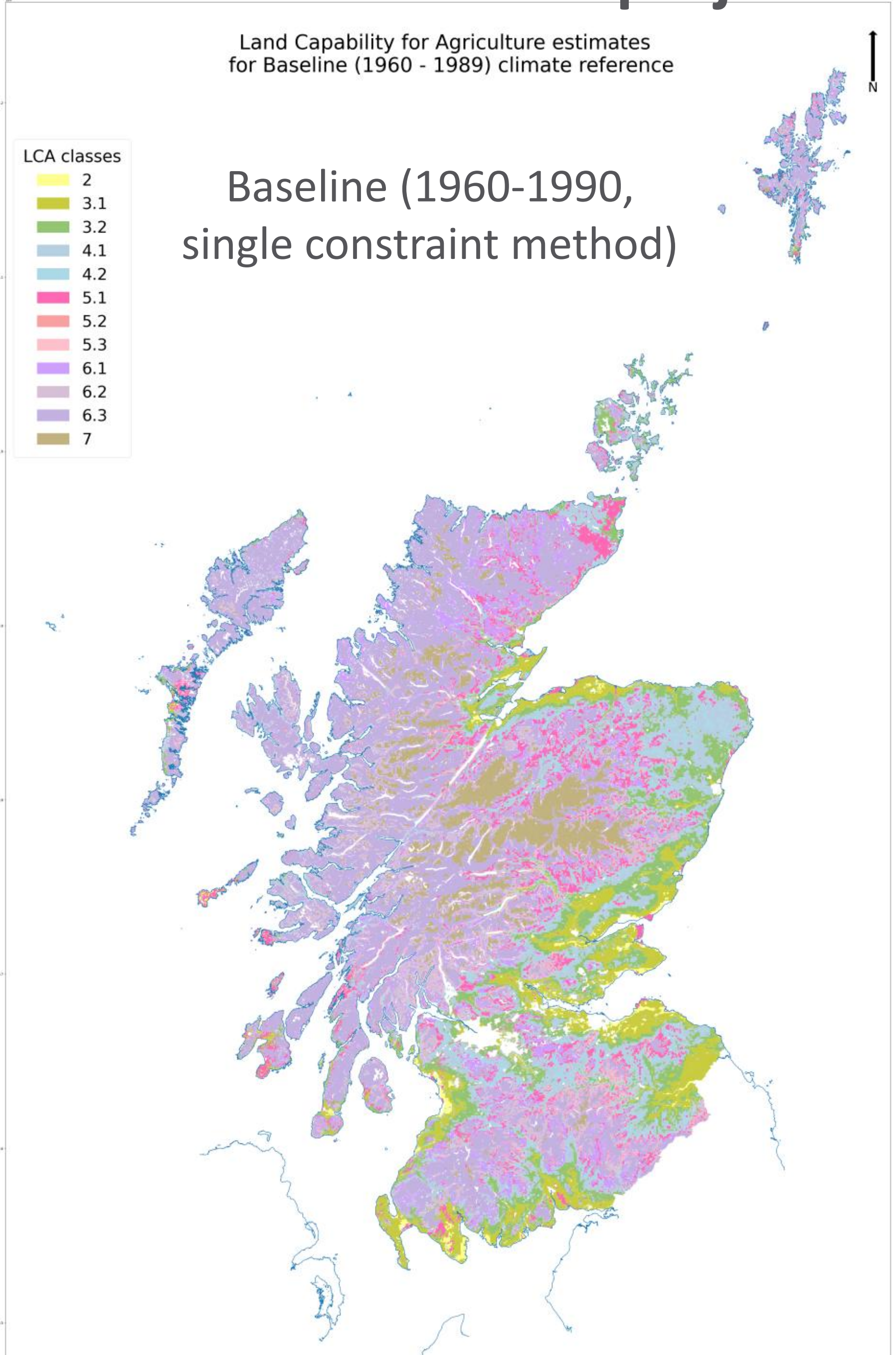


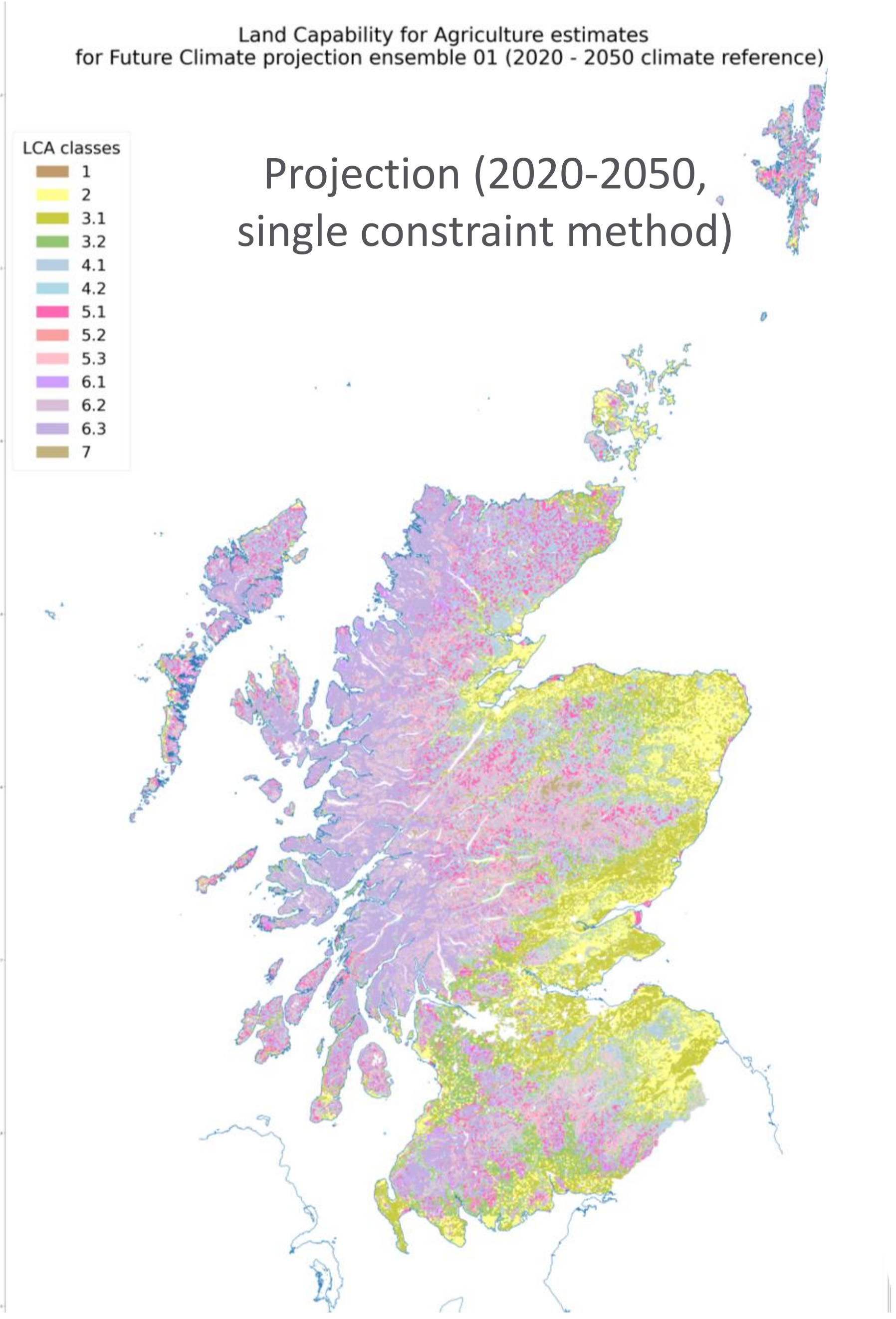
Climate projection range

- UKCP18
- x12 RCM runs
- Bias correction
- RCP8.5
- Daily data for precipitation, Tmax, Tmin, Solar radiation



Baseline and 2020-2049 projection





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Change matrix: Baseline and 2020-2050

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Change Matrix 2020-2050 of Baseline (1960-1989) and climate project ensemble 01 (2020-2050) hectares (x10^2)

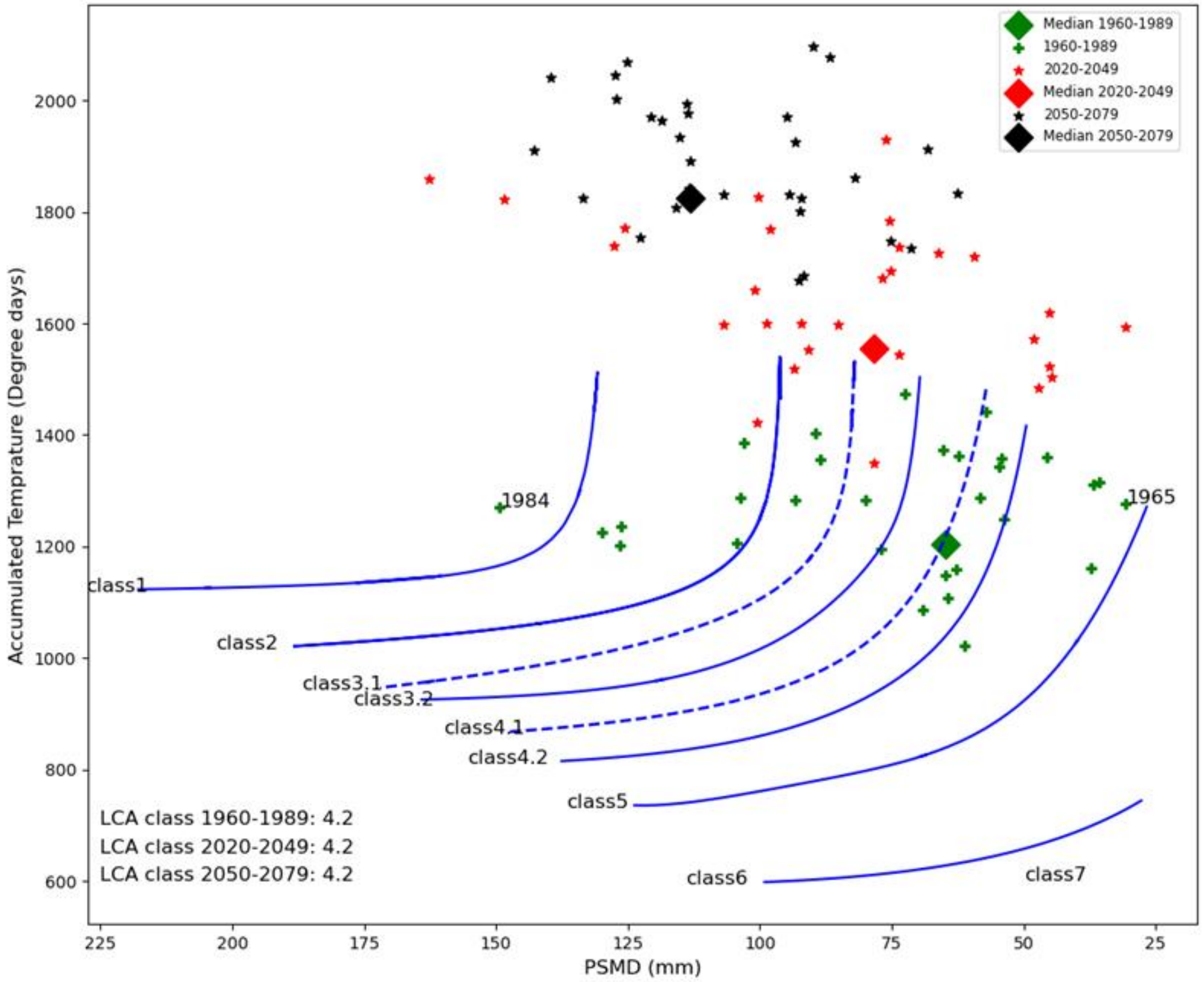
LCA estimates @smd

Ensemble 01@2020-2050 \ LCA classes Baseline@1960-1989	1.0	2.0	3.1	3.2	4.1	4.2	5.1	5.2	5.3	6.1	6.2	6.3	7.0	Total Area
2.0	1962.7	89256.8	28057.8	2889.4	85.7	0.7	8.2	0	0	0	24.2	0	0	122286
3.1	4255.3	228086	278567	16758.8	2071.7	64.5	1112.1	0	0	0	131	0	0	531047
3.2	2013.4	210502	164620	132153	7634.3	592	1056.7	0	0	0	559.9	0	0	519131
