A Land Cover-Based Assessment of Ecosystem Service Provision in UK Farms and Estates

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Summary

A land cover and benefit transfer approach is used to calculate the annual monetary value of ecosystem services provided by natural capital assets in five UK farms and estates. Three LULC maps are used as input land cover data, and their suitability assessed. Results indicate valuations are primarily driven by differences in the amount of woodland, farmland, and for one site heather detected. The CEH Land Cover Map has the highest spatial resolution, and records the most woodland at each site, increasing valuations. Despite their expected importance, the contributions of other land covers to valuations, such as freshwater, are minimal.

KEYWORDS: natural capital, ecosystem services, agriculture, land cover

1. Introduction

Natural capital refers to the world's stock of natural assets, such as soil, plants and water, which yield flows of benefits to humanity. These flows are known as ecosystem services, and can include a woodland providing timber, or a wetland removing pollution.

Natural capital has emerged as an important concept in recent years, with the recognition that it must be documented, conserved and enhanced. With the UK's upcoming withdrawal from the European Union and Common Agricultural Policy, the possibility of a replacement agri-environment scheme centred around payments to farmers for conserving and enhancing natural capital assets has been proposed by some groups.

Here we explore the use of a land cover and spatially explicit benefit transfer-based approach, combining LULC mapping with existing valuations sourced from the literature. The technique has been used to quantify natural capital and ecosystem service provision globally (Costanza *et al.*, 1997, Costanza *et al.*, 2014) and regionally (Troy and Wilson, 2006, Brenner *et al.*, 2010). Here we apply the technique to a local scale, producing ecosystem service valuations for individual farms and agricultural estates within the UK.

2. Materials and methods

Work was carried out on five farms and estates within the UK with a wide geographical distribution. Sites of different size, spatial configuration, land cover and farming style and practice (**Table 1**, **Figure 1**) were chosen.

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Table 1 Summary of the key characteristics of the farms and estates studied.

Site	Location	Size (ha)	Type
A	Fife	651	Arable, pasture, forestry
B	Northumberland	4,897	Upland sheep farming
C	Cumbria	4,157	Sheep farming, pasture, some arable
D	Derbyshire	315	Dairy
E	Surrey	900	Traditional mixed estate

