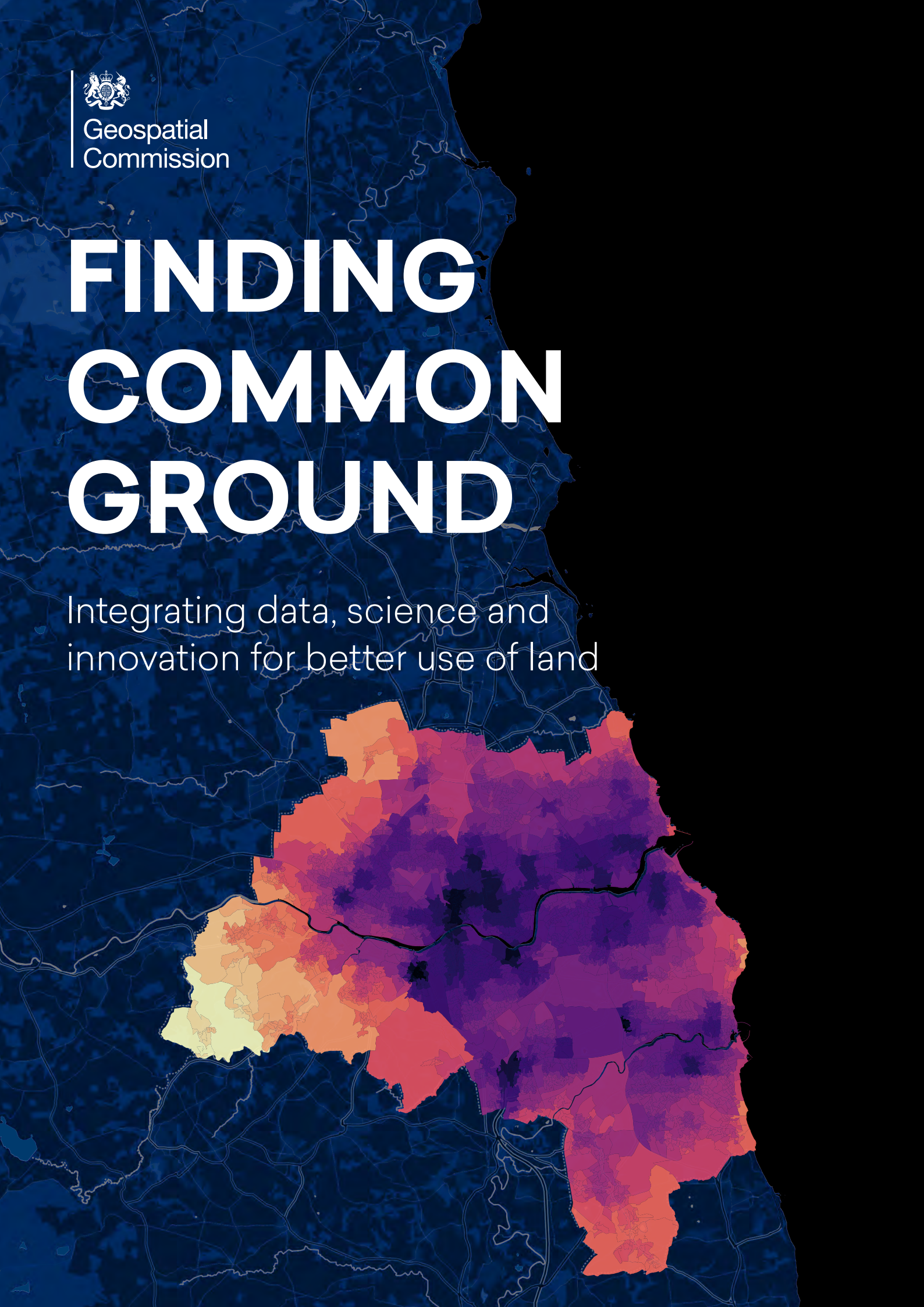
Geospatial Commission

FINDING COMMON GROUND

Integrating data, science and innovation for better use of land



CONTENTS

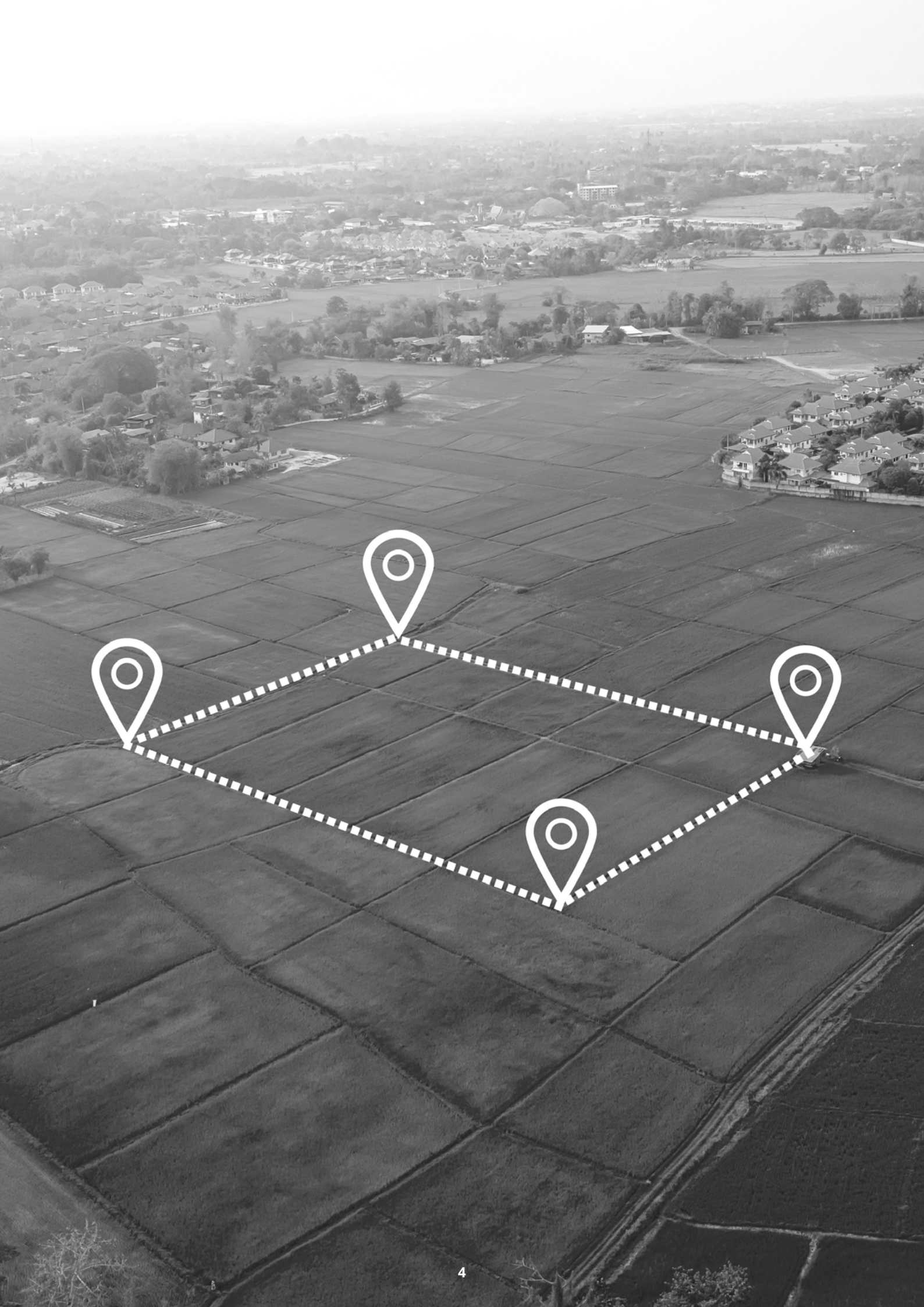
A note on devolution

A number of policy areas which are directly related to land use are devolved to Scotland, Wales and Northern Ireland, including: local government, housing, agriculture, environment, planning, transport, water and flood defence.

The Geospatial Commission has a UK-wide role, and the devolved administrations are represented at our Board of Commissioners. We have engaged with the devolved administrations in the development of this report and we have included insights and case studies from across the UK.

In this report when we refer to government policies we are usually referring to powers that reside with the UK Parliament, and some of the findings and recommendations relate to England only. We will continue to work with the devolved administrations to encourage UK-comparable data where appropriate.

Cover: Air pollution outcomes of modelled land use scenarios in Newcastle, developed by The Alan Turing Institute as part of the National Land Data Programme pilot.



MINISTERIAL FOREWORD

Land makes up 29% of the earth's surface and provides the basic requirements for terrestrial life. It produces the food we eat, supports the ecosystems we rely on for clean air and fresh water, provides the space for us to live and work, and is the primary source of the critical minerals and energy we need to power our economy and adapt to climate change.

Human innovation has radically altered our landscapes. From the emergence of farming 12,000 years ago, to the industrial revolution sparked by Britain's abundance of coal and iron, through to today's green energy revolution – our ability to harness the potential of land to generate ever greater economic and social benefits has been fundamental to the advancement of our civilisation. Current debates about the location of solar farms, high-speed rail and housing developments show that this is not just an economic question; land use is interwoven with our sense of place, identity and culture.

Today we face new pressures on our limited supply of land. As well as maintaining food and energy security, land use change will be required to build new housing and infrastructure, to achieve net zero emissions by 2050, and to protect 30% of the UK's land by 2030. The government has committed to publish a land use framework in 2023. This will support sound decisions to be made about how land is used, such as ensuring that housing is close to public transport and employment, that green energy infrastructure is placed in optimal locations, that rivers are kept clean and that nature is protected.

Advances in data science, technology and innovation can support land use decisions to be taken much more effectively, increasing output while protecting the environment and responding to what matters to local communities. For example, by bringing together large amounts of data we can model wide ranging scenarios and produce powerful visualisations that support meaningful local engagement and identify new opportunities for multifunctional land use.

The UK is world leading in geospatial data analysis and AI. But there are further opportunities to unlock the power of location data. This report considers the key demands on land, and the evidence gaps in different sectors including energy, housing, biodiversity, food, water and transport. It sets out key findings and recommendations that will enhance the UK's spatial data capabilities and support the forthcoming land use framework.

I want to thank the Geospatial Commission, their delivery partners and departmental colleagues for their contributions to the National Land Data Programme. By integrating data, science and innovation we can support better use of land and protect this vital resource for future generations.

Viscount Camrose
Minister for AI and Intellectual Property

EXECUTIVE SUMMARY

The UK's ambitions to deliver economic growth, fairly distribute opportunity across different geographic communities and meet the demands of a growing population, while protecting the environment, adapting to climate change and achieving net zero emissions will require significant land use change in the coming decades.

Complex decisions will need to be taken about how best to use and manage the UK's land, given that it is a finite resource which faces increasing demands. These decisions will require a holistic view of land that considers the spatial patterns and system wide impacts of land use change in order to manage trade-offs and avoid unintended consequences.

Data, science and innovation will be crucial to improving our understanding of how land can be better managed to balance demands and deliver our national priorities. Land use models – from digital maps that show land use change over time, to predictive and scenario-based models that incorporate algorithms to demonstrate alternative futures – bring together and visualise land use datasets. This can help us to spatially assess a range of economic, environmental and social factors to support decisions about the best use of land.

The UK has a wide array of high quality datasets about land, which have been vastly enhanced by advances in earth observation technologies including satellites and environmental sensors. But challenges exist around integrating the multitude of datasets, bridging analysis across different sectors and spatial scales, and making better links between technical expertise and decision makers who own land or influence how it is used.

Recognising land use pressure as a cross-cutting national challenge, the Geospatial Commission initiated the National Land Data Programme (NLDP) which has explored key land use challenges and demonstrated where innovative data analysis and evidence can support better land use decisions. This report sets out our key findings and makes recommendations for how the UK's data capabilities can be enhanced to support land use decision making at a range of spatial scales, with a necessarily more integrated understanding of urban and rural needs.

Section 1 of the report outlines the pressing challenge of making better use of land given the complexity of the land economy. The section argues that this is fundamentally a spatial challenge that requires better use of data, science and innovation.

Section 2 considers land use pressures in six sectors and highlights some of the current data and evidence gaps for land use decision making:

Energy: Increasing sustainable energy production in line with the energy ambitions set out in the government's Net Zero Strategy and Powering Up Britain plan will require land use change. However, based on current published analysis it is difficult to predict the scale, location and impact of this change.

Housing: The government's aspiration is to deliver 300,000 new homes a year in England. Spatial constraints on land for housing and competing land use priorities mean that there is high competition for viable development land. It can be challenging for developers and local authorities to understand where suitable land is located or where land is accessible for development.

Biodiversity: Halting biodiversity decline is the apex goal of the Environmental Improvement Plan. 30% of the UK's land will need to be protected, while increasing wildlife rich habitats, tree planting and peatland restoration to meet environmental and net zero goals. Understanding the biodiversity baseline and monitoring change will be crucial in delivering this.

Food: The government's commitment to broadly maintain current food production levels, while also releasing agricultural land for other uses, will require efficient use of our most productive agricultural land. Better use of data can help to identify the most productive agricultural land, opportunities for multifunctional benefits and less productive land which could be freed up to meet other needs.

Water: As the population grows and climate change leads to more frequent periods of extreme weather, including droughts and flooding, further strain is placed on the UK's ability to manage water, which can limit how we are able to use land. Enhancing water quality and quantity needs to be integrated into land use decisions.

Transport: Investment in new transport infrastructure accelerates regional growth, makes housing development viable and connects people to jobs and each other. Large scale projects can lead to land use change, not just for the infrastructure itself but through their impacts (positive and negative) on surrounding land. Planning for future transport networks needs to be carefully integrated into wider land use decisions.

Section 3 outlines our key findings and recommendations:

National policy decisions

National policies that affect land use change should consider the whole land use system, including the complex interactions between different land use sectors, spatial scales and opportunities for multifunctional land use.

The UK lacks a shared, spatially-explicit, evidence base that integrates data, technology and scientific knowledge to underpin land use decisions.

Recommendation 1: Establish a Land Use Analysis Taskforce. Bringing together, through appropriate new cross-departmental governance, a shared, spatial evidence base will help decision makers consider the range of opportunities and trade-offs, ensuring national priorities are delivered within the land available in the UK.

Local and market decisions

The UK has a wealth of data and innovative data companies are serving some land use sectors well.

However, there is a growing need for decision support tools which help landowners, land managers and local communities understand the opportunities for multifunctional land use.

Recommendation 2: Champion the market for decision support and visualisation tools to enable better land use decisions which create multifunctional benefits. Innovative tools could provide better information about land use choices, and enable local stakeholders to contribute meaningfully to land use frameworks.

Analysis and evidence

Connections between evidence and policy are crucial and can be strengthened.

A comprehensive land use model would help decision makers think holistically, assessing the connections between different land use sectors.

How we conceptualise and classify land use and land cover could mean missed opportunities for better land use.

Quantifying the economic and non-economic value of land use is complex, but there are a range of approaches to land valuation that can be applied to decision making.

Recommendation 3: Strengthen the links between land use policy design, academic research and industry practice. The creation of the Department for Science, Innovation and Technology is an opportunity to encourage and capitalise on vital interdisciplinary collaboration between academia, government policy and industry in the context of land use decision making.

Data improvement

The UK's geospatial data is world leading and there is a wealth of land use data. Some specific improvements to datasets would be valuable and there are already a range of data improvements underway.

There is no agreed taxonomy for land use that meets the needs of UK land use decision making, for example, that clearly defines what is 'urban' and what is 'rural' land.

Information about land ownership and control can be opaque, causing inefficiencies in the property development and planning system.

Recommendation 4: Develop a standard taxonomy for key land use data to support improvements to the interoperability of land use data and analysis. A common land use Data Product Specification, building on the prototype developed by NLDP, could help to encourage, coordinate and track improvements to key data.

