

# Assessing the Extent and Severity of Erosion on the Upland Organic Soils of Scotland using Earth Observation

Jarman, M., Keyworth, S. and Medcalf, K.,

*Environment Systems Ltd, 8G Cefn Llan Science Park, Aberystwyth, SY23 3AH*

Phone: +44 (0)1970 626688 Email: [mark.jarman@envsys.co.uk](mailto:mark.jarman@envsys.co.uk)

## Abstract

Peatlands are an important ecosystem in terms of their feedback to global climate change, playing a key role in the global carbon cycle through the sequestration of atmospheric carbon during peat accumulation, and the release of carbon gases in the form of CO<sub>2</sub> and methane when they erode. Much of Scotland's uplands are covered by organic peat soils, forming a significant proportion of the global peat resource. This project sought to determine a cost effective means of identifying and monitoring peat erosion features.

For the study area based in the Monadhliath Mountains in Scotland, SPOT5, IRS P6 and ASTER satellite imagery were fully prepared and integrated into an automated processing chain with current digital aerial photography. This image data was then complemented by GIS datasets which provided a set of core topographic and thematic information.

Definiens eCognition object orientated rule-based classification software was used to classify the imagery into a set of 'core level' data, which in turn was used to produce 'application level' data; in this case in the form of peat erosion maps. Overall map accuracy was calculated as over 84%, with clear visual coincidence between the classified map and both the in-situ field data and aerial imagery.

**Keywords:** *Peat, erosion, remote sensing, eCognition, Scotland*

## 1. Introduction

Estimates of the global extent of peat forming systems vary significantly, and there is a real need to better quantify their extent and subsequent role within the global carbon (C) cycle (Anderson 2002). To understand the C budgets within peatland complexes, it is essential to understand the spatial extent and mosaics of exposed peat, vegetated bog surfaces and pools (Bridgham *et al.*, 2008).

Peatlands play a fundamental role in the global C cycle through the sequestration of atmospheric C and the release of C gases in the form of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) (Limpens *et al.*, 2008). It has been estimated that peatlands contain between 329 and 525 x 10<sup>15</sup> g C, or 19% of the global soil C pool (Batjes 1996), which is 75 times larger than annual anthropogenic CO<sub>2</sub> emissions (Bridgham *et al.*, 2008).

Blanket peat covers 9% of the UK and 10.45% of Scotland's land surface (Taylor 1983). The UK deep peats (over 45 cm) contain approximately 5000 Mt C which represents around half of the C in UK soils (Cannell and Milne 1995). A high percentage of these are bogs, and the majority (over 70%) are found in Scotland (Lindsey and Immirzi 1996). Scotland's peatlands are an intrinsic ecosystem in a European context. They are located on the Atlantic extremity of the continents climatic gradient and are generally less degraded when compared to the peatlands of mainland Europe (Bragg 2001).

Mapping of peatlands as a distinct land cover type has evoked many challenges and has often led to their omission or inconsistent representation within global vegetation maps (Frey and Smith 2007). Improving the representation of these areas within land cover maps is therefore an important objective for future global mapping and will subsequently increase the understanding of their effects on the global climate change (Herold *et al.*, 2008). Previous attempts to map the distribution of upland peatlands have been reliant on aerial photography and broad Earth Observation (EO) sensors such as Landsat (McMorrow *et al.*, 2004). In this study, by using sensors such as SPOT5 and incorporating current high resolution aerial photography, an increased level of spectral and spatial detail for the mapping of upland peatland areas was achieved.

This approach was tested for an area of upland peatland in the Monadhliath Mountains in the Scottish Highlands (Figure 1). The region is known to contain large amounts of blanket bog which are located within areas of gently sloping ground and are concentrated within the valley bottoms and upland plateaus. Smaller areas of blanket bog are found throughout the site forming in depressions and in mosaic with wet heath and acid grassland (Dayton 2006).

## 2. Data

The EO data investigated during this study was captured over the period 2006/2007. SPOT5, ASTER, and IRS P6 cloud-free or relatively cloud free images were acquired covering both spring and summer so that a time series was available for analysis. In addition to the spaceborne images, very high resolution 2006 aerial photography (red, green, blue) was also obtained from Getmapping UK. Ancillary GIS data layers (e.g. OS MasterMap) were also incorporated into the classification process alongside the NEXTMap Digital Terrain Model (DTM) data which provided information on landscape position.

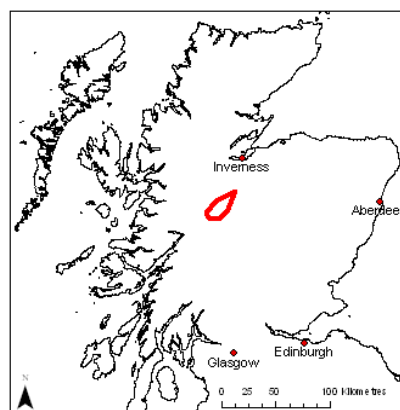


Figure 1: Monadhliath study area location within Scotland

## 3. Methodology

### 3.1 Setup

Experiences gathered from work in Wales (Lucas *et al.*, 2006) have demonstrated that atmospheric correction of optical (e.g., SPOT and IRS sensor) data to surface reflectance is a critical stage in developing consistent decision rules and classifications. Therefore, all imagery supplied was calibrated to radiance ( $W m^2 sr^{-1} \mu^{-1}$ ) and subsequently to surface reflectance (%).

A pragmatic approach was taken to categorising the vegetation classes as this project was about analysing soil erosion classes rather than habitats. Vegetation classes were selected based on the amalgamation of land cover types that could be separated into the fewest groups by the spectral content within the satellite imagery and the aerial photography. The broad habitats that resulted from this were then named with descriptive titles which outlined the sort of plant communities that could be expected to fall within these areas.

