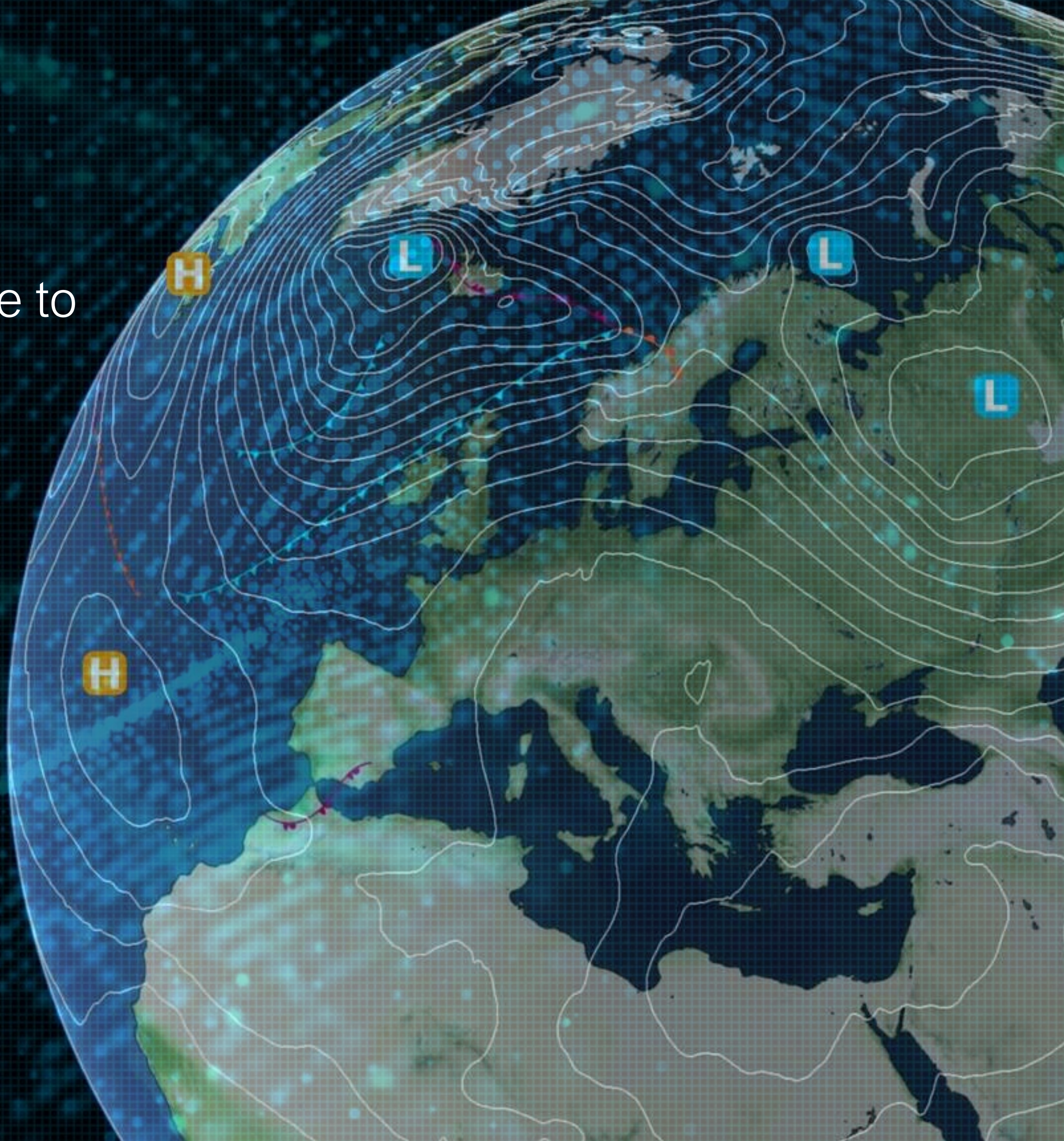
Met Office

QUEST: Quantifying near-Urban Exposure to climate hazards under Socioeconomic paThways

A TWINE digital twin pilot to explore **data-driven spatial planning for green belts**, combining **climate** and **land surface** modelling, with **land-use** and **population scenarios**.

Dr Edward Pope

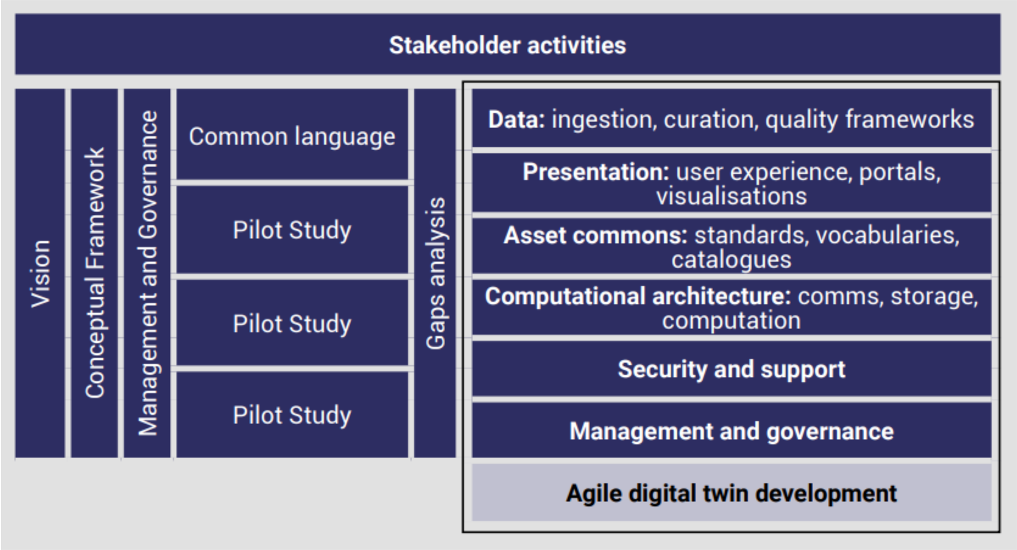
NERC Digital Gathering, 11th September 2024



Overview of the TWINE programme

Joint programme between NERC and the Met Office

1. Supports the development of Digital Twins in the natural environment for addressing challenges relating to **climate change adaptation and mitigation, biodiversity and ecosystem loss, and natural hazards**
2. Provides a means for the UK to develop and apply Machine Learning, AI methods and EO data to further strengthen decision-making
3. Build the foundations of a **coherent and lasting landscape of digital twins** for environmental science, with a high level of cross-fertilisation of learning and a focus on design for interoperability with current and future activities



TWINE is part of a larger family of funded investments

UK Marine and Climate Advisory Service (MCAS)

Transatlantic Data Science Academy

TWInning capability for the Natural Environment (TWINE)

TRUTHS

Aeolus-2

FutureEO

InCubed-2

EO Technology Programme

Digital Twins Earth

Small Satellite Calibration Facility

Surface Temperature Radiometer Network

UK/Australia EO AgroClimate Programme

UK EO Climate Information Service (EO-CIS)

