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Identifying pressures • Informing policy • Developing solutions

TaLAM: Mapping Land Cover in Lowlands and Uplands with Satellite Imagery

Authors: Fiona Cawkwell, Christoph Raab, Brian Barrett, Stuart Green and John Finn

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Government of Ireland
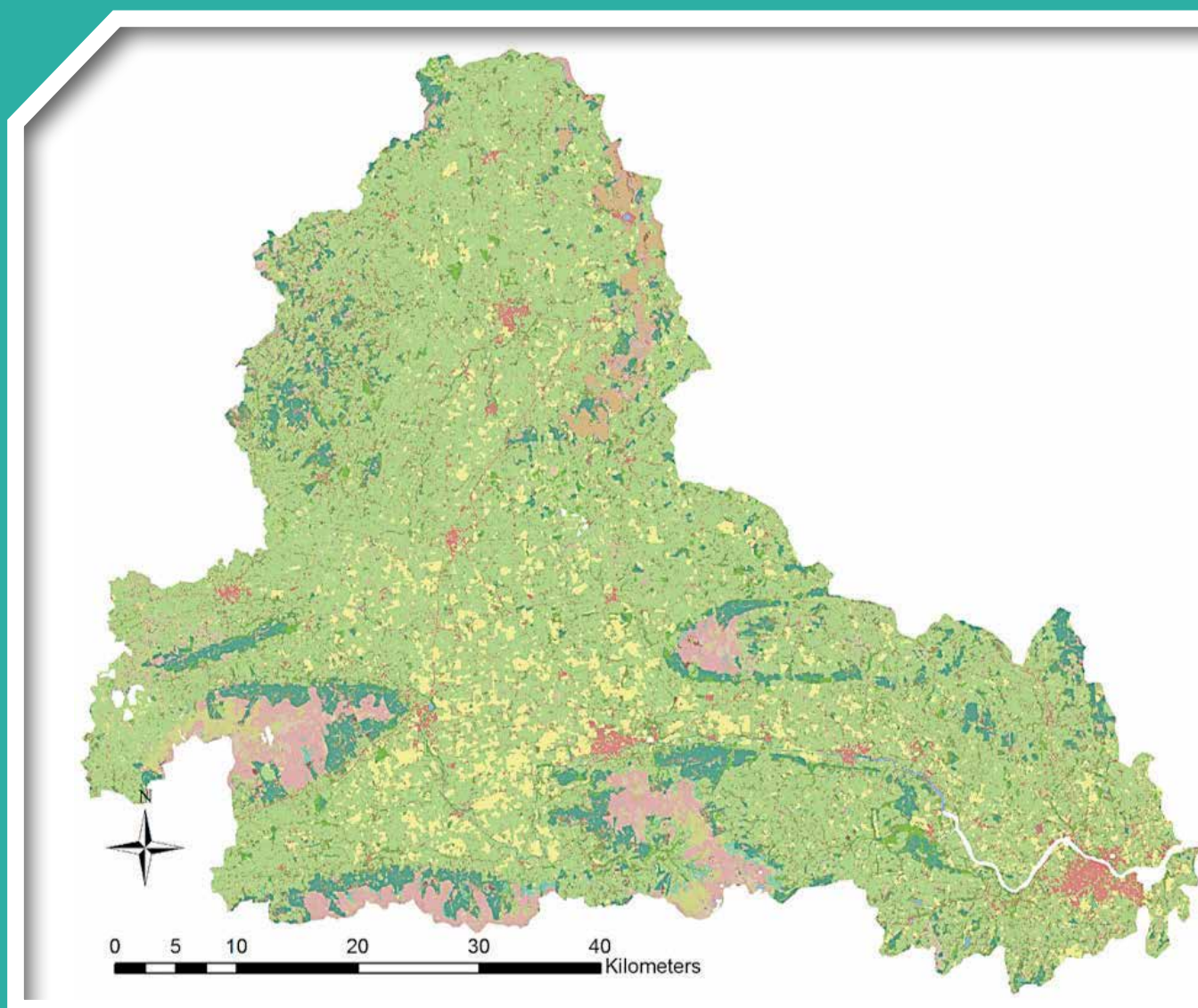
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The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

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EPA RESEARCH PROGRAMME 2014–2020

TaLAM: Mapping Land Cover in Lowlands and Uplands with Satellite Imagery

(2013-SL-MS-1)

EPA Research Report

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DISCLAIMER

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Executive Summary

Ireland has a need for maps of land cover and land use[1] to improve environmental management, policy implementation and calculations of the annual greenhouse gas budget.

The currently available data for Ireland [e.g. the European Coordination of Information on the Environment (CORINE) map] have their limitations because of scale, the types of land cover classified and the update cycle. Most other European countries have their own land cover mapping programmes; however, in 2016, Ireland did not.

Ireland can take advantage of being a latecomer to land cover mapping by adopting emerging best practice for land mapping systems that try to describe the wide variety of land covers and habitats that occur on a parcel of land, rather than attempting to give each area a single label. Best practice is to use satellite imagery in combination with existing official mapping to be able to give every area of land a cover and use designation.

The Towards Land Cover Accounting and Monitoring (TaLAM) project is part of Ireland's response to creating a national land cover mapping programme. Its aims are to demonstrate how the new digital map of Ireland, Prime2, from Ordnance Survey Ireland (OSI), can be combined with satellite imagery to produce land cover maps.

Prime2 maps the entire country seamlessly, with every road, building, watercourse and field defined as separate objects. Satellite images can be used to give more information on these objects, but in mountainous areas there are no defined objects and Prime2 leaves them as large, empty areas. Therefore, one important objective of the TaLAM project is to design a method that can fill in the blanks and map the land cover in these unenclosed areas.

To ensure TaLAM outputs are acceptable and useful to the professional community, a workshop was held to canvass opinion on mapping and reporting land cover change in Ireland. Using the Crowd Wise consensus-building approach, participants were introduced to a range of scenarios and, after discussion, individuals voted anonymously to rank each scenario from their least to most preferred choice.

For enclosed fields in Prime2, the preferred option was a minimum mapping area of 0.5 ha labelled with the percentage cover of all land cover classes within. For unenclosed upland regions, the preference was for the region to be broken up to create Prime2-type polygons of 2–5 ha, with all land cover classes labelled as a percentage and updated at 5-year intervals.

The Suir catchment was selected as a trial area and, using a technique called a random forest classifier, very high overall accuracies (>92%) were achieved for a land cover map of enclosed areas automatically created from satellite images (NASA's Landsat-8 satellite).

Methods for classifying the upland regions focused on the Galtee Mountains, the Comeragh Mountains and Mount Brandon. It was concluded that medium spatial resolution (5–50 m) imagery acquired from optical and microwave sensors enables mapping and monitoring of upland vegetation in broad categories. However, such imagery cannot replace detailed field mapping of habitats, and the subtle differences between habitats that are sometimes required, especially by conservationists and ecologists, cannot always be distinguished. Therefore, for detailed habitat mapping, the satellite mapping must be complemented by field mapping.

