In brief

"All the best science in the world without translation into policy really is of no practical value in the world of tomorrow. Doing the science itself is not enough - we have to work with those who are in positions of making decisions, as these will affect everybody's lives".

SIR LESZEK BORYSIEWICZ, VICE-CHANCELLOR OF THE UNIVERSITY OF CAMBRIDGE

Feeding the world

How can food supplies and supply chains be made more resilient? Given the pace of change, how do we collect and analyse data in a way that feeds into policy processes most effectively?

At a glance

Security and resilience in food supplies and finding ways to harness and layer together the wealth of information being generated at global and local scales were recurring themes across Cambridge Forum for Sustainability and the Environment meetings. A rich mixture of policy and decision makers from government and business, technical experts and researchers were invited to be 'witnesses' to help to explore these. They each provided their perspective on the gaps in our knowledge and these were used to as a springboard to identify key 'unknown unknowns' and to formulate 'burning' questions in need of more research.

Three of these meetings were jointly hosted with the Joint Research Centre (JRC) of the European Commission and formed the core of a pilot activity under a new Memorandum of Understanding between the two institutions to enhance inter-institutional collaboration. 'Green growth and sustainability' was chosen as the pilot topic and the Forum worked with JRC and University Strategic Initiatives, including the Cambridge Conservation Initiative and the Global Food Security Initiative, to develop a series of meetings and projects to explore potential areas for future collaboration. Three co-hosted Forum meetings formed the focal point of this programme and each month, expert witnesses and guests from the JRC came to Forum meetings and helped to shape the theme as a whole.

This summary provides an overview of some of the 'wicked problems' and questions generated during these discussions. Additional outputs put these questions in a broader context and explore potential future collaborations between the JRC and Cambridge.

Taking a global view

Dr Alan Belward, the Head of the Land Resource Management Unit at JRC , argued that rapid advances in satellite remote sensing technology driven by the democratization of space, increased resolution of satellite images (from 80 m to 30 cm) and free and full access to satellite data archives. These open up for new possibilities of research related to topics such as food security and mean that there is huge capability to obtain high resolution data. However, our ability to understand change on a global scale is still limited. Professor Alan O'Neill, the founding Director of the NERC National Centre for Earth Observation, echoed this observation and added that big data is providing new kinds of datasets and opportunities to measure resilience and risk at a global scale in real-time and at high resolution. However, the volume, complexity and heterogeneity of large-scale datasets also pose challenges for both researchers and policymakers. As a result, there is a need to train more scientists who are not only technical experts but also familiar the underlying environmental, social and economic issues. Such training will enable them to know both what questions to ask and also how the data can be used to answer them. Dr Matthew Smith, an ecologist who works in the Computational Science Lab at Microsoft Research, went a step further and issued a challenge to universities to design courses aimed at preparing students for the kinds of questions we will need to answer in the future. In the context of food security, this could involve creating courses which bring together quantitative ecology, environmental science, meteorology and agriculture. Although the content of such courses will be inherently cross-disciplinary, changing people's perspective on how to approach and solve

Key questions

Through our discussions, we identified three key areas where more research is needed:

- **How can we move from tracking historical trends in food and water supplies to identifying emerging risks and creating future projections and scenarios?**
- **Decisions are taken at multiple scales from local to international. What place does satellite data have in decision-making at all of these scales and is it feasible to use it to make local scale decisions?**
- **Given the pace of change, how do we collect and analyse data in a way that feeds into policy processes in time to be most effective?**

Cambridge Forum for Sustainability and the Environment

UNIVERSITY OF CAMBRIDGE

problems will also be important. For example, there could be opportunities for better engagement between biologists and mathematicians if the goal of a project were problem based rather than discipline based.