SECTION 1
THE LAND ECONOMY

Land is a finite resource

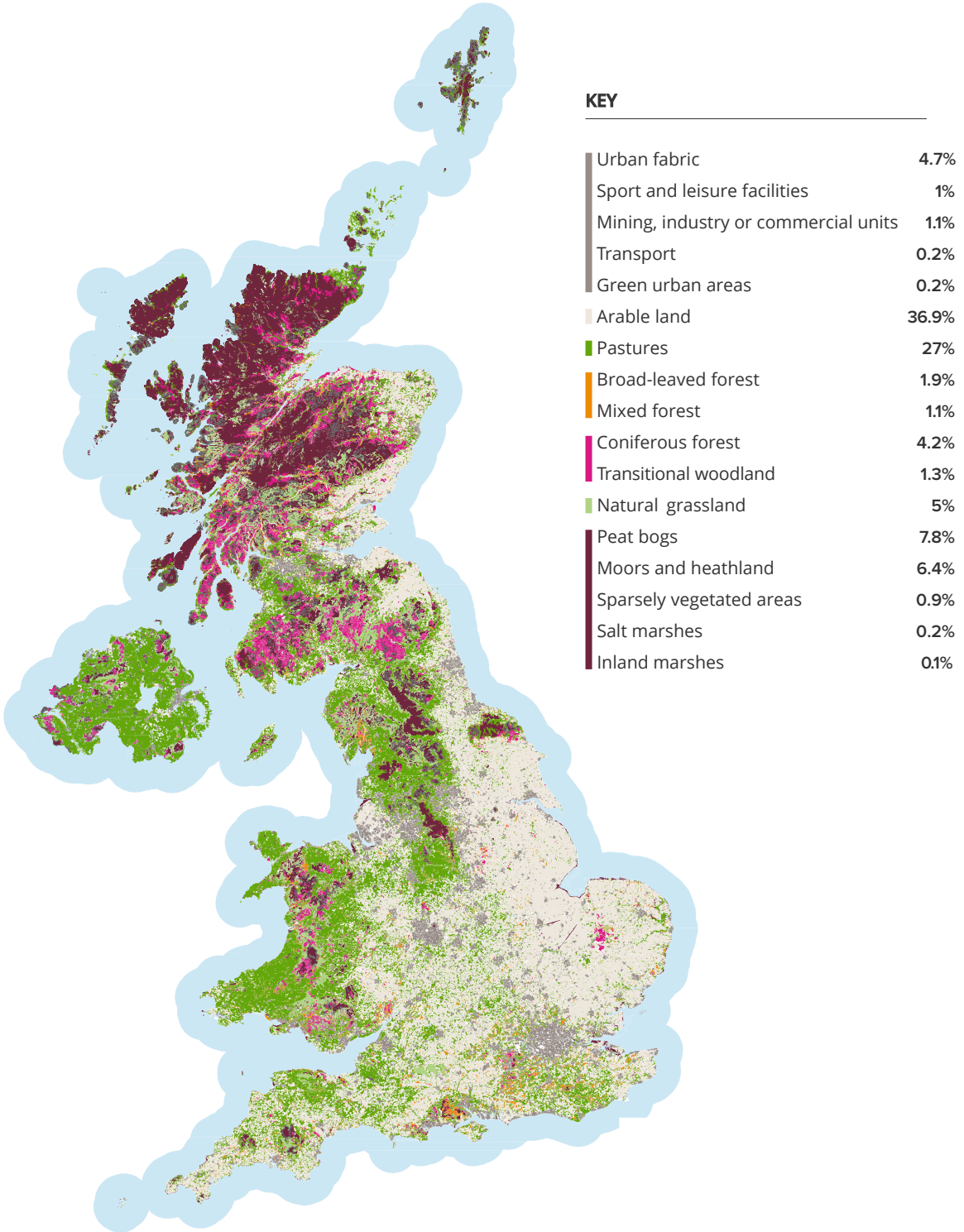
Land is a fundamental requirement for our very existence. It provides the food, clean air, fresh water and shelter for all forms of life; and the minerals and space required for humans to produce manufactured goods and technologies. How landscapes are altered by human activities – from the emergence of farming 12,000 years ago, to today's debates over solar farms, high-speed rail, or housing developments – often dominate the national conversation and are interwoven with our sense of place, identity and culture.

Land is also a finite resource that is facing increasing and competing demands for energy, food, housing, major infrastructure, climate change and improving our resilience in the face of global shocks. The government has set a range of commitments that all require significant land use change:

- **Energy:** Accelerate the transition from fossil fuels to renewables, such as increasing solar capacity from 14GW to 70GW by 2035.[1]
- **Housing:** Meet the government's aspiration of 300,000 homes per year in England.[2]
- **Biodiversity:** Protect 30% of the UK's land for nature by 2030. Restore or create more than 500,000ha of a range of wildlife-rich habitat in England by 2042.[3]
- **Forestry:** Increase tree canopy and woodland cover to 16.5% of England's total land area by 2050 (increase of around 250,000 ha, equivalent to an area the size of Cheshire).[4]
- **Food:** Broadly maintain current levels of domestic food production in England.[5]
- **Infrastructure:** Significant public investment in strategic road and rail, UK-wide gigabit broadband roll-out, EV chargepoints, water resilience and flood defence.
- **Net Zero:** Emissions in agriculture, forestry and other land use sectors could need to fall by 17-30% by 2030 and 24-30% by 2035, relative to 2019 levels.[6]
- **Water:** Restore 75% of our water bodies to good ecological status.[7]

Recent analysis by the Royal Society indicates the extent to which the UK's land is "overpromised". The Royal Society estimates that approximately 1.4 million hectares of additional land (equivalent to the area of Northern Ireland) would be needed by 2030 to meet current policy targets for net zero and biodiversity (if current agricultural production, diets and food waste remain static). This rises to 4.4 million hectares by 2050 (over twice the land area of Wales and 18% of total UK land area).[8]

To respond to these challenges, significant changes to how we use our land will be required now and in the coming decades. Difficult choices need to be made about trade-offs and there are tensions between what people want to see in their local communities and what is needed to meet national and global challenges. However, there are significant opportunities too: the idea of multifunctional land use – using the same piece of land for more than one purpose or having a range of land uses delivering multiple benefits at a landscape scale – offers a way to deliver greater economic benefit while also protecting and enhancing the social and environmental value of land.



Map of UK Land Cover, Royal Society (2023), Multifunctional Landscapes *(adapted from UK CORINE Land Cover 2021. UK Centre for Ecology and Hydrology)*.

Land use is a complex spatial challenge

Land use is influenced by a complex system of interconnected social, environmental, political and economic factors – and decisions made in one system have knock-on consequences in others. Land use decisions are made by lots of different people at different scales and geographies, all reacting to a broad range of influences, initiatives and incentives.

Land use decision makers

- **Consumers / citizens:** Influence how land is used based on market demand and through planning consultation processes. For example, developers may choose sites for new housing based on where local demand exists and the views of existing residents are taken into account in the planning process.
- **Land owners / managers:** Have a range of choices about how to use the land that they own or manage, but are influenced by incentives including government funding, planning permission processes, profit driven by consumer demand or other factors including environmental outcomes and maintaining natural landscapes.
- **Private companies:** Can invest in land for various uses, for example developers buying land options or land for housing; companies buying land for carbon offsetting.
- **Local planning authorities:** Carry out planning functions for a specific area to meet the needs of their communities and to help deliver national policy priorities at a local scale.
- **Public bodies:** Deliver National Policy Statements and Nationally Significant Infrastructure Projects such as HS2 which can require significant land use change.
- **National governments:** Set policies, regulations, incentives and guidance that can determine or influence how land is used.

Land use governance and frameworks

- **National Planning Policy Framework (NPPF):** Sets out the government's planning policies for England and provides a framework within which locally prepared plans for housing and other development can be produced, as well as setting guidelines for conserving and enhancing landscapes such as National Parks.
- **National Policy Statements:** Produced by the government, set out the government's objectives for the development of nationally significant infrastructure projects.
- **Local Development Plans:** Developed by local planning authorities, sets out the vision, growth strategy and strategic policies for a local area.
- **Local Nature Recovery Strategies (LNRS):** England-wide system of spatial strategies that will establish priorities and map proposals for specific actions to drive nature's recovery and provide wider environmental benefits.[9]
- **Environmental Land Management scheme:** Agricultural policy reforms designed for England's countryside and environment.[10]
- **Devolved administrations:** Have a range of policies and mechanisms in place such as the Strategic Planning Policy Statement for Northern Ireland and Planning Policy Wales. Scotland has a strong focus on land use, publishing their Third Land Use Strategy in 2021 and has established the Scottish Land Commission, which considers land use system challenges in order to drive land reform.

Moreover, land use change is an inherently spatial challenge. Every farm, factory, power station or forest has to be somewhere, and some uses of land do not sit well alongside one another, for example, planting the wrong trees in the wrong place or building homes where there is low demand or a high flood risk can lead to suboptimal or incompatible outcomes.

The Foresight Land Use Futures project highlighted the drivers of change (including economic growth, demographic change, climate change) and sectoral pressures (including water resources, conservation, agriculture) that could exacerbate land use tensions and challenges over the next 50 years.

Recognising these complexities, the UK government is increasingly taking a systems-thinking approach to developing land use policy. For example, the Department of Energy Security and Net Zero (DESNZ) and the Department for Environment, Food and Rural Affairs (Defra) have developed a Net Zero Systems Tool, which helps policy makers visualise the effects of changing one element in the system, see interdependencies and project the possible impacts of different policy choices.[11]

The government has committed to publish a Land Use Framework in 2023 to ensure food security is balanced alongside climate and environment outcomes. This will also reflect and respond to the work of the House of Lords Land Use in England Committee.[12]

As this report will show, it is critical that the new Land Use Framework is supported by a shared, spatially-explicit evidence base that integrates data and scientific knowledge, and encourages innovative decision support technologies.

CASE STUDY:

Modelling environmental land systems at Defra

Defra has developed a strategic land use modelling capability to identify the possible scale and distribution of land use change required to meet their policy objectives. This capability provides high level support to decision making around the feasibility and acceptability of different policy options in terms of their land use change implications.

The model integrates a set of modifiable assumptions on land take, related to the government's headline ambitions for land use change, with a range of geospatial data such as the suitability of land to support given activities, like tree planting and spatial constraints to action such as from protected sites. The modelling simulates the reallocation of current land use to meet government ambitions under different scenarios and considering different trade-offs in policy objectives.

The resultant reallocation of land can then be assessed in the context of wider government objectives, including around biodiversity, water quality, food production and energy production. This spatial analysis can determine the deliverability of different policy options and can lead to the further exploration of multifunctionality and the impact of different assumptions on land use.

CASE STUDY:

A digital future for planning

The Digital Task Force for Planning is a not-for-profit organisation which aims to empower planners to use and develop digital tools that help address challenges facing cities and regions, building on international best practice.

Digital planning has been identified as a priority in the Planning for The Future White Paper (2020) However, the Task Force's research identified that there is a significant digital skills gap in planning authorities and a lack of national consideration on how to achieve the digital capacity required to deliver government priorities.

Its report, A Digital Future for Planning: Spatial Planning Reimagined calls for a cyclical planning system informed by multidisciplinary evidence and empowered by data and digital technology.

Their recommendations include:

- Developing a 'common spatial data environment' based on national mapping and datasets to allow better simulation and modelling
- Setting up a National Network of 'Regional Data Observatories' – tasked with collecting and analysing demographic, economic, social and environmental data
- Introducing planners to digital tools and techniques which can be employed and integrated in spatial planning

Moving towards an integrated, digitally enabled approach to spatial planning can facilitate better access to data, improve evidence based land use decision making and enable faster planning processes. The Task Force's research has been recognised internationally.

Land value is closely associated with land use

Land can have significant market value where it enables economic activity through employment, production, the extraction of natural materials, delivery of housing, infrastructure or supply of other goods. It also has significant social and environmental value, which can be more difficult to quantify. The natural capital approach, the importance of which was highlighted in the Dasgupta Review, is the most widely recognised method of assessing the social and environmental value of land use change.

Understanding the total value of land (economic and non-economic) can be complex. Economic, social and environmental uses can overlap, complementing or conflicting with each other and can contribute to the value of land to varying degrees. Land value can also be affected by the likelihood of future potential use, as well as what happens to adjacent land and global markets.

Some aspects of land valuation are well understood such as housing and development, farmland for crops, livestock products or forests for timber. Others are less mature, including the value of biodiversity and the interactions of different land uses and how they can positively and negatively influence each other when in the same place.

This report does not cover land valuation in detail, but includes some evidence from stakeholders and experts who raised this as an important area requiring further research.

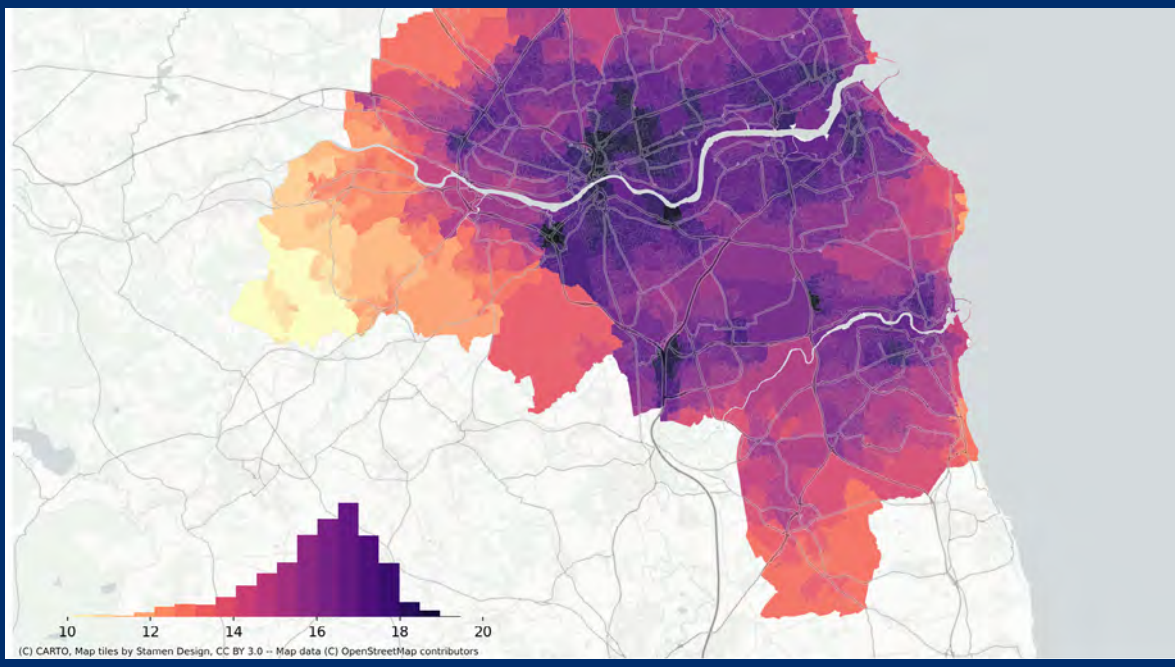
Data, science and innovation are essential

To get the best value from land we need to have good quality data and information that describes its current use and the ability to apply analysis to determine potential future uses and their impacts. Robust baselines are needed to understand how landscapes are used today; monitoring programmes are needed to track change; and scientifically sound models are needed to predict how policy decisions are likely to affect the spatial pattern of land use change in the future.

Recent advances in spatial data science and technologies, such as machine learning and AI, have dramatically improved data processing, analysis and visualisation capabilities. Once trained, these technologies have the potential to interpret large quantities of data to recognise patterns far more quickly than humans and sometimes more accurately. The value of this technology is well proven in areas, such as climate science and natural language processing, with ChatGPT being the most recent and high profile example. These technologies could play an increasingly significant role in enhancing our understanding of land cover and land use – whether that be through image interpretation or helping to develop, analyse and test potential future scenarios for land use change.