It is recommended that medium spatial resolution (5–50 m) optical and microwave satellite data are used for the land cover mapping of Ireland. The Prime2 fields integrate well with satellite imagery for creating land cover maps for enclosed areas; however, where these are not available, as in the upland areas, automatic segmentation techniques can derive land cover classes directly from the imagery.

Satellite data will never entirely replace field work, and a campaign to provide field data for a national

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1   Land cover tells you what is on the ground (grass, for example); land use explains the purpose (grazing, for example).

land cover map is needed. Automating the process for identifying change and updating national land cover maps remains a challenge, but with more image data available such automation will become a realistic possibility.

1   The Challenges of Land Cover Mapping

Globally, the mapping of land use and land cover and land use and land cover change (LULCC) is driven primarily by climate modelling needs, the monitoring of food security and wider environmental concerns, principally habitat loss.

In developing a land cover map, one of the first concerns is what land cover class labels to use. Historically, the question was first posed by western agronomists used to parcelling land according to a single use and a single cover (Stamp, 1948) and this practice became the norm in land cover mapping using remote sensing approaches (Anderson *et al*., 1976) and in many projects such as the Coordination of Information on the Environment (CORINE) – the internationally accepted and used European land cover map – which is still widely used today.

However, while land may be managed in parcels, these are boundaries that nature does not respect; a field in Ireland may be predominately grass but could have a patch of rushes or scrub, or any number of small habitats including the hedgerows that surround the field. A parcel of land often has more than one use (a forest may be used for timber but also recreation; a field may be used for grazing but also hay cutting).

This is even more true for natural landscapes, and so it is recognised that simple labels fail to adequately map the real world (Rocchini *et al*., 2013); as a result, more nuanced labelling systems are being developed as a soft or fuzzy classification, allowing multiple land cover types in an area, with the proportion of that pixel apportioned to each class indicated.

Satellite images (familiar to many from Google Earth) capture information in a similar way to a digital camera. The images are made up of pixels, each representing an area on the ground, and the data captured in each pixel represent the amount of reflected light (the colour) of all the land covers within that pixel. However, the world is not made up of discrete pixels. On a satellite image, the viewer recognises objects, such as a house or a field, not a pixel, and maps that classify objects are more easily interpreted than maps that classify pixels (the former are also often more accurate).

Where a predefined object exists, such as a mapped field boundary, a land cover map can classify that object based on the reflectance information from all the pixels within that object. Where predefined objects do not exist (for example in a commonage area), a process called image segmentation combines pixels in an image into regions with similar characteristics. These image-segmented objects often represent distinct areas on the ground (a patch of bracken or a scree slope for example). However, image segmentation is an ill-defined problem with no ideal solution or systematic rules for implementation (Carleer *et al*., 2005). Moreover, image-derived objects often do not maintain spatial integrity within a season, or between years, because of natural changes in vegetation, shadow and other illumination effects, cloud and atmospheric scattering, and human intervention (Hofmann *et al*., 2008). This makes monitoring change and defining areal measurement of changes in dynamic vegetation environments (Radoux *et al*., 2010) difficult and unreliable.

1.1   Land Cover Mapping in Ireland

Environmental Protection Agency (EPA) reporting on national annual statistics of LULCC relies on Central Statistics Office (CSO) information generated from a survey of approximately 30,000 farms, published on a county-wide basis each year (CSO, 2008). While data from the survey can provide gross area values of land cover types, only estimates can be made of how any one parcel of land changes over time (O'Brien, 2007).

The Europe-wide CORINE Land Cover (CLC) datasets remain the most widely used source of information for area and land use within Ireland, with data available for 1990, 2000, 2006 and 2012, reported at a minimum mapping unit of 25 ha, and 5 ha for land cover change. However, it is now widely accepted that these are not appropriate scales for mapping Irish land cover.

The absence of a suitable Irish-designed, national LULCC programme has been a noted failing for over a decade and has been highlighted by many users as having potentially serious consequences. This resulted in the establishment of the National Land Cover and

Habitat Mapping (NLCHM) inter-departmental working group to coordinate land cover mapping outputs with a medium-term goal of establishing a national land cover programme.

A number of projects have addressed specific elements of land cover, such as the national hedgerow map (Green, 2011), MOLAND (Monitoring Land Use Cover and Dynamics) for urban areas on the east coast (van de Voorde *et al*., 2009) and PIMLI (Peatlands of Ireland Mapped from Landsat Imagery) for identifying exposed and vegetated peatlands (Cawkwell *et al*., 2010). Other important national datasets that are used include the Land Parcel Identification System (LPIS) from the Department of Agriculture, Food and the Marine (DAFM), a high-resolution dataset containing unique identifiers for individual land parcels, with information on land use therein, and the Forest Inventory and Planning System (FIPS). While these datasets are useful for dedicated activities, many challenges exist in aggregating them for coherent national reporting because of their different spatial and temporal resolutions, and varied means of attributing land cover types.

Since 2006, the Irish national mapping authority, Ordnance Survey Ireland (OSI), has been developing a new geospatial database structure, Prime2, for intelligent, seamless mapping of boundary information which will support digital vector and cartographic products (OSI, 2014). Data capture resolution is between 0.1 m in urban areas and 0.5 m in rural areas, with the possibility to reduce the resolution to 3 m, 6 m or 15 m depending on the needs of a project. The EPA Irish Land Mapping Observatory (ILMO) project established Prime2 as the ideal mapping base for a national land cover map.

Daily overpasses from low-resolution sensors have been proven to acquire sufficient cloud-free data to allow creation of time composites of key phenological stages (O'Connor *et al*., 2012) but the 250–1000 m resolution of these datasets is not compatible with the Irish field scale. Work done by Nitze *et al.* (2015) demonstrates that the classification of Irish grasslands can be undertaken from selected dates throughout the year, representative of the different growth stages of different vegetation classes, with the acquisition of three to four cloud-free images required per year from optical sensors. High-resolution sensors (less than 5 m) have been used for mapping a variety of

LULCC for small regions within Ireland, but persistent cloud cover can cause problems in acquiring national imagery at suitable times of year.

In contrast to the optical systems, microwave wavelengths can penetrate through cloud cover and record the reflected energy from the ground beneath, making microwave radar sensors usable 24 hours a day in all weather conditions. Despite this value, microwave sensors have not been widely used for land cover mapping, as the processing of the data is more challenging and each sensor records at only a single wavelength, making it much harder to conclusively discriminate between land cover types. However, in recent years a growing body of research has demonstrated that, from a time series of microwave images, different land cover types can be distinguished with as much reliability as can be achieved in the optical domain (e.g. Barrett *et al*., 2014).

A number of approaches to land cover categorisation and definition have been adopted in Ireland, with the Fossitt (2000) classification the most widely utilised by field scientists. However, while valuable in the field, such a detailed classification approach is not realistic for satellite-based classification systems, which need broader definitions to successfully map vegetation types (most satellite images can be used to distinguish between broadleaved and coniferous forests easily, but not between Sitka and Norway spruce for example). In addition, satellite images can be used to map at only certain scales (satellites cannot generally identify species plants in a community in the way an ecologist may use a single species as a key indicator of habitat). Therefore, it is important that field scientists understand the limitations of satellite observation, and image processing scientists need to understand the requirements of users.

