Developing and Evaluating an Earth Observation-enabled ecological land cover time series system

Progress report #2 to JNCC: Change detection update

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1. Change detection progress

The change detection work is a key element of the project. Progress has been made in a number of areas and rapid progress is expected in the coming months.

Three main methods of change detection are currently being tested:

- Post-classification – post-classification is the change between 2 classifications and will provide baseline accuracy against which to assess the success of the other two methods. We do not yet have results on change detection from this method, so progress on this is reported under section 3: Classification update.
- Image to Image (also known as image differencing)
- Classification to Image

Image-image change detection looks at the difference in spectral properties between two images at different points in time. Typically, differences are calculated between spectral index/transform values, rather than the image digital index, radiance or reflectance values. The method works best with ‘anniversary’ images e.g. April 2002 and April 2011, as this reduces phenological differences between images, which can be a major confounding factor in this type of analysis.

Classification-image change detection is a novel technique which takes a classification and a satellite image as inputs. The method uses a land cover classification to provide the land cover status at time 1, whilst a remote sensing image provides data on land cover at time 2. Knowledge of the location of a particular class (from the classification) is used to extract class-specific spectral properties (from the satellite image). The change between land cover is assessed by calculating spectral distance between the core class spectral properties (the blue area in Figure 1) and the pixels corresponding to that class. Pixels that have not changed are expected to show standard spectral properties for their class and will fall in the blue area of Figure 1. Pixels that have changed are likely to show different spectral properties and will fall outside the core area and will be flagged as anomalous. The method assumes that spectral outliers are likely to indicate change.

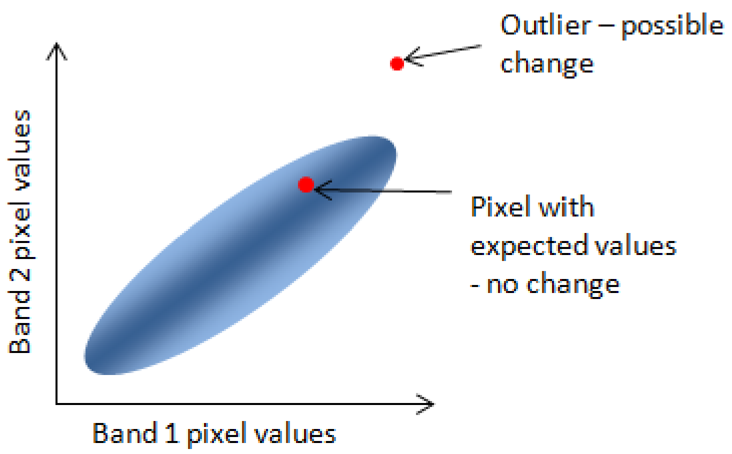

Figure 1: Illustration of the class-specific spectral values for class 1 (blue area) based on two spectral bands and a single outlier (change pixel).

2.1 Methods

2.1.1 Image-Image

The image-image change detection for Norfolk used images from April 2002 and 2011. The results shown are based on Principal Components Analysis (PCA) of a 12-band image based on 6 bands of Landsat-TM from April 2002 and 6-bands from April 2011. In the resultant 12band PCA image, bands 4-6 were found to correspond most strongly to change, with bands 1-3 dominated by image brightness and greenness.

2.2.1 Classification-Image

The classification-image method was applied to a Landsat TM image from May 2002, with the classification data from Land Cover Scotland 1988 (LCS88)**.**

2.2 Results

2.2.1 Image-Image

Figure 2 shows the 2002 and 2011 images, with annotated changes corresponding to:
1- Deforestation
2 – Standing water in 2002
3 – Gt. Yarmouth Outer Harbour (constructed 2007)
4 – More prominent water channels