4.1	2865.1	336629	316072	150582	64292.9	905.9	8947.9	0	0	0	5580.1	0	0	885875
4.2	267.9	75840.2	66255.6	92028.7	27590.4	105706	2287.8	875.8	0	0	1541.2	0	0	372394
5.1	1705.1	50948	88470.8	93859.1	145386	17637.6	108404	0	0	11646.2	0	0	0	518057
5.2	0	0	0	0	0	64759.9	0	13028.2	0	3999.2	0	0	0	81787.3
5.3	0	0	0	0	0	0	0	0	131268	2831.9	0	0	0	134100
6.1	9088	28244.1	51224.5	36462.6	174026	21537.9	110482	6310.4	18255.2	190780	0	0	0	646411
6.2	2828.8	38656.6	38683.6	36580.5	52148.4	26712.7	41625.9	12983.3	55210.7	0	216386	0	0	521817
6.3	4941.6	12402.9	31166.9	31388.4	389237	102162	320580	60631.5	128754	0	0	1.27428e+06	0	2.35555e+06
7.0	129.6	523.9	25590.4	10006.2	160137	42748	137471	29892.9	56748.5	0	345431	0	30934.7	839614
Total Area	30057.5	1.07109e+06	1.08871e+06	602709	1.02261e+06	382828	731976	123722	390237	209257	569654	1.27428e+06	30934.7	7.52806e+06

