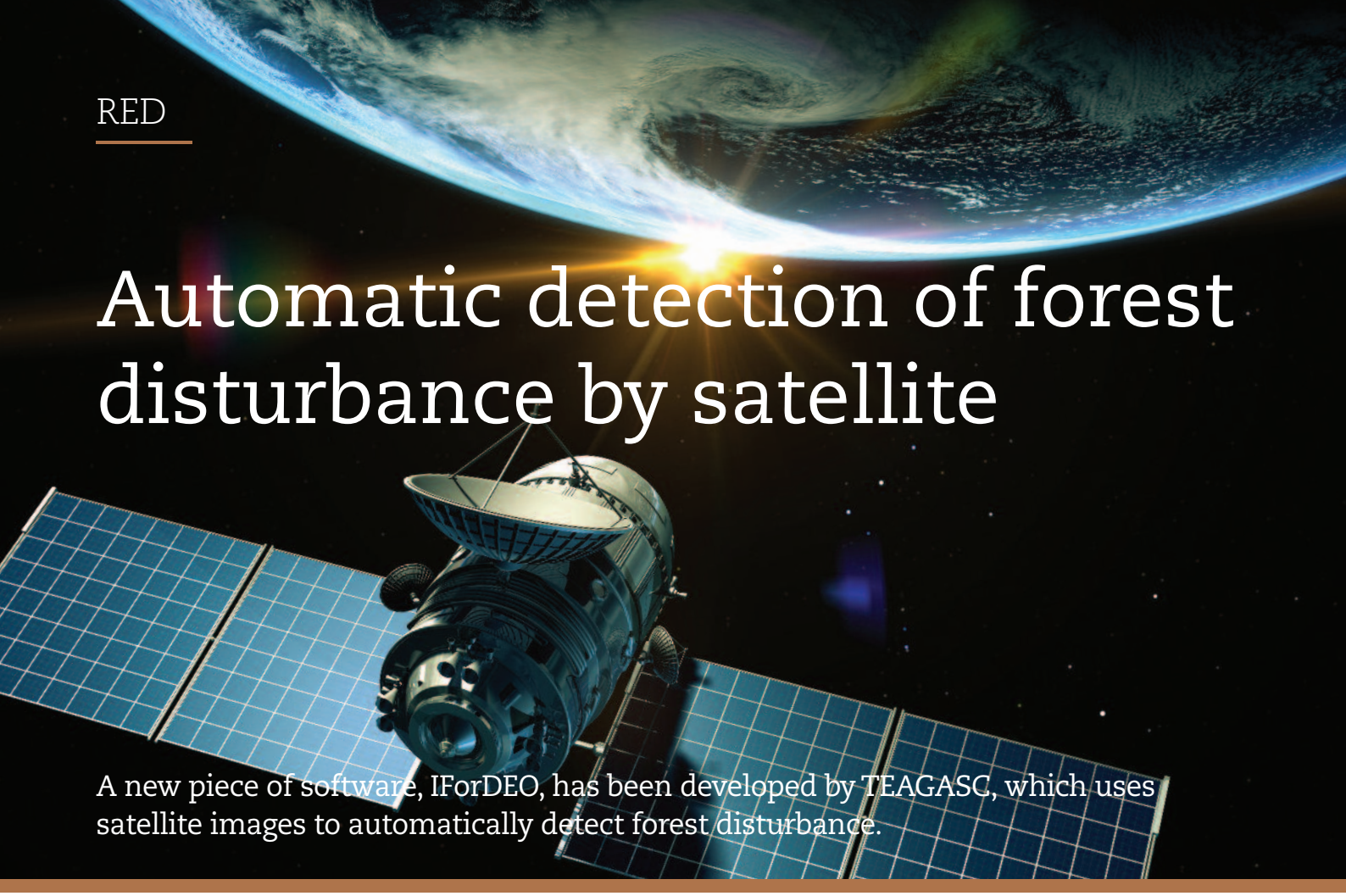
Automatic detection of forest disturbance by satellite



A new piece of software, IForDEO, has been developed by TEAGASC, which uses satellite images to automatically detect forest disturbance.