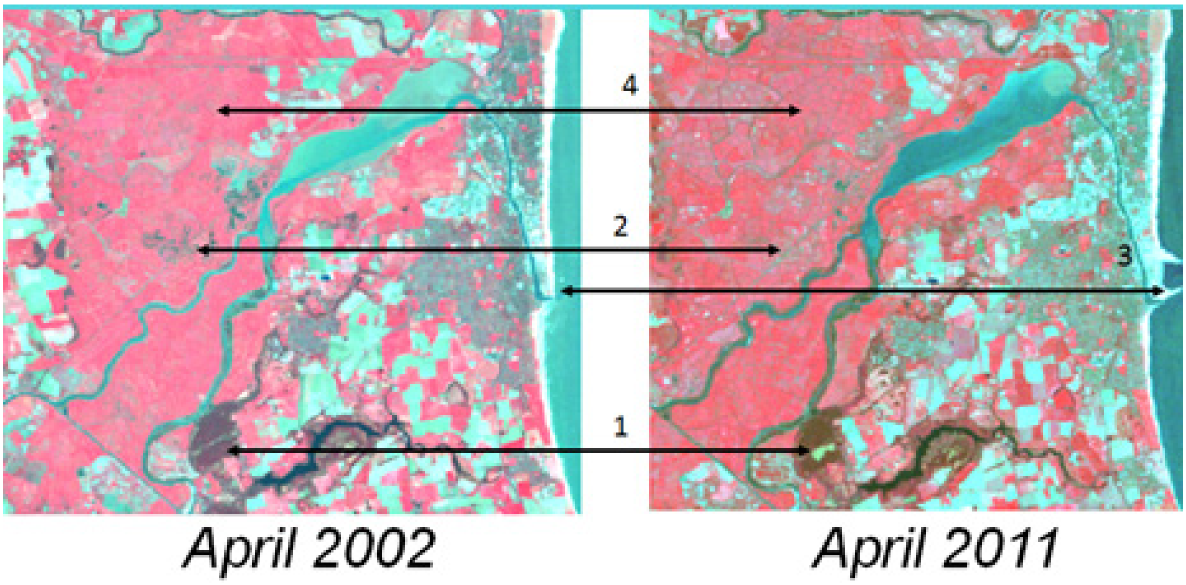

Figure 2: Landsat-TM False Colour Composite of Norfolk for April 2002 and 2011 illustrating both permanent and temporary changes.

The largest changes were due to changes in crop type, so these were removed using a mask of areas classified as arable in LCM2000 and LCM2007. However, some arable fields are still visible in Fig. 3. The areas of greatest change are the areas of brightest colour. A composite PCA index was derived from PCA bands 4, 5 and 6 (Figure 4), as it is simpler to optimise a threshold on a single image as opposed to three thresholds for three images. The bands of the multi-temporal PCA that corresponded most to change were found to be bands 4, 5 and 6 (Figure 3), although this will be scene-dependent. Change will be captured by different bands of the PCA, depending on how widely change affects the scene. This is not ideal for an operational system.

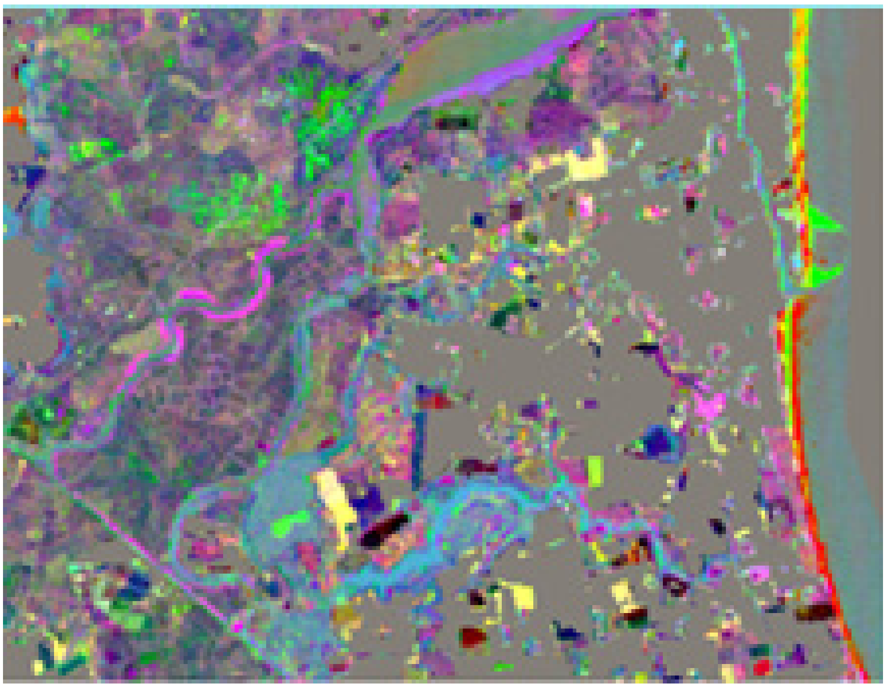

Figure 3: Principal Components Analysis image (bands 4,5,6 as RGB respectively) derived from a 12-band multi-temporal image comprised of the April 2002 and 2011 images.