The goal of this project is to develop a process for mapping land cover that is compatible with Ireland's current and future needs. The outputs of the classification process will be used to populate OSI's Prime2 parcels for enclosed areas, and to generate and populate robust parcels in unenclosed areas.

The project name TaLAM derives from the old Irish word for land, *talamh*, a timely link between the historic needs for understanding and representing our landscape and the ongoing work with evolving technologies Towards Land Cover Accounting and Monitoring (TaLAM).

2   Review of Land Cover Systems Across Europe

Several European countries have developed national monitoring and accounting strategies. All of these approaches use remote sensing (satellite imagery or aerial photography) in combination with additional geospatial data. Together, these strategies are recognised as state-of-the-art approaches to land surface and change characterisation and monitoring (Hazeu *et al*., 2011). Increasingly, there is a need for these national land characterisation approaches to be integrated with European activities. The Harmonised European Land Monitoring (HELM) project was funded by the European Commission's Seventh Framework Programme to provide a framework for integration, and this report (Ben-Asher, 2013) has informed the findings and recommendations from the TaLAM project.

Land cover mapping programmes in the UK, Spain, Austria, Germany and Sweden were examined. Table 2.1 shows the broad characteristics of each

approach. The conclusion of this component of the study is that current standard approaches to land cover mapping use a mix of satellite and other sources of remote sensing data; they also use state-of-the-art object-oriented machine-learning classifiers. The objects are defined, where possible, from national authoritative mapping databases, but image segmentation is used to fill gaps.

Across Europe, the attribution of objects with percentage values for multiple land covers is common, and the smallest object mapped [minimum mapping unit (MMU)] is typically 0.5 ha. The maps are validated against existing databases or specially acquired field samples and have accuracies (where stated) ranging from 85 to 95%. This review of European land cover initiatives informed the selection of options that were put before the stakeholder group.

Table 2.1. Characteristics of some national land cover mapping initiatives across Europe

Country	Name	Year	Imagery	Map source	Schema	MMU	Overall accuracy
UK	LCM2007	2007	Landsat TM images	UK Master Map/ Image segmentation	Land cover	0.5 ha	83%
Spain	SIOSE	2009	Medium and low resolution	Spanish cadastre	Total % of land cover	0.5–2 ha	Unknown
Germany	DeCover	2008	Medium and high resolution	German cadastres	Dual description to each object	0.5 ha	>90%
Austria	LISA	2015	Satellite, aerial and LIDAR	Image segmentation	Multifactor object description	25-50 m	90–95%
Sweden	CadasterENV	Pilot	Medium and high resolution	Image segmentation	Single label	0.5 ha	Not tested

LCM2007, Land Cover Map 2007; LIDAR, light detection and ranging; LISA, Land Information System Austria; SIOSE, Sistema de Información de Ocupación del Suelo en España; TM, thematic mapper.

3   User and Producer Encounters

To ensure that the land cover maps produced by the TaLAM project are of the greatest possible benefit to Irish ecological and mapping professionals, a 1-day workshop was held on 23 October 2014 at Teagasc (the Agriculture and Food Development Authority), Ashtown. The object of the workshop was to set guidelines on mapping and reporting change in the TaLAM project in such a way that satisfies as many as possible of the day-to-day requirements and varied needs of the user community.

The TaLAM team began by giving a number of presentations on current approaches to land cover mapping in Ireland and across Europe (see Chapter 2 of this report). The group was then introduced to Crowd Wise, the formal method chosen to ascertain and record the consensus opinion. Finally, the voting process was undertaken followed by further open discussion on the results, leading to the formal conclusion and common agreement that a consensus had been reached.

In a Crowd Wise consultation, a number of scenarios that address the issue are presented. These scenarios are discussed and, during open group debate, the scenarios are amended or new scenarios added. Then, using a secret ballot, the scenarios are ranked for preference (with 1 being the lowest rank) by each participant. The votes are tallied and the scenario with the highest total rank is declared the consensus preference. The results are presented to the group with the option of further refinement and re-voting if the vote is close.

The key questions posed to the workshop participants were:

1. What is the smallest area we should map?

2. What is the smallest area we should map for change?

3. How pure should a land cover be?

4. How often should we map?

5. How persistent should a land cover be in order for it to be reported?

6. Should forest management be recorded?

7. Do we need to record the direction of change, or is area-based change sufficient?

In the enclosed areas, four scenarios were proposed with two added during discussion, and in the unenclosed areas, six scenarios were presented with one added during discussion

Before voting on the scenarios took place, the group was split into two and an exercise in participatory mapping was undertaken (Figure 3.1). Each sub-group

Figure 3.1. Comparing notes after the mapping activity.

was given large printed copies of an image of the same ground area and marker pens, but little instruction on what and how to map. The results of the discussions and annotation demonstrated how different outputs can satisfy the same apparent need, with each sub-group choosing to identify some features and not others, grouping common areas into larger polygons or keeping small discrete polygons.

3.1   Voting

Each participant anonymously ranked the scenarios from the least to most desirable and the voting sheets were tallied to determine the popularity of each scenario (it should be noted that the TaLAM team did not vote or express an opinion during voting).

The voting produced a clear winner in the unenclosed scenario, but a very narrow margin of difference between two options for the enclosed areas. This close result was discussed and the group decided not to re-vote. In both cases, the "classic" pixel-by-pixel approach was the least favoured.

For enclosed regions, the preferred option selected by the expert group was for a minimum object size of 0.5 ha and for each object to be labelled with the percentage cover of all land cover classes, as shown by the example in Figure 3.2. The desired repeat period is cover-type dependent. Land cover changes have to persist for at least 1 year to be recorded. Prime2 object integrity does not need to be respected, with sub-divisions allowed according to pre-determined rules. A very close second choice was for the

percentage cover of all land cover types recorded for each Prime2 object, with a minimum object size of 2–5 ha.

For unenclosed regions, the preferred option selected by the expert group was for image segmentation to create Prime2-type management polygons with a 2–5 ha range size (see Figure 3.3). Updates should be

Figure 3.2. Example of land cover percentages apportioned to enclosed Prime2 objects (where GS1 is dry calcareous and neutral grassland, GS4 is wet grassland, GM is marsh and WS2 is immature woodland).
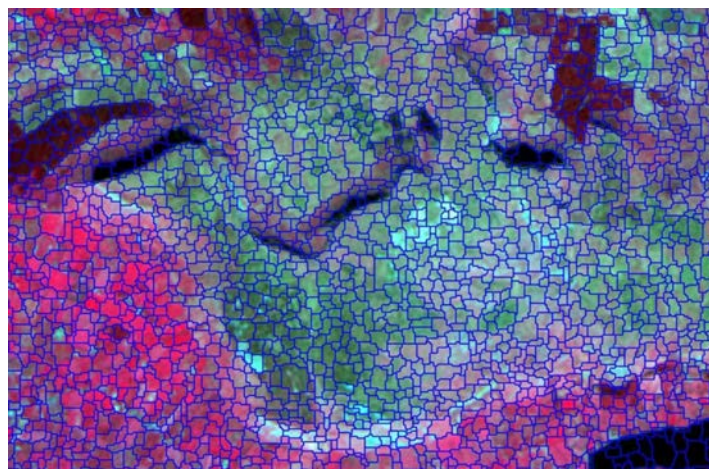
Figure 3.3. Example of segmentation (blue polygons) of unenclosed areas into Prime2-type objects; a false colour infrared image is shown.

undertaken at intervals of 5 years, with the integrity of individual polygons not respected between iterations.