UK EO Marine & Climate Mission Development Programme

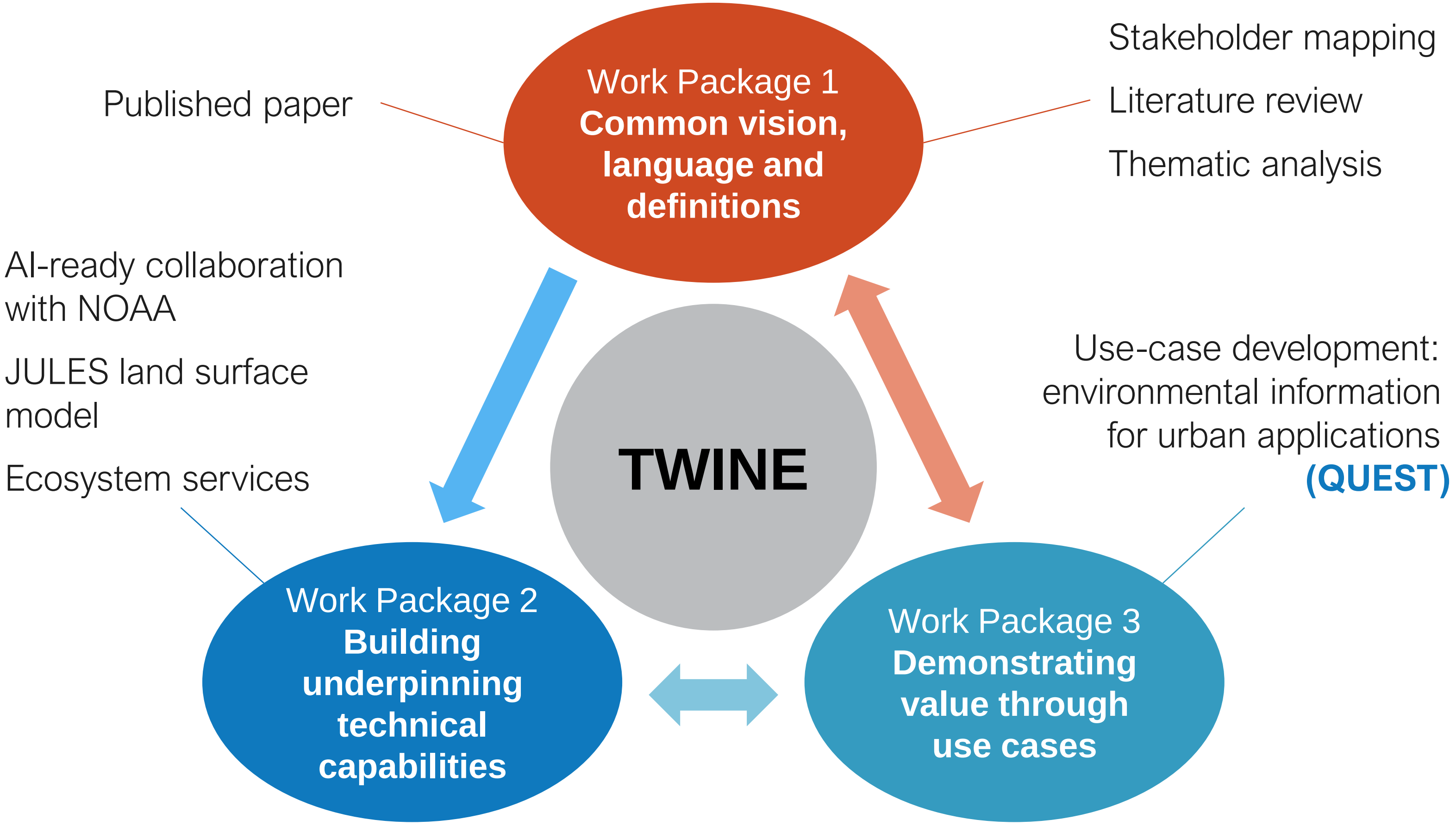
EO Data Hub

SENSE CDT

Innovation in EO

TWINE at the Met Office

Vision: to equip the Met Office to build and contribute to digital twins of the environment



Impact areas of potential interest

- Wind, snow, ice, surface flooding, heat stress
- Landslides, coastal erosion, **wildfire**
- Inshore marine (including fisheries)
- **Urban meteorology and climate**
- **Food, water and energy security**
- Dispersion of hazardous chemicals and radioactive materials
- Space weather
- **Multiple hazard impacts**
- …

Building partnerships

- TWINE community
- Turing Research and Innovation Cluster in Digital Twins (TRIC: DT)
- National Digital Twin Programme (NDTP)
- National Oceanic and Atmospheric Administration (NOAA)
- NERC Centres
- Alan Turing Institute Urban Analytics team
- …

Met Office TWINE team

- **Project Executive** – Edward Pope
- **Project Manager** – Zorica Jones
- **Land surface modelling/Climate/Data Science** - Andrew Cottrell
- **Ecosystem service modelling/Climate/Data Science** - Michael Eastman
- **Climate/Data Science, DT landscape analysis** - Joana Mendes
- **User insights and engagement, thematic analysis, information value chain** – Angela Heard
- **User insights and engagement** - Hannah Findlay
- **Urban climate applications** - Maria Athanassiadou
- **Scientific Software Engineer** (data/system management) – Joshua Wiggs
- **Scientific Software Engineer** (coordinating code development) – Francis Galloway
- **Scientific Software Engineer** (front-end development) – Paul Hallett

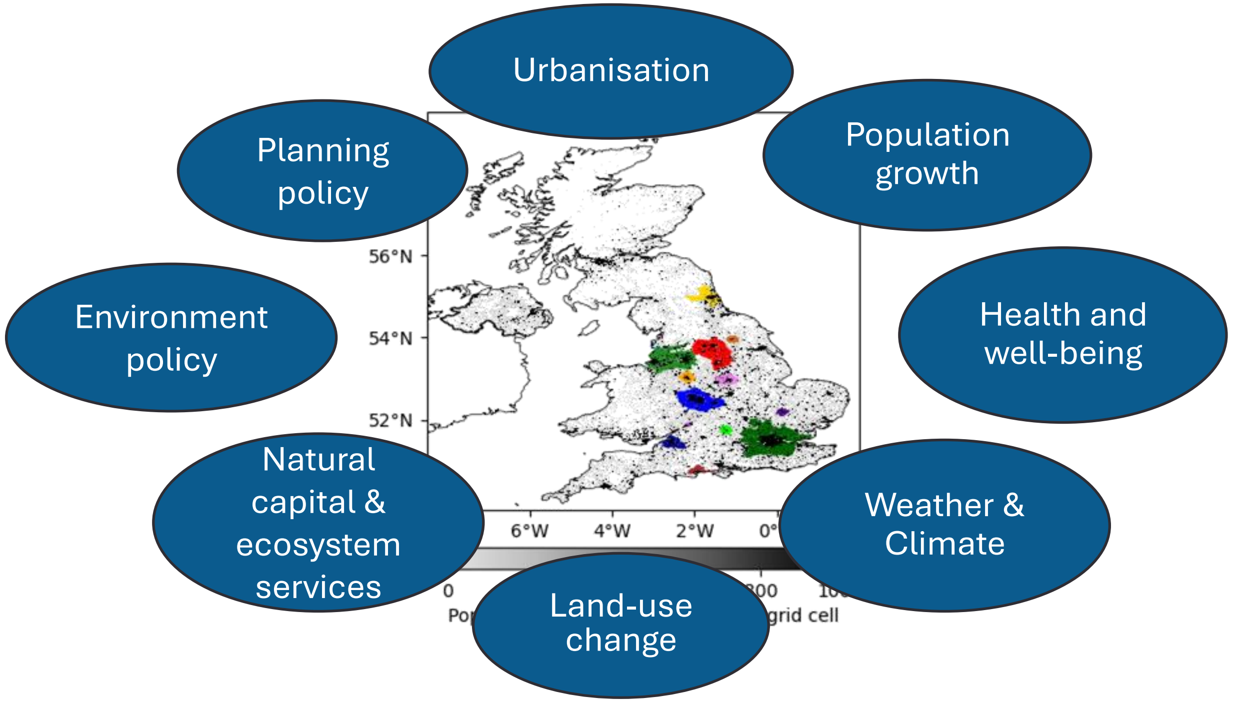
Green belts are important green spaces for 30 million people in the UK