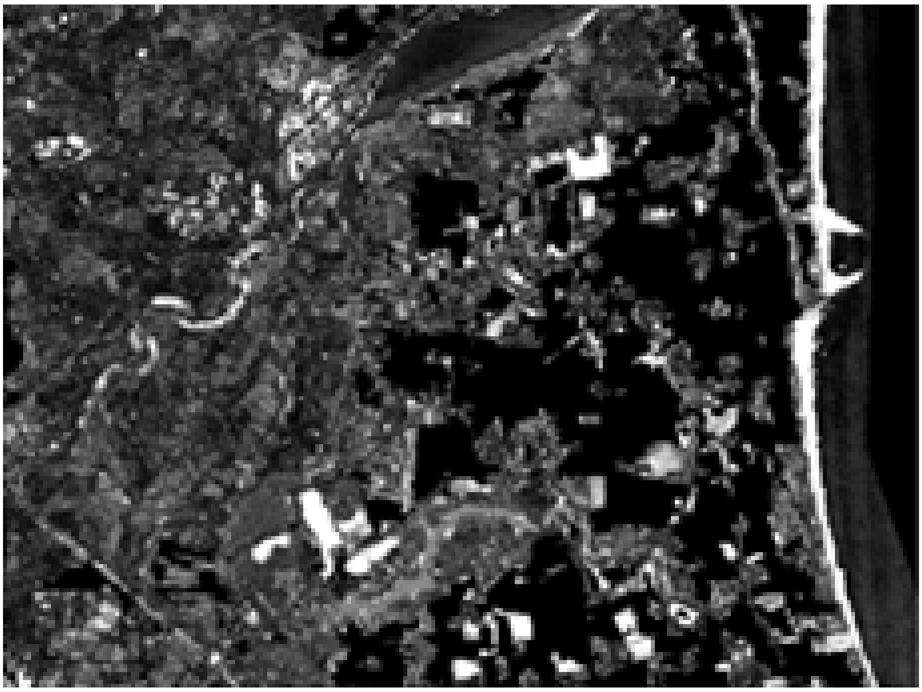

Figure 4: Principal Components Analysis composite index. Brightness represents change magnitude.

2.2.2 Classification-Image

Figure 6 shows the May 2000 image and the associated spectral distance based on the extent of the heather class in 1988 and the spectral values in 2000. Non-heather land cover in 1988 is masked from the spectral distance images, so the remaining high spectral distance pixels (white in Figure 6) show high spectral distance from the core heather signature and are likely to represent change. Figure 7 shows similar results for conifer; the highlighted changes all represent stands harvested, between 1988 and 2000.