LCA classes Baseline@1960-1989

Annual variability

- Large variation between years
- Shifts in Median only tells part of the story.
- Necessitated extension of original curves, may not be safe assumption



Soil Water Balance modelling

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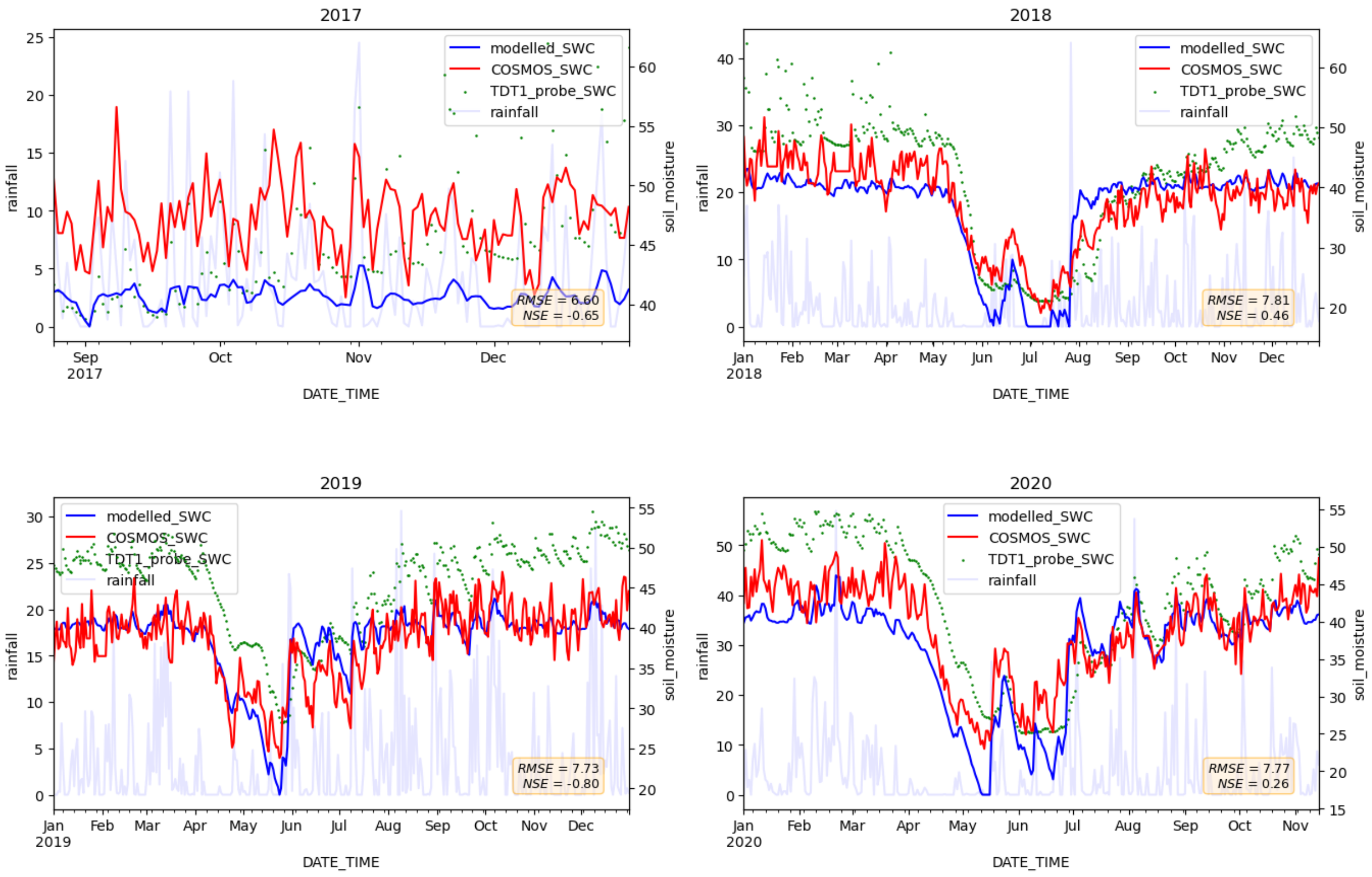
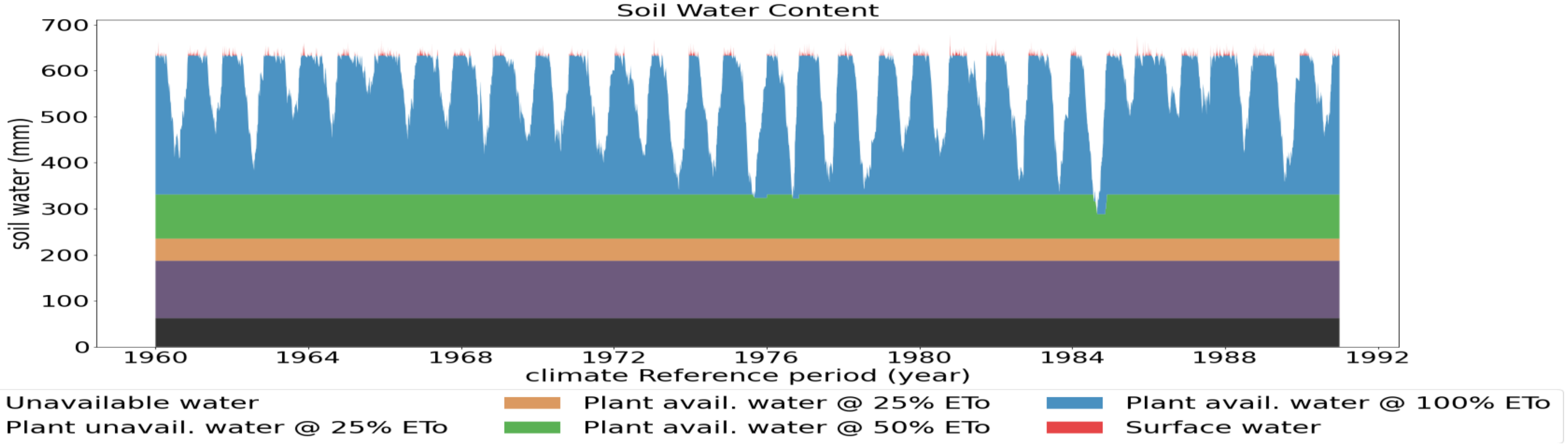
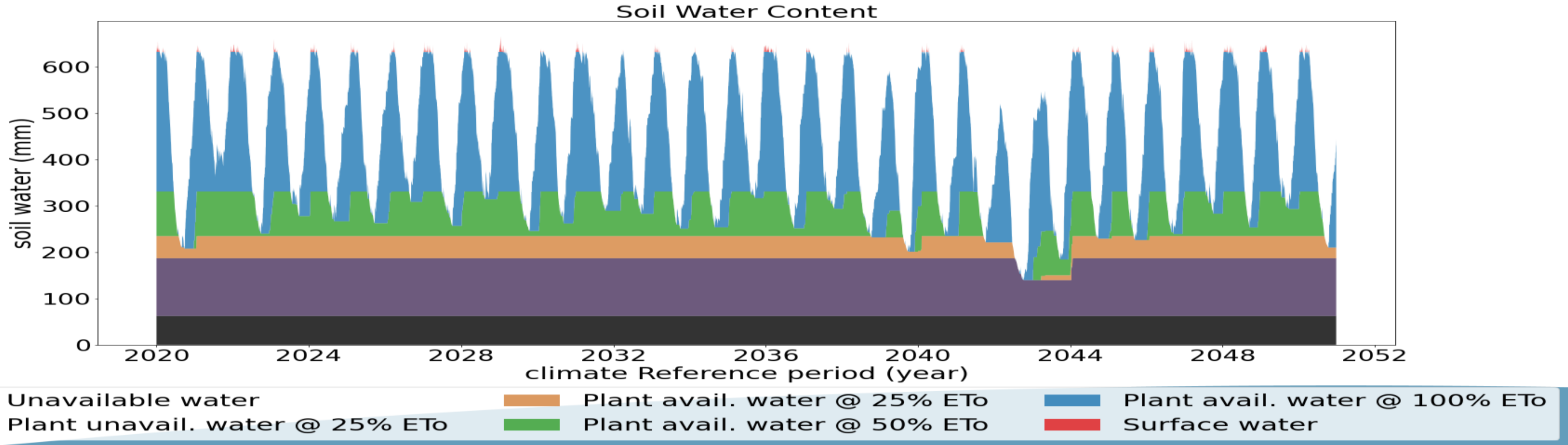
Assessing the utility of the soil moisture content for LCA class estimation.
SWB model compared to COSMOS and moisture probe data



