

The Land InSight Digital Twin of the UK's soil carbon and water is exploring a number of challenges in the creation of Digital Twins of the Environment, and developing our understanding of how a digital twin approach can deliver better information on soil moisture and soil carbon uptake as we seek to move to Net-Zero

## Improving understanding of soil processes for Net-Zero

Understanding the interactions at the land surface, in particular the roles of soils for water and carbon retention, is critical to the UK's response to the climate emergency. Soil moisture has a huge influence on both flooding and drought, predicted to be the greatest direct impacts of climate change on the UK. Increasing the uptake of soil carbon through land management will be critical to achieving net-zero targets. We need to improve understanding of land surface processes and predictions of soil behaviour under land management scenarios as we move to warmer summers and wetter winters.

## What is a Digital Twin of the Environment?

Digital Twins of the Environment are a genuinely new paradigm offering a pathway for the discovery of new knowledge about environmental systems, improving our ability to model and predict the functioning of these systems and provide information for decision making in real-time or for constructed scenarios.

They offer an opportunity to bring together and exploit:

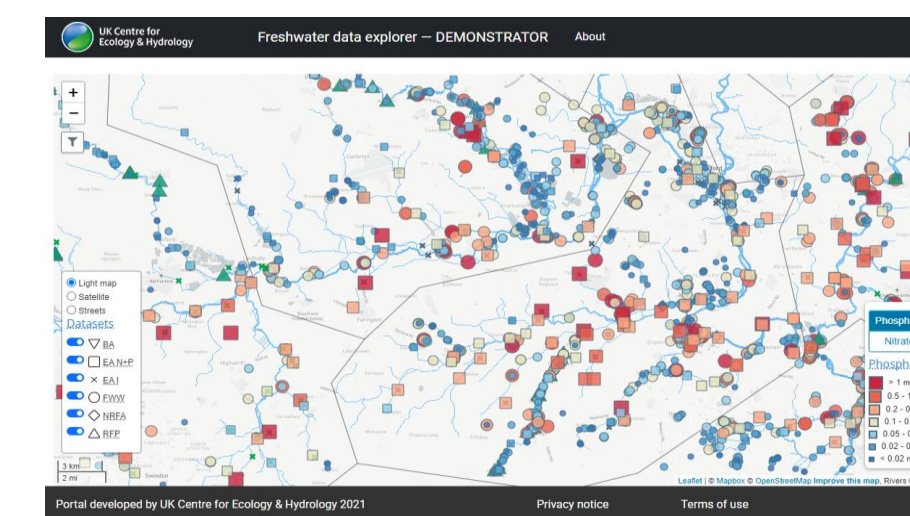
- Increasingly prevalent networks of real-time sensors
- Data science, including AI for modelling of heterogeneous data sources
- Data and data science within real time environmental models which incorporate our process understanding
- New computing infrastructures for sharing data, deploying code and integrating models
- Advances in data accessibility, visualisation and delivery to support decision-making processes