- Green belts are important green spaces for 30 million people living in 16 of the UK’s most populous cities, covering 12% of the UK’s land area.
- Currently, their primary function is to prevent urban sprawl.
- Green belts present an opportunity to help address critical challenges in urban areas of climate change adaptation & mitigation, water resource management, biodiversity and ecosystem loss, food security, and health & well-being.

Why is spatial planning difficult?

1. Increasing pressures on land for economic, environmental and social uses make green belt planning and land management decisions complex and challenging.
2. Decisions need to interpret and balance competing policies, using information that is hard to understand, uncertain, incomplete, or difficult to access.
3. Best practice for climate-related decision-making currently lags other applications, which can lead to decision paralysis and under-utilisation of climate information.

➢ **Need digital tools to explore scenarios, and identify potential synergies and trade-offs.**



<u>QUEST</u>: a greenbelt digital twin for urban climate resilience and sustainability

Scope: interactively model and explore green belt ecosystem services and multifunctional benefits for climate change adaptation & mitigation, water resources, and biodiversity, and explore their exposure to current and future climate hazards.

Value creation (“Avoid”): *informing national planning policy to reduce and avoid loss and damage to green belt natural capital, through improved understanding of current and future multifunctional benefits and climate-related risks under socioeconomic pathways.*

Benefits: improving *assessment, evaluation and awareness raising of multifunctional benefits provided by green belt natural capital, trade-offs resulting from green belt land-use changes, and risks to green belt ecosystem services* through interactive integration of climate information, simulations, and socioeconomic scenarios

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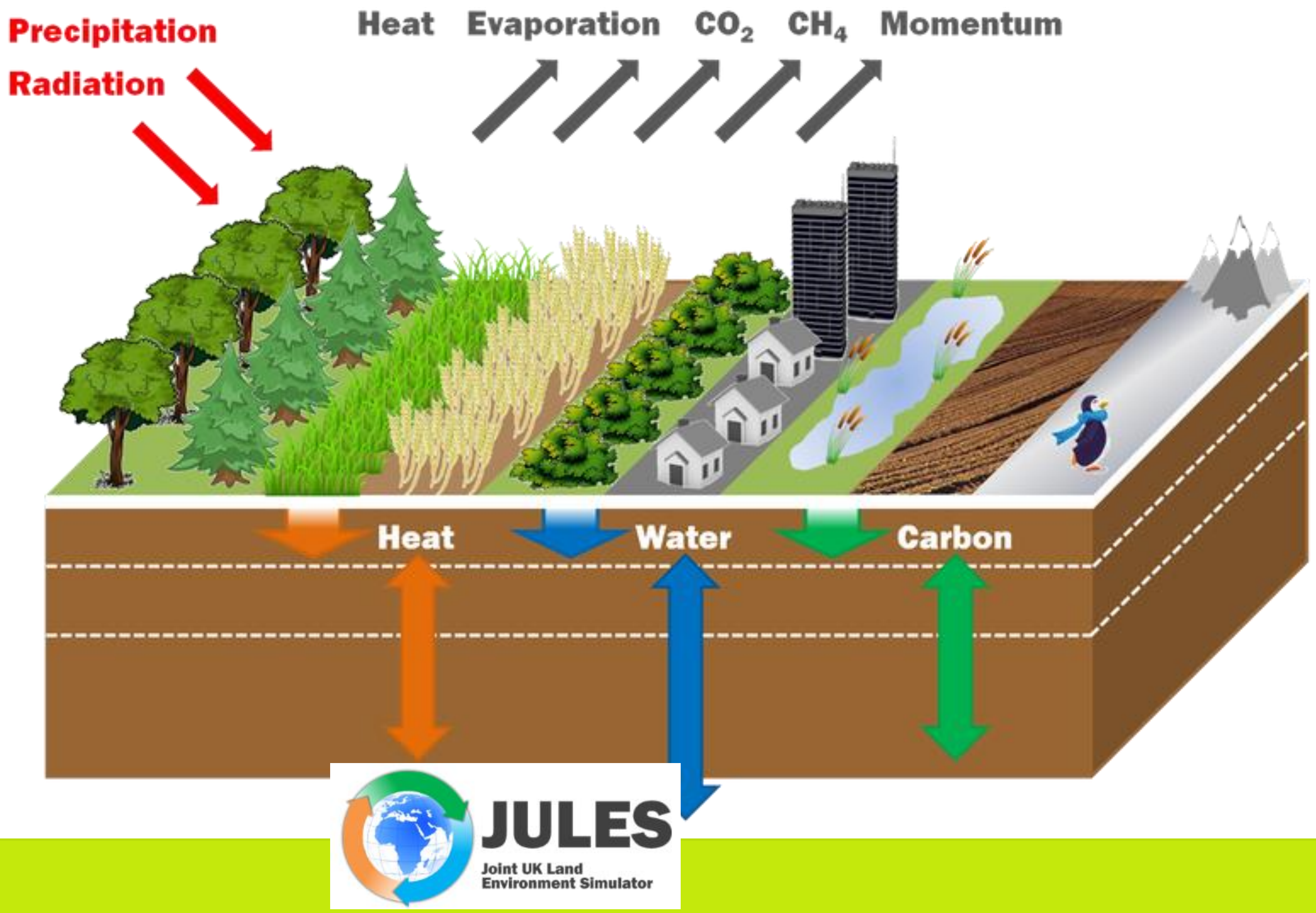
Land surface modelling

Natural Environment Research Council

- QUEST is using technical and scientific capability of the Joint UK Land Environment Simulator (JULES) land-surface model and applying it to site-specific and gridded areas
- Now running land surface simulations using historical climate (ERA5-Land data; 1970-2023)
- Focussing on soil and vegetation conditions (moisture, carbon) and associated risks (e.g. drought and Fire Weather Index).