Additional outputs: Soil Water Balance

(for one of the 477,209 unique soil-climate combination)





Time series of soil water balance for a Peaty Alluvial Soil (unique ID 104). Top: 1987-2017, Bottom: 2020-2050 for ensemble member 12. Y axis is soil water (mm), X axis is Year.

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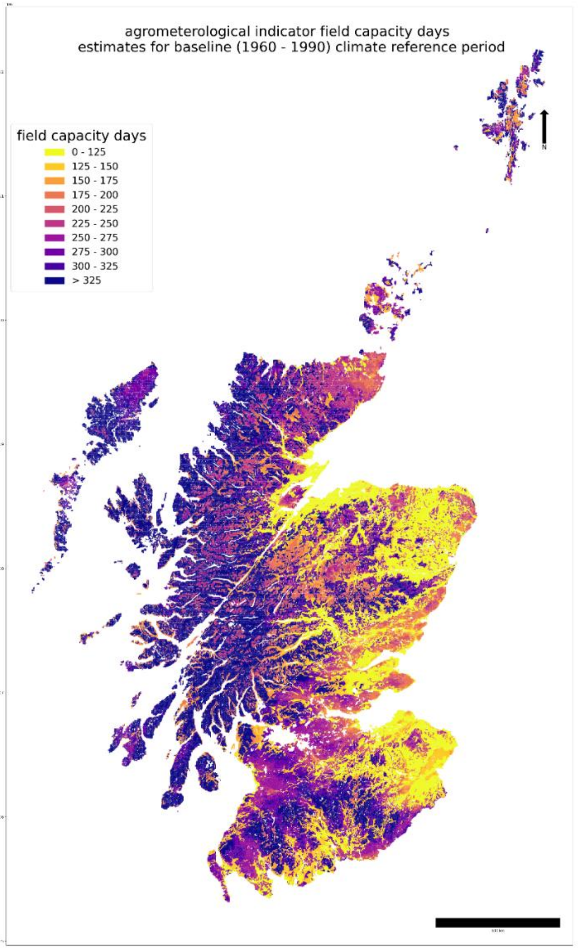
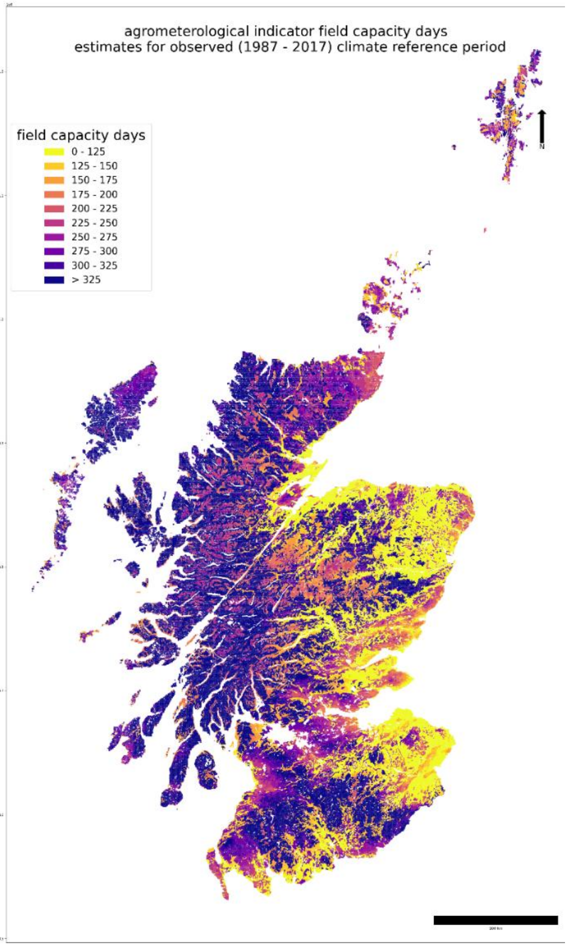
Additional outputs from attributes tables: i.e. Field Capacity Days

