Using annually updated but coarse resolution EO derived land cover products for greenhouse gas accounting. A case study for the UK.

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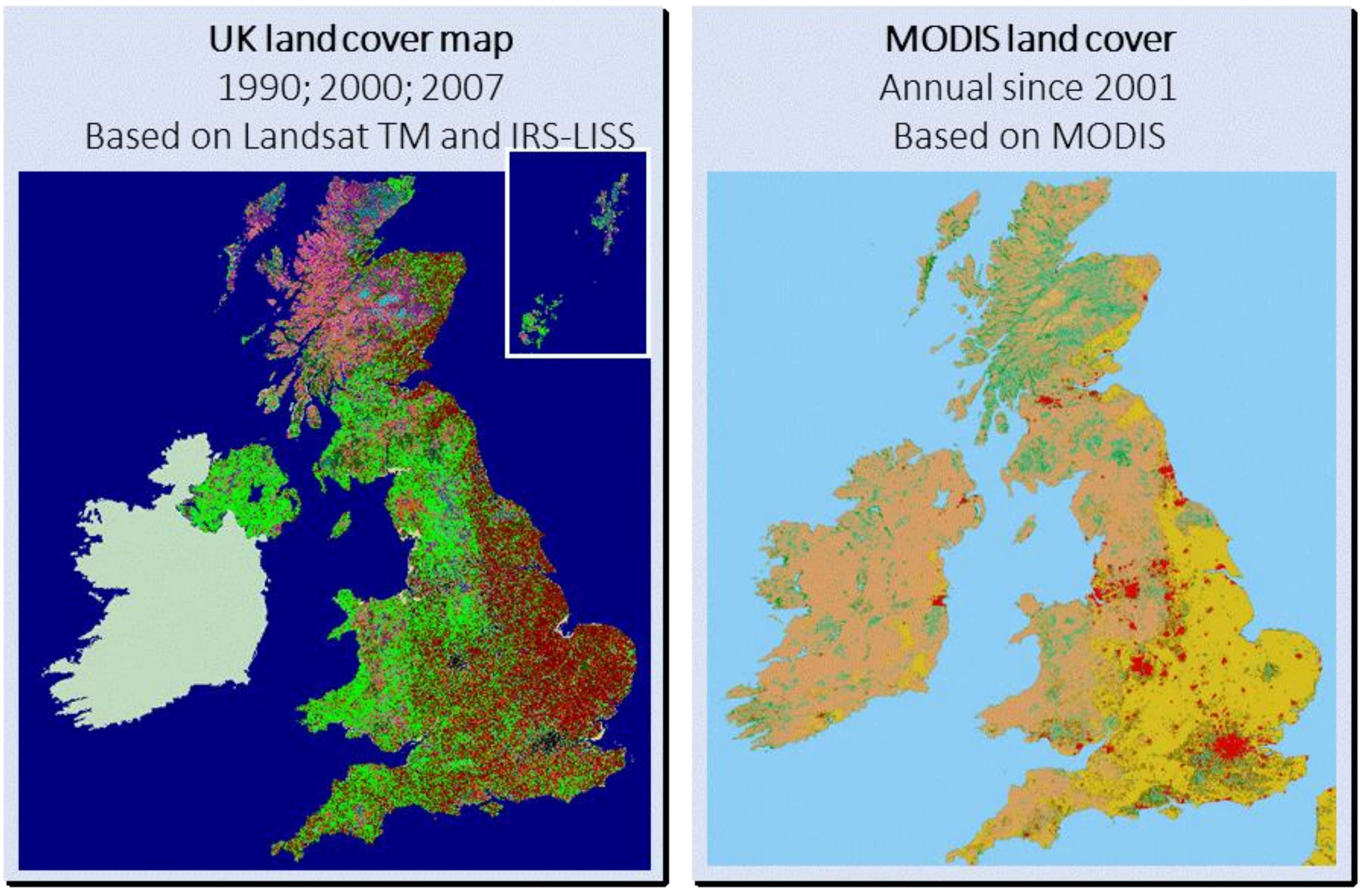
Background