Core focus

Quantifying and mapping green belt carbon storage, and hazard exposure

Top-level capabilities:

1) Mapping, quantifying and comparing green belt land-cover types
2) Mapping, quantifying and comparing selected climate hazards (water resources/drought, heat and wildfire) across green belts
3) Mapping, quantifying and comparing green belt carbon storage across different land-cover types
4) Mapping, quantifying and comparing exposure of green belt carbon storage to selected climate hazards

The following slides explain the types of comparisons QUEST would enable, and how they might be visualised

Basic Structure: key capabilities/components

- **Core focus: Quantifying green belt carbon storage (e.g. vegetation & soil carbon; absolute and per unit area) and hazard exposure**
  - Capability 1: Mapping, quantifying and comparing green belt land-cover types
    - Current and projected UK Green belt maps and population projections
    - Individual green belt land cover maps and pie charts showing proportion of green belt land cover types
    - Comparison of land use fractions across green belts
  - Capability 2: Mapping, quantifying and comparing selected climate hazards (water resources/drought, heat and wildfire) across green belts
    - Area-average/total hazard time series for each green belt
    - Fraction of green belt area exposed to categorised hazard, e.g. low, moderate, severe drought
    - Radar plots showing fraction of different land-cover types exposed to selected hazards
  - Capability 3: Mapping, quantifying and comparing green belt carbon storage across different land-cover types
    - Time-summarised vegetation and carbon storage maps for each green belt
    - Area-average/total vegetation and carbon storage time series for each green belt
    - Comparison of area-averaged vegetation and soil carbon across green belts
    - Bar plot comparing vegetation carbon across different land cover types within each green belt. Comparison between different green belts
  - Capability 4: Mapping, quantifying and comparing exposure of green belt carbon storage to selected climate hazards
    - Fraction of green belt vegetation and soil carbon exposed to categorised hazards, e.g. low, medium and severe drought
    - Box and whisker plots comparing fraction of woodland exposed to categorised hazard for a selection of green belts
    - ...

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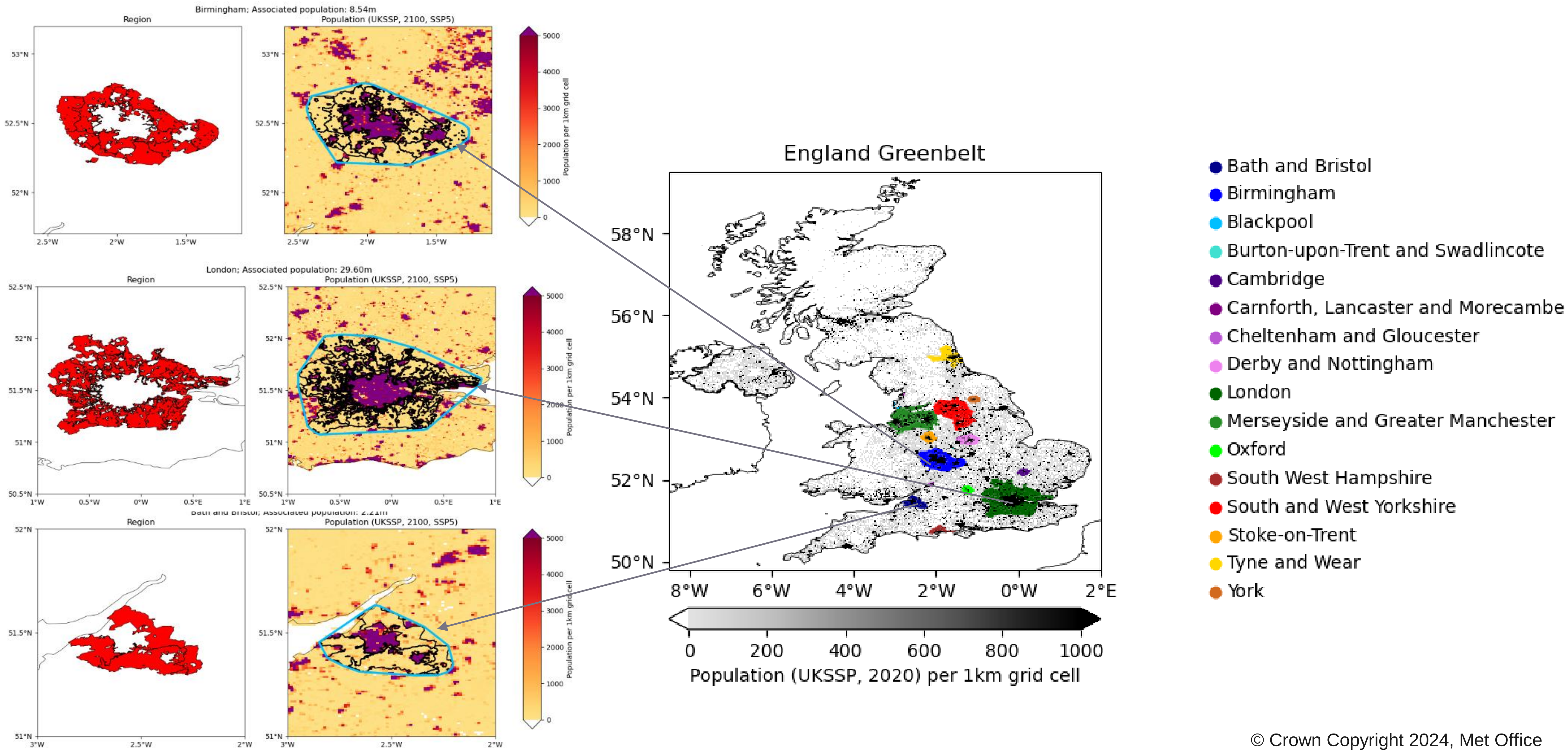
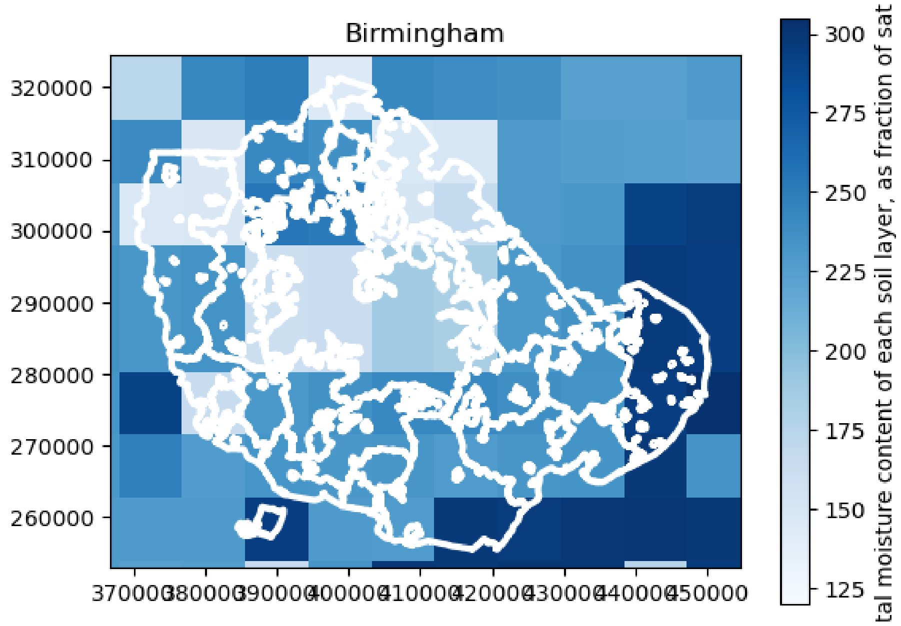
Basic Structure – linking key capabilities with data and models