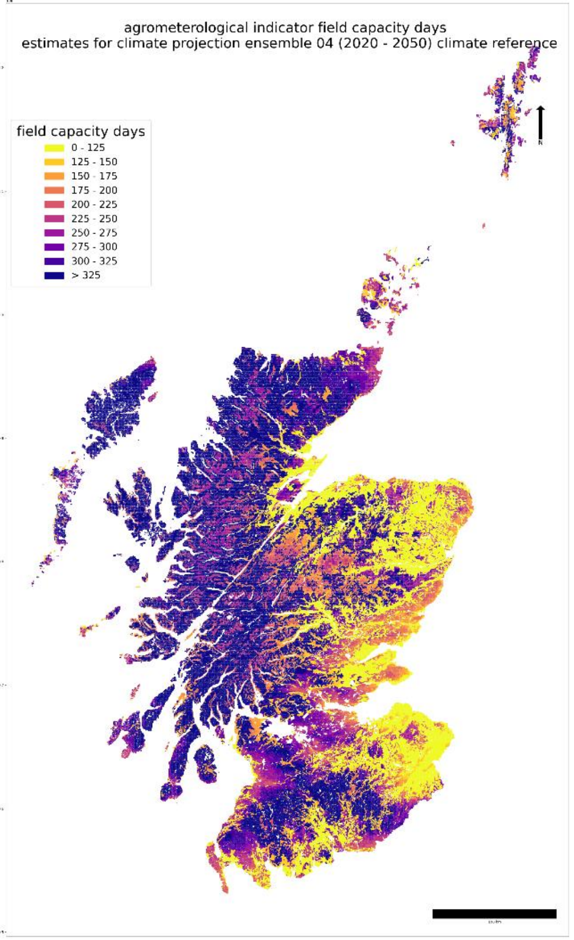
1960 - 1990



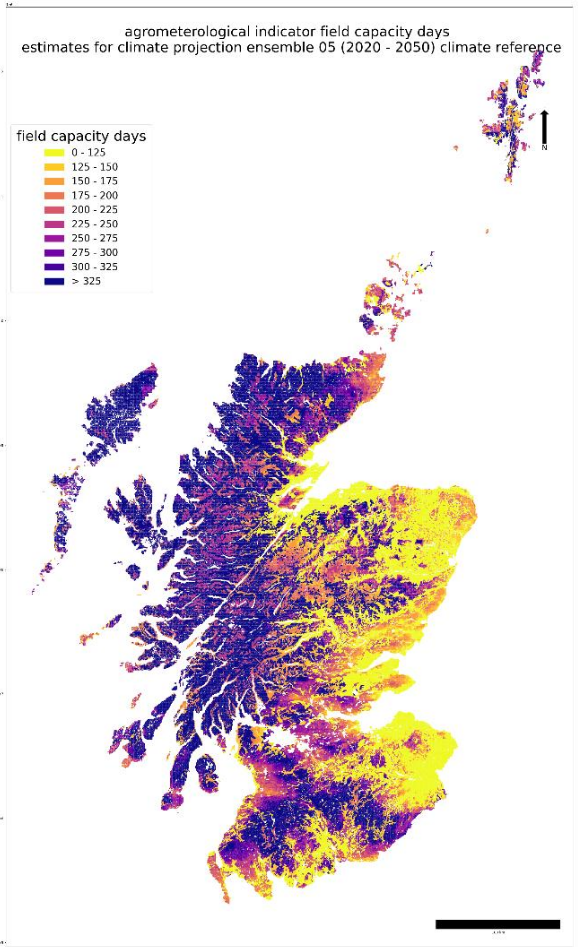
1987 - 2017



2020 – 2050 EM04



2020 – 2050 EM05



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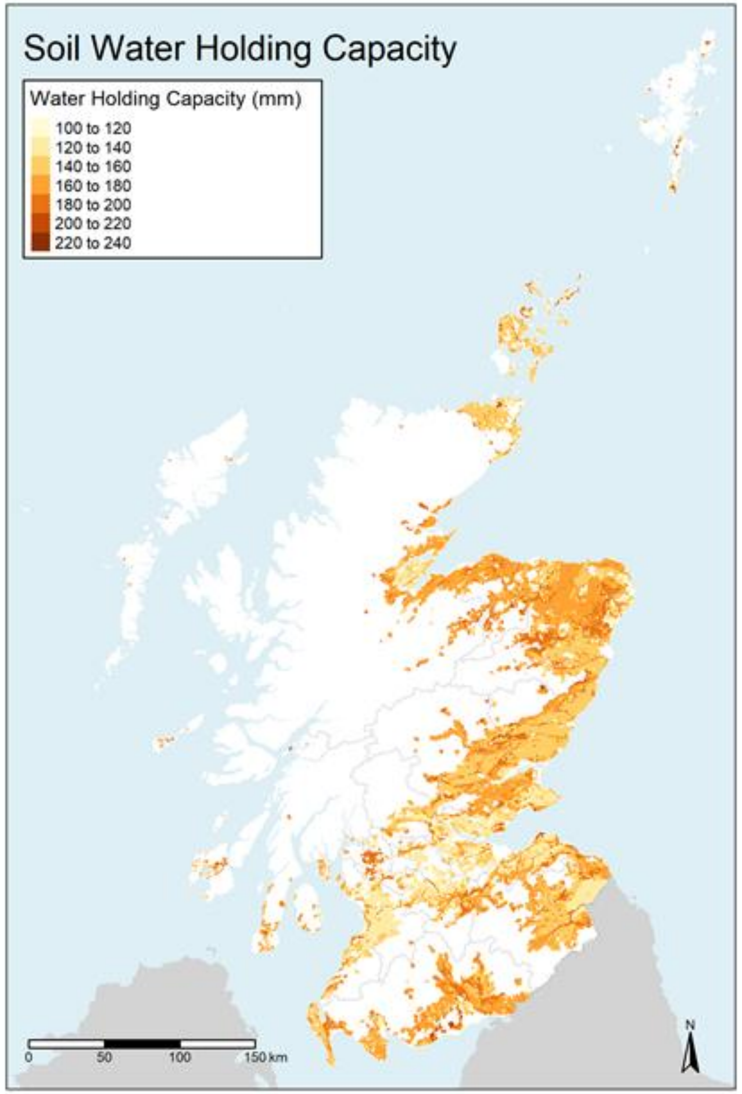
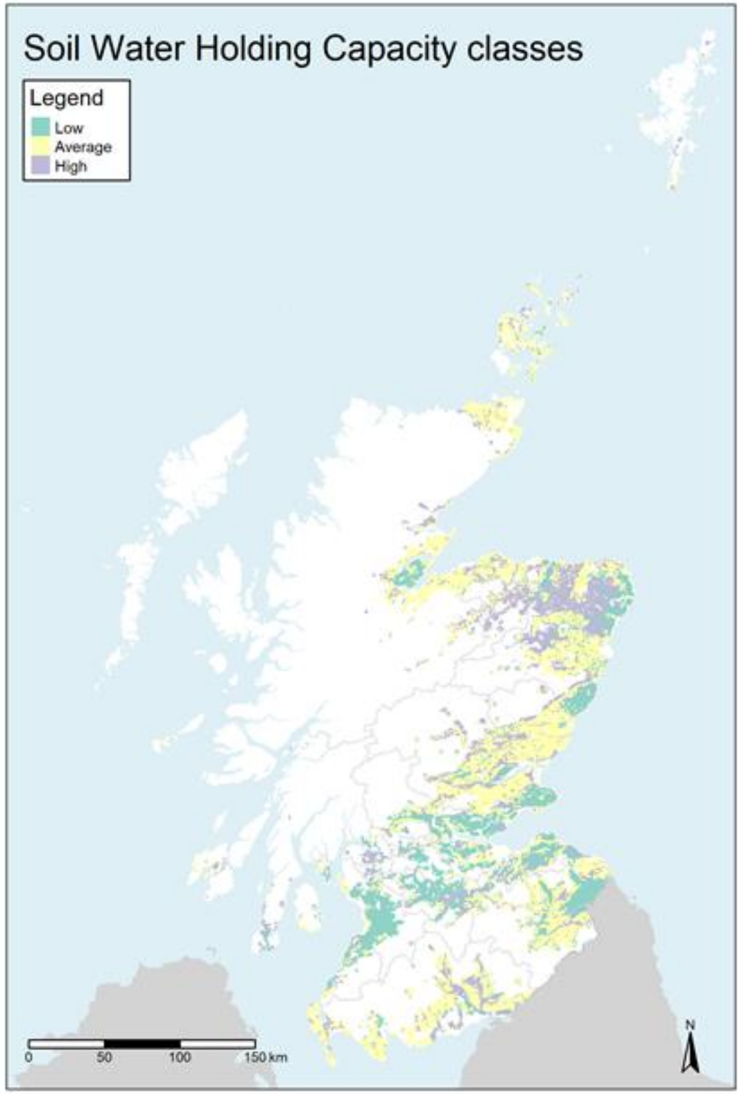
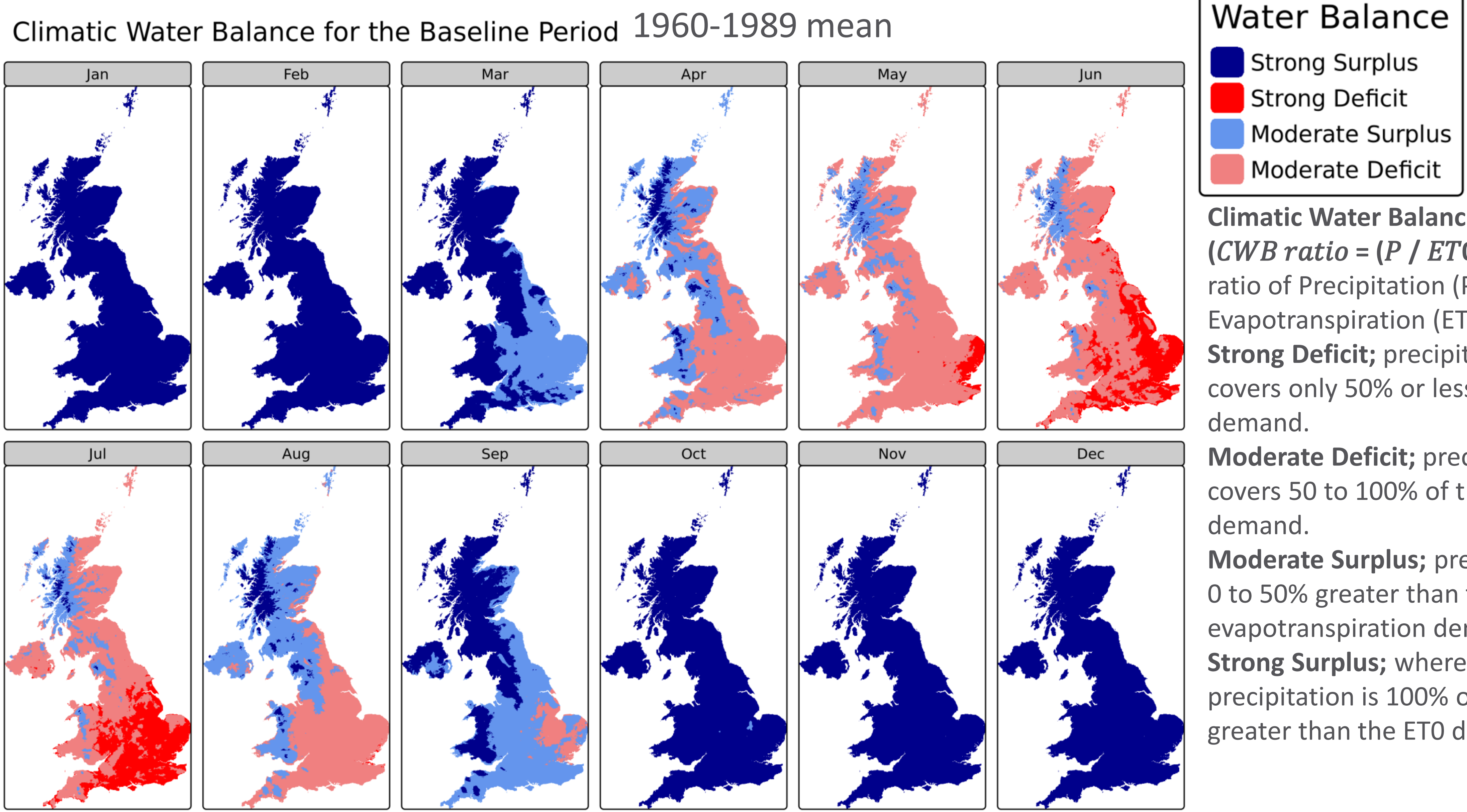
Soil water holding capacity: identifying areas at risk





Changes in meteorological water availability



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Climatic Water Balance Ratio
(*CWB ratio* = (*P* / *ET*0)
ratio of Precipitation (P) to Evapotranspiration (ET0).

Strong Deficit; precipitation covers only 50% or less of ET0 demand.