Although innovation and developing new techniques is important, solving some of these problems may not necessarily involve more advanced technology. Dr Matthew Smith argued that technical solutions already exist to some of the data challenges we face. Moreover, some of these techniques, such as machine learning or data analysis and storage, may already be being used to solve problems in other fields. Stephen Peedell, a specialist in geospatial information technology from the Land Resource Management Unit at JRC, gave examples of phone tracking data being used to look at congestion in cities and to track the movements of illegal loggers or hunters in tropical forests. Finding ways to apply existing technology to data-driven challenges is therefore going to be as essential as developing new technologies. Building 'bridges' between both different disciplines and between industry, policy and academia through mechanisms such as the Forum was agreed to be an essential step towards making some of the connections needed to solve such problems.

> ***'Computational capabilities don't seem to be the limiting factor. We can develop machine learning techniques, collect data and design devices. Where we seem to be lacking is the support for doing the middle layers – the analytics and presenting the information in the best way for people to be able to use it.'***
>
> Dr Matthew Smith, Microsoft Research

In addition, Thierry Nègre, the Head of the Food Security (FOODSEC) Group at JRC, suggested that, despite the recent advances in data collection, there is an issue with the scarcity and quality of data in areas such as food security or food production. This was, particularly in developing contexts because of issues such as the lack of resources or funding and institutional barriers rather than due to any particular technological limitations. This compromises the ability to develop accurate models in key areas. The limitations posed by institutional barriers with regard to both data collection and effective use of data was mentioned frequently throughout the meetings.

Turning data into information

A related problem was that of turning data into useful information and then communicating that information in a meaningful way to end-users. Currently, there is a disconnect between the amount of data, the information gleaned from these data and people's ability to turn theory into practical solutions. Programmes such as the European Union's Earth Observation Programme, Copernicus, are also generating vast amounts of high-resolution data which will enable will enable global environmental changes to be seen in a way never before possible. In a public lecture, Dr Alan Belward, provided an overview of the Sentinel 'family' of satellites. Each Sentinel mission is based on a constellation of two satellites which carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring. All of these data are publically available, both in their raw form and processed into images or maps. The information has a wide range of applications, including urban area management, sustainable development and nature protection, regional and local planning, agriculture, forestry and fisheries, health, civil protection, infrastructure, transport and mobility, as well as tourism.

Of particular relevance to food security, the two Sentinel-2 satellites were launched in 2015 and 2016. Their primary application is to monitor agriculture, forests, land-use change and land-cover change; map biophysical variables such as leaf chlorophyll content, leaf water content, leaf area index; and monitor coastal and inland waters. Images of floods, volcanic eruptions and landslides will contribute to disaster mapping and help humanitarian relief efforts. Orbiting 180° apart, they cover all Earth's land surfaces, large islands, inland and coastal waters between 84°N and 56°S every five days. They carry a variety of visible, near infrared and shortwave infrared sensors with a resolution of between 10m and 60m.

Being able to process and analyse data on such a massive scale is a huge challenge in itself. However, it was agreed that ultimately, it is not the data in itself that holds value, but the information it contains. Programmes like Copernicus offer many new opportunities for open data and services but a number of witnesses cautioned that there has been relatively little investment in talking to people about what they want the data for, finding ways to provide it to them and then feeding that information back into the system to make it more effective. An increasing number of on-line tools and services are beginning to address this but it was agreed that much more research is needed to make the most of this wealth of information. Dr Alan Belward added that finding common ground between observation and reporting standards of the three Rio Conventions - on Biodiversity, Climate Change and Desertification - would be hugely beneficial. Identifying commonality between them will help to both determine the observations needed and to make policy links between biodiversity loss, food security and climate change.

Turning data into a form that people can use to make decisions adds another layer of complexity. Craig Mills, the CEO of Vizzuality, described the work his company does to visualise complex scientific datasets to create clear, communicable messages that people can interact with and understand. He and his team often have to work closely with researchers to ensure that the messages from the data are clear and simple while still maintaining its scientific integrity. Presenting complex information is a real challenge and both technological solutions and the way the results are communicated needs to be adapted to suit the target audience. For example, the aim of a new project they are working on with the Zietz Foundation is to take live data feeds from satellites and send information to poor famers in Kenya via their mobile phones to help them to improve their crop productivity. Although mobile phones are very widespread, most of them are low tech, text only phones rather than smartphones. Key questions therefore centre on ways to present big data on a small screen for localised use: How does the satellite data relate to what is happening on the ground? How can that information be communicated in a way that helps people to make practical decisions?