All participants felt the day was rewarding and the Crowd Wise process simple and effective, with many commenting that they would recommend the approach. As an outcome, it is interesting to note that the two scenarios selected are not the ones that the TaLAM team would have chosen. This can be seen as both a vindication of the Crowd Wise approach for recording consensus and also the necessity of seeking expert opinions.

Following the successful consensus-building exercise in October 2014, a second opportunity was offered for stakeholder interaction to guide the remainder of the project and to continue ensuring that the outputs from the project would be of maximum value to the Irish end users. The TaLAM team presented their interim results on 30 April 2015 at the Teagasc School of Horticulture in Dublin Botanic Gardens. Many of the same participants who had attended the original consensus-building workshop were in attendance again. In advance of the workshop, the participants were encouraged to view and explore the interim products which were uploaded to a freely accessible ArcGIS mapping portal. The interim products were well received and, in the discussion that followed, the participants remained in agreement that the parameters voted for in October 2014 were the best-case scenarios for their needs. With this mandate, the TaLAM team continued to work on the mapping outputs.

4 Mapping with Optical Satellites

Taking into account the wishes of the stakeholder group, what is known regarding the European state of the art in land cover mapping and the availability of other mapping datasets in Ireland, two approaches to land cover mapping were tested. One was based on the integration of all geographic information system (GIS) datasets; the other was based on the classification of Landsat imagery.

The River Suir catchment in the south-east of Ireland (an area of approximately 3600 km^2 with altitudes ranging from near 0 to about 915 m above sea level) was selected as the test site. The predominantly rural land cover is characterised by arable and pastoral land in the lowland areas. The upland areas, including the Comeragh and Galtee Mountains, are associated with large areas of semi-improved grassland, heath and peatland.

The classification schema adopted by the National Survey of Upland Habitats (NSUH), funded by the National Parks & Wildlife Service (NPWS), and principally based on Fossitt (2000), was used. A total of 15 level 1 classes and 18 level 2 classes (see Table 4.1) were identified and a stratified random sampling approach was adopted for the selection of training and validation data.

4.1 Datasets and Methods

4.1.1 GIS data

The GIS datasets used were:

- OSI Prime2: the new national map base, providing a digital outline of all objects (fields, roads, rivers, etc.);
- DAFM LPIS: a database for farm payments where all land parcels are outlined and labelled as crop type;
- DAFM FIPS: a payment database from the forest service that maps all funded forestry (the Coillte database was also incorporated).

GIS techniques were used to fuse these maps into a single entity, ascribing crop or forest type from LPIS and FIPS to Prime2 objects.

4.1.2 Remote sensing data

In order to derive land surface information covering the Suir catchment for the 2013–2014 period, a set of 16 Landsat-8 (Level 1 Terrain Corrected) acquisitions were obtained, with three near cloud-free images selected. Landsat-8 carries on board the Operational Land Imager (OLI) sensor, which is constructed to record reflectance at a 30 m spatial resolution along a 185 km swath in the visible, near-infrared (NIR) and short-wave infrared wavelengths.

In Ireland, cloud cover is one of the major limitations in optical remote sensing (Nitze *et al*., 2015), and topography can also cause distortions and shadows. A number of approaches are available for dealing with these. As part of this project, the performances of different atmospheric and topographic correction strategies were evaluated (Raab *et al*., 2015) and recommendations made as to the best approach for Ireland (see end of project report for details).

4.1.3 Land cover classification of satellite imagery

The land cover classification of satellite imagery aims to relate a specified class label to the spectral characteristics of a pixel. Given its superior performance in other Irish studies (Nitze *et al*., 2015) the supervised random forest (RF) (Breiman, 2001) machine learning algorithm was used, trained to detect the land cover types listed in Table 4.1.

The Prime2 dataset provided the principal mapping objects in lowland areas, but in the uplands, image segmentation is needed to define contiguous regions of a single land cover. The segmentation process aggregates a minimum of five neighbouring pixels based on their quantitative and qualitative similarities, with each segment subsequently labelled with an appropriate class. As agreed during the stakeholder consultation, the segments should be between 2 and 5 ha in the upland areas. Three different segmentation scenarios with minimum object sizes of 1 ha, 2 ha and 5 ha were derived and subsequently populated with the pixel-based land cover classification, using zonal statistics.

Table 4.1. Classification schema with class descriptions, adapted from Fossit (2000)

Level 0		Level 1		Level 2		Description
G	Grassland	GA	Improved	GA1	Improved	Grassland on well-drained soils, usually consists of highly managed pastures
		GS	Semi-improved	GS3	Dry humid grassland	Semi-improved grassland over acid soils
				GS4	Wet grassland	Semi-improved grassland on poorly drained soils
H	Heath	HH	Heath	HH1	Dry siliceous heath	Usually occurs on free-draining acid soils where the vegetation is open and dwarf shrubs are present
				HH3	Wet heath	Usually found on lower slopes of upland areas on peaty soils
				HH4	Montane heath	Substantial cover of dwarf shrubs occurring at high altitudes and/or very exposed locations
			Dense Bracken	HD1	Dense bracken	Areas of open vegetation dominated by bracken
P	Peatland	PBR	Raised Bog	PB4	Cutover bog	Mostly located in the lowlands of central and mid-west Ireland with accumulations of deep peat (3–12 m)
		PBB	Blanket Bog	PB2	Upland blanket bog	Usually occurs on flat or gently sloping ground (above 150 m altitude) on variable peat depths (>0.5 m depth)
				PB3	Lowland blanket bog	Usually confined to wetter regions along the western seaboard, occurs on flat or gently sloping ground below 150 m altitude
W	Woodland	WBR	Broad leaved Woodland			Areas dominated by semi-natural broad leaved trees
		WC	Coniferous Woodland			Areas dominated by modified, non-native species
		WST	Scrub/ Transitional			Areas dominated by scrub and immature woodland
E	Exposed Rock	ER	Exposed Rock	ER1/ ER3	Exposed siliceous rock/scree and loose rock	Areas of natural and artificial exposure of bedrock and loose rock (excluding sea cliffs)
		DG	Disturbed Ground	ED1/ ED2	Exposed sand, till or gravel	Areas of exposed sand, gravel or till
A	Arable					Areas of cultivated agricultural land
B	Built land					Developed land including transportation and settlements
M	Water					Bodies of permanent fresh and/or salt water

4.2   GIS Map Results

All of the available vector datasets were integrated into the Prime2 Vegetation objects for the Suir catchment by intersection using an automated Python workflow. This provides an indication of the best available current land cover data in Ireland before any satellite imagery is used. This is not a trivial task, for example the LPIS dataset for the Suir catchment alone consists of 267 unique crop descriptions as a mixture of land use and land cover information. Therefore, a generalisation of the LPIS semantics is essential to simplify the very diverse unique crop descriptions into standardised classes. Since this was done manually, it must be considered as subjective and therefore insufficient for an annual, national application.