	Capability 1: Mapping, quantifying and comparing green belt land-cover types	Capability 2: Mapping, quantifying and comparing selected climate hazards (water resources/drought, heat and wildfire) across green belts	Capability 3: Mapping, quantifying and comparing green belt carbon storage across different land-cover type	Capability 4: Mapping, quantifying and comparing exposure of green belt carbon storage to selected climate hazards
Landcover data, agricultural land classification, National Parks, SSSIs, green belt shapefiles	✓	✓	✓	✓
Satellite imagery		✓	✓	✓
Climate data (reanalysis and UKCP18 projections)		✓	✓	✓
Land surface modelling (JULES) – run offline		✓	✓	✓
Ecosystem service modelling (JULES, InVEST, agrifood.py) – run offline			✓	✓

Capability 1: Green belts and population (projections)



Capability 2 example: green belt climate hazard information



5th percentile of summer total soil moisture in 3rd soil layer of Birmingham greenbelt (1999-2023)

note to change this to mean instead of total

Hazard

- ❑ Drought
  - ❑ Annual
  - ❑ Summer
  - ❑ Winter recharge
- ❑ Fire weather index
  - ❑ …

Greenbelt

- ❑ Bristol
- ❑ London

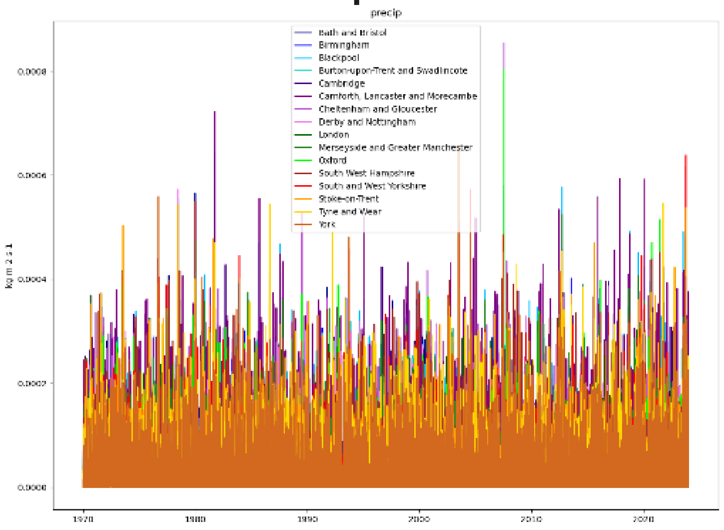
Climate Scenario

- ❑ Baseline
- ❑ 2C
- ❑ 4C

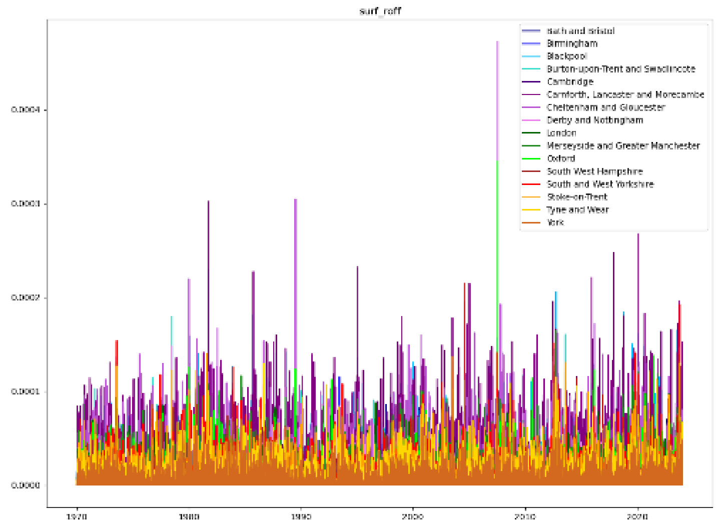
Comparison of precipitation and surface runoff time series across green belts

- *Consider supplementing/replacing with box plots of drought metrics (e.g. summer precipitation total)*

Precipitation



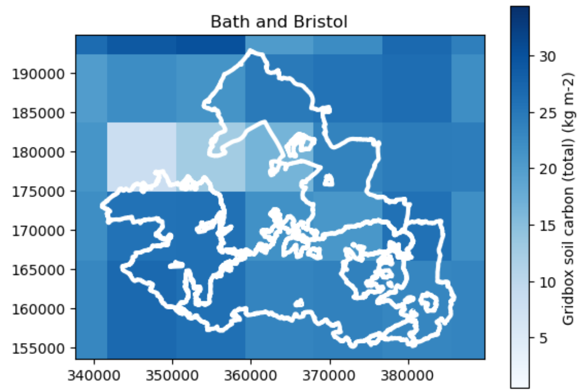
Surface runoff



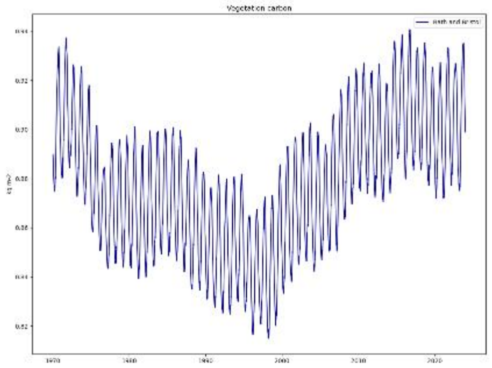
Capability 3 example: carbon storage information

- Single scenarios of single variables could be visualised in time series and maps
- Multiple time series on a single plot would enable users to interpret temporal variation of a few levels at the same time

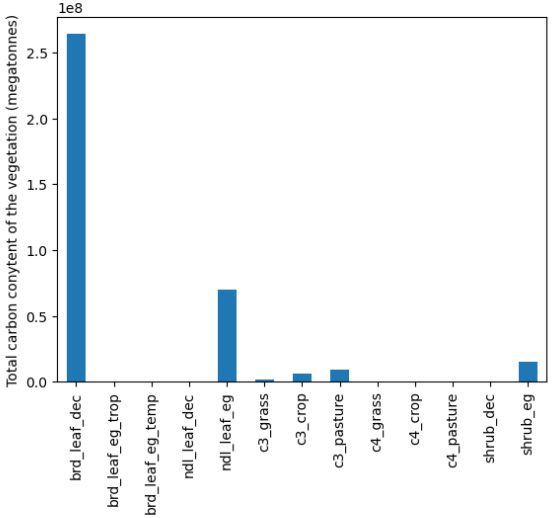
Map of mean Gridbox soil carbon totals in Bath and Bristol greenbelt