The **Cambridge Forum for Sustainability and the Environment** was established in 2013 in the University of Cambridge. Chaired by Lord Martin Rees, it meets once a month, bringing together thought leaders from the worlds of research, policy and industry to talk about some of the great sustainability challenges the world faces in the future and the research pathways which will help to prepare for and address those challenges.

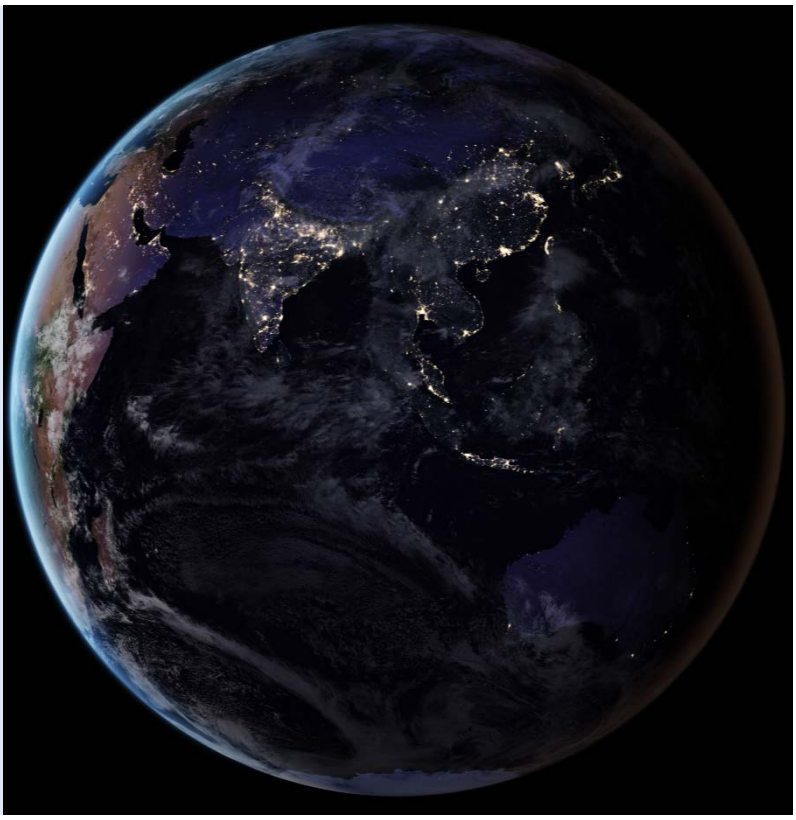
Catalyzing collaboration

To help facilitate the collaboration between JRC and Cambridge, an EPSRC Institutional Sponsorship Grant was given to a joint project between the Forum and the Global Security and Crisis Management Unit at JRC. This four-month project employed a Cambridge-based research assistant, Adrià Descals Ferrando, to start to explore questions which could be answered by overlaying two of JRC's remote-sensing datasets:

Global Surface Water Explorer, which measures changes in the location and persistence of surface water globally, by region or for a specific area.

Global Human Settlement Layer, which provides information about where people live, how big settlements are, how they have changed over time and the density of built up areas.

Both of these have unprecedented levels of spatial detail for global data (30m resolution) and span the last 30 years. This proof of concept project explored ways in which combining data from both of these could provide information to inform policy, such as tracking progress towards the Sustainable Development Goals, and enable faster responses to environmental extremes and acute threats. The preliminary results produced by this project are now being used as the basis for a deeper parallel exploration of both these datasets.