## Components of a Net-Zero Digital Twin

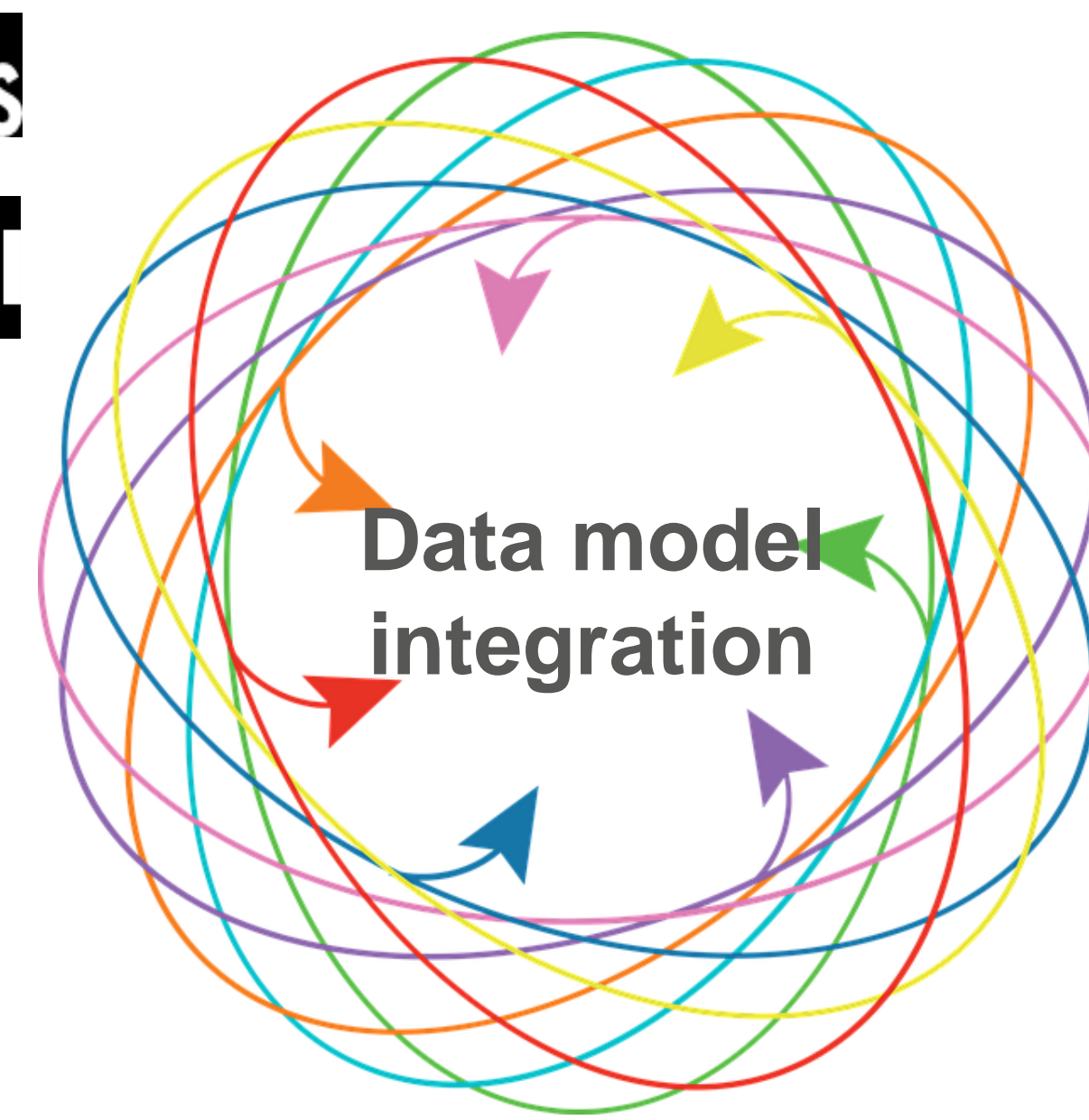
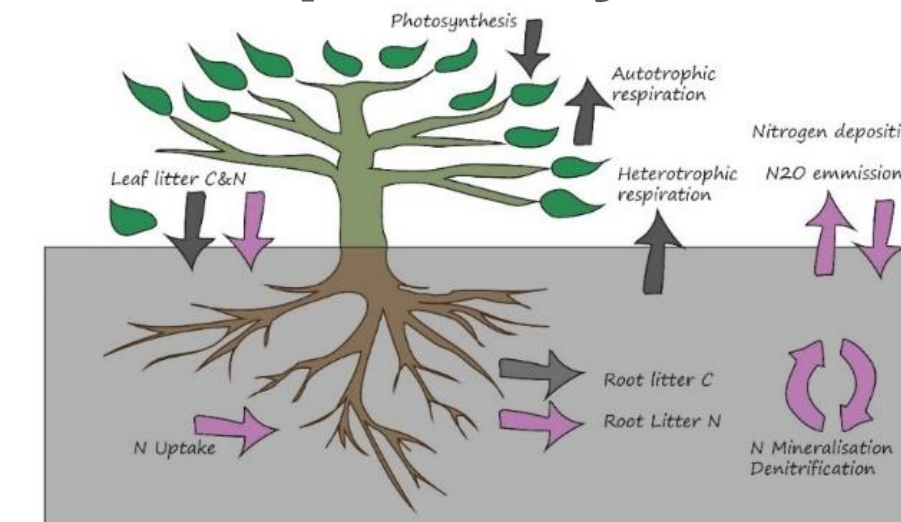
Infrastructure for digital twins



