Space-enabled Innovation in Peatland Monitoring

Case Study on the Peatland Assessment in South East Asia by Satellite (PASSES) Project

About the UK Space Agency's International Partnership Programme:

1. The UK Space Agency's International Partnership Programme (IPP) is a five-year, £30 million per year initiative designed to utilise the UK space sector's research and innovation strengths to deliver sustainable economic, societal and/or environmental benefits to developing countries. Projects within IPP span a range of themes including: building climate/disaster resilience; improving agriculture; reducing deforestation; preventing and reducing maritime pollution and illegal fishing; optimising renewable energy production; and improving access to appropriate and affordable financial services.

2. IPP is funded from the Department for Business, Energy and Industrial Strategy's (BEIS) Global Challenges Research Fund (GCRF). This £1.5 billion Official Development Assistance (ODA) fund supports cutting-edge research and innovation on global issues affecting developing countries. ODA-funded activity focuses on outcomes that promote long-term sustainable development and growth in countries on the OECD Development Assistance Committee (DAC) list. IPP is ODA compliant, being delivered in alignment with UK Aid Strategy and the United Nations' (UN) Sustainable Development Goals (SDGs).

Space-enabled Innovation in Peatland Monitoring: Case Study on the Peatland Assessment in South East Asia by Satellite (PASSES) Project

The Peatland Assessment in South East Asia by Satellite (PASSES) project was supported by the UKSA International Partnership Programme in Indonesia and Malaysia from 2018 to September 2020. This case study explores the value of peatlands, the challenges associated with assessing their condition and the development of an innovative, space-enabled approach, applicable to the monitoring of peatland conditions in South East Asia and beyond.

Peatlands provide vital ecosystem services but are being rapidly degraded

Peatlands are a type of wetland that occur in almost every country on Earth. The term ‘peatland’ refers to the peat soil and the wetland habitat growing on its surface. Peatland landscapes vary across the globe, ranging from blanket bogs with open, treeless vegetation in areas of Scotland to the dense swamp forests of Southeast Asia. New areas are still being discovered, such as the vast area of peatland recently found in the Congo Basin.

In peatland areas, year-round waterlogged conditions slow the process of plant decomposition to such an extent that dead plants accumulate and eventually form peat. Over millennia, this material builds up and can become several metres thick. Large amounts of carbon, fixed from the atmosphere into plant tissues through photosynthesis, are locked away in peat soils. Peatlands represent the largest natural terrestrial carbon store on earth.

> *Peatlands and organic soils contain 30 percent of the world’s soil carbon but only cover 3 percent of the Earth’s land area. Fifteen percent of peatlands are drained and used for agriculture, grazing, peat mining and forestry, especially for bioenergy plantations. Including emissions from peat fires, these drained peatlands emit almost 6 percent of anthropogenic CO_2 emissions. This represents almost 25 percent of emissions from the entire land use, land use change and forestry sector. Once the peat carbon is lost, the losses are virtually irreversible. Peatland conservation, restoration and improved management are low-hanging fruit for climate change mitigation.* ***(FAO, 2012)***[1]

As well as acting as effective carbon stores, peatlands provide a range of other vital ecosystem services. In their natural, waterlogged state, they regulate water flows, minimise the risk of flooding and drought, and prevent seawater intrusion. In many parts of the world, peatlands supply food, fibre and other local products that sustain local economies.

Unfortunately, the role played by peatlands in the supply of these ecosystem services has not been widely appreciated. This has led to widespread degradation of peatlands from the tropics to the poles as a result of drainage, agricultural conversion, burning, mining for fuel, and other damaging actions. Some of these, such as converting land for agriculture or forestry use, can lower the water table. When the water table in a peatland is drawn down, oxidation occurs. This leads to a rapid loss of stored carbon into the atmosphere, mainly in the form of the greenhouse gas (GHG) carbon dioxide (CO_2). Degrading peatlands emit huge amounts of greenhouse gases that persist for years if not decades.

Mapping of peatland conditions is essential for sustainable management and restoration but extremely challenging.