When and how to use remotely sensed data was another recurring theme. Stephen Peedell and Scott Hosking both argued that remotely sensed data does not replace the need for ground sensors and information, but instead compliments it. Remote sensing data will always needs to be 'ground-truthed' – verified using data collected at a local level. Finding ways to be able to support long-term, ground and air based datasets will be an essential part of answering the questions we need to ask about food security in the future. Aligning remote sensing data with other kinds of datasets also provides context and cements connections between changes in the environment and the effects on people's lives. Dr Francois Kayitakire, who also works at JRC, agreed. He leads a team focusing on resilience and on food and nutrition security assessment and highlighted the multi-dimensional approach they are taking to look at food crises and food need, based on bringing together information on social, economic, people's behaviour and their diet with remote sensing data. An emerging area of development for both them and the European Commission is to think about food security in terms of resilience and building safety nets, putting in place response mechanisms and managing risk. In order to tackle challenges such as this, it was agreed that a key focus for future research needs to be finding ways to forge links between large-scale datasets and data that are gathered at a more local level.

Steven Peedell also highlighted research gaps related to the collection and processing of data to measure resilience and risk, and to be able to use past information as a means of informing and validating future predictions. Focusing on protected areas, he argued that although a lot is known about risks, there is relatively little comprehensive information about the local conditions within and surrounding them and the drivers and pressures these exert. There is therefore a need to look beyond simple area-based targets and instead concentrate more on the effectiveness and vulnerability of protected areas, both now and in the long term.

This discussion led to the following question: How do we collect and analyse data given the pace of change? Julian Huppert, former MP for Cambridge, argued that there is a lot of good evidence-based policy-making in areas of governance where the is less scrutiny resulting from ideological, political pressures. While it is possible to collect information about what is happening and use it to try to predict what may happen in the future, to be able to see those changes well enough in real time and then create responsive policies is particularly challenging. For example, when looking at environmental change, there is a tendency to look back in time at long-term changes, such as land use in 1990, 2000 and 2010. However, the pace of change is now so much faster that there is a need to find ways to turn raw data into information products that feed into policy processes much more rapidly. In principle, such information could be used to make decisions at both a local scale and to track progress toward international-level targets such as the Sustainable Development Goals. Conversely, more research into how data affect decision makers was also recommended, as there are inevitably external factors that override the influence of scientific advice on policy decisions.

There were also concerns over the proprietary nature of some datasets, issues regarding data standards and data confidentiality. Publicly funded institutions such as the Joint Research Centre have open data policies and strict guidelines surrounding data standards as well as the infrastructure to provide technical and content updates and support. Other data providers, such as private companies, do not have such obligations and can choose which data they put in the public domain, for how long and the conditions they attach to using it. Privately held data contains a wealth of detail and information and there is a danger that if these datasets are not openly and transparently made available, opportunities to address local and global scale challenges may be lost. There are many commercial datasets which can be applied to answer environmental questions, such as using images from Google Earth to look at the development of new roads which might increase the vulnerability of protected

What role can citizen science play in this ‘new world’ of open, big data?

areas to logging and hunting. How do researchers steer the collection and dissemination of these commercial datasets in the a direction that will help target the pressing environmental challenges of the future? Ultimately, sharing data may raise confidentiality concerns, but it was agreed that these should be weighed against the potential value derived from data being examined from a wide range of perspectives.

A systems approach

The resilience of food chains was examined, and Dr Mukesh Kumar, from the Institute for Manufacturing, identified three principle areas of concern: crop failure, product failure and supply chain failure. This was echoed by Professor Jaideep Prabhu from the Judge Business School who discussed food waste in developing countries stemming from supply chain issues, such as the lack of information for farmers concerning neighbouring areas and consumer requirements, as well as the need for a better cold chain.

Throughout the three months the need for a multidisciplinary approach to food security was emphasized. Dr Francois Kayitakire argued that there are a number of interrelated issues that must be considered as part of a system approach. These range from conflicts surrounding resources to the need for income-related social protection to help bolster access to food. Our goals and the means to achieving them should therefore orientate around a problem, rather than a discipline. This general approach was echoed by Dr Drew Purves, an ecologist who now works for Google Deepmind. He emphasised that food must be part of a global system, particularly given the increasing risk posed by climate change. It was also repeatedly stated that a long-term view is needed to build resilience in food and water systems, although short-term interventions are also needed when an immediate impact is required.