The advent of earth observation (EO) has transformed the amount of spatial data that can be collected with many areas of the world now able to be imaged multiple times a day with features, such as cars and road markings, distinguishable from space and in some cases in near real-time. More accurate and cheaper local and regional scale land cover and land use maps are able to be created. EO imagery enables new types of land cover or land use classifications to be produced, such as maps of solar farm locations, field boundaries or mature trees, providing more robust and detailed land use evidence. It is also enabling the monitoring of land use change over time, which will help track policy impacts, such as peatland restoration and reduce illicit activities like illegal logging. The Geospatial Commission is working with Airbus Defence and Space to deliver an earth observation pilot that will provide 35 public sector bodies with access to a range of satellite data products to trial over the next 12 months.

The UK is a data rich country with a diverse array of environmental, social and economic datasets. While there are some data gaps and specific quality and accessibility issues (see section 2), the greater challenge lies in integrating the multiple datasets, along with expert scientific knowledge and technological innovation, to generate decision-ready insight. There are pockets of cutting edge expertise in the UK, but our work has highlighted a disconnect between academic capabilities, market innovation, government policy making and local decision making.



CASE STUDY:

AI reveals hidden land use patterns in Newcastle

Newcastle City Council faces challenges in identifying sites for future development due to land use constraints, including the River Tyne and surrounding Green Belt area.

As part of NLDP, the Geospatial Commission funded The Alan Turing Institute to leverage their data science and AI capabilities and help Newcastle City Council identify sustainable development sites and understand the impact of different development scenarios on key outcomes for the city.

A model was developed which can suggest scenarios that would lead to desired outcomes. Planners are able to input target growth goals into the model, which then uses machine learning and AI to suggest a range of interventions that could achieve the required objectives. A visualisation tool was developed to allow Newcastle City Council planners to explore the trade-offs between these scenarios.

This modelling system will support Newcastle City Council's strategic spatial planning by evaluating the impact of high level development options against policy priority indicators including air pollution, access to jobs and green space and house prices.

Spotlight on: The Public Sector Geospatial Agreement and the Ordnance Survey National Geographic Database

Negotiated by the Geospatial Commission, the Public Sector Geospatial Agreement (PSGA) is a £1 billion investment over 10 years in national location data which gives over 5,500 public sector organisations access to Ordnance Survey data and services via their online Data Hub.

Land cover and land use datasets currently available in the PSGA include topography, greenspaces, built up areas, retail geographies and those made available within the National Geographic Database (NGD) which provides land use data for several themes including transport and buildings. The NGD unites authoritative data sources into a single store of data covering Great Britain, providing richer data that is more easily accessible, enabling accurate location data to be at the centre of land use decision making, products and services.

As part of the PSGA, enhancements will be made to the land cover and land use datasets which include new land use sites for a much wider range of site types (residential, commercial and amenity), cross references between sites and Unique Property Reference Numbers, land use information provided on individual area features, land use attribution mapped to the National Land Use Database (NLUD) classification scheme and improved data currency through three-monthly updates for high priority features.

Understanding the challenges

Recognising the complexities of land use decisions and the opportunities offered by advances in spatial data science, the Geospatial Commission initiated the NLDP to explore the challenges and how innovative data analysis can help address them.

Through regional pilots we explored how data analysis and modelling could support local land use decision making in:

- **Devon and Cambridgeshire:** We, alongside the British Geological Survey, supported the Food, Farming and Countryside Commission to develop local land use frameworks, and design prototype decision support tools that help articulate the impacts of different land use change scenarios to local stakeholders.
- **Newcastle:** We worked with The Alan Turing Institute and Newcastle City Council to develop a prototype scenario modelling tool, leveraging data science and AI to help inform land use decision making at a local authority scale.
- **Northern Ireland:** We partnered with Ordnance Survey Northern Ireland to develop a prototype land use and land cover map to bring together disparate land use and land cover datasets which are often hard to access.

Our Land Use Dialogues project brought together stakeholders across local and national government, academia and industry to explore the land use challenges associated with a range of policy priorities and the data and modelling tools that could help improve decisions. The dialogues focused on three themes:

- **Energy:** Where to locate new energy infrastructure and how best to balance the land required for energy security with other important land uses
- **Housing:** The impact of housing policy on land use and the challenges around identifying land for housing
- **Water:** How government decision-making on water infrastructure could be better supported by better use of spatial data and modelling tools

We partnered with Ordnance Survey GB to design a logical data model and data product specification which can improve the interoperability of UK land datasets at a variety of spatial scales.

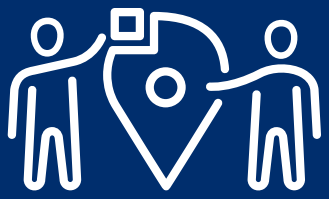
The findings which have surfaced through NLDP are outlined in this report. Please see the National Land Data Programme: Pilots and projects overview for further information about NLDP.

NATIONAL LAND DATA PROGRAMME IN NUMBERS

89 PUBLIC SECTOR ORGANISATIONS ENGAGED

28 PRIVATE SECTOR ORGANISATIONS ENGAGED

23 ACADEMIC INSTITUTIONS ENGAGED



306 STAKEHOLDERS ENGAGED

11 EVENTS HELD

55 DATASETS CONSIDERED

DIFFERENT LAND USE DECISION MAKERS REQUIRE DIFFERENT TYPES OF ANALYSIS

Land owner / farmer

I am a landowner in Devon, with several hundred acres of land. I want to make the right decisions as a steward of the land, but there are a lot of land use constraints, such as planning restrictions and sites of special interest, and it is hard to understand the most viable opportunities.

I would like a tool that provides multi-sector data and insights, usable for field scale analysis and which also has data at different spatial resolutions to reflect farm, catchment, county and national scales. Granular, high resolution data will help me to identify priorities for land use change and if my actions can be combined with neighbours to achieve greater impact (both financial and ecological).

Planning Officer

I am a Planning Officer working for a local authority to develop its Local Development Plan. Our priorities include promoting economic prosperity, working towards net zero emissions, improving environmental outcomes and delivering accessible housing. However, it is difficult to balance these demands with the land constraints we face. Analysing the data on these different demands is challenging as it is often siloed and site specific.

A land use scenario modelling tool would help me to take a city-wide, systems wide view of land use, explore trade-offs and simulate the impacts of proposed land use change more efficiently. This tool should be easy to use given time and resource constraints and ideally the data would be openly accessible so that outputs can be shared and communicated easily.

Flood Risk Officer

I am a Flood Risk Officer at the Environment Agency. I want to model flood risk and monitor the 'real-time' progress of a flood. However, I am using data from different sources which is held in various places and which uses different scales and resolutions.

A register of relevant data, models and information in a single entry portal would save me time collating data sets from different sources. A standard data model would help ensure datasets are being developed in a format which would enable their interoperability. A tool that visualises flood risk data in an easy to understand way would also be helpful to communicate flood risk to a range of stakeholders.

Land manager

I am a land manager on a large rural estate who wants to make informed decisions to determine the best use of the land. However, many companies offer spatial data / analysis tools and it is difficult to know what is best to use, especially when time to research is short.

A portal that brings together information on the different tools available, what they can be used for and case studies of where they have been used before would help me understand how I can use existing products to better inform my decision making, without having to do excessive, time-consuming research. A tool or portal that distils the funding opportunities associated with different types of land use change available through Environmental Land Management schemes and other central government backed funding schemes, would be useful as part of this.

Government estate manager

I work for a central government department which has a large land estate. I want to assess the estate to ensure that our assets and land holdings are being used sustainably, ensuring that we adhere to the Government Property Sustainability Strategy, which is focussed on creating a smaller, better and greener public estate. However, I do not have sufficient spatial data on the entire estate, particularly in relation to its natural capital value.

I would benefit from a tool that provides accurate spatial data on the footprint, land cover and land use of the estate. Data and metrics on the ecosystem services across the estate would help me assess the land's natural capital, which will help inform our sustainability strategy.

Housing developer

I am the CEO of a housing developer. I want to find the most efficient and accurate way to make land use decisions, identify local sites, monitor plans, make contact with landowners, run high-level appraisals and source sites faster so that we can hit and exceed our housing development targets. However, this requires accessing and analysing a range of geospatial datasets maintained by the public sector including land ownership, land use constraints data, such as flood risk zones and protected sites, as well as local authority data, such as brownfield land registers and strategic housing land availability assessments.

I would benefit from a platform, which can pull together all the required land cover and land use datasets. This would allow my team to source sites faster and be more competitive, as we have been able to pick up sites that others might not have spotted.

SECTION 2 DEMAND ON LANDS

Increasing demands are being placed on land from the growing population, climate change and global economic pressures. This section considers the key land use pressures in different sectors and highlights some of the current data and evidence gaps for land use decision making. We have identified six sectors where land use demands are evident: energy, housing, biodiversity, food, water and transport.

Each of these sectors face their own specific challenges. Land use within each of these sectors are influenced by human decision-making and biophysical processes. These sectors also do not operate independently on one another. For example, the location of new housing developments may require new transport and energy infrastructure, whose construction will need to consider the impact on local biodiversity and not adversely impact on water quality.

This section is not exhaustive and many other sectors face land use pressures. For example, we note the importance of land used for employment, which is a significant demand area to the economy. Employment land has a strong interrelationship with different land use sectors and trade-offs will need to be considered as more land is devoted to housing and society demands stronger protections for land for environmental, leisure and utility reasons.

ENERGY

Sharp rises in energy prices driven by geopolitical shocks, including the invasion of Ukraine, have exacerbated the need for secure, affordable and sustainable energy production. Government plans, set out in the Powering Up Britain report, will help achieve this by reducing dependence on imported oil and gas and decarbonising the electricity system by 2035. This will require an increase in domestic energy production, including through renewable energy deployment.

Pressures on land

Demands: There is no official published analysis of the land take required to meet energy requirements, however there is a growing demand for increasing sustainable forms of domestic energy production, for example through ground mounted solar, wind or growing bioenergy crops. The Climate Change Committee's Land use: Policies for a Net Zero UK suggested pathway to net zero emissions assumes 23,000 hectares of bioenergy crops are planted per year from the mid-2020s.

Spatial constraints: Whether land is suitable for siting energy infrastructure depends on different constraints from natural features, such as geology, gradient, wind speed, sun exposure and flood risk, to economic and commercial considerations, such as proximity to existing grid connections and price of land.

Trade-offs: Key trade-offs include whether land should be used for 'food or fuel' and considerations of environmental impacts (biodiversity, noise, water quality, greenhouse gas emissions) and social impacts (visual amenity, public consent) need to be taken into account when locating energy infrastructure. Protected sites from areas of outstanding natural beauty (AONB) to sites of special scientific interest (SSSIs) can often limit specific forms of energy production.

The government is also seeking large-scale solar deployment across the UK, looking for development mainly on brownfield, industrial and low/medium grade agricultural land.[13]

Multifunctional opportunities: Land around and underneath ground mounted solar, onshore wind turbines and overhead power lines can have biodiversity benefits. The government is seeking widespread deployment of rooftop solar in commercial, industrial and domestic properties across the UK which can sustainably power homes without taking up additional land.[14] The concept of 'agrivoltaics' outlines various ways in which land can address the dual needs of energy and food production.[15]

Technological advances

Advances in science, innovation and technology over the last decade have reduced the cost of renewable energy sources and will continue to play an important role in helping meet our energy targets. In the long term, this could reduce the demands on land from new energy infrastructure. For example, the retrofitting of homes with the latest installation technologies could improve the energy efficiency of buildings, reducing energy demand, meaning less new energy infrastructure is required.

Advances in data science can help decision makers make sense of a wealth of data to support more granular decisions on where new energy infrastructure should be located, taking into account opportunities and constraints of potential sites. Academics and experts from the scientific community have developed a range of land use models that help answer questions on the least contested locations and potential impacts of land use change for energy infrastructure development. These spatial models could help guide national-level decision making around locating energy infrastructure.

CASE STUDY:

Modelling optimal locations for renewable energy

The ADVENT-NEV model is a spatially-explicit optimisation model that suggests where to locate ground mounted solar farms, onshore wind farms, bioenergy power stations and bioenergy crops while minimising the total cost of the energy system. The model applies a natural capital approach to take into account both market costs, including the cost of construction, operations, maintenance and transport and non-market costs of land use change, including visual amenity, carbon sequestration and flooding and water quality impacts.

This spatial optimisation model can help support decision making by identifying opportunities and trade-offs for renewable energy development. For example, it has been applied to assess the impacts of implementing exclusion zones from energy development, such as national parks and high grade agricultural land.

Whilst exclusion zones have perceived biodiversity benefits, this analysis showed their implementation could increase the cost and spatial footprint of solar, wind and bioenergy, make bioenergy targets infeasible due to lack of suitable land and may increase the social costs of energy development.[16] Applying this modelling to different policy scenarios can therefore support planners and policy makers to make informed and joined up decisions around effective land use options for renewable energy development.

CASE STUDY:

A systems approach to local level energy planning

Local Area Energy Planning (LAEP), pioneered by Energy Systems Catapult, is a data driven, whole systems approach, which identifies the best route for local areas to achieve national and local net zero targets. This approach involves the development of a spatial plan that identifies the change needed to the local energy system and built environment over incremental time periods to meet interim and final net zero targets up to 2050.

Local area energy plans are developed using spatial analysis, standardised assumptions and datasets and modelling multiple future scenarios and pathways that consider the ways in which our energy might be supplied, managed and consumed in the future. The outputs of a LAEP include a preferred pathway for net zero, identification of near term and low regret projects, as well as longer term interventions and opportunities for energy innovation.

LAEPs can support local authorities, businesses and individual households in making decisions to cost-effectively cut carbon emissions, through a range of options, including decarbonising heating, increasing local energy generation and storage, and developing electric vehicle charging.

Energy evidence gaps

The government's Net Zero Strategy and Powering Up Britain plan showed a range of possible 2050 energy pathways but based on current published analysis, there is no consensus for how the UK's landmass would need to change to deliver these pathways alongside a myriad of other land-based policy goals.

We have found that there is a lack of understanding about how much land suitable for energy infrastructure is likely to be contested by land owners or through the planning system. For example, knowing how many nuclear power stations will be built could help us calculate the remaining land that will be needed for renewable energy generation, however it is hard to estimate this due to the commercial and societal influences on nuclear power station planning and approvals processes.

It is also unclear how much land can and needs to be used in multifunctional ways to help deliver government targets. For example, identifying where land can be used for both ground mounted solar farms and livestock grazing could help meet energy and food security priorities.

Spotlight on: Getting to the Point – Accelerating EV chargepoint rollout through geospatial data

The UK government has set a vision for EV charging infrastructure that 'works for everyone, wherever they live, work and travel'. In 2022, the Geospatial Commission published a report identifying the role of location data to site chargepoints in the right places by understanding demand, the available land and any spatial constraints.

Location data can expedite site selection by improving our understanding of energy capacity and identifying site constraints, hazards and opportunities on the kerbside. Site selection typically includes detailed assessments and surveys about prospective locations for chargepoints. Planners engage with local stakeholders and identify any legal considerations, including who owns the land and whether planning permission is required.

Where sites are identified, submissions are made to the relevant distribution network operator to check if there is sufficient network capacity and to provide cost estimates for connection to the network. Planners also carry out assessments of other constraints, including the surrounding sub-surface and surface level assets (for example underground pipes and cables, lamp posts and trees).