For the validation, 557 points were randomly distributed across the study area and manually referenced based on Bing and Google Earth imagery. A date could be assigned to each point according to the acquisition of the reference image, ranging from 2006 to 2013 for Google Earth and 2012 for Bing. Table 4.2 shows the accuracy with which selected

classes can be mapped and the number of reference points on which that is based [producer's accuracy (PA) is a measure of how well a given land cover on the ground is mapped, and user's accuracy (UA) is a measure of how likely a mapped area of land cover is to be that land cover on the ground].

An overall accuracy (OA) of 78% was obtained. This illustrates that datasets not specifically designed for land cover mapping, although containing valuable information, cannot themselves provide a robust and accurate land cover map, especially when a combination of different sources is used. The classification accuracy of these available datasets is below that which is required; thus, this map was improved using satellite imagery.

Table 4.2. Producer's accuracy and user's accuracy for the GIS data intersection

	PA	UA	Count
Pasture	0.97	0.82	373
Semi-improved Pasture	0.03	0.33	39
Arable	0.86	0.76	49
Broadleaved Woodland	0.17	0.50	6
Coniferous Woodland	0.71	0.60	35
Scrub/Transitional	0.04	0.13	55

4.3   Satellite Land Cover Map Results

The Landsat images were classified using a number of different data combinations, but the best results were obtained with RF classification of raw satellite data combined with processed image derivatives (Tasselled Cap, texture and vegetation indices) as well as ancillary data including elevation, soil, sub-soil and bedrock information.

Using the region-growing image segmentation routine implemented as *i.segment* in Geographic Resources Analysis Support System (GRASS) GIS, a 1 ha, 2 ha and 5 ha segmentation was derived with a similarity threshold of 0.2. The segments were combined with the classified map to produce an object-based map of land cover. Each object is labelled with the majority land cover in the object but also contains the percentages of other land covers in the object.

The error matrix shown in Table 4.3 provides a more comprehensive indication of misclassification. The vegetation classes are the most likely to be confused, such as Improved Grassland and Dense Bracken, because of their similar spectral behaviours. The OA for the map is 91%. In Table 4.3, the numbers in bold represent the points that were matched correctly on the map and on the ground with the other numbers representing misclassifications.

Table 4.3. Suir catchment error matrix for final satellite classification; mapped points compared with ground observations (the abbreviations in the top row are equivalent to the class names in the first column; the numbers in bold represent the correctly mapped points)

Class labels	Error matrix													
	W	IG	SIG	H	DB	RB	BB	BW	CW	S/T	R	S	B	A
Water Bodies	**90**								3					
Improved Grassland		**357**	10	2	19		3	1		8	1			5
Semi-Improved Grassland		5	**235**	11	11		13			11				
Heath			11	**345**		1	11							
Dense Bracken		11	6	4	**187**									1
Raised Bog						**81**	2							
Blanket Bog		1	4	9			**219**		1		1			
Broadleaved Woodland		1			1			**210**	5	2				
Coniferous Woodland	3			2				17	**277**	1				
Scrub/Transitional		14	6	4	3		3	5	2	**102**				4
Bare Rock		1		1			2				**56**		19	
Bare Soil		2									2	**16**	2	
Built Land											1	1	**236**	
Arable Land		15		1			1		1	2	1			**486**

The feasibility of a medium resolution (30 m) land cover reporting strategy for Ireland was successfully demonstrated for the Suir catchment in 2013 and 2014. These results are consistent with other studies of machine learning land cover mapping in Ireland by Nitze *et al*. (2015) and Barrett *et al*. (2014). An extract from the final Suir Map is shown in Figure 4.1.

Existing maps with a land cover element can be integrated for the purposes of more comprehensive mapping; however, the different spatial scales, semantics, timing and data sources have an inevitable impact on the accuracy of the final product. The

OSI Prime2 geospatial framework does, however, provide a very useful geometry, or vehicle, that can be populated with more detailed land cover class data. The IDL-based ATCOR3 atmospheric and terrain correction strategy proved most robust, but the results indicate only marginal differences between the different correction strategies in terms of the resulting classification accuracies. Using the RF classifier, very high OAs were achieved for a land cover map derived from three Landsat-8 images, with the inclusion of ancillary data improving the accuracy slightly, but incorporating texture and vegetation index measures also caused confusion.
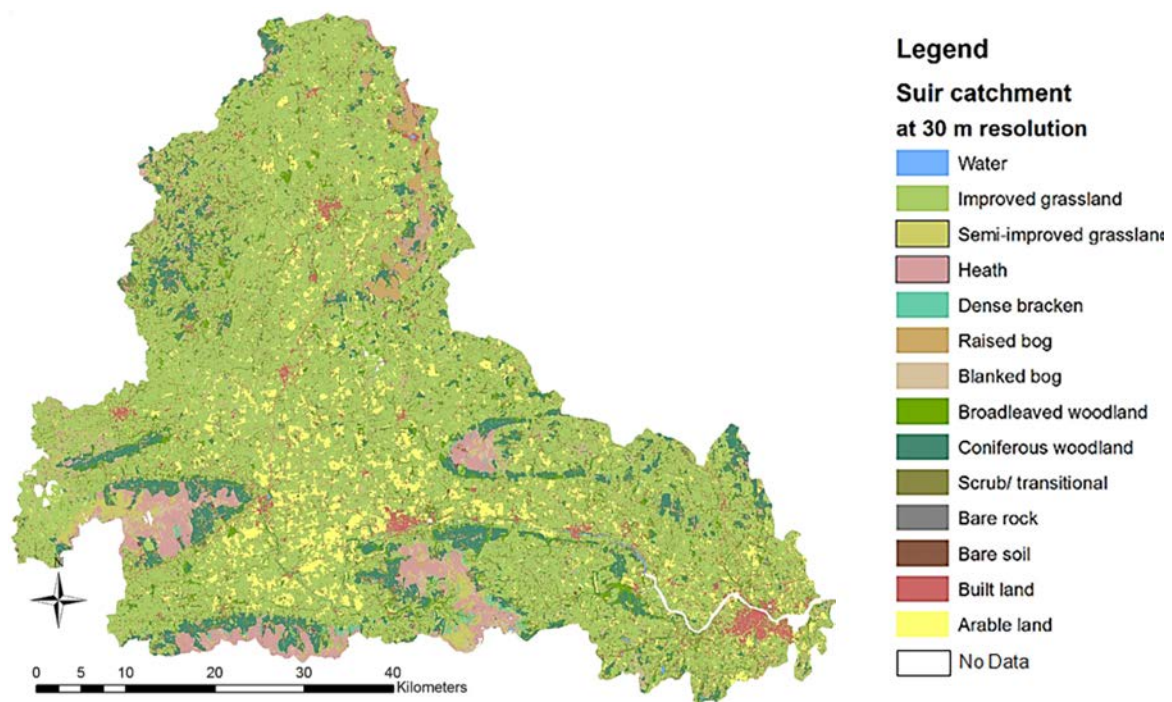

Figure 4.1. Land cover map for the Suir catchment produced from the random forest classification of three Landsat-8 images.