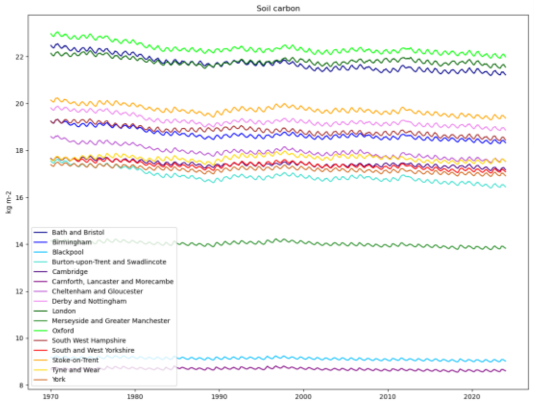
Mean vegetation carbon across a single greenbelt



Bar plot showing carbon stored by different land cover types



Mean vegetation carbon across all greenbelts



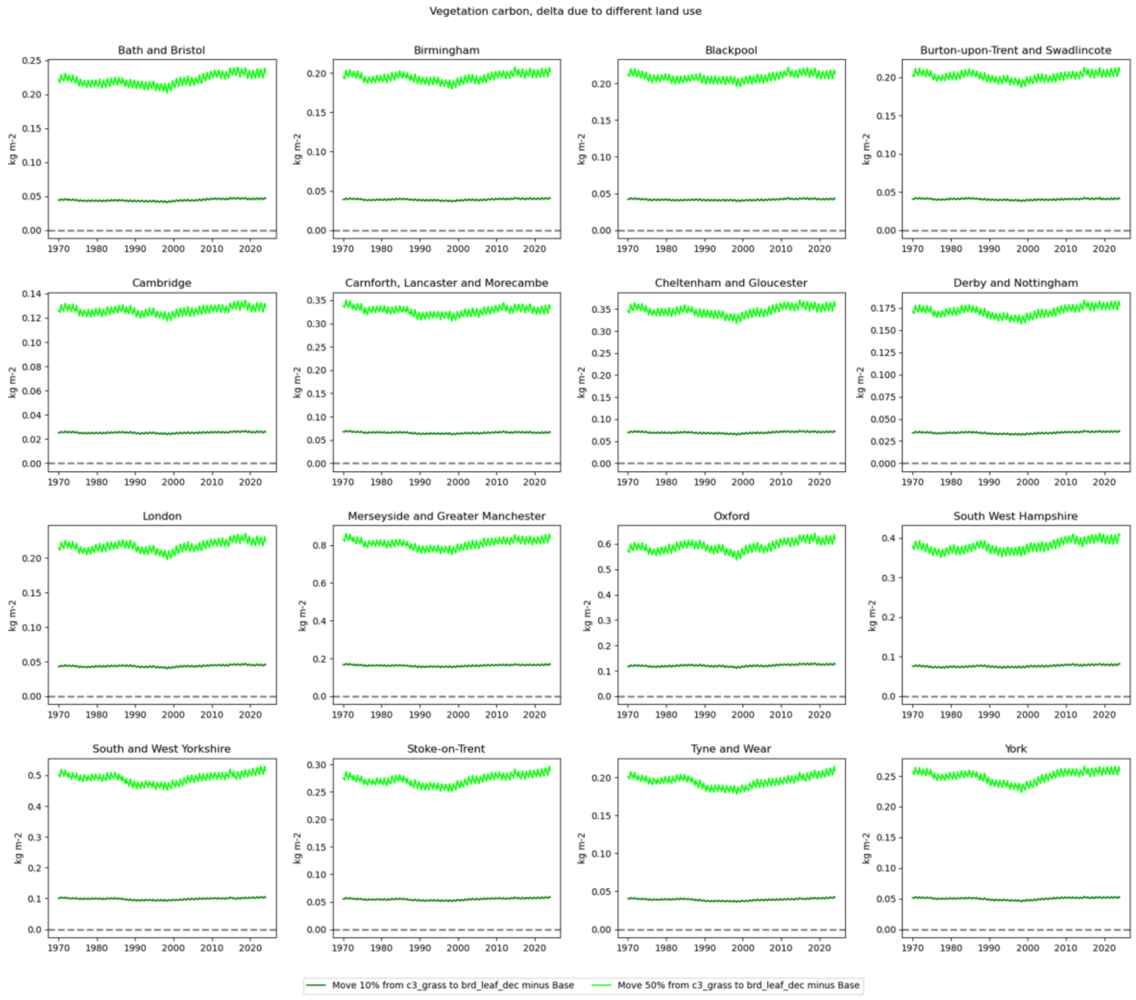
Carbon variable
- ❑ Vegetation carbon
- ❑ Soil carbon