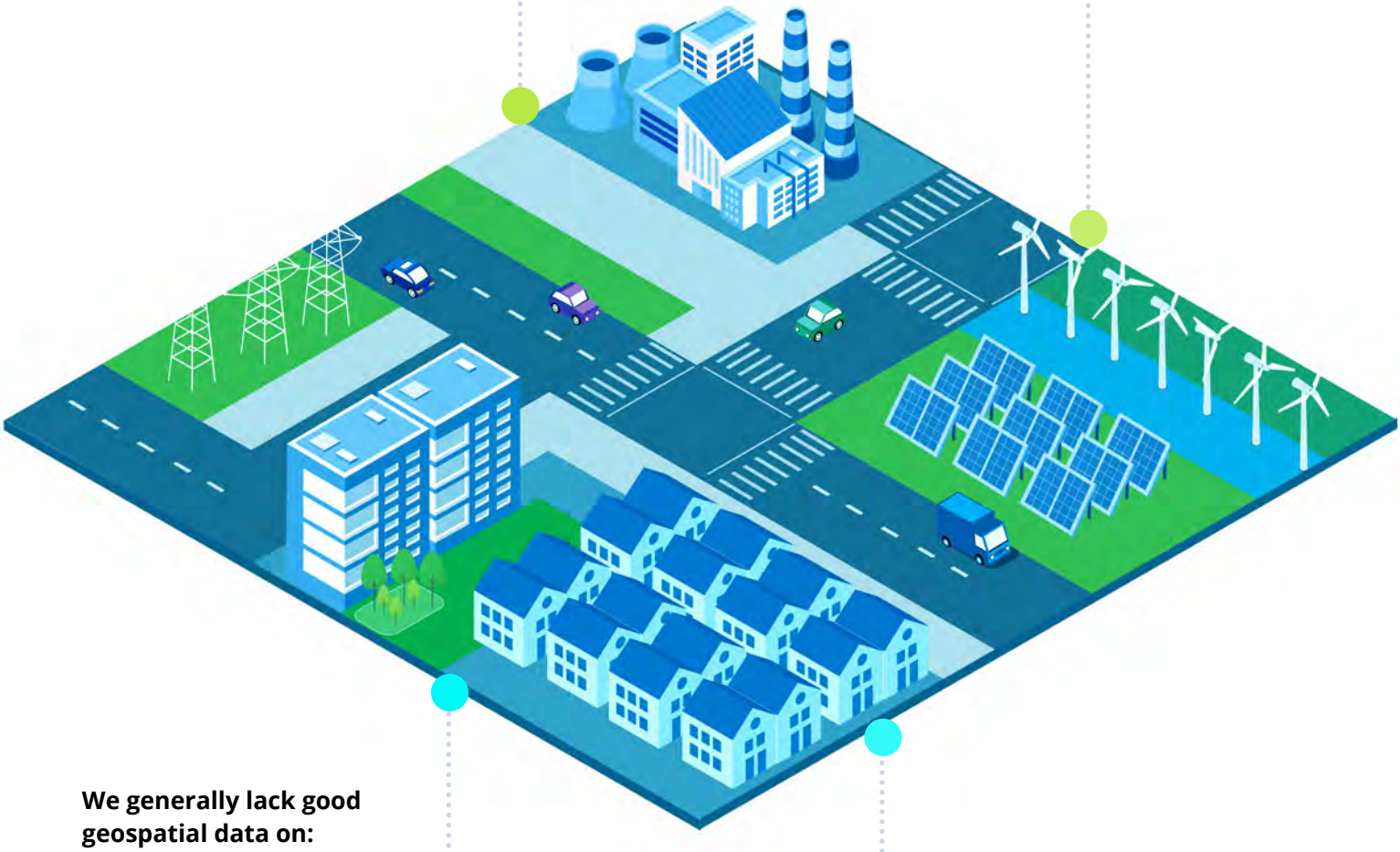
Good data is generally available on:

Energy assets:

At a national level the government has an understanding of where existing and retired energy assets are and where planned changes to assets are due to take place. The UK Energy Research Centre (UKERC) publishes a wide range of national and third party energy asset datasets via the Energy Data Centre.

Energy consumption:

The DESNZ publishes annual statistics on energy consumption in the UK, including energy intensity by sector and how consumption trends have changed.



We generally lack good geospatial data on:

Capacity of power assets:

The location and capacity of power assets at distribution network operator (DNO) level have varying degrees of accessibility, in part due to the commercially sensitive nature. This could be a barrier to understanding the distribution network needed for new energy sources. However, there are some emerging examples of best practice being led by some operators such as UK Power Networks (UKPN).

Social and human factors:

Data on factors such as public attitudes to visual impact and scenic beauty is rarely collected and not well understood. These factors are important to understand as they can significantly impact the planning process for new energy assets, particularly onshore wind.

HOUSING

Where you live has an impact on your wellbeing, health outcomes and can form a strong part of your identity.[17] Ensuring that there are enough safe, high quality, affordable homes to meet the needs of the UK's growing population is a key government priority. The government has also strengthened its commitment to build enough of the right homes in the right places with the right infrastructure.

Pressures on land

Demands: Around 8.7% of land in England is classed as 'developed', of which 1.3% is 'residential'.[18] Compared to the land use change required in other sectors, the amount of land required to deliver the government's aspiration of 300,000 new homes a year is a small proportion. However, due to different geographical constraints and competing land use priorities, the places that are suitable for new homes are very specific and there is high competition for viable development land.

Spatial constraints: Most housing needs to be located near to existing settlements, infrastructure and employment. Many towns and cities are constrained by a shortage of available viable land for development. Planning policy strongly encourages the use of brownfield land, but strategic brownfield sites suitable for larger developments are limited, the costs of decontamination can be high and smaller brownfield sites are less desirable to developers. New housing needs to be located near to existing infrastructure connections or developers can face prohibitively high costs to connect. Challenges securing local consent, preservation policies and restrictions around building height can constrain development in certain areas.

Trade-offs: When identifying suitable sites for housing and considering the design for new developments, developers need to consider how to mitigate any negative environmental impacts, such as biodiversity loss and increased air pollution. New

developments also have to consider their impact on water quality – some sites will have to adhere to nutrient neutrality and from November 2023, developments in the Town and Country Planning Act 1990 will have to adhere to biodiversity net gain requirements. There are also needs for land for industry and employment in growth industries, which may compete with housing requirements.

Multifunctional opportunities: Energy efficient homes, homes connected to geothermal and district heat networks and rooftop solar installations on homes can all help contribute to net zero and decarbonisation targets. 'Green features' in housing developments, such as biodiverse roofs and sustainable urban drainage systems, can help protect the environment and increase biodiversity. Urban densification can increase economic growth, for example through increased footfall to local shops.

Technological advances

The proptech sector has emerged to help individuals, public sector and businesses to identify, appraise and acquire sites for residential and commercial development, among its other functions including for property management and residential engagement. Many of these companies have built products using cloud and AI technologies, which bring together disparate data sets about land including ownership, land value, site characteristics and constraints, allowing an easier evaluation and comparison of sites. Some of these companies have invested in 3D modelling capabilities, allowing users to visualise in an advanced way how developments could look and what their impacts may be.

Proptech platforms can enable large amounts of spatial data to be brought together and considered as part of land use planning, leading to more informed, join up decisions. Some also allow users to work on the same project at the same time using interactive mapping to improve productivity, collaboration and join up, reducing siloed working. However, these products typically serve private sector developers rather than local authority planners due to their cost which can be prohibitive.

Commonly, local authorities will rely on in-house geographic information system (GIS) capabilities to help bring together the commercial, in-house and planning spatial data they hold to help identify sites for housing development as well as other development needs. Many use their own GIS web platforms and some work with external companies to explore options using their modelling capabilities and platforms. Local authorities' GIS usage can vary significantly depending on resources and in-house GIS expertise.

CASE STUDY:

Creating a land ‘market place’

Finding sites for development can be a time-consuming and repetitive task due to the large amount of data collation required to assess viability and risk.

Addland is a proptech company that has created a platform that brings together the latest in mapping technology alongside key datasets to make finding, researching, buying and selling land across England and Wales easier. Customers range from individuals looking to buy land to local and national developers and land agents undertaking due diligence and site appraisals. Addland’s members can access multiple map styles to identify on and off-market land in a given area and view the critical data associated with these sites, including point-to-point boundary calculations for centimetre-level accuracy on key considerations.

There are over 40 boundary, environmental, agricultural and infrastructure data layers which use datasets from Ordnance Survey, HM Land Registry and the Environment Agency, including land classification, planning history, ownership, valuation and planning constraints. Combining information and insights into a single platform allows members to easily identify opportunities and potential risks, enabling more efficient and informed land decisions.

CASE STUDY:

Gamifying local planning

Bolsover District Council and proptech firm The Future Fox, supported by Department for Levelling Up, Housing and Communities' (DLUHC) PropTech Innovation Fund, have developed an interactive, web-based 'PlaceBuilder' masterplanning tool that gamifies plan-making consultation to drive collaboration and engagement.

The masterplanning tool provides citizens with the same choices about potential land uses that planning officers and developers have when planning new development sites and allows users to create and submit their own planning proposals by putting land use tiles on a potential development site. Users are able to see the cost-impacts of their decisions in real time and can consider how they can balance their budget between income generating land uses, such as new housing and expenditure on local infrastructure.

The PlaceBuilder masterplanning tool was created for use as part of the Council's trial of a mobile first, young person oriented consultation on the Shirebrook Growth Plan, alongside the Council's traditional consultation methods. The exercise aimed to encouraging engagement particularly from young people who are most affected by future growth plans but in the authority's experience, are the least likely to turn up to traditional in-person events or respond to consultations.

Increasing public engagement in land use choices and the specific focus within the created 'PlaceBuilder' masterplanning tool on the financial trade-offs in planning decisions can help to ensure that local communities feel more involved in what is planned in their local area and better understand the development proposals put forward by councils and developers that will affect them.

Housing evidence gaps

Identifying where brownfield sites are located can be challenging. Whilst local planning authorities maintain brownfield land registers, the accuracy of these can vary significantly. Where brownfield sites have been identified, further analysis is often needed to assess issues such as land ownership, whether these sites are likely to be suitable and viable for housing development or whether they need remediation.

The cost to remediate brownfield land is often a major constraint in terms of its re-use for housing which can make the land unviable from a development perspective. There is limited information on contamination levels which make it hard for local planning authorities to consider opportunities for alternative land uses, such as creating brownfield habitats or siting renewable energy infrastructure.

Release of greenfield land may be required to meet housing ambitions, however there is often a lack of information about the quality of sites from an environmental perspective. Understanding this could help identify the best sites (where there is least environmental impact) for housing development.

There is currently no easy way of establishing how much land is tied into land option agreements and the duration of these agreements, although they can be noted against registered land at HM Land Registry. DLUHC are currently considering ways to collect more data about arrangements which allow someone other than the landowner to control use and development of land, with high level provisions currently included in the Levelling Up and Regeneration Bill to help make this information more accessible. This could help provide a better understanding of the housing land supply pipeline.

Spotlight on: Geospatial opportunities in the property sector

There has been an increasing move towards digitalisation and the adoption of new technologies in the property sector, which can be supported and enabled by effective use of spatial data.

The Geospatial Commission, alongside our partner bodies, has been working closely with industry, academia and the public sector over the last year to identify key opportunity areas across the ecosystem from location data related to domestic and non domestic properties.

The Geospatial Commission plans to publish a report in summer 2023 which will consider how improved geospatial data, services and technologies can drive better decisions and drive innovation throughout the property lifecycle, from planning, construction, conveyancing and building maintenance to demolition and regeneration.

Good data is generally available on:

Land use change statistics:

Based on Ordnance Survey data, DLUHC produces openly accessible annual land use change statistics. Information provided also includes the amount of land changing use from previous use to its new use.

Planning permission and construction rates:

DLUHC publishes planning application statistics at national and local planning authority level. Additionally, commercial providers such as Glenigan provide a more detailed paid-for database which records all planning applications and decisions made by local authorities from 1995 onwards.

Ownership of registered land:

HM Land Registry keeps the Land Register which is the definitive and guaranteed record of property ownership, containing more than 26 million titles and covering 88% of the land area of England and Wales.

We generally lack good geospatial data on:

Brownfield sites:

Local planning authorities in England are required to publish brownfield land registers, however these are often not kept up-to-date and there are inconsistencies in the quality of brownfield site data between different local authorities. The volume of housing that brownfield sites could potentially provide is also often unavailable.

Development and Infrastructure pipeline:

There is a lack of data on what land or infrastructure has already been assigned for development.

BIODIVERSITY

We are dependent on the environment and nature for clean air, our water, our food and to help mitigate the effects of climate change. However over the last century, we have seen nature decline significantly, due to pressures on land that have increasingly degraded and fragmented habitats and reduced biodiversity.

The government has set legally binding targets as part of its Environmental Improvement Plan to address this and halt the decline of species by 2030. As well as restoring nature, these targets can help us meet the UK's target to deliver net zero emissions by 2050, through supporting the implementation of nature based solutions, including tree planting and peatland restoration, which can remove carbon dioxide from the atmosphere.

The delivery of the government's environmental targets will be supported through Defra's Environmental Land Management schemes including the Sustainable Farming Initiative, Country Stewardship and Landscape Recovery schemes[19]; local nature recovery strategies (LRNS) and biodiversity net gain requirements for developments in the Town and Country Planning Act 1990, which will be applied from November 2023.[20]

Pressures on land

Demands: The government has set a range of targets for measures to restore nature and protect our environment. These include, but are not limited to, planting 30,000 hectares of trees per year by 2024/5, increasing tree canopy and woodland cover from 14.5% to 16.5% of total land area in England by 2050, restoring or creating more than 500,000 hectares of wildlife-rich habitat by 2042.[21]

Spatial constraints: When implemented in the wrong places these measures can cause significant negative impacts. For example, trees planted in the wrong places can ultimately release more carbon than they sequester by drying up peat bogs.

Trade-offs: Choices may need to be made between protecting sites or releasing them for other land uses, such as development, including greenfield land, or where nutrient neutrality restrictions are in place.

Multifunctional opportunities: Green infrastructure and nature-based solutions can provide environmental, social and economic benefits. For example, planting more trees can create new habitats, improve biodiversity, improve access to nature and reduce flood risk. Agroecological farming can also enable sustainable food production that can reduce negative environmental impacts such as deteriorating soil health.

Technological advances

Spatial data can help land managers better understand the natural footprint of their land and therefore make more informed choices about how to optimise their land to maximise environmental, economic and societal benefits. Spatial data and tools underpin the government's guidance on enabling a natural capital approach to policy and decision making.

Technology that uses spatial data can help land managers assess options to better understand what to do with their land. For example, the Ecological Site Classification (ESC) tool is a web based decision support system developed by Forestry Research, to help forest managers and planners select tree species that are ecologically suited to particular sites, instead of selecting a species and trying to modify the site to suit. It incorporates future climate change projections for the 2050 and 2080 low and high scenarios to allow users to incorporate future suitability into planting decisions.

Modelling can also help policy makers understand the different land use pressures related to the environment and nature based solutions, to assess trade-offs needed to deliver priority policy outcomes. Defra has invested in a spatial modelling capability that sits within their Environment, Science and Analysis Unit, to help understand different land use pressures and trade-offs associated with delivering the government's energy targets and the 25 Year Environment Plan. Additionally, the modelling has supported the development of the England Land Use Framework which is due to be published in 2023.

Other innovative technologies could help with the transition to net zero emissions, including engineered solutions that remove carbon from the atmosphere, such as Direct Air Carbon Capture and Storage (DACCS), which does not require the use of land directly, however it requires a lot of energy which would require land for energy production.

CASE STUDY:

Assessing the natural capital of land

Defra has received research and development funding of £140 million over three years towards delivering the Natural Capital and Ecosystem Assessment (NCEA) programme. This will provide high quality data to assess the state and condition of natural capital assets, ecosystems, and biodiversity in terrestrial and freshwater environments.

NCEA will map the extent, condition and change over time of England's ecosystems and natural capital assets. The new data, gathered via a number of monitoring networks, will address critical evidence gaps and in-turn improve decision-making.