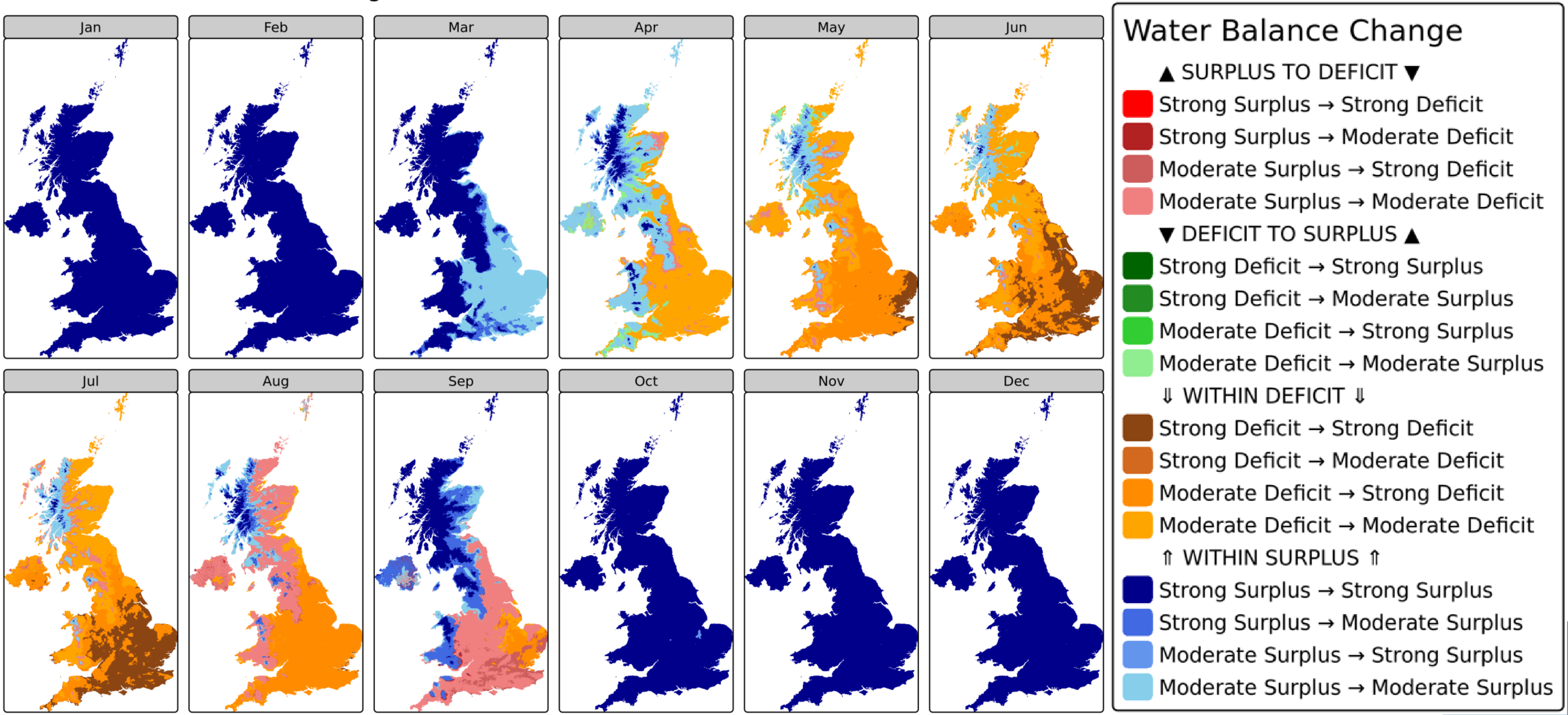
Moderate Deficit; precipitation covers 50 to 100% of the ET0 demand.

Moderate Surplus; precipitation is 0 to 50% greater than the evapotranspiration demand.

Strong Surplus; where precipitation is 100% or more greater than the ET0 demand.

Changes in mean meteorological water availability: baseline to 2020-2049

Climatic Water Balance Change for the Period 2020-2049 - Ensemble Member 06 (2°C warmer, 2% wetter)



Dashboard

- Linking LCA estimates to:
  - Climatic Water Balance (surplus / deficit categories)
  - Farm types
  - Land use
  - By Local Authority or Agricultural Region
- Live demo: Farm Type Table CWR - ClimaticWaterRatio_20251001 - Power BI

Key conclusions: climate impacts on LCA

- Climate change will ease some constraints leading to an increase in land capability potential.
  - Some of the best land may decrease in capability due to water scarcity (no Class 1 land)
- The area of Prime Agricultural Land will increase
- There is likely to be large variation in land capability per year due to increasing climate instability and more variation
- Land previously consider as marginal may become more productive leading to land use change, but these locations often have soils with higher levels of carbon, risking increased emissions

Challenges for policy use?

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- How does Scottish Government want to use the LCA?
- We can be confident in assessing the class values through analysis of the constraints per polygon
  - Meaning use for NPF4 is feasible, i.e. planning applications, Local Authority strategic planning
- But a challenge in assessing large areas accounting for cases where the estimate of the LCA is contested
  - i.e. Changes in land area per class – need to explore tolerance ranges
- Which climate future? Developing adaptation across the range of possibilities
- Future LCA may not reflect impacts of climate change on land uses and productivity.
- Annual / seasonal variability may be more important indicator of land capability and resilience than 30-year median.