The main aim of the case study was to evaluate the use of the annually updated land cover product derived from 500 m MODIS satellite imagery for greenhouse gas (GHG) accounting in the UK.
The options available to estimate the extent of the land cover and use in the UK that are associated to GHG emissions are limited. One information source which is already incorporated into the accounting is the UK land cover map (UK LCM), a remotely sensed (RS) derived land cover map delivered at a 25 m pixel resolution. The main disadvantage of the UK LCM is that, so far, it has only been updated twice (in 2000 and 2007) since its first version was created in 1990. For the purpose of GHG accounting an annual update is required. The MODIS land cover product (MODIS-LC), supplied for free at a 500 m pixel resolution on an annual basis, has been identified as a viable complementary source of information. It is clear that both products have their advantages and disadvantages in terms of spatial resolution, temporal update frequency and the accuracies attained. The key is to establish whether a higher update frequency delivered at a lower spatial resolution, taking into account the difference in accuracy achieved, will help reduce the uncertainties in the current GHG accounting.

The accuracy of a RS derived land cover and use map is established by comparing the map with an independently produced reference data set. The result is a correspondence matrix which contains information on the overall map accuracy and the accuracy achieved for the individual classes (i.e. providing class specific information on omission and commission error) (Congalton, 1991). There exist four different sources of mismatch which contribute to a reduction in correspondence between the RS derived map and the reference data. This includes a genuine miss-classification error, inherently due to the type of RS data used and/or the classification algorithm implemented; a mismatch in minimum mapping unit; a mismatch in the geo-location of the datasets; and finally a mismatch in the class definitions and the number of classes mapped.

The MODIS-LC is a global product, designed to deliver global cover classes which are mapped accurately on average across the globe. As a result, the regional and local accuracy of this product is known to vary (Friedl et al. 2010). National land cover maps such as the UK LCM are designed to achieve the best possible national accuracy. Taking advantage of daily coarse resolution imagery, could be an option for future RS UK mapping activities, and it would be fair to assume that a UK focus would result in higher accuracies than those achieved by the current MODIS-LC. So a key part of the evaluation was to establish which proportion of a mismatch would be caused by the low spatial resolution of the RS imagery used and which by the applied classification procedure.



Approach

The main part of the case study involved implementing the Pareto boundary, a method proposed by Boschetti et al. (2004), as a means to quantifying the impact of image spatial resolution on the mapping accuracy of an individual class. Reductions in accuracy caused by a mismatch between the reference data and the evaluated map was assumed not to exist, while errors caused by a mismatch in nomenclature were minimised by carefully translating the classes of the UK LCM, MODIS-LC and the reference data, used for the evaluation, to a common nomenclature (i.e. Land Use, Land Use Change and Forestry (LULUCF)).

Pareto requires a spatial reference data set with a higher spatial resolution than the resolution of the maps that are being evaluated. Two reference datasets were used to produce error of omission and commission and the Pareto boundary: (1) the 2007 Countryside Survey that produced 1 km^2 stratified random samples distributed across the UK and (2) the annual IACS survey that delivers a high spatial resolution use map of the land owned by framers in England. Because error of omission and commission and the Pareto boundary are class specific, the evaluation and comparison of MODIS-LC and UK LCM was carried out for the three main LULUCF classes Woodland, Crop and Grassland. To evaluate the impact of scale on change detection, we used the IACS derived changes in Woodland, Crop and Grassland as a reference to produce the Pareto boundary and calculate the omission and commission error for the changes identified by MODIS-LC.