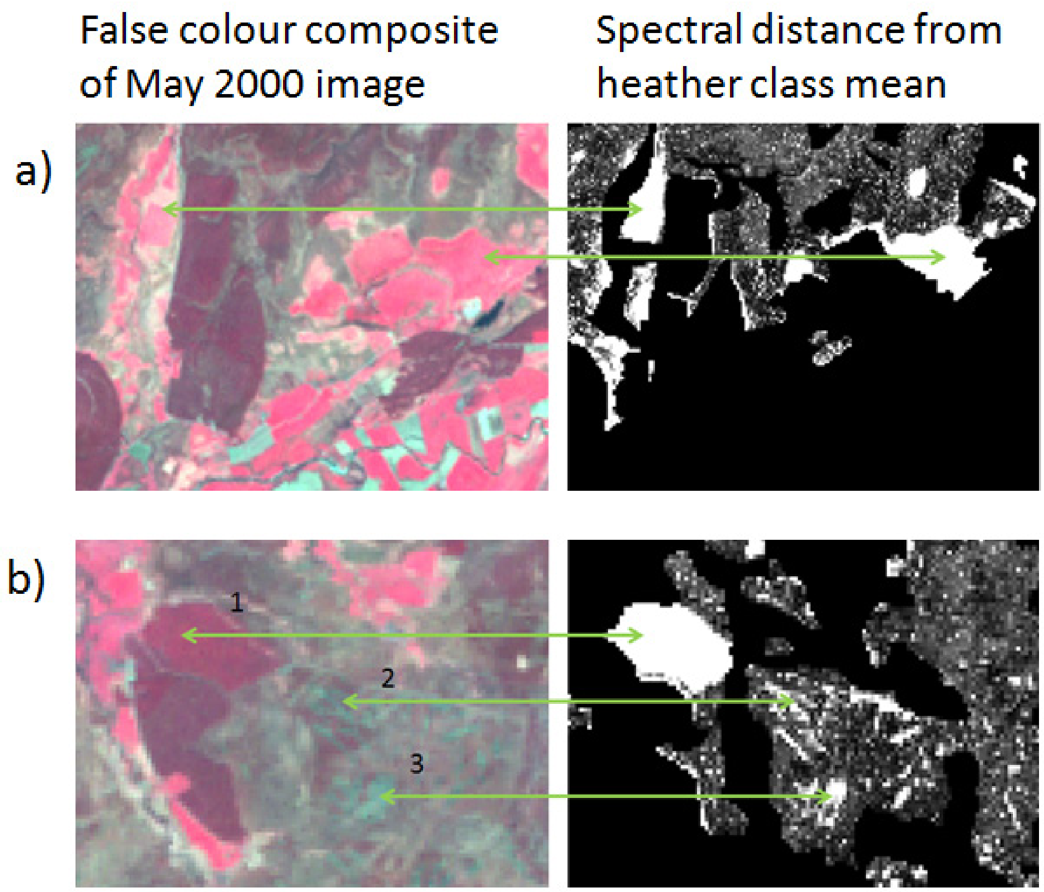

Figure 5: Examples of land cover change for the Scottish test site between 1988 and 2000 a) heather to improved grassland conversion; b) area 1: conversion from heather moorland to young conifer plantation; areas 2 & 3: areas of heather burning or heather clearance.

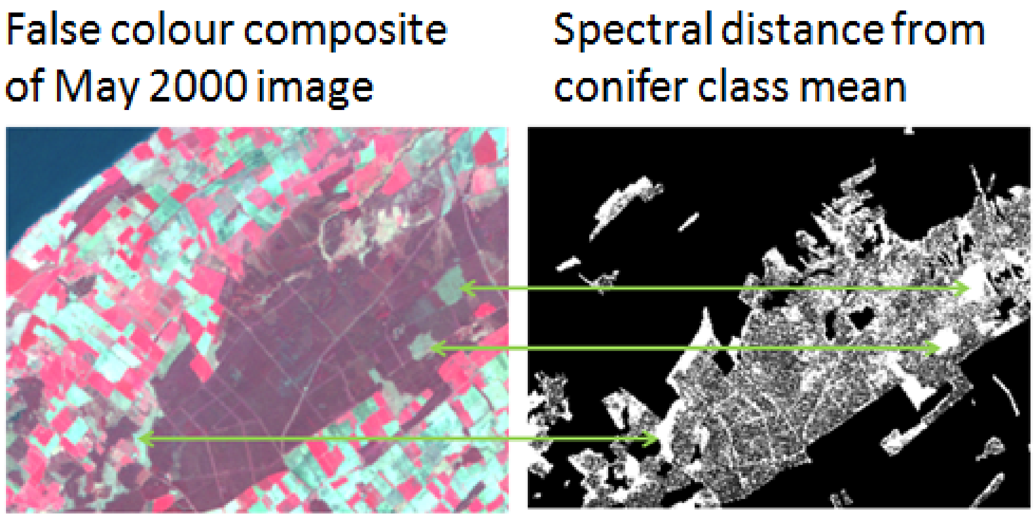

Figure 6: Examples of conifer harvesting for the Scottish test site between 1998 and 2000.

2.3 Change detection - next steps

The next steps are to:

- create a set of manually verified change areas against which to quantitatively assess the accuracy of the different Norfolk change products
- assess the efficacy of different methods of determining thresholds for the Norfolk change products
- test the change detection method underpinning the US National Land Cover Database (NLCD) against the Norfolk data set (Xian *et al*., 2009)
- apply the classification-image method to all the main classes in the LCS88 product, plus analyse which classes it works well for and identify any classes that are problematic
- apply the most successful change detection method for Norfolk to the Scottish data
- write up the results

3.0 Classification update

Random forest classifications have been conducted for multi-date imagery for 2011 and classification of the 2002 is currently in progress. Validation areas have been defined for both 2011 and 2002. Once the 2002 classification is complete then we will be able to analyse key issues, including the:

- Impact of number and timing of images on the classification accuracy
- Impact of training algorithm on classification accuracy
- Impact of ancillary data sets on classification accuracy
- Change detection between the 2002 and 2011 classifications

References

Xian, G., Homer, C., & Fry, J. (2009). Updating the 2001 National Land Cover Database land cover classification to 2006 by using Landsat imagery change detection methods. *Remote Sensing of Environment*, **113**(6), 1133-1147.