### 3.2 Classification

Definiens eCognition object orientated rule-based classification software was used to classify the imagery into a set of 'core level' data, which in turn was used to produce 'application level' data; in this case in the form of peat erosion maps. The segmentation procedure involved the creation of three levels which were used to classify object features at different scales. Within the upper level (Integration Level), all external datasets (e.g. OS MasterMap) were synchronised within a chessboard segmentation procedure and excluded from further classification.

This segmentation was subsequently carried down to create an EO level with a 'multi-resolution segmentation' algorithm then used to classify all land covers present within the EO data. A finer multi-resolution segmentation within the SPOT data was then applied to areas of blanket bog to allow of the classification of smaller peat features within the EO data.

An Air Photo Level was then created below the EO Level with a very fine 'multi-resolution segmentation' using the aerial photography performed to delineate peat erosion features present within the aerial photography. This segmentation was applied within the areas previously classified to be potential peat erosion regions within the EO layer. The integration, of EO and Air Photo levels forms the basic data building blocks for the production of a range of maps at the level of detail required.

## 4. Results

Example maps produced from the core level (Air Photo level classification) and from the application level (Erosion risk classification) are shown in Figure 2. Both qualitative (visual) and quantitative

(statistical) accuracy assessment were carried out. Overall map accuracy following field assessment was calculated at over 84%, with the classified map and both the in-situ field data and aerial imagery clearly coinciding with one another.

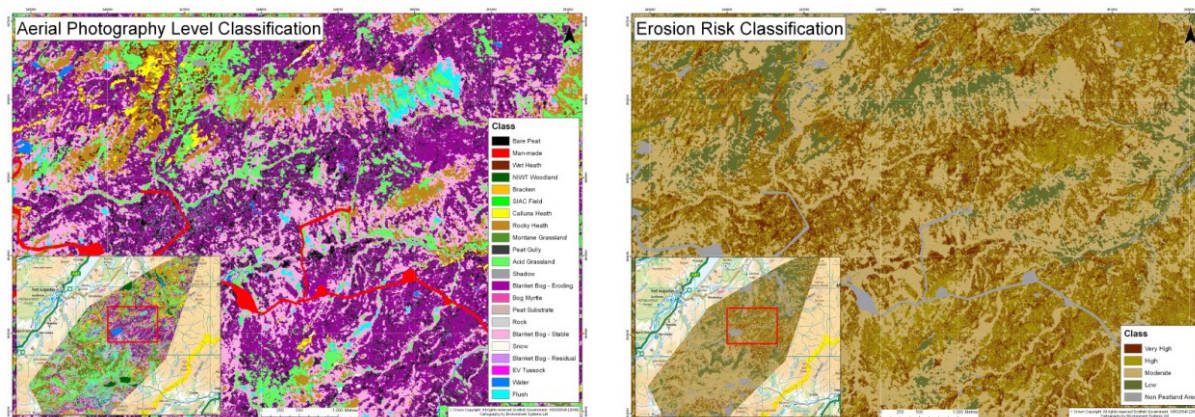


Figure 2: Air photo level (left) and erosion risk (right) classifications.

## 5. Discussion

Specific small scale peat erosion features such as gullies could not be identified through only the use of EO data such as SPOT5 and ASTER. However, it was possible to establish the larger areas of bare peat which are present through use of the SWIR band. The SWIR band within both sensors was integral within the classification of peatland areas as also noted by BenDor *et al.*, (1997). This should be of considerable use within future mapping of peatland areas due to the potential for frequent update and revisit times of these sensors (McMorrow *et al.*, 2004). The upcoming European Space Agency (ESA) Sentinel programme will also be of much use for future mapping due to the proposed accessibility to captured datasets.

The use of aerial photography enabled the smaller scale peat erosion features such as gullies to be delineated and classified to a high level of detail. The classification indicates an extensive presence of many gully systems within the study area. It was not possible to completely assess the severity of erosion within each gully system using the data and approach employed. However, following field visits to the study site, it is likely that these systems have been present for many years as little human impact within many areas was observed. This is supported by Tallis (1998) who noted that many gully systems in British blanket peats are several hundred years old, and thus many pre-date intensive human exploitation.

The use of aerial photography alone though did not enable the discrimination between areas of bare peat, and dark, vegetated areas dominated by species such as *Calluna vulgaris*. Therefore it was necessary to utilise the greater spectral information of satellite based EO data to initially target areas, within which the finer resolution aerial imagery could be applied. This has also been noted by Geneletti and Gorte (2003) who found that high resolution images lack the spectral information required to perform a classification. To overcome this and in order to produce accurate classifications, segmentations should be applied differently to each image and the subsequent results combined.

## 6. Conclusions

The object orientated rule based classification produced through using a combination of very high resolution aerial photography, with high and very high resolution multispectral satellite imagery shows it is possible to integrate these EO data sources with knowledge of the landscape processes to extract erosion features at the appropriate fine scale. However it was not possible to assess erosion severity at a local scale, with the approach best suited for providing an assessment of potential erosion risk.

The success of the approach was not simply based on considering this as an ecological project, or as a remote sensing project. Rather, the coupling ecological knowledge with remote sensing expertise and EO information content provided a solution to a complex mapping challenge. EO, and in particular

the combination of airborne and spaceborne imagery, offers the opportunity for consistent, objective mapping over a range of mapping scales.

Of the main types of peat erosion in the uplands, large single episodic events such as bog bursts and peat slides are the easiest to sense and trace remotely. However these events are infrequent and although of great extent, have been shown to be less significant than continual local erosion through gulling and rills on blanket bogs at high altitude and shallow slopes. Therefore, the focus of this work has been on the identification of these gullies and rills through the application of EO.

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