Mapping peat and monitoring its condition are essential for effective planning and implementation of peatland management and restoration activities. At global and national levels, the importance of peatlands is receiving growing recognition. A number of national and international conventions and policies have highlighted the need for sustainable peatland management, including those aimed at protecting habitats, biodiversity and carbon stocks, and reducing GHG emissions. The United Nations Framework Convention on Climate Change (UNFCCC) includes peatlands in its Kyoto Protocol, the Paris Climate Agreement, and national GHG reporting and accounting frameworks. The Intergovernmental Panel on Climate Change (IPCC) provides technical recommendations to the UNFCCC and has produced guidance on reporting on GHG emissions from drained, rewetted and burning organic soils, including peat. GHG emission reporting must follow the principle of transparency in its measurement, reporting and verification (MRV).

Effective peatland mapping and monitoring enables those charged with managing peatlands to:

- Locate peat deposits and more accurately assess peatland area and carbon stock
- Obtain information on the peatland condition (i.e. intact or degraded, and the extent, type and likely causes of degradation) and identify areas at risk or in need of restoration
- Formulate appropriate action plans including enforcement of land use regulations
- Monitor the success of management interventions and inform corrective action.

Proxy indicators of peatland conditions include soil moisture status, ground water levels, and the vertical displacement (or 'subsidence') of the peat surface. Downward vertical displacement is associated with draining peat and deteriorating peat condition, whereas upward displacement is associated with improving peatland conditions. Historically, there are two main techniques for measuring subsidence. The first is ground monitoring, typically done by setting up a station with a measuring pole driven through the peat and into the bedrock, and periodically observing the relative level of the peat surface. The second uses aerial LIDAR, whereby an interferometric sensor is mounted on an aeroplane and makes scans of strips (transects) of a given area.

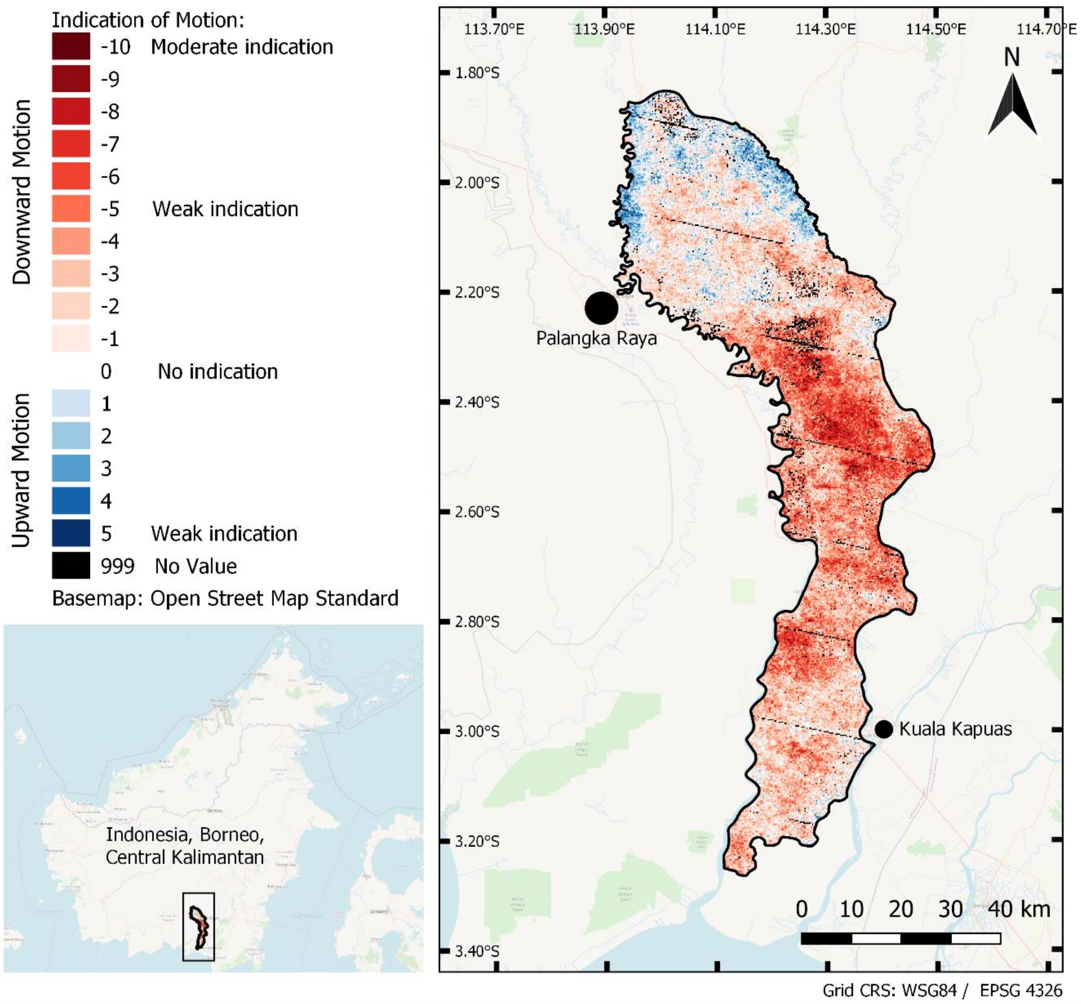
The challenges facing these approaches include the very large scale of peatland areas in countries such as Indonesia and Malaysia, inaccessible terrain, complexity of peat composition, safety issues related to manual data recording on the ground, damaged or lost equipment, human error, and the high cost of time series monitoring over large areas. The use of satellite-based remote sensing technologies has the potential to offer a solution but also faces challenges:

- Peatland conditions are affected by many complex factors, e.g. topography, peat texture, management practices and fire. This means satellite monitoring needs significant ground-truthing and field measurements for calibration and informing interpretation processes.
- Optical Earth observation (EO) techniques for mapping and monitoring of peatlands in tropical forest regions are affected by the amount of cloud cover and the dense forest canopy.
- Although radar based remote sensing approaches can penetrate cloud cover, they are plagued by 'noise' interference caused by the surface vegetation.

PASSES is an innovative INSAR-based[1] solution to monitoring the condition of peatlands with many potential applications

The PASSES project aimed to provide a solution to these challenges. The project was implemented by a consortium led by CGI UK Ltd. While CGI had responsibility for project management and software development, the core innovative component of the PASSES approach is the Intermittent Small Baseline Subset (ISBAS) satellite radar data processing technique, which is the propriety product of the consortium partner, Terra Motion.[2] Other members of the PASSES consortium were the University of Leicester (UoL), University of Nottingham (UoN) and Liverpool John Moores University (LJMU). IPE Triple Line provided monitoring and evaluation support to the project.

Product: PASSES PeatMotion-Index. **Area of Interest:** Peatland Hydrological Unit (PHU) between Kahayan and Kapuas rivers, Central Kalimantan, Borneo, Indonesia. **Epoch Dates:** 04/01/2016 to 24/12/2017. **Colour ramp:** Stretched across majority of scale for feature identification in this epoch.



The ISBAS algorithm at the heart of the technique is designed to filter out the abundant 'noise' from ground cover vegetation and provide a probable aggregate measures of ground motion from the remaining measurements.

---

[1] Interferometric Synthetic Aperture Radar (INSAR)
[2] Formerly known as Geometric Ventures Limited (GVL)

The PASSES project originally aimed to develop a comprehensive and cost-effective satellite-enabled monitoring solution through processing data freely available from the EU Sentinel-1 and Sentinel-2 satellites (S-1, S-2 and S-3). The team considered using combinations of radar Sentinel-1 data and optical Sentinel-2 data, but decided to focus efforts on the use of the ISBAS technique and the development of a product for monitoring the indicative displacement of the peat surface as a proxy indicator of peatland condition, which has been named as the PASSES 'PeatMotion' product.

PeatMotion has been validated for use in peatlands by using field instruments deployed in test areas representing a range of peatland conditions under several different land use scenarios. Although more widespread and longer time series validation is required, evidence so far indicates that it is a reliable method for monitoring the trends in the vertical movement of the peat surface in vegetated areas such as peat forest canopy. This means the product can be used to understand the likely indicative movement of the peat surface, from which a user can conclude whether the area being observed is rising, falling, or remaining stable, and what this means for the peat condition. The figure above illustrates how PASSES PeatMotion data can be presented to inform assessments of peatland conditions over wide areas.

The PASSES PeatMotion product has the following technical characteristics:

- The information provided in each pixel is a qualitative indicator of net surface motion occurring over approximately two years.
- The surface motion direction is either up or down perpendicular to the surface.
- The surface motion indicator applies to the area encompassed by each pixel, which is approximately 250m by 250m.
- Where the PeatMotion product shows a strong indication of surface motion, there is a correspondingly strong expectation of net surface motion at that location in the landscape over the two-year period that the product applies, in the direction indicated by the product.
- Where there is weak or no indication of surface motion, there is an expectation that the landscape is likely to be stable overall within the 250m by 250m pixel area.
- The product is a geospatial raster in Geotiff format with pixel size of 250m. Landscape-scale features, such as a peatland hydrological unit or region of forest / agriculture, can be investigated using one or more pixels of this size.
- The PASSES products cover the peatlands of Indonesia and Malaysia, with the earliest observations starting in 2016.