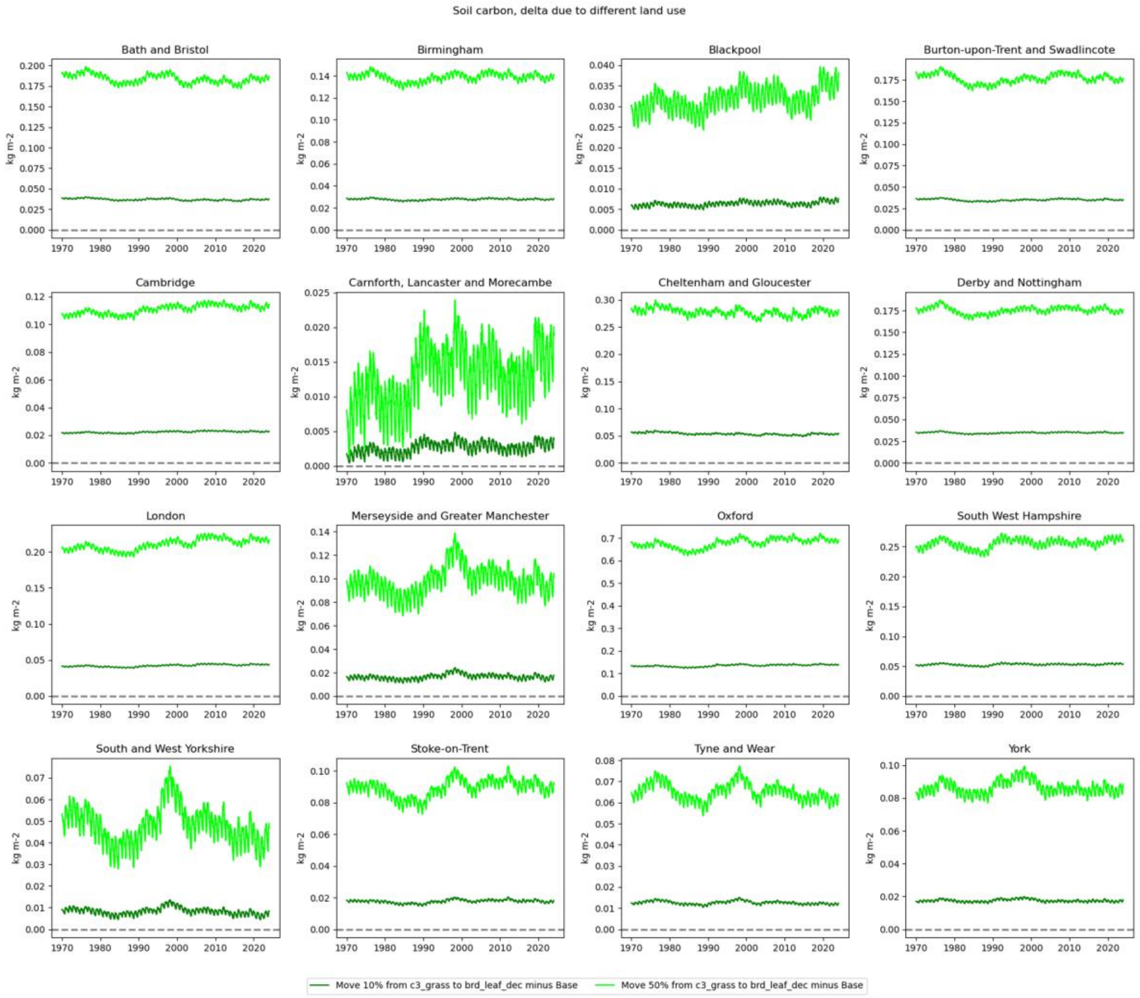
Greenbelt
- ❑ Bristol
- ❑ London

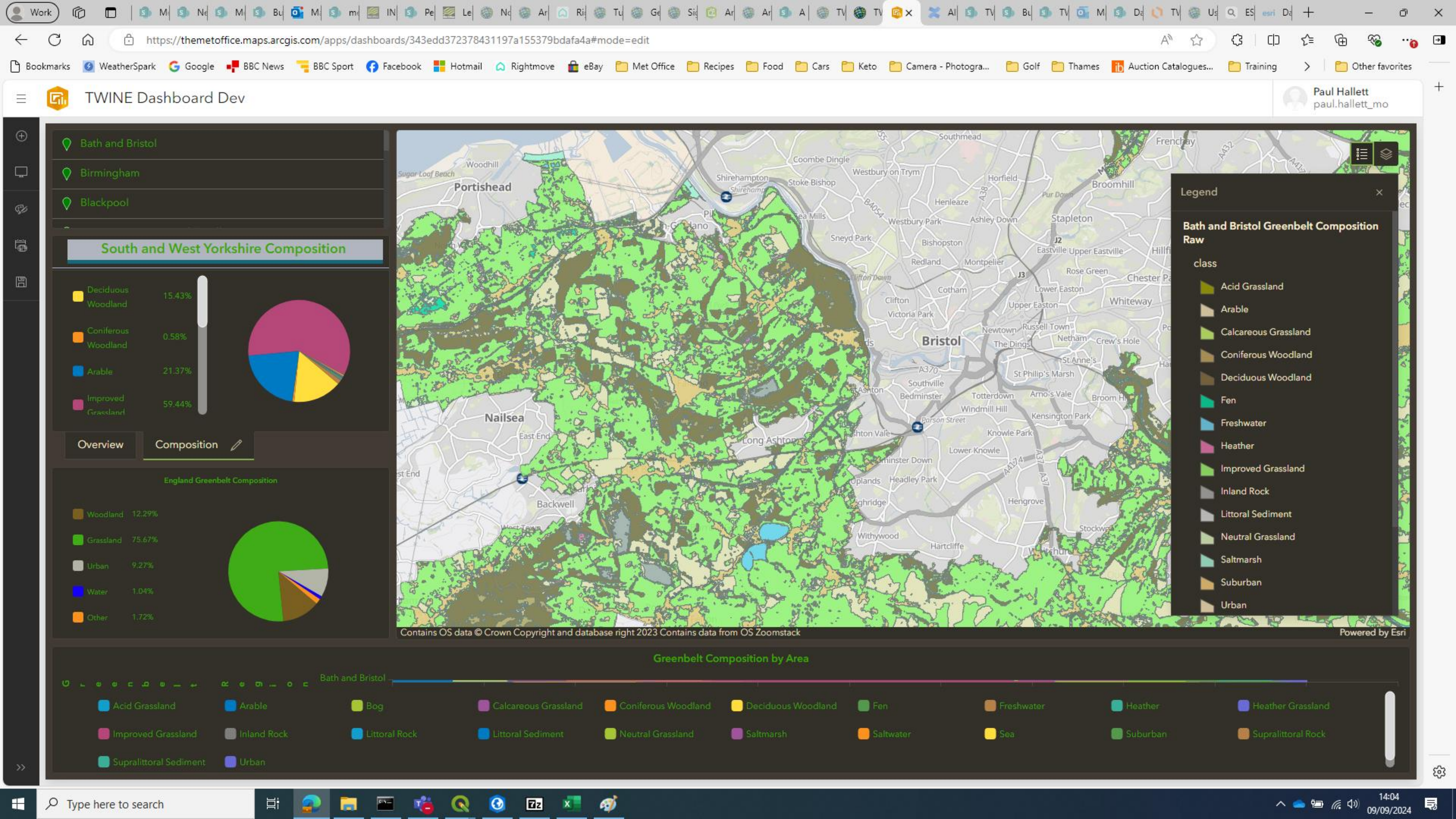
Climate scenario
- ❑ Baseline
- ❑ 2C
- ❑ 4C