For example, one NCEA project is to bring together existing, but disjointed data alongside new data (field surveys, earth observations and peat cameras) to produce an England Peat Map, which can be used by policy teams working on carbon accounting and restoration priorities.

NCEA supports the design and evaluation of new policies and interventions including Environmental Land Management schemes, the 25 Year Environment Plan, and Biodiversity Net Gain.

CASE STUDY:

Carbon monitoring for nature based solutions

Traditional soil carbon measurements provide a snapshot of soil carbon levels every five years, which makes it hard to give people confidence that the measures they are taking on their land are increasing levels of carbon stored in the short term.

Quanterra Systems is an organisation identified through our Devon pilot work, that was set up as a 'spin-out' from the University of Exeter, to address this challenge by providing cost effective measurement of the flows of carbon dioxide between the atmosphere and ecosystem, showing whether carbon is being sequestered or emitted.

Carbon flow measurements are provided every 30 minutes covering approximately 4 to 10 hectare area of land per measuring station. Measurements on other important indicators of ecosystem health can also be taken, including water and energy exchanges. This can help users better identify how their land use and management practices are impacting carbon sequestration, which can help drive their decision making on land use change. It can also be used to support monitoring and verification for payments for ecosystem services.

Biodiversity evidence gaps

We found that land managers have varying levels of understanding about their 'environmental baseline'. Some stakeholders mentioned that their environmental data was disparate and hard to access in a way that can support current decision making.

Whilst some land managers are collecting soil organic matter (including carbon) information, they do not have a systematic approach or tool for doing so and are not aware of how they might need to use the data in the future. There is a lack of understanding around the opportunities generated by improving levels of organic matter will bring to land managers and owners. There is a need to better articulate these to stakeholders as we found that financial risks and opportunities are the main drivers for land managers to consider land use change.

Better informed and targeted maps could help identify where to plant trees to provide natural capital benefits whilst taking into account environmental and social constraints. Defra and the Forestry Commission are working collaboratively to: combine existing sensitivity maps, which highlight areas less sensitive to woodland creation with low-risk afforestation mapping; improve existing datasets and add further necessary data layers to the Forestry Commission map browser.

Spotlight on: Digital tools reveal nature-based solutions in Devon

Natural habitats, such as forests, wetlands and grasslands, contain large amounts of carbon. Nature-based solutions can help stop emissions from damaged habitats, or begin new carbon sequestration by creating new habitats - with the added multifunctional benefits of improved flood management and enhanced biodiversity.

In Devon, we ran a pilot to test how a land use framework can help decision makers balance different land use requirements, including the need to build new homes, restore nature, maintain food production and develop renewable energy infrastructure.

Interviews with local stakeholders showed that land managers want to find opportunities for nature-based solutions. But without better information it is difficult to understand how the landscape works holistically, where carbon is stored, or which solutions would be financially viable when considering new government funding streams.

We partnered with the Food, Farming and Countryside Commission (FFCC) and the British Geological Survey (BGS) who led a design sprint with local stakeholders, to design a digital solution to support decisions on long-term carbon sequestration (e.g. woodland) and storage (e.g. soils) in Devon's rural landscape. The designed solution enabled users to view a summary of their land cover and soil data and assess how changing their use of land would impact carbon storage and the financial opportunities available.

Co-designing this tool with local stakeholders highlighted the value of providing land managers with clear, easy to interpret information about the options available to them based on the unique geographic conditions of a particular place.

Good data is generally available on:

Land cover:

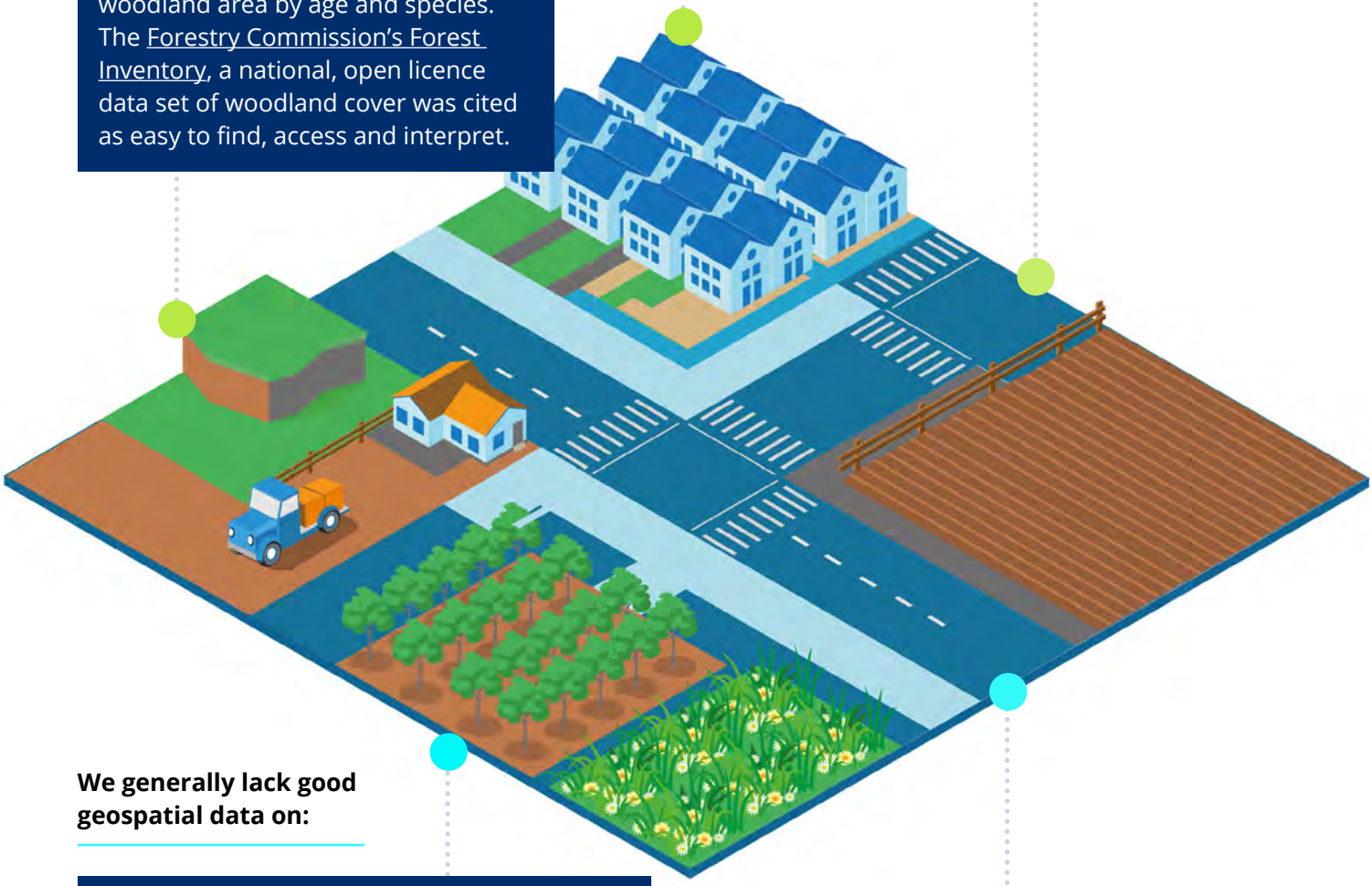
Land cover data collected using satellite imagery is openly available and multiple products exist, such as the UK Centre for Ecology & Hydrology's (UKCEH) Land Cover Maps, CORINE Land Cover Maps, and global mapping and routing products such as Google Earth.

Tree Planting and Woodland Cover:

Forestry Statistics are published annually by Forest Research and the National Forest Inventory on woodland area by age and species. The Forestry Commission's Forest Inventory, a national, open licence data set of woodland cover was cited as easy to find, access and interpret.

Climate change and net zero:

The government publishes a range of climate change and net zero related data and statistics, made accessible via the Climate Change Data portal including: greenhouse gas emissions, ecological status of surface waters, renewable energy production share and new planting of woodlands. The Met Office models UK Climate Projections and makes this data openly available.



We generally lack good geospatial data on:

Species:

Various organisations collect species data at a range of spatial scales in the UK however a previous Geospatial Commission report found that approximately 50% of potentially useful species data were identified as "currently inaccessible" due to a reluctance to share data to the NBN Atlas and that there are important species taxonomy and spatial gaps in data, especially outside protected areas.

Local-level Priority Habitats:

Local record centres collect highly granular data on habitats, however we heard that it is challenging to make the data publicly available due to the cost of maintaining the dataset. Natural England holds the Priority Habitats Inventory (PHI) national data set, which is an open data layer on the Defra MAGIC platform but stakeholders raised concerns with its accuracy and consistency.

FOOD

Nearly two thirds of England's land is used for agriculture, giving it the biggest land take of any sector.[22] Since World War II, food production has historically been regarded as the highest priority use of England's land[23] and the National Planning Policy Framework includes consideration of the impacts from planning decisions on 'Best and Most Versatile' (BMV) farmland. Recent rises in food prices as a result of food shortages caused by geopolitical events, such as the invasion of Ukraine, continue to demonstrate the need for food security and that domestic food production is an important component of a resilient food supply chain.

Pressures on land

Demands: As the dominant land use in England, with 63.1% of the land, agriculture faces the largest land use change in spatial terms. In the Sixth Carbon budget, the Climate Change Committee has said that around one-third of agricultural land will need to change in use to meet carbon reduction goals. At the same time, the government has committed to broadly maintain current levels of self-sufficiency in food as we deliver our climate and environmental goals in the Food Strategy, so we need to consider the ways in which food is produced to free up and make more productive use of agricultural land.

Spatial constraints: A combination of climate, topography and soil characteristics determines how suitable land is for crops or pasture. Defra-commissioned research suggests that under a high warming scenario, climate change could reduce the proportion of 'best and most versatile' land for agriculture from 38.1% to 9.2% by 2050, however there is high uncertainty about projections of this kind. In 2017, 57% of agricultural economic output came from just 33% of the farmed land area[24], so it may be possible to target land use change at the least productive land, to

increase the environmental benefit from farming and to increase yields with minimal impact on food production.

Trade-offs: Agricultural land use may need to change to accommodate habitat creation and restoration, forestry, to restore peatland, to improve water quality/availability and develop sites for property, transport or employment. To realise bioenergy production ambitions, agricultural land would be required to grow bioenergy crops to use as a fuel source for bioenergy carbon capture and storage (BECCS) rather than growing food or silage crops. Large scale solar deployment across the UK will require development on low / medium grade agricultural land.[25] While out of scope of this report, it is important to note that changes to diet may impact the extent of these trade-offs.

Multifunctional opportunities: Examples of this include animal grazing on solar farms, growing of both trees and arable crops on the same piece of land (agroforestry) and agroecological farming techniques that simultaneously support food production, wider environmental outcomes and natural flood management.

Technological advances

Innovation in new farming techniques and approaches will enable the delivery of greater multifunctional benefits from land use. Defra have announced that they will be spending over £270 million across their Farming Innovation Programmes to boost food production and profitability and reduce environmental harms. Funding and research will support progress on a wide range of issues, including vertical farming, alternative proteins, gene editing and the use of feed additives to reduce methane emissions from livestock.

Land use modelling that incorporates spatial data can be used to help policy makers understand the drivers of land use change and can help estimate the potential impact of policy decisions around land use prior to their implementation, for example ensuring agricultural policies are sustainable and viable.

The government's Land Use Framework will be published in 2023 which will set out a series of principles, and local levers, such as Local Nature Recovery Strategies (LNRS), which will be implemented to incentivise land use change and more effective land use planning. These land use strategies will need to be underpinned by data and evidence.

Data and modelling can also be used by local decision makers to make the most optimised use of agricultural land, which takes into account economic, environmental and social factors. For example, land managers can use modelling services to analyse species data to assess where biodiversity levels are low on their land and whether changing land use practices would help improve this.

CASE STUDY:

Assessing land use change through digital mapping

The Land App is a user-friendly, digital mapping tool whose mission is to help people make the right land use decisions through technology.

The Land App brings together a range of data through its online platform, which currently helps over 17,000 landowners, farmers and advisors (covering 8 million hectares) to understand their current land usage and plan for future land use changes.

It can help farmers and advisers find ways to appraise and drive revenue, apply for government grants or prepare for natural capital markets with compliance in mind by having easily downloadable and interactive data and reports.

It can also be used to help organisations plan projects and work together – for example, Riverford Organic, a veg box company operating in Devon, is using the Land App mapping tool to codesign agroforestry projects together with farmers to help meet their climate action plan goals.

CASE STUDY:

Informing, monitoring and evaluating sustainable land management

The Integrated Modelling Platform (IMP) is a business critical classified computer model that supports the development of new policies in Wales focused on natural resource management, land use and agriculture.

Jointly designed by the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP) consortium and the Welsh Government, it simulates the effects of policy options and external factors on agriculture and the natural environment. It has been used to investigate the impacts of new trade deals on the agricultural sector and other environment outcomes, and the development of the Welsh Government's CAP replacement Sustainable Farming Scheme (SFS).

The IMP allows emerging policy ideas to be explored and stress-tested prior to final design and implementation, to greatly enhance value for money of public spending and help avoid unintended consequences of proposed land use changes.

Food evidence gaps

We have found that most land owners and managers are interested in exploring ways to change their use of land to improve its productivity. For example, a move from intensive arable farming to agroecological practices and technological solutions could improve biodiversity and nature recovery and maintain food production levels by improving crop yields.

However, we found that data to help support these decisions can often be out of date, hard to access and data sets are not always comparable, therefore land managers do not always have the information they need to make informed decisions around changing their land use. We found that data is often used as a way to back up decisions that are often already well on their way to being taken, as opposed to being the starting point for thinking about change.

The government's Food Strategy sets out that with 57% of the UK's agricultural output coming from just 33% of the farmed land areas, it is possible to target land use change at the least productive land to improve land outcomes and productivity (thinking beyond its agricultural output) without significant impact to overall food production levels. Beyond this, there is a lack of understanding about which land for food production should be freed up for other uses or converted to land for multifunctional use, for example agroecological farming.

The impacts of land use changes at a systems level are not always well understood. For example, if we convert agricultural land to use for energy production we would need to consider whether this would necessitate increased food imports to meet our supply needs and therefore if it would relocate rather than resolve negative environmental impacts.

The agricultural land classification system (ALC) data and methods are decades old and not always reflective of current agricultural land quality. Therefore a significant amount of current Best and Most Versatile agricultural land is likely to now be lower quality or less productive agricultural land which could 'free up' land for other uses.[26]

Access to accurate, field scale soil data will allow farmers to identify where improvements can be made to soil health which could help improve their yields and increase food production. It may also show where land use practices should be changed to ensure sustainable land use. However, data on soil carbon levels and soil health is not typically collected due to the cost of undertaking soil testing. When this data is collected, it is usually inaccessible as it is held by land owners or commercial organisations who are not incentivised to share it, or is not suitable for reuse as it has been collected using inconsistent methodologies.