The 250m pixel size was chosen to highlight key features of ground motion at a scale that end-users could utilise for peatland management. The product could also be augmented with other EO or ground-based observations such as land use, landscape features, history of drainage activities and fire history to further understand the peatland context and interpret the PeatMotion data.

Interviews with potential users and observations during product demonstrations and knowledge exchange meetings indicate many potential applications of the current PeatMotion product: it could help prioritise areas for peatland restoration activities; it could make estimations of GHG emissions from peatland areas more accurate by acting as an additional variable in methodologies; and it could assist with landscape level land-management interventions such as the regulation of oil palm production on peatland areas.

In the longer-term the ISBAS PeatMotion product could be used more widely. The measurement of vertical displacement is thought to be transferrable to other bioclimatic contexts.

Members of the consortium already have links to programmes monitoring peatland conditions in central Africa, where large areas of peatland have recently been discovered and are under threat from exploitation and degradation, and South America. Consortium members believe that there is also potential to adapt the technology to monitor extensive areas of permafrost in Alaska, Canada and Russia, where there is a risk of climate change leading to thawing of permafrost and the release of carbon.

What next?

Towards the end of the UKSA funding period, the demonstration of the PASSES PeatMotion product generated interest from several potential users and intermediaries. The sustainability of PASSES products and services and the potential scaling of their application in South-East Asia and beyond is dependent on several factors. These include building on the collaborative relationships developed, securing funding for further product development, navigating the complex institutional landscape in the region, and developing marketing strategies to reach potential users.

It is clear that some of the approaches developed under PASSES will be continuing. The FAO has expressed interest in co-operating in the parallel development of the PASSES PeatMotion product and its SEPAL programme for peatland monitoring, and there has been a verbal agreement that some members of the consortium will continue to cooperate with FAO beyond the period of IPP funding. Sample PASSES products have now been shared on the PRIMS platform[3] operated by WRI on behalf of the Indonesian Peatland Restoration Agency, providing exposure to a range of potential users who already have an interest in peatland management and restoration.

As part of the process of establishing ground-truthing data to support the development of the PeatMotion product, the PASSES team designed, built and installed low-cost, camera-based peatland monitoring stations (see figure below for an example monitoring station installed in a farmed peatland area in Indonesia). This simple and inexpensive technology has proved to be reliable and is popular with collaborating partners in Indonesia and Malaysia, with some replicating the innovative design for their own peatland monitoring activities. The monitoring stations established through PASSES will continue to be operated by collaborating partners including WRI, Malaysian Palm Oil Board, University of Palangka Raya and the Borneo Nature Foundation, building up the ground-based data over a longer time period. This is essential to support the further refinement and validation of the PASSES PeatMotion product and will also contribute to the general scientific body of knowledge on peat behaviour in the region. The consortium member CEH will collate this data as well as the data collected in a growing global network of peatland monitoring stations.

---

[3] Peatland Restoration Information and Monitoring System (PRIMS)

At the same time as developing and testing the application of the PASSES PeatMotion product for peatland condition monitoring, Terra Motion and partners have been developing a refined version of the ISBAS product which operates at a significantly higher resolution (20m or less) and with higher frequency data, providing opportunities for greater accuracy, quantified estimates of vertical displacement, and the potential to provide data which allows practical application to inform sustainable peatland management and restoration activities. Such applications would include those identified as useful by potential users, including monitoring the efficacy of rewetting activities such as canal blocking or monitoring the impact of land management and ground water level management in oil palm or pulp and paper plantations on peatlands. It could also be used by government agencies, non-government organisations and industry market regulators to monitor the performance of private sector companies and their compliance with sustainable peatland management guidelines and regulations.

The experience and learning gained through the development of the PASSES PeatMotion product represents an important step towards more effective monitoring of peatland conditions over vast areas. This technology has great potential for further development. It can contribute vital information to inform better sustainable management and restoration of peatlands. This is essential to ensure that peatlands can continue to store GHG and provide their wide-ranging ecosystem services.