The Department of Agriculture, Food and the Marine-funded project, CforRep, led by UCD with partners in University College Cork, University of Limerick and FERS Ltd., aimed to improve Ireland's reporting of the forest carbon budgets and how they change. Teagasc's role was to estimate a baseline for forest cover in 1990, devise a method for detecting disturbance in the current forest cover, and to build a system to remotely monitor forestry. Disturbance of forestry is important (whether planned like felling or thinning, or unplanned like storm damage), as the disturbance events can possibly alter the carbon stored in the forest soils. Our partners are experimenting to see exactly how soil carbon pools are disturbed, and in Teagasc we are using remote-sensing satellites to detect that disturbance.

Software for analysing forestry cover

Remote-sensing satellites orbiting the earth continually record images of the surface below. These images are not only recorded as conventional visible images, but the systems also measure non-visible components of the reflected sunlight. These multi-spectral images can be processed within specialised computer systems and the image pixels classified into different land covers. This is a multi-stage process that involves receiving raw image data, correcting and geo-coding, and quality control through to classification and assessment. The project needed to be able to track the lifecycle of every forest in Ireland from the 1980s using thousands of satellite images. This objective required that processes be automated. The software developed is an open source Python library of modules and scripts – IForDEO (Ireland Forest Disturbance from Earth Observation). The modules operate automatically to process, classify, and assess satellite images as they become available. Significant work was also put into creating a long-term archive of imagery from a number of satellite receiving stations across Europe, to create the historical image archive existing for the island of Ireland.

Landsat archive

Every available image in the Teagasc Landsat Archive that was acquired between March 23 and October 10 (March 24 and October 11 in leap years; currently 2,345 images) is classified, along with any new imagery available from the United States Geological Survey (the system currently utilises LANDSAT (TM), ETM+, and OLI/TIRS data, and European Space Agency Sentinel-2 data will be incorporated in the next iteration). The data is quality controlled, re-projected into Irish Transverse Mercator (the geographic co-ordinate system for Ireland) projection, and checked for cloudy and cloud-shadowed pixels. All clear land pixels are classified, resulting in a time series of land covers from the year 1984 on for every pixel. This time series is processed for outliers using a series of statistical and logical rules (for example, a pixel can't go from forestry to urban to forestry over a month – clearly the urban classification is an error).

National forestry inventory

The basic land use classifications are forestry, grassland, cropland, natural vegetation, and urban. Thus, the software can produce a basic land cover map for any year since 1984 and into the future. One important land cover map produced was in the year 1990. This year is important as it is the baseline reference year for land use change under the Intergovernmental Panel on Climate Change (IPCC) reporting protocols. Up until now, there was no land use data for 1990 of sufficient spatial resolution to act as a reliable reference for reporting land use change in Ireland. The IForDEO 1990 land use map allows us, for the first time, to estimate the land use of current forestry in the National Forest Inventory as it was in 1990 and, thus, improve our estimate of carbon sequestration achieved by the national forest planting programme. The final module in the IForDEO suite tracks activity within the Forest Inventory Parcel System (FIPS). The same process of classification and time series analysis is instead used to classify year-on-year activity within

Forest cover change in the Ballyhoura Mountains

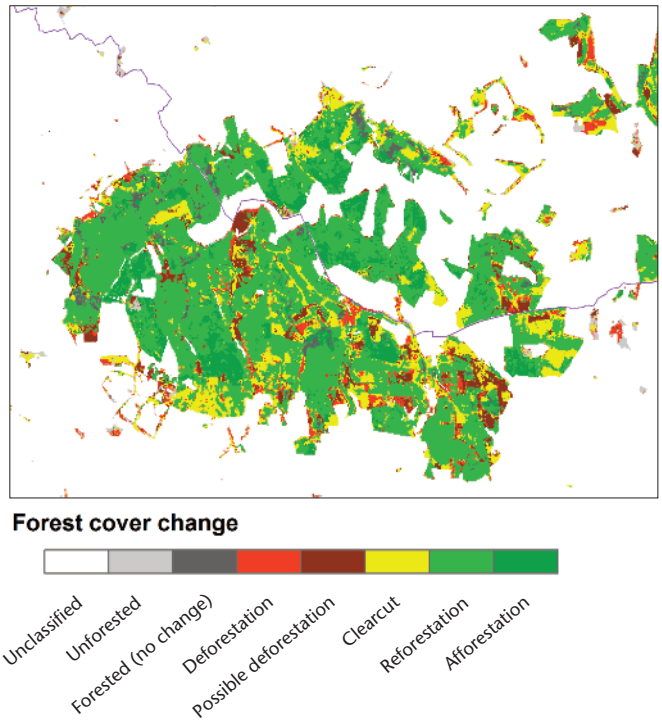


FIGURE 1: Landsat-derived 1990 land cover for forestry in the Ballyhoura Mountains, in counties Limerick and Cork.