5 Seeing Through the Clouds: Radar-based Classification of Upland Areas

The problem of clouds obscuring a satellite's view of the ground is a particular issue in upland areas, as mountains create clouds in a process known as orographic lift. As part of the TaLAM project, augmenting optical image-derived land cover maps with satellite radar data was considered. Radar sensors emit a microwave signal that penetrates cloud and records the signal that is reflected back to the satellite. The strength of the returned signal is a function of topography, and the roughness and electrical properties of the surface.

Suitable study areas were selected from a list of candidate sites:

- **Mount Brandon** is located on the Dingle Peninsula in West Kerry, in south-western Ireland. It is a mountainous area that includes the second-highest peak in Ireland (Mount Brandon at 952 m).
- The **Galtee Mountains** span across three counties, Cork, Tipperary and Limerick, and are the highest inland mountain range in Ireland (Galtymore at 920 m).
- The **Comeragh Mountains** are located in County Waterford and are a designated Special Area of Conservation (SAC 001952).

5.1 Data

The Advanced Land Observation Satellite (ALOS) was launched by the Japanese Aerospace Exploration Agency (JAXA) on 19 January 2006 and operated until 12 May 2011 with the Phased Array-type L-band Synthetic Aperture Radar (PALSAR) instrument on board.

To complement the radar data, optical data were also acquired. The Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) instrument on board the ALOS satellite is a multispectral sensor that acquired data in the blue (0.42-0.50 μm), green (0.52-0.60 μm), red (0.61-0.69 μm) and NIR (0.76-0.89 μm) spectral channels.

All data were received as level 1B2 products (radiometrically and geometrically corrected by the data provider). The scenes were geo-rectified using ground control points (GCPs) collected from OSI orthophotography, atmospheric correction was performed using the MODTRAN (MODerate resolution atmospheric TRANsmission) correction model as implemented in ATCOR-2. A C-factor topographic correction was applied to the data using a sun illumination terrain model derived from a NextMap 5 m spatial resolution digital elevation model (DEM) and implemented in GRASS (GRASS Development Team, 2012). The AVNIR-2 data were processed to produce a number of image attributes, such as vegetation indices and texture.

The PALSAR scenes for each study area were co-registered and speckle filtered using a multitemporal De Grandi filter (De Grandi *et al*., 1997), and subsequently radiometrically and geometrically calibrated and converted to dB using a range-doppler approach and a NextMap 5 m spatial resolution DEM.

Finally, two different groups of ancillary variables were chosen for inclusion in the classifications:
(1) topographic, namely elevation and slope, and
(2) soils. Soil and subsoil information was derived from the Teagasc-EPA Soils and Subsoils dataset (Fealy *et al*., 2009) and topographic data were obtained from a NextMap 5 m spatial resolution DEM.

5.2 Radar Classification

The RF machine learning classifier (Breiman, 2001) was used to relate the vegetation types to the satellite and ancillary data. RF was chosen as the preferred classification method, as it has consistently demonstrated its value for vegetation mapping using various types of data (Chapman *et al*., 2010; Barrett *et al*., 2014; Feilhauer *et al*., 2014) and can handle high-dimensional datasets and not suffer from over fitting. Eight different combinations of optical, radar and ancillary datasets were analysed to compare

the improvement (or deterioration) in classification accuracy depending on the input variables.

The highest overall accuracies (93.2–94.3%) were obtained for the combined optical, radar and ancillary data classifications across all three study areas (Table 5.1). Using the radar and texture data alone, the F-scores (a test of separability) for many of the vegetation classes (GS3, GS4, HH1, HH3, HH4, HD1 and PB2) are low for all three study areas, indicating that using only the information contained in microwave imagery cannot reliably separate these classes. The final output classification maps for the three upland region study areas are shown in Figure 5.1.

Table 5.1. Level 2 classification results for the different datasets at each of the three study sites: Mount Brandon (BR), the Galtee Mountains (GT) and the Comeragh Mountains (CM)

	BR	GT	CM
OA (%)	94.3	93.2	93.8
Kappa	0.94	0.92	0.93
Improved Grassland			
(GA1) PA	0.99	0.99	0.97
UA	0.98	1.00	1.00
Dry Humid Grassland			
(GS3) PA	0.95	0.94	0.92
UA	0.98	0.91	0.93
Wet Grassland			
(GS4) PA	0.97	0.97	0.87
UA	0.94	0.87	0.81
Dry Siliceous Heath			
(HH1) PA	0.90	0.85	0.84
UA	0.92	0.89	0.72
Wet Heath			
(HH3) PA	0.86	0.81	0.81
UA	0.79	0.78	0.70
Montane Heath			
(HH4) PA	0.87	0.84	0.88
UA	0.90	0.75	0.77
Dense Bracken			
(HD1) PA	0.97	0.91	0.88
UA	0.91	0.95	0.94
Upland Blanket Bog			
(PB2) PA	0.83	0.88	0.92
UA	0.95	0.93	0.96
Lowland Blanket Bog			
(PB3) PA	0.93	/	/
UA	0.78	/	/

Table 5.1. Continued

	BR	GT	CM
Woodland			
(W) PA	1.00	0.99	0.99
UA	1.00	1.00	0.99
Exposed Rock			
(ER1) PA	0.94	0.91	0.79
UA	0.91	0.76	0.85
Disturbed Ground			
(ED1) PA	/	0.96	0.85
UA	/	0.79	0.96
Builtland			
(B) PA	1.00	1.00	1.00
UA	0.99	1.00	1.00
Coastland			
(C) PA	0.99	/	/
UA	1.00	/	/
Water Bodies			
(M) PA	1.00	1.00	1.00
UA	1.00	0.98	1.00

5.3   Discussion

The RF classifier is increasingly being used in ecological applications (Cutler *et al*., 2007; Chapman *et al*., 2010; Rodriguez-Galiano *et al*., 2012) and the results from this study demonstrate its advantage when integrating Earth observation (EO) satellite data from multiple sensors to improve vegetation mapping in upland regions. Even though it may not be surprising that the multispectral data by themselves outperform the radar data by themselves, there is merit in incorporating both data types in the classifier models. The inclusion of ancillary datasets containing information on the soil and elevation further improves the classification accuracies, for example by helping to more accurately distinguish between upland and lowland blanket bog.