Good data is generally available on:

Agricultural land registration:

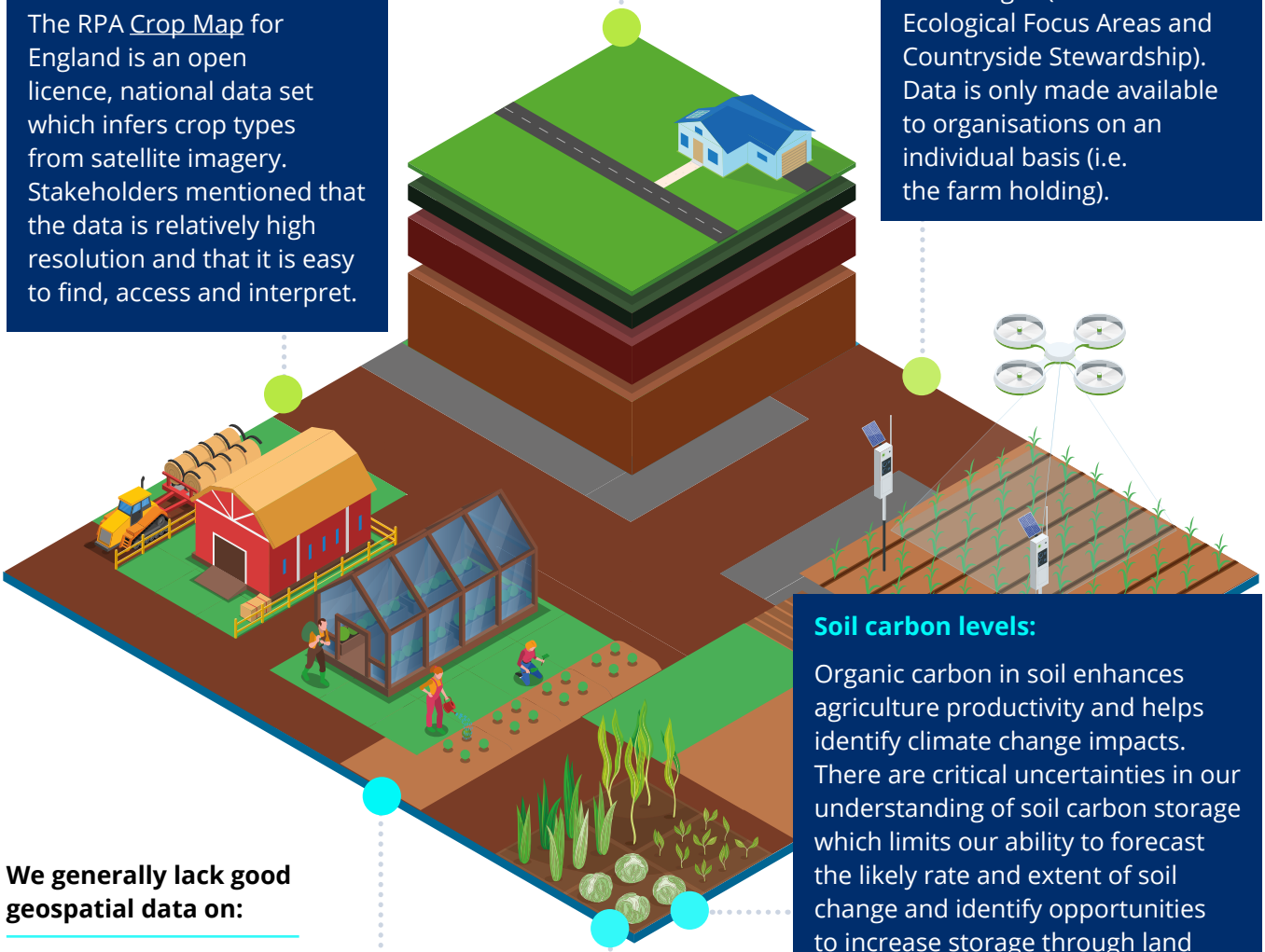
The Rural Payments Agency (RPA) systematically reviews and updates data held on the Rural Land Register each year using evidence from data sources such as aerial photography, satellite imagery and Ordnance Survey MasterMap updates. However, this data is not openly accessible due to commercial sensitivities.

Crop mapping:

The RPA Crop Map for England is an open licence, national data set which infers crop types from satellite imagery. Stakeholders mentioned that the data is relatively high resolution and that it is easy to find, access and interpret.

Land parcels:

The RPA provides farmers, land managers and land agents with Land Parcels (the registered field boundaries), Land Covers (the classified land cover features which fall within the field boundaries) and Hedges (recorded for Ecological Focus Areas and Countryside Stewardship). Data is only made available to organisations on an individual basis (i.e. the farm holding).



We generally lack good geospatial data on:

Soil carbon levels:

Organic carbon in soil enhances agriculture productivity and helps identify climate change impacts. There are critical uncertainties in our understanding of soil carbon storage which limits our ability to forecast the likely rate and extent of soil change and identify opportunities to increase storage through land management policies and practices.

Quality of agricultural land:

The current grading of agricultural land through the Agricultural Land Classification system (ALC) is likely to be over classifying the amount of Best and Most Versatile (BMV) land in England – the ALC 1-5 grading scheme may be too coarse and ALC system would benefit from being updated as it is partly based on old datasets.

Soil condition:

Soilscapes is the national soil dataset and is maintained by the National Soil Resources Institute (NSRI) of Cranfield University, however there is a fee to access this data and stakeholders did not consider the dataset accurate enough to inform decisions at more localised scales. However, Defra has committed to publishing a baseline map of soil health for England by 2028 in their Environmental Improvement Plan 2023.

WATER

Water is a critical resource that supports many uses of land including for housing, agriculture and industry. However, the combination of climate change induced changes to the water cycle, resulting in extreme weather, such as droughts and flooding, with unsustainable development and high levels of water leakage, is placing stress on the UK's ability to manage water supply, water quality and flood risk.

Government guidance on water industry strategic environmental requirements suggested that without change, rivers could have up to 80% less water in summer by 2050 and it will not be possible to meet the growing demands of people, industry and agriculture. Analysis by the Local Government Association suggested that around 20,000 new homes a year have been put on hold as a result of legal protections to clean and protect our waterways.

The government's 25 Year Environment Plan sets out its ambition for "clean and plentiful water" and its commitment to improve at least three quarters of waters to be close to their natural state as soon as is practicable, alongside meeting its other priorities including housing, energy and food production. This will all need to be considered alongside projected increases in water demand with the population of the UK rising from 67 million to 75 million by 2050[27] and expected reductions in water supply by 10-15% due to climate change.[28]

The Environment Agency's Flood and Coastal Erosion Risk Management Strategy sets a long-term vision for a nation ready for, and resilient to, flooding and coastal change. Actions include greater focus on providing timely and quality planning advice that helps avoid inappropriate development in areas at risk of flooding and coastal change, and making greater use of nature-based solutions that take a catchment led approach to managing the flow of water to improve resilience to both floods and droughts.

Pressures on land

Demands: The UK's water supply faces demands from agriculture, construction, development, industry, the power sector and domestic uses. There is regional variation of water use across the UK caused by different types of industry, population levels, as well as current levels of water company leakage. The National Infrastructure Commission has recommended, due to the increasing pressures, that around 4 billion litres of additional water a day will be needed in England by 2050.[29]

Spatial constraints: Land use change can be constrained by the need to manage the existing and future water supply, including taking into account projected impacts from climate change. Developments may require abstraction licences, granted and regulated by the Environment Agency, and may be limited in flood risk zones in river catchments and coastal areas.

Trade-offs: Certain land uses can negatively impact water quality, for example through runoff from agricultural land and construction activities, such as house building, increasing the amount of pollutants (ammonia, nitrates, phosphate or toxic metals) entering waterways. Developments that require significant water abstraction may also constrain water supply. Planning applications in certain areas may therefore only be granted if developments can demonstrate nutrient neutrality and water neutrality.

Multifunctional opportunities: Tree planting in the right places can help sequester carbon, reduce surface run-off, improve biodiversity and help restore groundwater sources. Sustainable drainage systems, including natural water features and water storage solutions, can support activities such as peatland restoration.

Technological advances

Adopting innovative approaches is key to delivering long term resilience of water and addressing challenges faced by the water sector including improving water efficiency, reducing emissions, improving flood and drought resilience and finding sustainable management of sewage and wastewater to reduce pollution. This is supported by Ofwat who have established a £200 million innovation competition fund to grow the water sector's capacity to innovate, enabling it to better meet the evolving needs of customers, society and the environment. The government has also launched the Floods and Droughts Research Infrastructure, led by the UK Centre for Ecology and Hydrology to facilitate the science and innovation needed to improve the country's resilience to floods and droughts.

Water quality modelling can be used to better understand sources of pollution and how the quality of the receiving waters can be improved, including through changes to land use and land management practices. Collecting and monitoring water quality data will enable the assessment of progress against environmental plan targets.

There are various water companies, regional scale and academic catchment scale spatial data and modelling tools, which can help inform decision making by bringing together data on current and future water supply and demand to assess where risks and opportunities lie and to test possible solutions. There are also various examples of integrated modelling projects developed by academics, which could be used further to support decision making on water planning and environmental decisions in the context of socio-economic and climate changes.

CASE STUDY:

Developing a national view of water resource solutions

Regional water resource planning groups build simulation models to help inform regional water management plans. But there are difficulties when combining these outputs into a fully representative national picture.

The National System Simulation Modelling Project (NSSM) has been commissioned to provide a strategic national view of water resources and explore the implications of inter-regional drought on new water supply infrastructure. The model integrates climate, hydrology, water infrastructure and water demand modelling and can be used to explore the impact of droughts on the water supply system under different scenarios.

NSSM's modelling approach ensures the interdependencies of different solutions and regulators investigations are incorporated, while maintaining compatibility with other models.

The outcomes are informing recommendations to Ofwat around future investment, and will help improve regional water resource planning.

CASE STUDY:

Understanding drought and water abstraction risks

Drought can cause significant impacts to agribusiness and the rural economy and these impacts may become more serious in the future partly due to proposed abstraction reforms. We saw the effects of this in summer 2022 where many farmers had limited water remaining in their storage reservoirs and little volume left on their annual licensed abstraction which caused real issues for crops such as potatoes. The Environment Agency noted how droughts reduce crop yields and crop quality and can have longer term impacts, such as reducing the crops farmers can plant in the following year.[30]

D-risk is a web-based decision support tool that helps agribusinesses and water and catchment managers evaluate the impacts of abstraction licence changes on their irrigated cropping programmes.

D-risk uses weather and hydrological data for specific river catchments to calculate the theoretical annual irrigation needs for crop-soil combinations which can be chosen by the user and the total water demand for each year.

Abstraction licence and storage data for individual farms are inputted to assess how irrigation demands compare against the annual licensed abstraction volume for the farm(s), taking into account abstraction licence constraints and on-farm water storage availability.

D-risk also has a reservoir sizing model function designed to help agri-businesses assess how the construction of an on-farm reservoir could reduce their drought risk.

This modelling can help British farming and horticultural enterprises and catchment water managers rapidly understand their local drought and abstraction risks and thereby support more robust decision-making regarding future irrigation investment and management.

Water evidence gaps

Multiple government departments and agencies carry out modelling focused on different areas of water management, including flooding, water quality and water infrastructure. More could be done to share data and modelling assumptions and outcomes between departments to enable effective cross-cutting work on water and associated sector policies. This could support more joined up spatial planning which takes a systems approach, aligning local housing needs provided by DLUHC, Defra's environmental modelling, and water company modelling outputs.

Several water management plans are produced at different scales and for different purposes across the UK, including regional water, flood risk, drainage and wastewater management, water resources management and river basin management plans. Analysing these plans in parallel is difficult and may lead to contrary action, inefficiencies and unintended consequences. Better integration of catchment information and management plans could help provide a more informed assessment of the impacts of each catchment's water resources, pollution and management on one another.

There is a lack of understanding about the areas with opportunities for multifunctional land use where investment aimed at flood prevention, nature restoration and agriculture to improve nutrient and water neutrality could be aligned to achieve mutually beneficial outcomes. Multifunctional water management tools, that help develop a shared picture of our water system across the public agencies and companies which manage our water system, could help decision makers understand interdependencies and reduce the risks of unintended consequences of water management solutions that have land use implications.

The land use impacts of longer term mitigation strategies of nutrient neutrality are not well understood. For example, offsetting activity such as the creation of new wetlands can help meet nutrient neutrality targets, however this could place additional demands on land that may conflict with other objectives for example supporting food production. Where this offsetting would occur spatially would need to be properly assessed to ensure that it does not create other risks to the environment such as increasing flood risk.

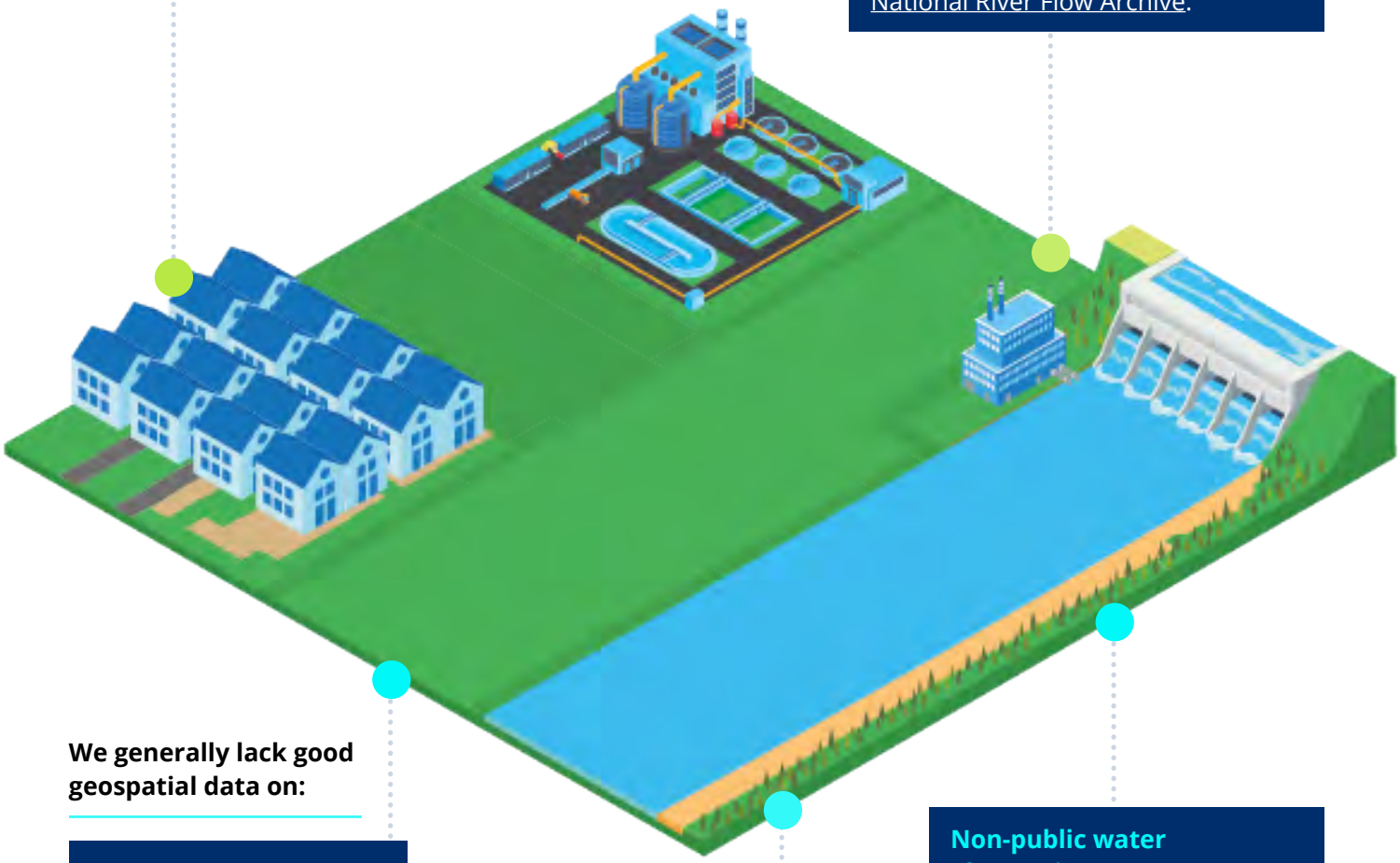
Good data is generally available on:

Flood risk:

The Environment Agency publishes datasets on historic flood outlines, properties at risks, flood defences and modelled flood risk for surface water, rivers and seas (based on cells of 50 metres for rivers and seas and 2 metres for surface water). The National LIDAR Programme provides accurate elevation data at 1 metre spatial resolution for all of England as well as derived products such as vegetation point clouds and digital terrain models.