Research challenges on the horizon

Many of the challenges we face when we think about securing future food and water supplies require a multi-disciplinary perspective, both to know what questions we should be asking and to know how to answer them. Training a new generation of researchers who are not only technical experts but also familiar with the underlying environmental, social and economic issues was agreed to be an important step. Finding ways to use existing technology and analysis techniques from a range of different disciplines and sources will also be essential. Many of the questions generated during these three meetings focused on ways to turn the massive amount of data being generated by satellites and programmes such as Copernicus into information that people can use to make decisions in ‘real time’. Those who could benefit from this information range from farmers looking for information on when to plant their crops to policymakers looking for ways to track progress towards global targets such as the Sustainable Development Goals. Many of the witnesses argued that we are in new territory when it comes to the speed and scale of data collection. Given this, turning raw data into information products to feed into policy processes and create responsive policies is particularly challenging. Although remotely sensed datasets contain a wealth of information, there is still a need to ground-truth those datasets and combine them with economic, social and biological information to build up a comprehensive picture of he current state of the global environment and our ability to withstand change. Witnesses from the JRC also emphasised the need to think about food security in terms of resilience and of building safety nets, putting in place response mechanisms and managing risk. In order to tackle challenges such as this, it was agreed that a key focus for future research is to forge links between large-scale datasets and data that are gathered at a more local level.

The **Cambridge Forum for Sustainability and the Environment Secretariat:** Prof. Paul Linden (Director); Dr Rosamunde Almond (Executive Secretary) and Simon Patterson (Content Writer and Editor).

Forum members for this topic were drawn from 15 Departments, Centres and Initiatives, including: Prof. Alison Smith (Dept of Plant Sciences); Prof. Danny Ralph (Centre for Risk Studies); Dr Emily Shuckburgh (British Antarctic Survey); Dr Helen Curry (Dept of the History and Philosophy of Science); Dr Hildegard Diemberger, (Dept of Social Anthropology); Prof. Doug Crawford-Brown and Prof. Ian Hodge (Dept of Land Economy); Prof. Ian Leslie (Computer Laboratory); Dr Jake Reynolds and Polly Courtice (Cambridge Institute for Sustainability Leadership); Dr Julian Huppert (POLIS); Prof. Koen Steemers (Dept of Architecture); Dr Miles Parker (CSaP); Prof. Paul Dupree (Dept of Biochemistry); Prof. Peter Guthrie (Dept of Engineering); Dr Shailaja Fennell (Centre for Development Studies) and Prof. Susan Owens (Dept of Geography).

We would like to thank everyone who took part in Forum meetings related to this topic, especially the expert witnesses and guests who joined us from across and outside Cambridge:

Witnesses:.Stephen Peedell, Dr Francois Kayitakire and Thierry Nègre (JRC); Dr Mukesh Kumar (Institute for Manufacturing, University of Cambridge); Prof. Alan O’Neill (Cavendish Laboratory, University of Cambridge); (JRC), Dr Matthew Smith (Microsoft Research), Craig Mills (Vizzulaity), (JRC), Prof. Jaideep Prabhu (Judge Business School) and Dr Drew Purves (Google Deepmind).

Internal guests: Dr David Coomes and Dr Will Simonson (Dept Plant Sciences); Prof. Keith Richards and Therese Rudebeck (Dept of Geography); Dr Marla Fuchs (Research Strategy Office); Dr Martin Roberts (Cambridge Centre for Sustainability Leadership); Dr Nazia Mintz-Habib (Centre for Development Studies) and Kirsten Van Fossen (IfM).

External Guests: Gregoire Dubois and Dr Pamela Kennedy (JRC); Daria Dadam (BTO); Dr Gavin Shelton, (FFI); Dr Graeme Buchanan (RSPB); Prof. Neil Burgess and Tim Wilkinson (UNEP-WCMC) and Simão Belchior (Vizzuality).