The retrieval of habitat information in Irish upland areas using EO data is challenging because of the topography and the difficulty of obtaining cloud-free acquisitions in these regions. Furthermore, habitat delineation is difficult to achieve, as the landscape is heterogeneous (in terms of composition and structure) and consists of a number of interlinked habitats at different scales (spatial, temporal and spectral) (Varela *et al*., 2008). Assessing habitat area is complex in this regard, as many of Ireland's upland habitats do
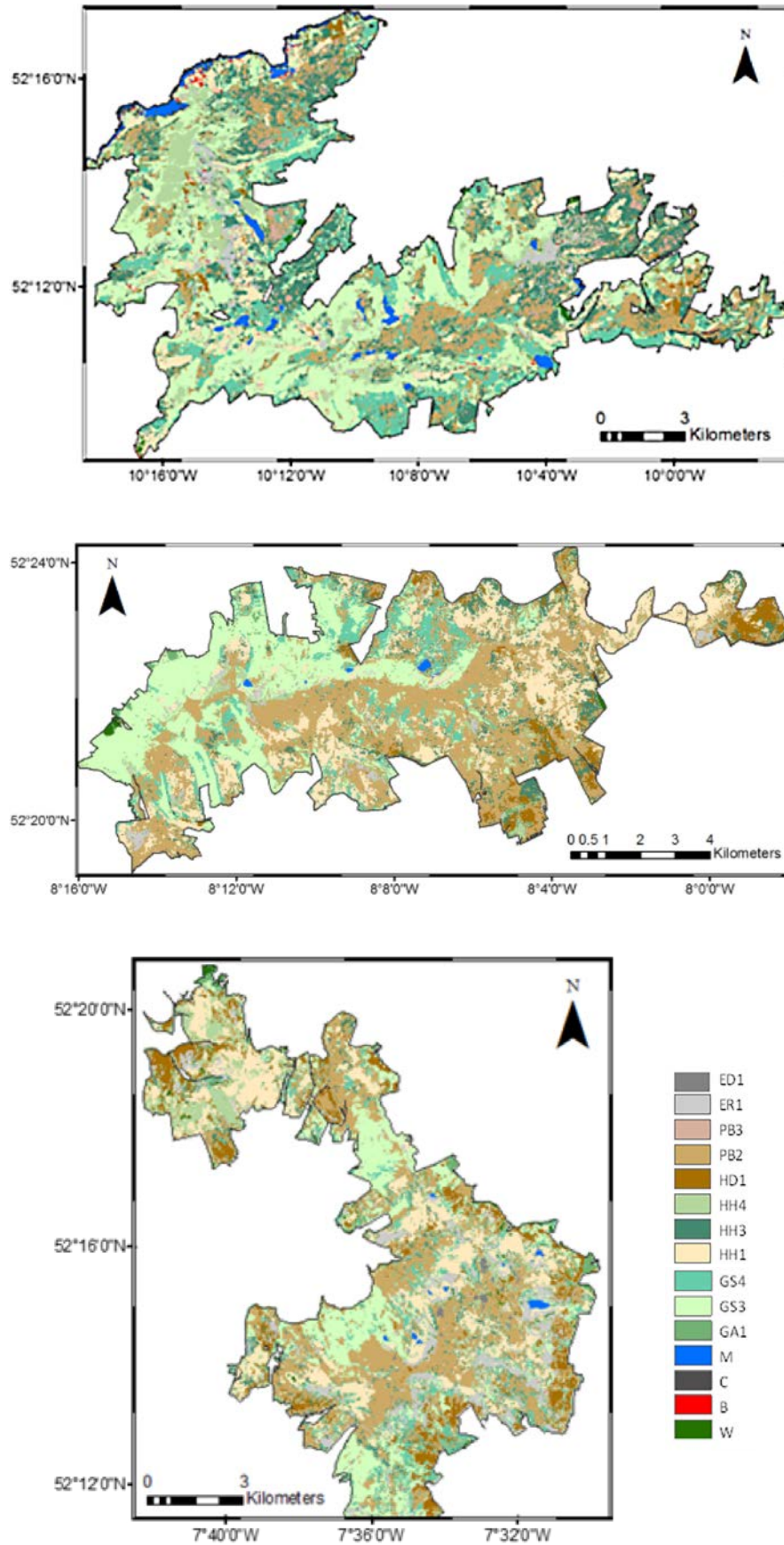
Figure 5.1. Land cover maps derived from the optical and radar datasets for (a) Mount Brandon, (b) the Galtee Mountains and (c) Comeragh Mountains study areas; the legend applies to all three sites (see Table 5.1 for class names).

not occur in discrete blocks, but rather as a complex mosaic of often closely related vegetation types, often in different conditions (Perrin *et al*., 2009).

With the current availability of satellite EO data at low or no cost and an increased number of satellites in orbit or planned for launch, there has never been a better time to incorporate EO data into operational vegetation mapping and monitoring programmes. Despite these advances, however, challenges remain that still discourage the uptake of EO approaches for mapping complex vegetative habitats, with ecologists concerned with discriminating individual plants at a species level (Spanhove *et al*., 2012). EO data will probably never provide the fine-scale information that can only be obtained in the field, but can offer a powerful complementary information source (Feilhauer *et al*., 2014; Pettorelli *et al*., 2014). From this study, it can be concluded that medium spatial

resolution (~15 m) satellite data acquired from optical and microwave sensors combined offers a basis for supporting mapping and monitoring of upland vegetation. The mapping approach was demonstrated over large areas in three distinctive upland regions, indicating the consistency and the transferability of the method. While ancillary data improved the OA as discussed above, caution needs to be applied with regard to the influence of soil and elevation on the output and therefore the difficulty of identifying change over time with these variables contributing to the classification. With the increasing archive of medium spatial resolution EO data from Sentinel-1 and Sentinel-2 more imagery will become available, allowing segmentation to be derived from a time series for more stable objects. Based on this work, therefore, the potential for satellite data to support future environmental management decision making in the uplands can take a significant step forward.

6   Automated Methods for Map Updates and Change Reporting

Automated, remote-sensing-based change analysis provides several opportunities for cost and labour efficiency. In this study, an approach to automated detection of potential change areas is applied to an unenclosed upland area within the Galtee Mountains

One cloud-free (12 April 2010) and two cloud-contaminated (23 May 2010 and 15 August 2010) 5 m spatial resolution RapidEye scenes were acquired over the Galtee Mountains in the south-east of Ireland. Pre-processing (including atmospheric and terrain correction, as well as cloud masking) was undertaken using the IDL-based ATCOR3. Several vegetation indices and texture measures were derived for each acquisition.

In line with the agreed outputs from the workshop, segmentation was performed and integrated in the existing Prime2 spatial data model. Field survey data, provided by the NPWS, were used for the RF model calibration and validation. For the final step, a RF pixel-based land cover map was derived and integrated into the object data model to give the land cover baseline for 2010. In order to identify potential change parcels since 2010, a cloud-free RapidEye scene for 2015 was obtained.

The RF land cover classification was executed and validated for six different input combinations of optical, vegetation index, texture and ancillary data. Differences between 2010 and 2015 for each parcel were labelled as potential changes. The highest OA could be seen for a combination of all variables including ancillary data (OA = 90.2% and K = 0.89).

A comparison of the 2010 land cover fractions per class and the 2015 output shows the largest class in all cases is Improved Grassland (about 30%) followed by Dry Heath and Woodland. The year 2015 revealed a decrease of Woodland and an increase in Scrub/ Transitional cover compared with 2010. The Improved Grassland cover for the 2015 classifications is about 29%, indicating a decrease from 2010.