The water cycle:

High quality and easily accessible hydrometric data which includes information on rainfall, groundwater characteristics and flow characteristics of surface waters, including river water quantity monitoring data, is made available from various sources, including the EA Hydrology Data API and CEH's National River Flow Archive.



We generally lack good geospatial data on:

Water resource availability:

The Environment Agency provides nationally consistent and openly available data, which is useful for getting a broad understanding of water resource availability, however it has not been updated since 2015 and it is modelled, not measured, data.

Water quality:

Water Framework Directive (WFD) data has not been updated since 2021 due to the discontinuation of WFD monitoring. Stakeholders have questioned the geographical coverage that Environment Agency monitoring sites provide and why some environmentally important areas are not routinely monitored.

Non-public water abstraction:

Statistics on the abstraction of water is provided using the abstraction rates by licence holders in England. This considers abstraction for electricity, agricultural, public water and private water supply. However, licences are only for more than 20 cubic metres per day and the figures are not reported frequently.

TRANSPORT

Transport is a critical enabler of growth and infrastructure development. It is also central to how we live our lives, connecting people to jobs, each other and places, and enabling the movement of raw materials, food, finished goods (and many services) to where they are needed. The government has announced that over £40 billion will be invested in transformational transport schemes over the next two years, helping to improve connectivity and deliver economic growth. This includes a continued investment in delivering HS2 as well as almost £8 billion in investment in major roads and more than £3 billion in active travel up to 2025.[31]

Pressures on land

Demands: Transport infrastructure, such as new roads and public transport links, are needed to support new developments, ensuring housing and employment areas are well connected to population clusters. Nationally significant transport infrastructure projects to support the increased connectivity between regions, will place additional demands on large areas of land across the UK.
Spatial constraints: Transport infrastructure may be constrained by planning restrictions, including the need for approval of environmental impact assessments. Obtaining local planning consent for new infrastructure may be challenging in certain areas, for example where construction will increase visual or noise pollution or involve the relocation of homes.

Trade-offs: Large scale transport projects and the design of transport networks can impact on the environment. For example building HS2 affects the Colne Valley Green Belt (which will have a 15-metre-high rail viaduct driven through it), which could have an environmental impact on protected habitats such as a special scientific interest (SSSI), sites of national importance for bird conservation and ancient woodland.

Multifunctional uses: Decarbonising transport and providing more active travel infrastructure can help meet net zero emissions targets and could reduce air pollution. A multifunctional perspective can enhance new or upgraded infrastructure, for instance schemes to make better use of roadside verges, incorporate wildlife corridors, or manage trackside vegetation to protect habitats while also reducing the 'leaves on the line' risk to the safe running of the railway.

Technological advances

The use of location data and technology to support transport decision making is well established and dates back decades. Of all the land use demand modelling sectors covered in this report, transport modelling is by far the most mature and is widely used operationally. Transport modelling can be used to test scenarios around future demand for transport and where new transport infrastructure could be located to maximise its impact and minimise disbenefits. There are a range of existing transport models for an array of different scales which have been developed to support strategic transport planning. Transport models often incorporate a range of spatial data sources, including population growth estimates for different regions, land cover and land use data as well as route mapping.

National scale: The Department for Transport undertakes transport modelling to analyse national transport policy and roads strategies and has maintained the National Transport Model since 2001. It is a multi-modal model of land-based transport in Great Britain and its data and assumptions have been updated regularly. The National Transport Model enables the Department for Transport to estimate the impact of transport policies or forecasting assumptions on key travel indicators, such as levels of traffic, congestion and vehicle emissions and to produce road traffic forecasts.

Regional scale: A large number of local planning authorities undertake specific transport modelling for their areas of interest. Depending on their resources, this can be undertaken by their own modelling teams, such as those within Transport for London and Transport for West Midlands. Alternatively, smaller teams can make use of a wide range of transport modelling products and services provided by the private sector and academia.

The Department for Transport recognises the important role of data in unlocking innovation and helping to meet its strategic objectives. Its Transport Data Strategy sets out the targeted interventions that the department is making to improve the discoverability, quality and accessibility of transport data, which can help support land use decision making by government, the public sector and industry.

CASE STUDY:

Understanding connectivity solutions

The Department for Transport is using spatial data and modelling to understand the impact of transport and how this varies across the UK. They have developed a 'Connectivity' metric to demonstrate this, which measures someone's 'ability to get where they want to go'.

This metric is produced for each combination of time of day, mode of transport and trip purpose, for each of the 35,000 Lower Layer Super Output Areas (LSOAs) and 181,000 Output Areas (OAs) in England and Wales. The metric is also produced for every 100 by 100 square metre in England and Wales.

The connectivity model and its resulting metrics can be used alongside other sources of information to determine potential impacts of transport schemes on future connectivity and to evaluate the impact on connectivity of past schemes. For example, by inputting timetables on planned rail or bus schemes, the impact of the schemes on connectivity can be calculated in advance, allowing rapid comparison of many varied options.

This information can be used as part of land use planning to find the interventions which will increase connectivity the most in their area. This can help assess the impact on connectivity of transport schemes and changes in land use such as the provision of new jobs or services.

CASE STUDY:

Increasing transparency of environmental impact mitigation

The HS2 Green Corridor will run alongside the railway line, creating a network of connected, climate resilience habitats and new green spaces. HS2 has created an openly accessible, online mapping tool that allows users to track the development of the Green Corridor, showing how the environmental impact of HS2 is being minimised and compensated for, as well as the progress of environmental and community projects, supporting the Government's 25-Year Environment Plan.

Users have the ability to overlay contextual data layers, view case study areas and view detail at a local scale by searching by address, postcode or project name. Displaying this data in a clear, easy to visualise way helps demonstrate the work going on to a range of stakeholders, including the public, local authorities and government departments and can help increase awareness, transparency and accountability around the ongoing environmental projects.

Transport evidence gaps

At a national and local level, transport models rely on forecast data inputs, such as population growth and age, future transport network conditions and societal values related to accessing jobs or how much time a trip takes. This data helps models with predictive functions that link non-transport inputs to travel demand, such as linking travel conditions to trip making. No model can precisely predict future scenarios so a number of assumptions need to be made and therefore a degree of uncertainty.

We heard that trust in model outputs was highly dependent on transparency and agreement on modelling assumptions. Trustworthy models are required if they are to be taken up and used widely by decision makers. The Department for Transport have recognised this issue and have produced the Transport analysis guidance (TAG) uncertainty toolkit which provides techniques for exploring uncertainty and how to present this data to decision makers.

At a local level, pressure to meet housing needs and prioritise brownfield sites for development means that local authorities are sometimes housing-led with the transport infrastructure impacts and needs not fully being incorporated at primary stages of planning. This can lead to land use challenges where land is not being optimised to balance the policy priorities of local authorities and land use trade-offs related to new infrastructure developments are not well understood which can lead to unintended consequences.

For example, building on brownfield land may be perceived as being better for the environment than releasing greenfield land for development. However, building on a greenfield site with low biodiversity levels and existing infrastructure connections may have a lesser overall environmental impact than building on a brownfield site where new roads or transport links will need to be built.

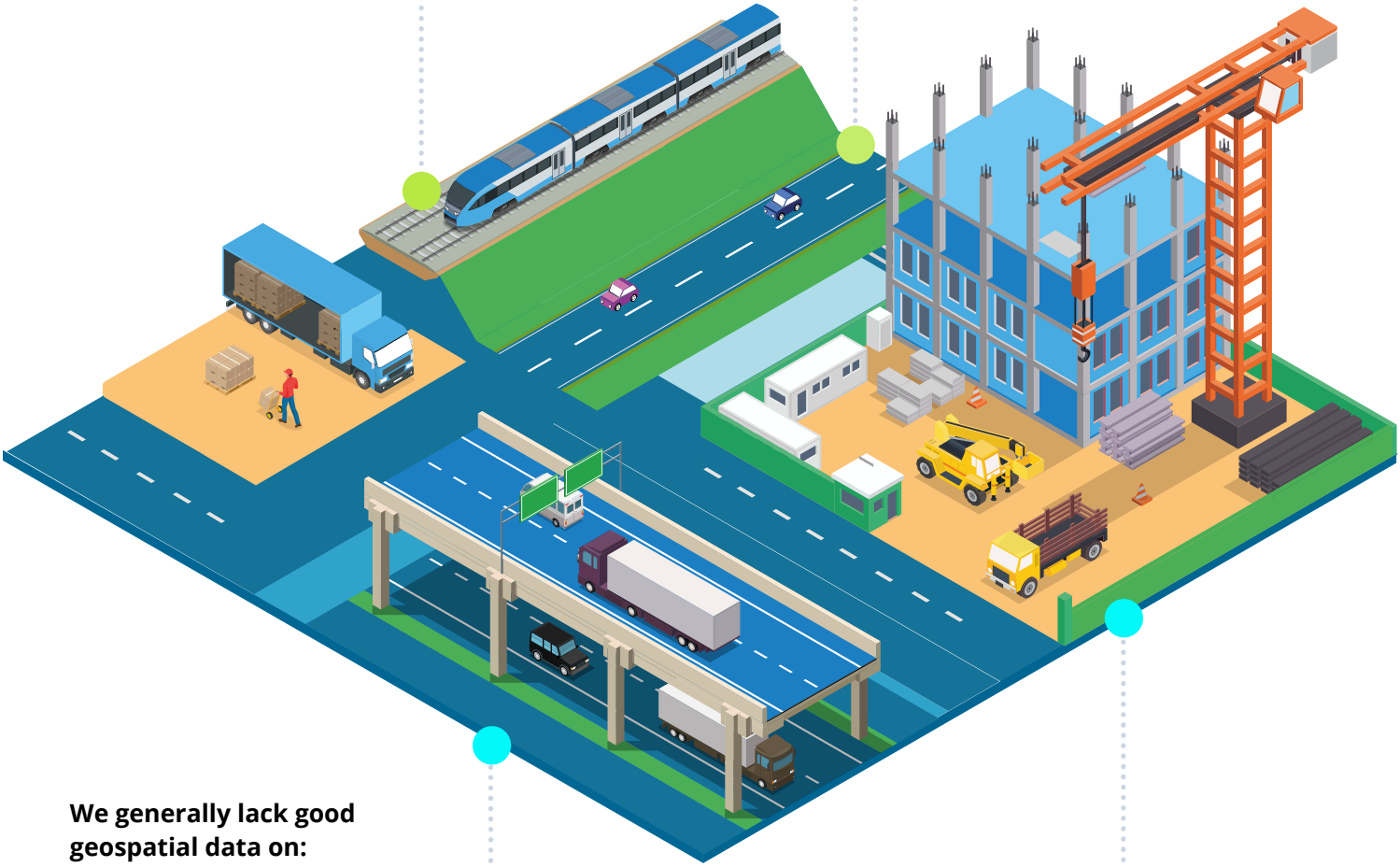
Good data is generally available on:

National road and rail networks:

This is well mapped and is accessible from the Ordnance Survey OpenMap Local, as well as other open sources. More granular and up-to-date network data is produced and made available via commercial products such as Ordnance Survey's MasterMap.

Traffic flows:

Data on traffic flow and density, collected by Highways England and made openly accessible, is important for assessing where new road infrastructure is needed and modelling interventions.



We generally lack good geospatial data on:

Movement of people and goods:

These patterns change over time so near-real time data is required for accurate modelling, however origin/destination data can be difficult to access, which can make planning or updating road infrastructure challenging. The Department for Transport is exploring the use of novel data sources and technologies to increase our understanding of origin data insights.

Planning and construction:

Details of new developments are not usually available in formats compatible with other GIS spatial data, making it difficult to use. Additionally, data is often not shared between stakeholders involved in a typical infrastructure project.

SECTION 3
KEY FINDINGS AND RECOMMENDATIONS

The National Land Data Programme (NLDP) explored the land use challenges highlighted in Section 2 at a national level through our Land Use Dialogues project and at a local level through our pilots. This section sets out some cross cutting insights from the programme, and our recommendations to improve the evidence base for land use decision making.

NATIONAL POLICY DECISIONS

National policies that affect land use change should consider the whole land use system, including the complex interactions between different land use sectors, spatial scales and opportunities for multifunctional land use.

The decisions made in one land use sector can affect the land use choices available in other sectors. A whole systems approach to land use will be needed to effectively manage the competing and interconnected demands on land use.

Systems mapping and models can help policy makers address the complexities in identifying and quantifying the interconnections between different policy areas. DESNZ and Defra have recognised this, developing a Net Zero Systems Tool to help policy makers think more holistically.

The impacts of some land use change can take years or even decades to materialise. It is therefore important that policies, which impact land use, have robust monitoring processes in place to ensure intended benefits are being realised and that unintended consequences are not missed. For example, between the 1940s and 1990s, large areas of UK peatland were ploughed and planted with conifers which had a negative impact on breeding birds and carbon sequestration. This is a good example of why policy makers should consider interconnections between current policy areas and conduct long term monitoring of interventions.

The UK lacks a shared, spatially-explicit, evidence base that integrates data, technology and scientific knowledge to underpin land use decisions.

Government departments produce a considerable amount of data and analysis related to their own policies. However, these approaches do not always take a holistic view of other policy demands for land use change outside of individual departmental priorities.

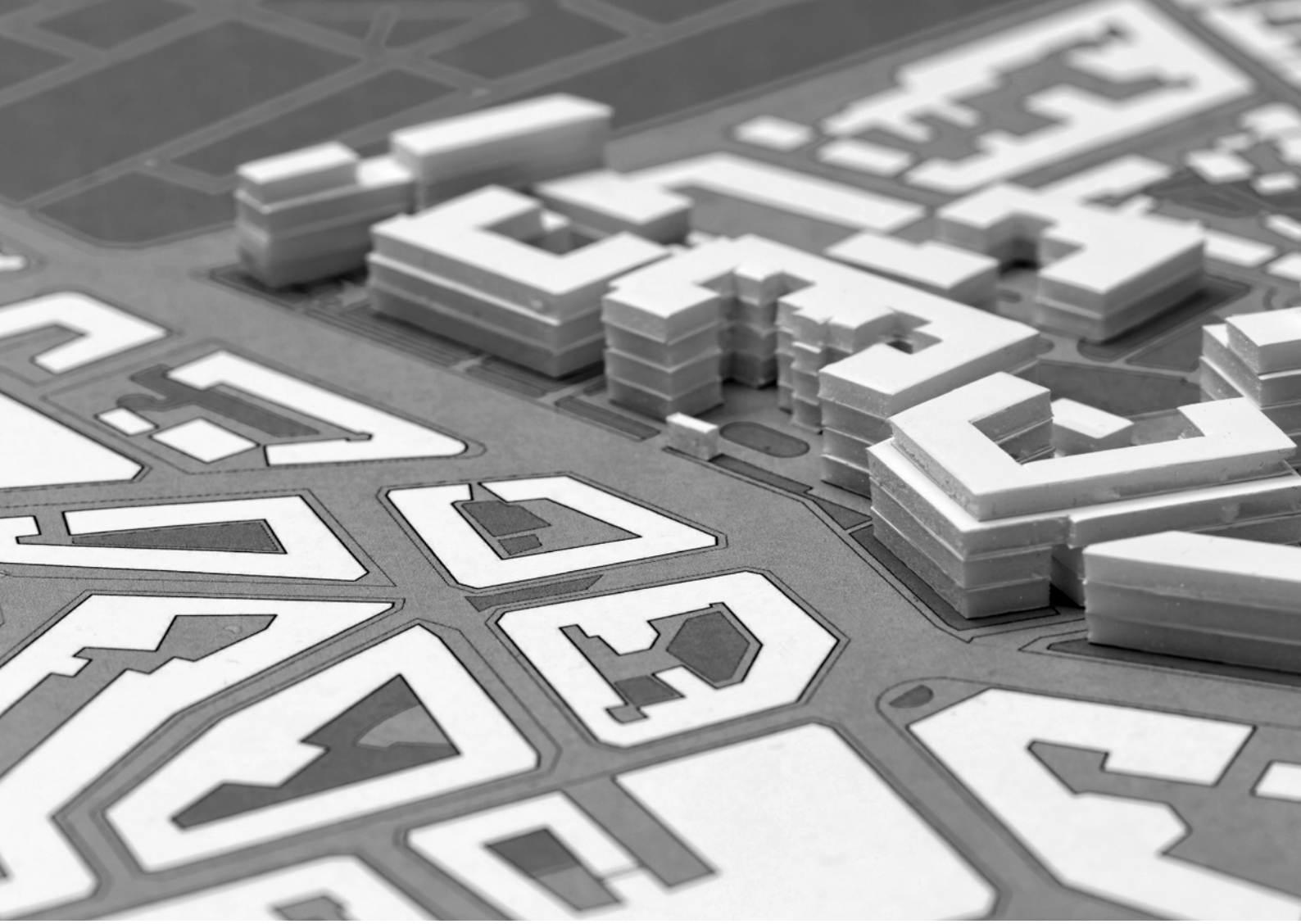
Some government departments are more advanced in their use of spatial data and analysis. For example, Defra's Environment, Science and Analysis Unit modelling capability is using spatial data and modelling to help understand Defra's land use pressures.