Land use scenario
- ❑ Baseline
- ❑ SSP1

Land-use change scenarios







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Bookmarks
WeatherSpark
Google
BBC News
BBC Sport
Facebook
Hotmail
Rightmove
eBay
Met Office
Recipes
Food
Cars
Keto
Camera - Photogra...
Golf
Thames
Auction Catalogues...
Training
Other favorites
TWINE Dashboard Dev
Paul Hallett
paul.hallett_mo
Bath and Bristol
Birmingham
Blackpool
South and West Yorkshire Composition
Deciduous Woodland 15.43%
Coniferous Woodland 0.58%
Arable 21.37%
Improved Grassland 59.44%
Overview
Composition
England Greenbelt Composition
Woodland 12.29%
Grassland 75.67%
Urban 9.27%
Water 1.04%
Other 1.72%
Legend
Bath and Bristol Greenbelt Composition Raw
class
Acid Grassland
Arable
Calcareous Grassland
Coniferous Woodland
Deciduous Woodland
Fen
Freshwater
Heather
Improved Grassland
Inland Rock
Littoral Sediment
Neutral Grassland
Saltmarsh
Suburban
Urban
Portishead
Nailsea
Bristol
Backwell
Long Ashton
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Powered by Esri
Greenbelt Composition by Area
Bath and Bristol
Acid Grassland
Arable
Bog
Calcareous Grassland
Coniferous Woodland
Deciduous Woodland
Fen
Freshwater
Heather
Heather Grassland
Improved Grassland
Inland Rock
Littoral Rock
Littoral Sediment
Neutral Grassland
Saltmarsh
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Sea
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Supralittoral Rock
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Urban
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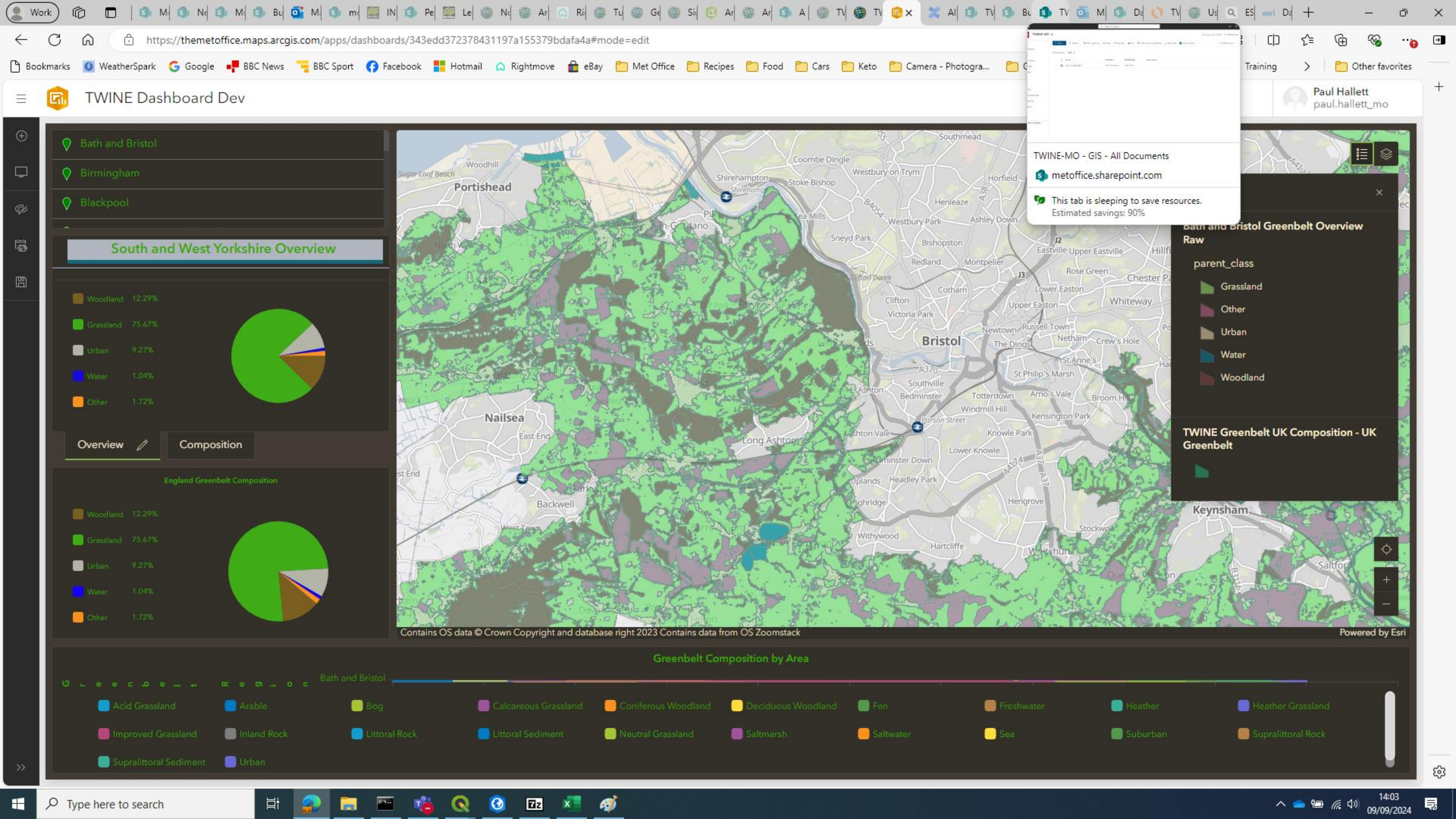
09/09/2024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TWINE Dashboard Dev
Paul Hallett
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Bath and Bristol
Birmingham
Blackpool
South and West Yorkshire Overview
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Urban 9.27%
Water 1.04%
Other 1.72%
Overview
Composition
England Greenbelt Composition
Woodland 12.29%
Grassland 75.67%
Urban 9.27%
Water 1.04%
Other 1.72%
TWINE-MO - GIS - All Documents
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Estimated savings: 90%
Bath and Bristol Greenbelt Overview Raw
parent_class
Grassland
Other
Urban
Water
Woodland
TWINE Greenbelt UK Composition - UK Greenbelt
Contains OS data © Crown Copyright and database right 2023 Contains data from OS Zoomstack
Powered by Esri
Greenbelt Composition by Area
Bath and Bristol
Acid Grassland
Arable
Bog
Calcareous Grassland
Coniferous Woodland
Deciduous Woodland
Fen
Freshwater
Heather
Heather Grassland
Improved Grassland
Inland Rock
Littoral Rock
Littoral Sediment
Neutral Grassland
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Sea
Suburban
Supralittoral Rock
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TWINE Dashboard Dev
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Greenbelt Composition by Area
Greenbelt Region
Bath and Bristol
Birmingham
Blackpool
Burton-upon-Trent and Swadlincote
Cambridge
Carnforth, Lancaster and Morecambe
Cheltenham and Gloucester
Derby and Nottingham
London
Merseyside and Greater Manchester
Oxford
South and West Yorkshire
South West Hampshire
Stoke-on-Trent
Tyne and Wear
York
Acid Grassland
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Greensight: Earth observation data for greenbelt, carbon modelling and digital twins

- **Activity 1: Comparison of JULES outputs and satellite observations -** November 30th 2024
  - Assess how physically plausible the JULES model outputs are during the recent historical period (e.g. 1980-2024)
  - Identify relevant EO data for comparing with carbon and soil moisture modelling
    - https://www.nceo.ac.uk/,
    - https://climate.esa.int/en/data/#/dashboard
    - https://land.copernicus.eu/en/products/vegetation
    - https://esa-worldcover.org/en/data-access
  - Identify relevant variables, e.g. Normalised Difference Vegetation Index (NDVI)
  - Start with basic temporal and spatial correlation analysis
  - Point of contact: Andrew Cottrell (andrew.Cottrell@metoffice.gov.uk)

- **Activity 2: Satellite observations of green belt hazards -** January 31st 2025
  - Explore if/how we can use historical and near-real time Earth Observations data to assess the exposure of green belts to natural hazards.
  - Initial focus on indicators of drought and wildfire, e.g. where have wildfires occurred in green belts, how many have occured, etc.
    - https://climate.esa.int/en/projects/fire/data/
    - https://forest-fire.emergency.copernicus.eu/
    - https://catalogue.ceda.ac.uk/uuid/bcef9e87740e4cbabc743d295afbe849/
    - https://data-search.nerc.ac.uk/geonetwork/srv/api/records/9821980dc18047f09b9113d44fc2c20b
  - Point of contact: Michael Eastman (michael.eastman@metoffice.gov.uk)

- **Activity 3: Integration and dissemination -** February 28th 2025
  - Ensure findings, data and code are integrated into wider QUEST digital twin
  - Point of contact for code: Francis Galloway (francis.Galloway@metoffice.gov.uk) - away till mid-October

- All activities will need to be finalised by 31st March 2025 (except finishing papers)
- Point of contact overall: Edward Pope (edward.pope@metoffice.gov.uk)

Questions?

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