Classes with very distinctive spectral behaviours, such as Woodland, Improved Grassland and Water Bodies are identified in the automated 2015 land cover map as well as in the 2010 classification. However, classes with more spectral variability (e.g. Montane Heath) revealed more inaccuracies, but this is in part attributable to the three images used for the 2010 classification and thus the ability to differentiate these classes based on their seasonal phenologies. Consequently, the results for the single-date comparisons must be considered with caution. Moreover, features were observed in the 2015 image that were not present in 2010, notably the burning of some of the upland regions. In the absence of a land cover class to depict this, the classifier identified these areas as a variety of other surfaces, including Bare Rock. This highlights the importance of having all potential classes present in the master map from which training areas are derived and the impossibility of identifying effects previously unseen.

Developing automated routines for processing of imagery in a world of big data is becoming an ever greater need, and is a stimulus for closer cooperation between computer scientists, satellite image processing experts and end users.

7   Conclusions and Recommendations

Remote sensing of land cover can meet most needs of the user community. It is possible to correctly ascribe a fractional land cover label to pre-mapped fields, roads and forests in the OSI Prime2 database, with greater than 90% accuracy.

In the upland areas, the technical demands of the user community for defining the boundaries of different land covers can be met with automated segmentation of imagery datasets. Radar data contribute to improved accuracies in land cover mapping in upland areas. However, to go beyond a level 1 discrimination, and move on from land cover to habitats in these upland areas, is still challenging to achieve with the degree of accuracy required for management and policy.

Automated change detection shows promise for cost and labour efficiencies, but it continues to prove to be problematic as a result of the error propagation between mapped outputs, leading to unsatisfactory error rates. Continual monitoring of land cover units of interest and land cover trajectory profiling are presented as solutions.

One of the most significant data gaps experienced in this study was the dearth of good-quality field-scale ground truth data contemporaneous with satellite data acquisition. Importantly, however, while it may be ecologists who collect the data, this needs to be done in conjunction with EO scientists who have an understanding and appreciation of the limitations of satellite sensors to discriminate discrete vegetation units on the ground. In addition to recording the status and species present on the ground, such EO-dedicated field campaigns could also acquire information on the condition and status of the vegetation and information on land use as well as land cover.

The value of the OSI Prime2 framework as a vehicle for land cover mapping has been proven, and the use of such a vector database is becoming standard practice across Europe.

With the launch of the European Space Agency (ESA) Sentinel series, a large volume of medium spatial resolution imagery is available now and will be, for land cover classification activities, for at least the next 5 to 10 years. Investment needs to be made in data retrieval, archiving and storage, as well as software, processing, training and project management.

Random forest classification has been proven to be the most robust form of classification in terms of accuracy of output, while also providing beneficial information on feature importance and generation of uncertainty measures. However, to enable the integration of images from different sensors, more work needs to be done on the inclusion of typical regional Irish atmospheres in the 6S atmospheric correction algorithm to ascertain whether one correction approach can be applied nationally or whether a more coherent national product should be generated from geographically informed correction strategies.

With the European Action Group on Land Monitoring in Europe (EAGLE) project recognised as a suitable framework for bottom-up land cover mapping that complies with both national and European requirements, it is possible that this will guide the next iteration of the CORINE land cover classification in 2018 (Arnold *et al*., 2016). It is important for Ireland to be prepared for this with an intensive ground truth programme during that year, with a classification schema for land cover, use and habitat characteristics that is of value to ecologists and EO scientists.

With a reliable national ground truth dataset, a robust approach to polygon generalisation and an archive of Sentinel and Landsat-8 imagery, a baseline land cover map can be derived from optical and radar satellite imagery for 2018 that fulfils both CORINE requirements and national needs. The unenclosed areas can be segmented on a time series of 3–4 years of Sentinel-1 and Sentinel-2 data, thus providing relatively stable polygons, and populated with information derived from both optical and radar imagery for maximum discrimination between different features. The enclosed areas can be mapped from a suite of optical imagery captured over the course of the year, with at least three images representing different phenological stages.

In summary, the next 5 years represent an opportune time for the development of a baseline map of land cover characteristics from time series EO imagery, followed by annual updates. Ireland's policymakers need to be prepared both technically and conceptually to take advantage of these images, and fulfil national and international land cover requirements.

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Abbreviations

ALOS	Advanced Land Observation Satellite
AVNIR-2	Advanced Visible and Near Infrared Radiometer type 2
CORINE	Coordination of Information on the Environment
CSO	Central Statistics Office
DAFM	Department for Agriculture, Food and the Marine
DEM	Digital elevation model
EO	Earth observation
EPA	Environmental Protection Agency
FIPS	Forest Inventory and Planning System
GIS	Geographic information system
GRASS	Geographic Resources Analysis Support System
LPIS	Land Parcel Identification System
LULCC	Land use and land cover change
MMU	Minimum mapping unit
NIR	Near infrared
NPWS	National Parks & Wildlife Service
OA	Overall accuracy
OLI	Operational Land Imager
OSI	Ordnance Survey Ireland
PA	Producer's accuracy
PALSAR	Phased Array type L-band Synthetic Aperture Radar
RF	Random forest
TaLAM	Towards Land Cover Accounting and Monitoring
Teagasc	Agriculture and Food Development Authority
UA	User's accuracy

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú

Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:

- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsáide carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíoch.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

epaResearch
Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

The Towards Land Cover Accounting and Monitoring (TaLAM) project sets out to address this issue by designing a method to combine land cover and land use information derived from satellite imagery with the Ordnance Survey Ireland's (OSI) Prime2 digital map of Ireland to create a comprehensive land cover map resource.

Identifying Pressures

Agriculture, forestry, land use change and other land uses account for about 24% of global greenhouse gas emissions. Ireland therefore requires maps of land cover and land use to aid assessment and reporting activities, including calculations of the annual greenhouse gas budget, as well as identify issues such as habitat loss, improve environmental management and support policy implementation. Field surveys allow mapping of habitats to individual species and assemblages, which is invaluable for small areas but unfeasible at a national level. As of 2016, the most detailed national land cover dataset for Ireland is the European Coordination of Information on the Environment (CORINE) map. However, despite being widely used, this has limitations because of its spatial scale, the types of land cover classified and the update cycle. With other European countries adopting best practice national mapping techniques that combine satellite imagery and spatial geoinformation to populate vector objects, this project aims to determine whether similar approaches can be adopted in Ireland.

Inform Policy

European and national policies on environmental management, the protection of nature and biodiversity, and climate change adaptation are closely linked to current and future land use practices. The outcomes of this project highlight the ability to label polygons within the Ordnance Survey Ireland Prime2 vector database with land cover derived from medium resolution satellite imagery and also to create land cover polygons where no pre-existing delineation information is available. Following the Paris Agreement, specific guidelines on recording the nature and status of sources, sinks and reservoirs of carbon are being developed, and satellite-derived land cover maps will be essential for objective, repeatable mapping to identify the contribution of land cover and its change to Ireland's annual greenhouse gas budget.

Develop Solutions

Medium resolution (5–50 m) satellite imagery is suitable for populating Ordnance Survey Ireland Prime2 polygons to map land cover within Ireland., Alternatively, satellite imagery can be used to derive such polygons where they do not already exist. This approach will support European and national scale reporting and legislation requirements. With the planned launch of future optical and microwave satellite sensors, this approach will continue providing land cover mapping information for many years to come.

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