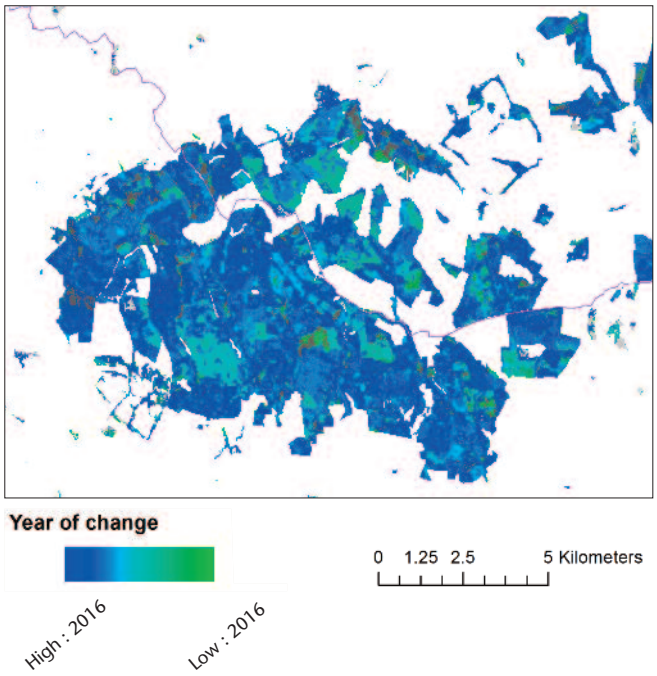


FIGURE 2: Type of forest cover change in the Ballyhoura Mountains (1985 to 2016), with date of most recent change.

forests. Because under IPCC accounting rules deforestation has a particular meaning (the permanent removal of forestry, not just the felling of trees), current activity in a forest plantation has to be assessed with reference to the previous ten-year period. Current forest conditions are classified as a number of states including continuing forestry, reforestation, and deforestation. Deforestation is classed where trees have been removed and there is no sign of replanting/regrowth within 10 years. Possible deforestation is where trees have been removed from an existing plantation less than ten years from the present, and accounts for situations where young forest canopies can be spectrally confused with grasslands or croplands due to the presence of visible understory vegetation (shrubs and plants growing under the main canopy of the forest). The software also maps the year of the last significant change.

State of the national forest

Teagasc and the Forest Service can now automatically produce an annual state of the forest map with little more than a touch of a button, though the full analysis can take a number of days to run.

With our partners in University College Cork, we are looking at integrating specialist synthetic aperture radar (SAR) imagery into our system. SAR is advantageous as unlike optical sensors, it can acquire data both during the day or at night, is unaffected by cloud cover, and is primarily sensitive to the geometric properties of the target. Thus, SAR is particularly useful for identifying the type of disturbance, e.g., distinguishing between felling and wind throw events.

In the future IForDEO will be adapted to use additional satellite data, including from SARs like Sentinel-1 and ALOS-2 PALSAR, and optical sensors like the ESA's Sentinel-2, DLR's EnMAP, and the NASA EO-1 Hyperion to improve our classification of current status. Furthermore, we will be adapting the process to look at grassland and cropland and other land cover/land use change dynamics. For details on the Landsat archive and scripts contact Guy Serbin at Teagasc Johnstown Castle.

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Authors

Stuart Green
Senior Research Officer, Teagasc, Rural Economy and Development Programme, Ashtown, Co. Dublin
Correspondence: stuart.green@teagasc.ie

Guy Serbin
Research Officer, Teagasc, Crops, Environment and Land Use Research Programme, Johnstown Castle, Co. Wexford

Fiona Cawkwell
Lecturer, Geography, University College Cork

Kevin Black
Director, Forest, Environmental Research and Services (FERS) Ltd.