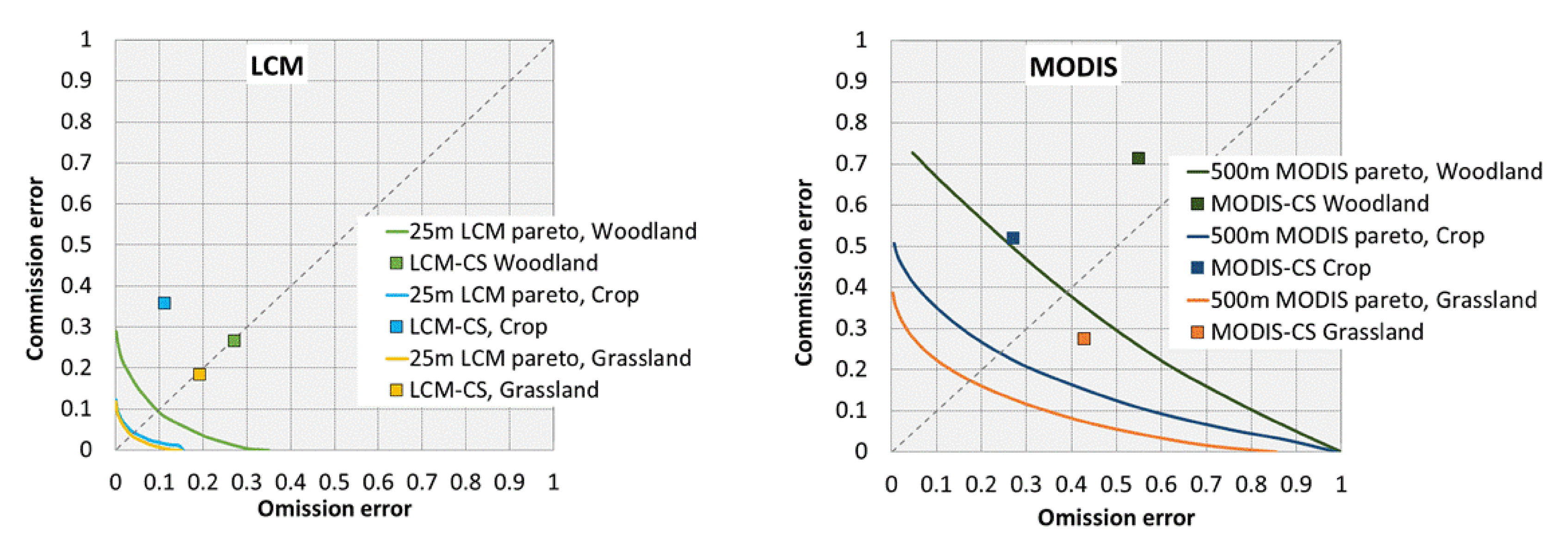
As part of the evaluation we also quantified the variation in area estimates and area change we should expect when incorporating coarser resolution maps into the GHG accounting. We analysed whether the MODIS-LC and IACS survey data produced similar estimates, in terms of land use coverage, land use change patterns and the flux of carbon dioxide arising from the land use change.

Findings

We were able to distinguish between mapping errors caused by the pixel size of the product (i.e. 25 m versus 500 m) and the classification algorithm used. We found that the image resolution contributes substantially to the resulting accuracy of a land cover map, but the impact varies with cover class. We suspect this is due to the patch size and shape distribution patterns of the classes. Differences in results obtained from using the two different reference data sets (CS and IACS) demonstrate this partially.

Our analysis showed that the mapping discrepancies of the MODIS-LC product with the CS survey sample data and the IACS survey data were substantially larger than those of the UK LCM. We found that the main factor causing the increase in error was the 500 m pixel resolution of the MODIS-LC product and that the 25 m UK LCM pixel was well suited to represent the land parcel shape and size distributions of the farmland land use classes in England. The impact of spatial resolution was amplified significantly in the mapped land cover changes.