Additional spatial data per polygon

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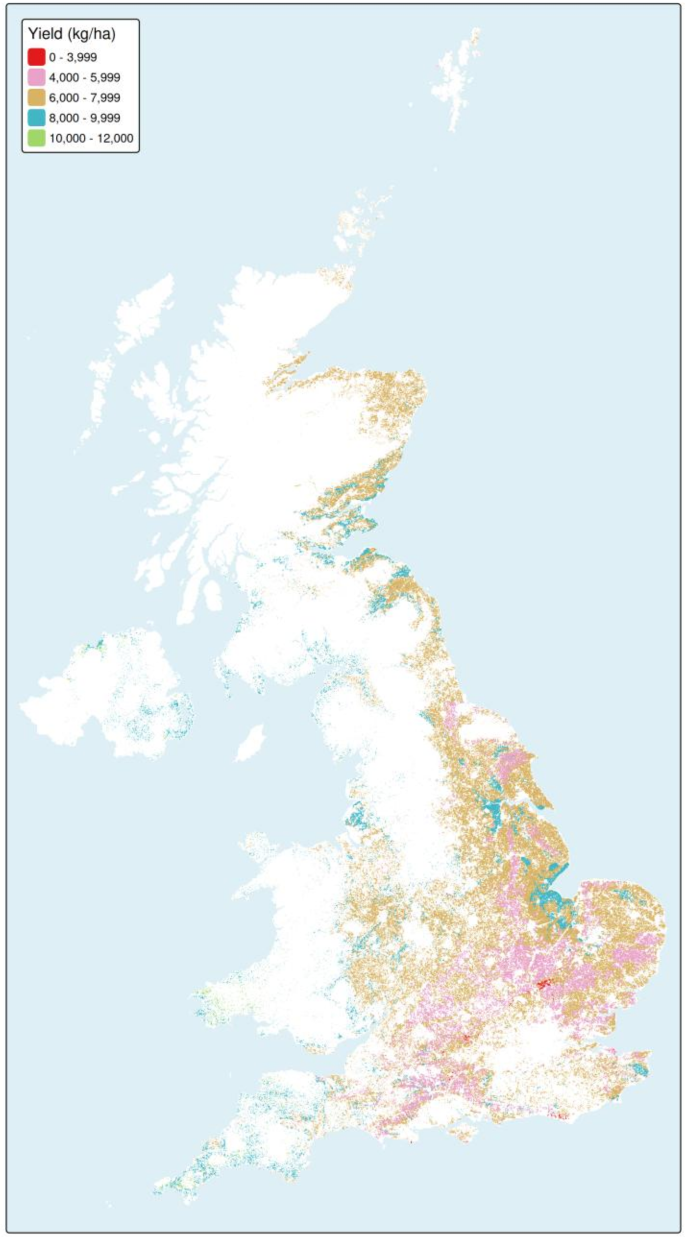
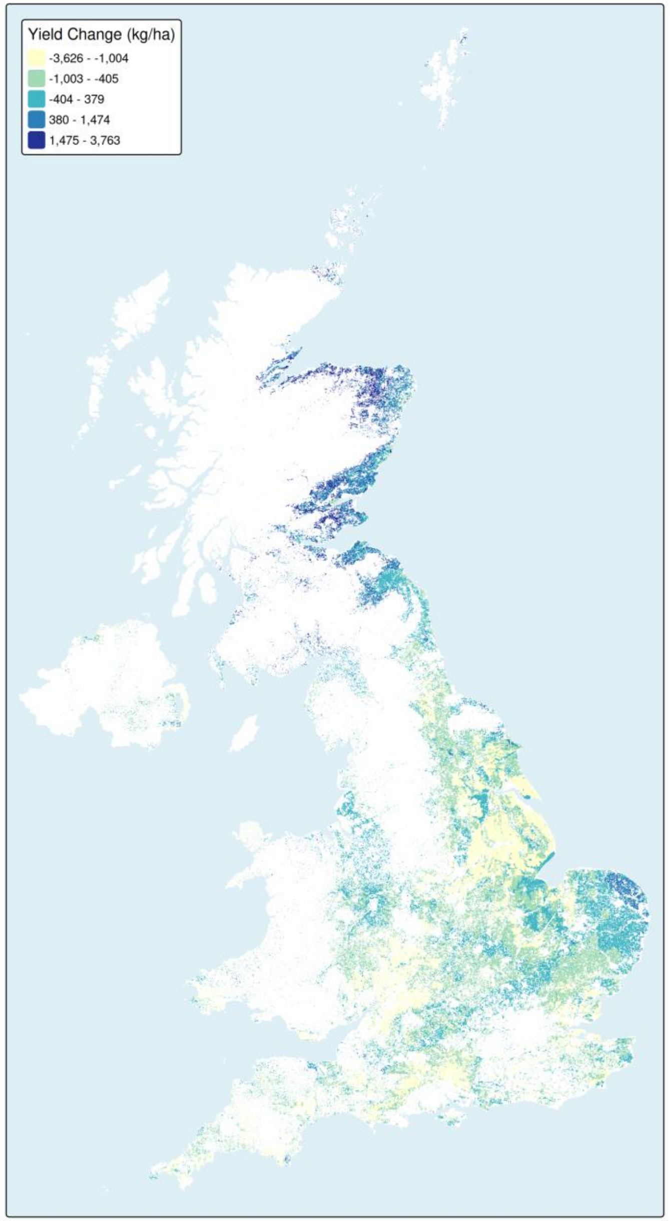
- Agrometeorological Indicators (The James Hutton Institute Climate Data Visualisation)
- Climate trends, future projections and extremes (Climate Change Impacts on Natural Capital - James Hutton Institute), probability of exceedance and return periods (JHI-D5-2)
- Crop yield estimates
  - Relating land capability to production capability
- Our Smart Farm (OurSmartFarm) (JHI-C5-1)
  - Potential for additional field-scale soils data to improve soils database (series selection, gley depths etc.)

Spatial Barley modelling (draft maps – not published)

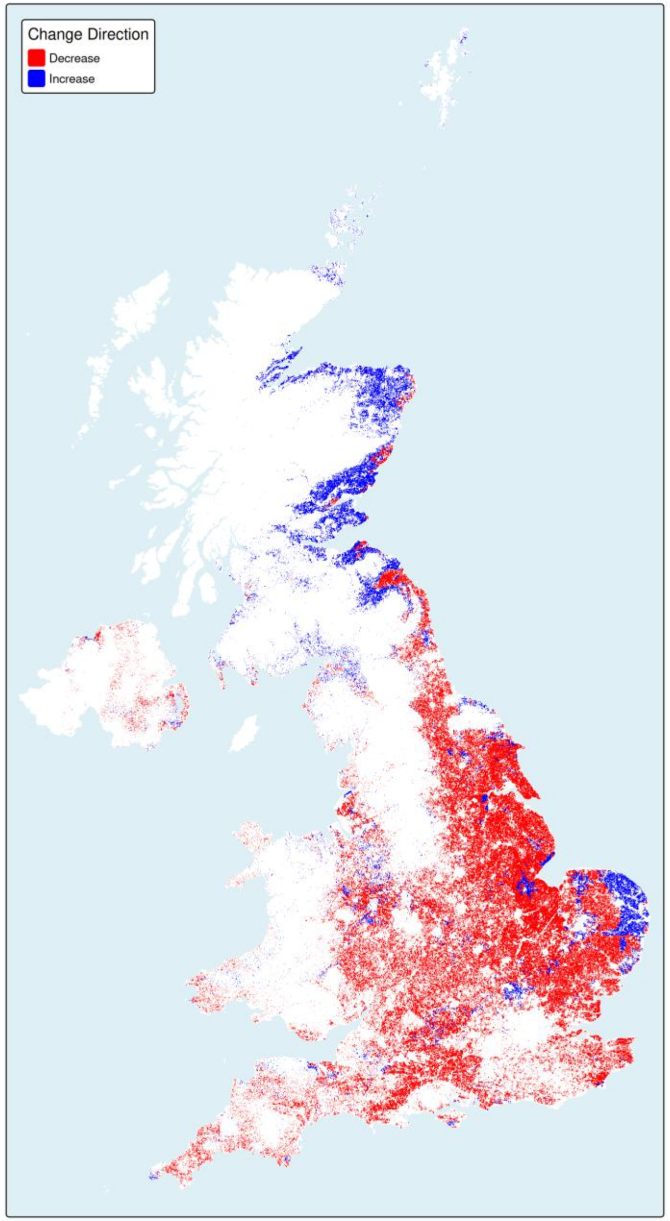
Grain Yield for the Baseline: 2010-2019



Grain Yield Change between 2045-2054 and the Baseline: 2010-2019
Ensemble Member: 01



Grain Yield Change Direction between 2045-2054 and the Baseline: 2010-2019
Ensemble Member: 01



Next steps: platform development

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- Re-write LCA paper and publish
- Improve estimation of soil water balance for Field Capacity Days, Wetness class, workability etc.
- Improve capabilities for assessing temporal variability in constraints and classes
- Class 6 divisions: incorporating climate change impacts on grazing value
- Add flood risk mapping
- Develop visualisation and analytical tools further
    - Integration with other climate projection data and indicators

Next steps: use in a policy support context

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- Broaden engagement with RESAS and wider Scottish Government colleagues
- Explore policy research needs and how the platform can inform analysis, thinking and future scoping

Next steps:

- Develop strategies for:
  - Use in a commercial context
  - Public release
- Needs very careful steps as large sensitivities as LCA used for land valuation, NPF4 and planning

Thanks

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