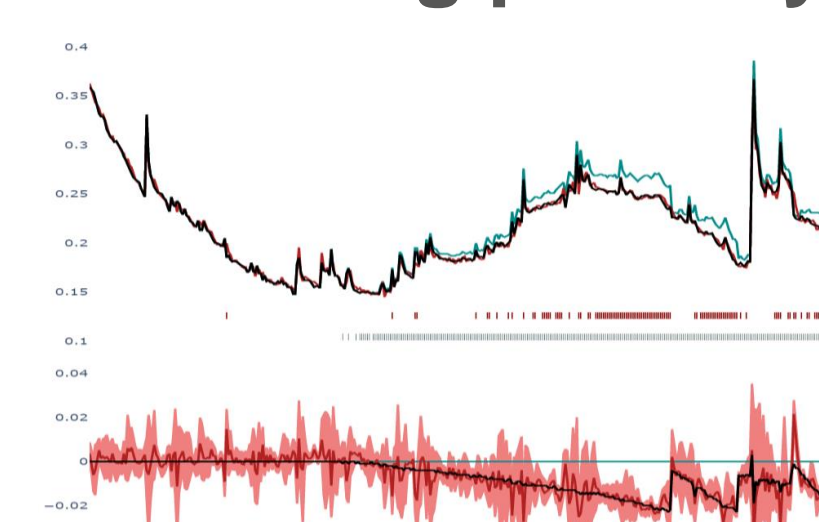
Integrated sensor networks



Process modelling pathways



Data-driven modelling pathways



User delivery



## Developing hybrid modelling approaches

Land InSight is bringing together data science and process-based modelling through a number of activities:

- Running the JULES land surface model at 1km over Great Britain in near-real time using downscaled ERA5T data on Jasmin
- Applying wavelet analysis techniques to understand how well JULES replicates the soil moisture dynamics at sites within the UKCEH COSMOS-UK network
- Developing models, using the UKCEH Greenhouse Gas Flux network, linking soil moisture to respiration to propose functional forms for respiration in land surface models
- Developing machine learning models to predict spatial patterns of soil moisture using meteorological drivers, COSMOS-UK data, maps of soil properties and topography, and satellite datasets

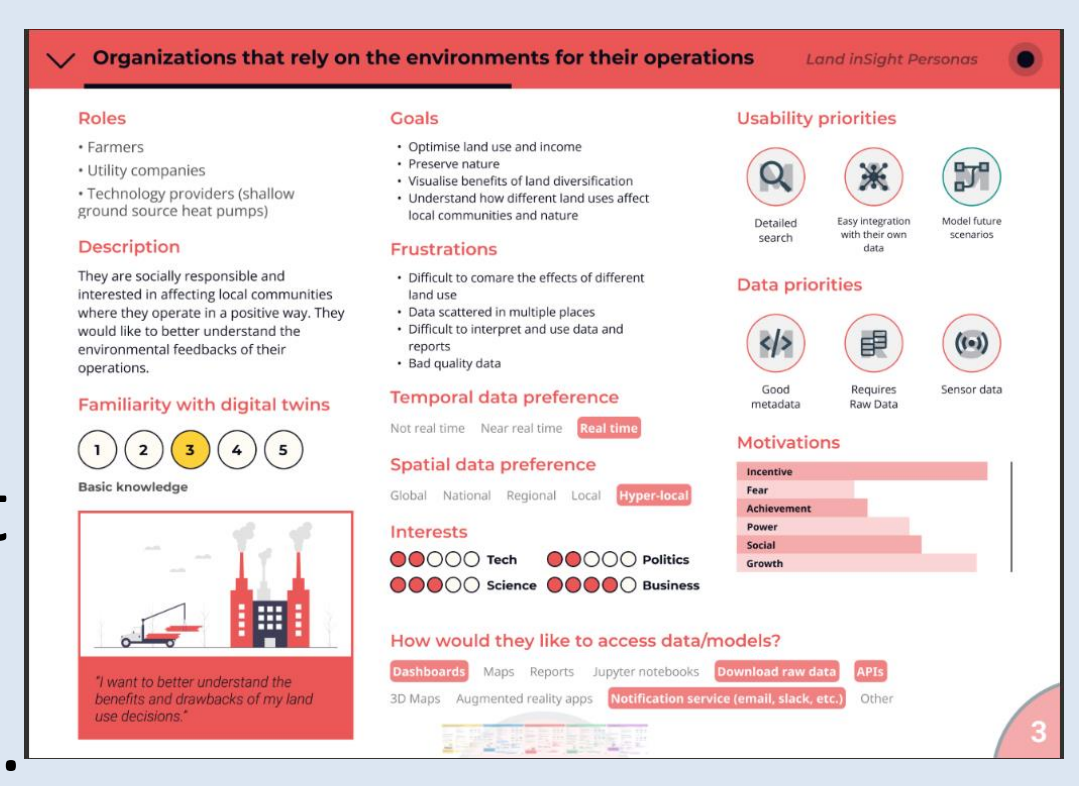
## Infrastructure for Digital Twins of the Environment

Land InSight tested the potential for digital twins to be delivered using aspects of existing research infrastructures:

- Process models running in automated workflows on the Jasmin Lotus cluster
- Use of Jasmin S3 object storage for sharing data with models and end users
- Data driven analyses running in NERC DataLabs
- Visualisation tools within NERC DataLabs (Jupyter notebooks, Shiny apps, python Panel apps)

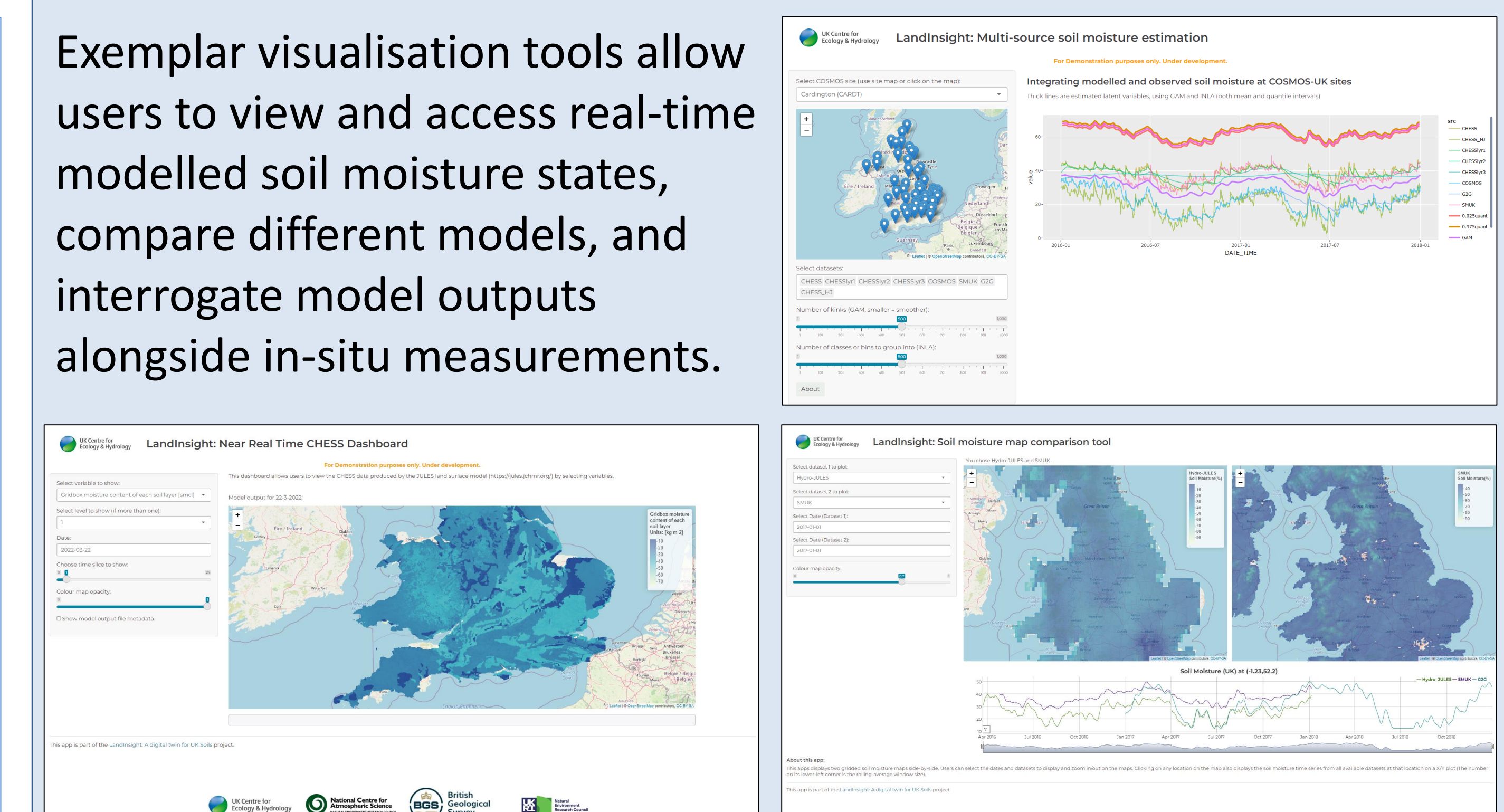
## Digital Twin user needs

User personas and stories have been developed to understand how a range of different stakeholders may want to interact with the digital twin. Detailed user engagement will be required as a next step.



## Visualising Digital Twin outputs

Exemplar visualisation tools allow users to view and access real-time modelled soil moisture states, compare different models, and interrogate model outputs alongside in-situ measurements.



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