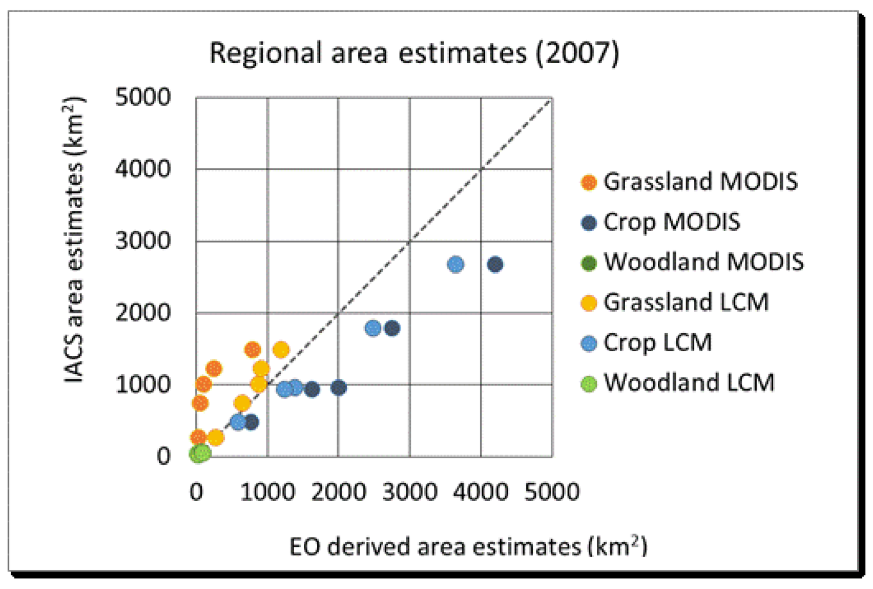
We also found that in both cases (MODIS-LC and UK LCM) there is scope for improving the classification procedure used and so further increase map accuracy. A more reliable separation between the crop and grassland classes is imperative which may not be achievable with optical remote sensing data only.