However, there is no shared spatial evidence base across departments that can inform the totality of land use pressures across multiple sectors. This makes it difficult to assess whether national priorities are deliverable with the land available in the UK and increases the risk of unforeseen impacts.

Recommendation 1: Establish a Land Use Analysis Taskforce

Government policies which have a bearing on land use should be underpinned by improved spatial analysis to more effectively assess and mediate potential land use trade-offs to deliver key national policy priorities. This should be supported by cross-departmental governance and the use of common spatial assumptions, data and technology to develop a coherent, robust and consistent evidence base at the required spatial scale. A shared evidence base should support an assessment of competing land use policy goals to ensure national priorities are deliverable with the land available in the UK.

First steps: The Geospatial Commission will explore the creation of a Land Use Analysis Taskforce, which will bring together, through appropriate new cross-departmental governance, a shared spatial analysis capability to provide a spatially-explicit evidence base that will help inform the delivery of key national priorities.



LOCAL AND MARKET DECISIONS

The UK has a wealth of land use data and innovative data companies are serving some sectors well.

There are many examples of companies innovating to create decision support and visualisation tools, which target a range of different users:

- Proptech companies serve the property sector, targeting property developers who can use their services to more efficiently assess land sourcing opportunities and development potential.
- Other companies typically serve the agricultural sector, targeting farmers and land agents. Their services help to visualise and assess the best use of their land and to make it easier to apply for funding through subsidies and grants.

While these products serve different customer bases, they all involve the collation of datasets and making these accessible via intuitive and easy to use applications. This saves their customers significant time and effort. These tools are often focused on addressing challenges in the early stages of the data value chain (data aggregation, transformation and processing). There are fewer examples of tools supplied by the market which provide services at later stages of the value chain (analysis and visualisation). DLUHC's PropTech Innovation Fund is currently investing in pilots in this area.

A number of spatial studies and modelling tools have been produced by academic institutions in the last decade. Given technological and computing power constraints, these models have typically focussed on addressing specific land use demands. Recent examples include: University of Exeter's ADVENT model, which explores the environmental impacts of different energy pathways in order to identify the optimal spatial configuration of energy infrastructure; and modelling by the University of Bath on how water security in the Thames river basin could be affected by urban development and land management change.[32]

However, there is a growing need for decision support tools which help landowners, land managers and local communities understand the opportunities for multifunctional land use.

Decision makers who are trying to make large scale land use decisions, including land owners and managers of large estates or holdings (such as a national park) or local and regional planning authorities, need to assess how the land can be used to achieve multiple outcomes and benefits. However, they often lack the sort of analytical applications that could provide them with that holistic view of land use choices and help them optimise land in accordance with incentives such as Environmental Land Management schemes.

This area of the market appears to be underserved. Decision makers often have to source, collate and interpret data sets themselves with limited resources. As a result, data is underused and important decisions are made based on limited evidence.

Recommendation 2: Champion the market for decision support and visualisation tools to enable better land use decisions which create multifunctional benefits

The private sector and academia should consider how to bring in land use decision makers and stakeholders, including smaller land owners and land managers, in the co-development of decision support tools to better visualise and assess multifunctional land use opportunities. The government and wider public sector (including local planning authorities) should consider how to support local stakeholder engagement and adoption of local decision support tools, applied to existing and emerging decision making forums.

First steps: The Geospatial Commission will promote the prototype decision support and visualisation tools developed through our pilots to highlight the potential of these applications to support emerging policy needs around local land use decision making. The Land Use Analysis Taskforce will also help drive innovation across the market.

ANALYSIS AND EVIDENCE

Connections between evidence and policy are crucial and can be strengthened.

There are multiple clusters of land use modelling activity in the UK, but many of the people involved would not recognise themselves as land use modellers. Building a more unified community could improve connections between those understanding land use analysis and land use decision makers who would benefit from these insights.

There are some good examples of connections between academia and policy making. For example, the Landscape Decisions Programme, funded by UK Research and Innovation (UKRI), has created a network of 59 interrelated research projects with teams working across multiple disciplines in institutions across the UK, to bring together expertise on how to deliver better, evidence-based decisions about how we use landscapes. The climate modelling community was also cited as an example of effective cooperation, both technically through the use of ensemble models and other tools, and through a focus on common agendas and policy objectives.

Sustained join up between academia and government would help ensure that policy makers are aware of useful analysis that could support their decisions and enable the development of models that test realistic policy scenarios.

The Land use for Net Zero Hub (LUNZ-Hub), funded by UKRI, Defra and DESNZ, will be an important step forward in increasing joint cooperation between the scientific community and government. The LUNZ-Hub will convene a cross-sectoral community to support the UK in achieving net zero while meeting other environmental and societal goals, through advancing research, identifying routes to impact and providing evidence that will inform policy development.

Additionally, increasing the adherence of academic models to government standards in relation to modelling, such as the Aqua Book, and ensuring modelling assumptions are made clear, could make academic models more useful to policy makers.

A comprehensive land use model would help decision makers think holistically, assessing the connections between different land use sectors.

Currently there is no model which considers the totality of land-related goals and whether they are deliverable with the land available. An overarching model exploring the breadth of the land use system would be an important tool to support the delivery of multiple policy objectives which impact how land is used. More specific model outputs that target particular parts of the land system could be cross-checked against this high-level model.

There is significant value to be unlocked in integrating recent advances in data science and AI with more traditional modelling approaches. AI can help unlock new data sources, such as high-resolution earth observation. For example, remote sensing combined with state of the art computer vision can help fill gaps in the availability and timeliness of data on many land uses including, infrastructure, building stock, and crops.

'Optimisation' is a type of modelling process that can help decision makers find options that result in improved outcomes while minimising trade-offs, by finding "better" compromises or ways to improve a situation. However, optimisation models have limits including incorporating stakeholder views about what land use change would be acceptable to the public or landowners. This can be accounted for to some extent through 'agent based modelling' which uses computer simulations to study the interactions between people, things, places and time. Nonetheless, all models should be treated like any other decision support tool: they are advisory to the human decision making processes.

Suggestions for improving model interoperability include the use of ensemble models (combining predictions from several models), pyramid structures of models (scenario evaluation with an optimisation level) and harmonisation of the various different assumptions and scenarios used in modelling.

New models may be needed to fill existing knowledge gaps, for example agricultural land quality, the probability of land ownership constraints, and social and behavioural factors.

How we conceptualise and classify land use and land cover could mean missed opportunities for better land use.

Land classifications, such as brownfield, greenbelt and agricultural land classifications, can be a useful guide to encourage land uses that are suitable for the conditions of a particular place or discourage unsuitable uses. However, used alone they can be a coarse and rigid indication of suitability. They can also become out-of-date as land conditions and pressures change over time.

For instance, the term 'brownfield' refers to previously developed land, but on its own it does not convey anything about the condition of the land or likely costs associated with making brownfield land viable. Innovative data tools, such as the British Geological Survey's Brownfield Risk Calculator, are helping to improve the understanding of brownfield viability. The calculator estimates risk and the associated mitigation costs derived from a range of environmental data available for the area of interest.

The agricultural land classification system (ALC) classifies land according to potential for food production. The National Planning Policy Framework uses ALC to define the best and most versatile (BMV) agricultural land and encourages its protection from development. However, the ALC climate datasets are decades old and land is still graded in accordance with the guidelines and criteria established in 1988. The publicly available maps are at a coarse spatial resolution and still do not reflect the 1988 ALC guidelines. Several reviews have recommended this should be updated to reflect current climatic conditions and continue to be of relevance.

Quantifying the economic and non-economic value of land use is complex, however there are a range of approaches to land valuation that can be applied to decision making.

Understanding the total value of land (economic and non-economic) can be complex. The economic, social and environmental uses and outcomes can overlap or conflict with each other and contribute to the value of land to varying degrees. Land use is often governed by legal or regulatory frameworks that add complexity to the assessment of value.

The accuracy of valuations of land depend on the maturity of the evidence base for conducting these assessments. These include an understanding of the extent and condition of land based features (natural capital assets), and evidence to attribute values for these. Professional standards such as RICS Global Valuation Standards, the Valuation of Rural Property, and the Valuation of Woodlands and Forests help professionals in these sectors to provide valuation information in line with client requirements.

A natural capital approach is the most widely recognised method of assessing the environmental value of land use change, linking the physical attributes of land to beneficial services that flow to society. The government's Enabling a natural capital approach sets out best practice around value attribution and provides a resource of valuations by service and habitat. There is work ongoing to address some of the gaps in our understanding of the natural capital of land assets, including Defra's Natural Capital Ecosystem Assessment programme.

Recommendation 3: Strengthen the links between land use policy design, academic research and industry practice

Greater collaboration is needed between government policy makers and analysts, academic researchers and industry practitioners. Strengthening ties would ensure that policy and decision makers are aware of relevant research and analysis that could help support their decision making. This would lead to land use models being developed in line with leading policy assumptions. Increasing the awareness and adherence of modellers from the academic community to government standards in relation to modelling and ensuring modelling assumptions are made clear, could aid the adoption of models by policymakers.

First steps: The creation of the Department for Science, Innovation and Technology brings together many of the strategic and analytical capabilities, including the research councils which fund national capability programmes such as UKCEH and the Land use for Net Zero Hub (LUNZ-Hub), geospatial agencies such as Ordnance Survey and the Geospatial Commission. We will consider how government, academia and industry practitioners involved in land use decision-making can improve links, including through the dissemination of outputs and common modelling assumptions and scenarios.

DATA IMPROVEMENT

The UK's geospatial data is world leading and there is a wealth of land use data. Some specific improvements to datasets would be valuable and there are already a range of data improvements underway.

We heard about the proliferation of data and how it can feel overwhelming to navigate to the best data and then to know how to use it. Many stakeholders talk about a desire for a 'one stop shop' when it comes to accessing data. Once found, there can also be difficulties accessing data due to complex licensing or a lack of common technical standards.

Some datasets are not kept up-to-date. This was true particularly for local authority brownfield registers, agricultural land classifications, water resource availability and water quality data.

The government is already making significant investments to improve the findability, accessibility and reusability of data – including Defra's Natural Capital Ecosystem Assessment, DLUHC's Digital Planning programme, HM Land Registry's Local Land Charges Programme and improvements to Ordnance Survey's land use data under the Public Sector Geospatial Agreement. Data hubs, such as the Ordnance Survey Data Hub and the Office for National Statistics' Integrated Data Service have the potential to enhance the findability and accessibility of data.

There is no agreed taxonomy for land use that meets the needs of UK land use decision making, for example, that clearly defines what is 'urban' and what is 'rural' land.

We found that there is no agreed taxonomy for land use. Different land use classifications exist, such as the National Land Use Database and INSPIRE, but these do not meet the needs of the UK land use analysis community and are applied inconsistently. This contributes to interoperability issues when trying to combine different datasets and different land cover / land use mapping products.

Across our pilots we heard that there is a lack of standardisation and uniformity across the data landscape, meaning that skilled resources are required to interpolate, match and join up data. This makes the process of preparing data highly specialised, time-consuming and prone to inaccuracy. The NLDP Data Product Specification outlines the basis of a system which could improve the interoperability of data.

Furthermore, existing taxonomies are not granular and flexible enough for some kinds of spatial analysis. For instance, urban areas may be a relatively small proportion of UK land cover, however they are home to the vast majority of the population, drive much of the UK's economy and produce a significant proportion of greenhouse gas emissions. Despite this, land classifications such as CORINE Land Cover do not classify urban areas in detail when compared to more rural land use types such as forests, agriculture and peatlands. Developing a more granular classification could help in strategic planning and determining opportunity areas for land use change to support new housing, create employment and design more sustainable towns and cities.

Information about land ownership and control can be opaque, causing inefficiencies in the property development and planning system.

HM Land Registry keeps the Land Register which is a guaranteed record of property ownership in England and Wales. A title register, accessible for a fee, provides information on the ownership of the land or property and lists the title number, who owns the property, how much the property was last sold for and whether the property has a mortgage, as well as details of any restrictive covenants or easements. A title plan, also accessible for a fee, shows the property's location and general boundaries. HM Land Registry's data publication platform, Use Land and Property Data, provides access to bulk datasets about all registered land and property in England and Wales.

Despite the availability of authoritative ownership information for registered land, we heard that some challenges remain. The registered owner may be a corporation or a body of trustees which can mask, either inadvertently or deliberately, who actually owns the land. The register may also not reveal the existence or details of land options or other contractual arrangements that allow others to control the use or development of land without being the owner. Additionally, around 12% of England and Wales's land area is currently unregistered and therefore lacks any ownership information.

DLUHC is currently considering ways to make information about interests in and control of land more complete and transparent, with provisions included in the Levelling Up and Regeneration Bill. This could help provide a better understanding of the land supply pipeline and identify where there are inefficiencies in the system, such as resource intensive land sourcing.

Recommendation 4: Develop a standard taxonomy for key land use data to support improvements to the interoperability of land use data and analysis

The lack of an agreed taxonomy that meets the needs of UK land use policy analysis means datasets are produced to a range of standards, with varying nomenclature and spatial scales. Significant resources are required to interpolate, match and join data up, cross-sector analysis is hampered because datasets are not interoperable, and we lack sufficiently granular classifications in some domains such as urban environments. The NLDP Data Product Specification outlines the basis of a system which could improve the interoperability of data.

First steps: The prototype Data Product Specification created by NLDP will be developed and considered for inclusion as a government data standard. The Geospatial Commission will work with its partner bodies and the Data Standards Authority to take this forward. The Land Use Analysis Taskforce could track and coordinate improvements to datasets in line with this standard.

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- Sir Bernard Silverman FRS (Chair)
- Nigel Clifford (Deputy Chair)
- Thalia Baldwin
- Professor Louise Heathwaite CBE FRS
- Alexandra Notay
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- British Geological Survey
- Food, Farming and Countryside Commission
- Newcastle City Council
- Open Innovation Team
- Ordnance Survey
- Ordnance Survey Northern Ireland
- The Alan Turing Institute
- Vizzuality

Cross Government Steering Group

- Department for Energy Security and Net Zero
- Department for Environment, Food and Rural Affairs
- Department for Levelling Up, Housing and Communities
- Department for Transport
- Office for National Statistics

Other organisations

- Addland
- Bolsover District Council
- Digital Task Force for Planning
- Drisk
- Energy Systems Catapult
- Environment Agency
- HS2
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- Newcastle University
- Ofwat
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- Royal Society
- Scottish Land Commission
- The Land App
- UK Centre for Ecology and Hydrology
- University of East Anglia
- University of Exeter
- University of Leeds
- Welsh Government

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