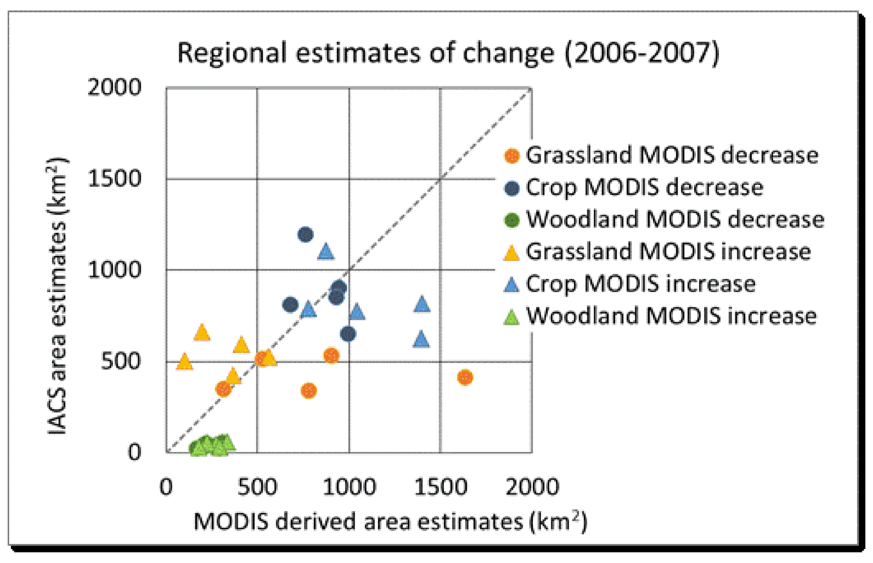


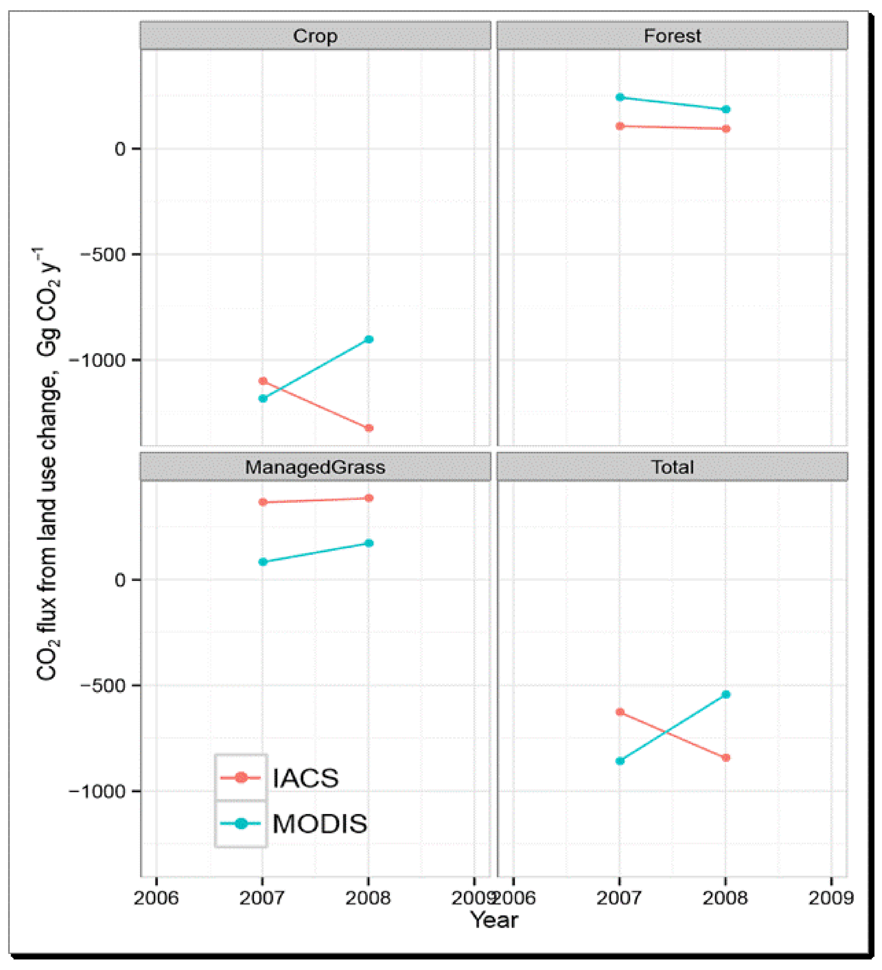
The class specific Pareto boundary and omission-commission errors of the UK-LCM (right) and MODIS-LC (left), both calculated using the CS squares located within England

Although the contribution of miss-registration (between land cover map and reference data) to classification error was not considered in this study, it is reasonable to assume that larger pixels sizes would exacerbate this type of error.

When comparing the regional estimates obtained from MODIS-LC and IACS, we found that the broad geographical patterns in land use were approximately similar, however estimates of land use change showed very large differences. MODIS-LC only detected the land use changes recorded in IACS in 1.3% of the 500 m pixels, and underestimated the extent of areas converted from cropland to grassland (and vice versa) by around 400 km^2. Because these conversions have opposite effects, the effects on the modelled fluxes were counter-balancing, and the difference in the total flux over all years was relatively small. However, the component fluxes differed by around 300 Gg CO_2 y^{-1}. Although the IACS must contain considerable amounts of error, it is directly based on reports from individual farmers with field-scale resolution. It is probably the best option for the inventory work at present.







Conclusions

The main conclusion is that because of its spatial resolution which causes unavoidable mapping errors and subsequent biases in area estimates, it is difficult to see a role for the MODIS-LC product in the inventory work at present. The focus should be on developing a cost effective RS method that delivers annual and accurate updates of the land cover and use at high spatial resolutions (25 m or less). The resulting map should aim to either match or improve on the accuracy of the existing and most recent UK LCM.

References

Congalton, 1991, Rem. Sensing Environ., 37, 35-46.

Friedl et al., 2010, Rem. Sensing Environ., 114, 168-182.

Boschetti et al., 2004, Rem. Sensing Environ., 91, 280-292.

Webinar: Novel UK Case Study

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