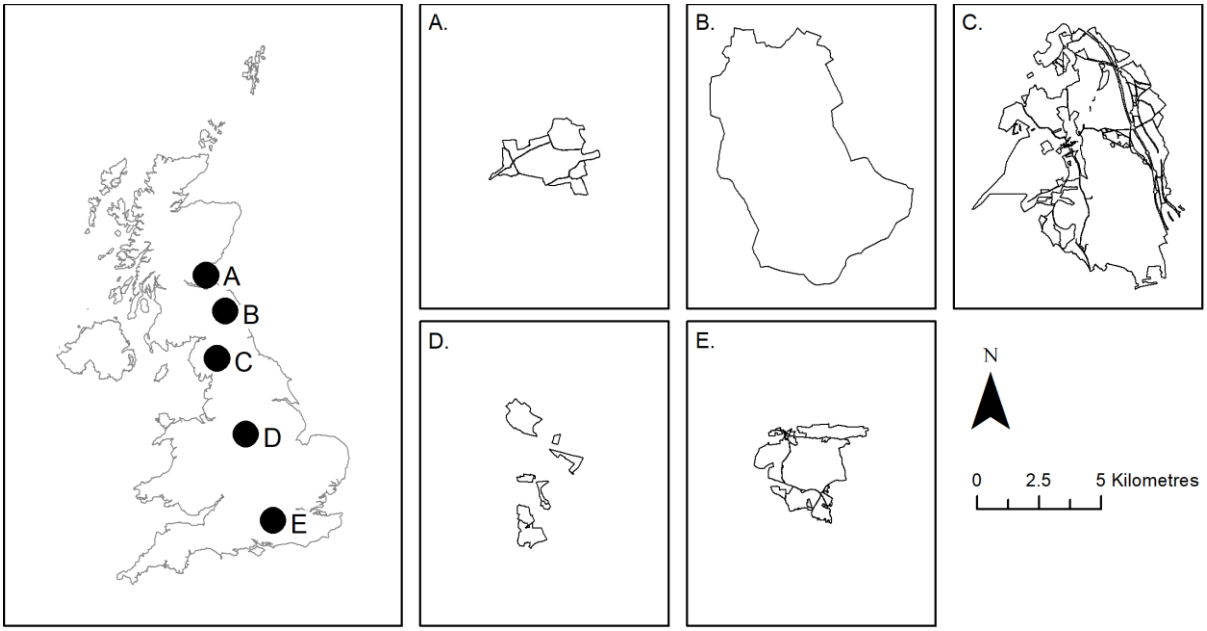

Figure 1 Locations and approximate boundaries of the farms and estates studied.

Three publicly available LULC datasets were used to provide the land cover data for ecosystem service valuation (**Table 2**).

Table 2 Summary of the key characteristics of the land cover datasets used.

	CEH Land Cover Map (2015)	CORINE Land Cover (2012)	ESA CCI Land Cover (2015)
Spatial Resolution	Min mappable area 0.5 ha, min linear length 20 m	Min mappable area 25 ha, min width 100 m. Captured at 1:100,000	300 m pixels (9 ha)
Spatial Extent	United Kingdom	Much of Europe	Global
Thematic Resolution	21 classes based on JNCC broad habitats	44 classes in a three-level hierarchy	22 classes, some further divided with regional information

Example ecosystem service valuations (**Table 3**) were primarily calculated from UK Natural Capital Ecosystem Accounts for Freshwater, Farmland and Woodland produced by ONS and Defra (Connors and Philips, 2017). This presents, in physical and monetary terms, the value of different ecosystem services provided by each land cover type for the whole of the UK. For each land cover, the total value of services it provides was divided by its area to derive an approximate value in £/ha/yr. Values for heather and bog, or comparable land covers, were not available, and so were sourced from the literature. Values for built-up areas and bare areas were assumed to be zero.

Table 3 Details of ecosystem service valuations used.

Land Cover	Value (£/ha/yr)	Source
Farmland	105	Connors and Philips (2017)
Freshwater	569	
Woodland	738	
Heath	384	Remme *et al.* (2015)
Peatland	412	
Built-up areas	0	
Bare areas	0	

Due to the disparate nature of the land cover classification systems used by the three data sources, a common classification system was devised and land cover categories harmonised to aid with comparisons between the data sources. The categories in this common classification system were then matched with the appropriate valuations.

Each input spatial data source was clipped to the boundaries of each farm and estate. The areas of each land cover type as recorded by these different data sources were then recorded for each site, resulting in physical stock natural capital accounts. To obtain monetary valuations, the area of land cover in an estate was multiplied by the valuation data (in the format value per hectare per year), to obtain a value in the format value per year.

3. Results

3.1. Comparison of LULC datasets

Visual inspection of the maps produced for each site indicates that while all datasets show broadly similar patterns of land cover, CEH Land Cover Map (LCM) is the most detailed spatially. This means that LCM can record small features unlike other datasets. For example, LCM is the only source to record freshwater at any estate, recording it at all sites other than Site D. For all sites, LCM detects the greatest variety of land covers, both when the default classification system is used, and when it is harmonised.

Where a land cover type is detected in all three sources, this ability to distinguish smaller parcels impacts the abundance recorded, especially with woodland. This can be seen clearly at Site C (**Figure 2**), where LCM is able to distinguish the small, narrow patches of trees scattered throughout the landscape. Here, 43% of the woodland recorded by LCM is present in parcels smaller than 25 ha (the minimum mappable area for CORINE), and 20% in parcels below 100 m width (the minimum mappable width for CORINE).

With regards to attributes, LCM was found to be best suited to the valuation system used. Its land cover classes, based on JNCC broad habitats, could be easily matched with ecosystem service valuations from the literature. CORINE's classification system includes land *use* classes, as well as land *cover* classes. This can be seen at Site D, where a large parcel is classed as *sport and leisure facilities*, a category that can include green space and buildings, both of which would have differing ecosystem service values.

Similarly, CCI uses several mosaic classes, aggregating together features that have quite different valuations.

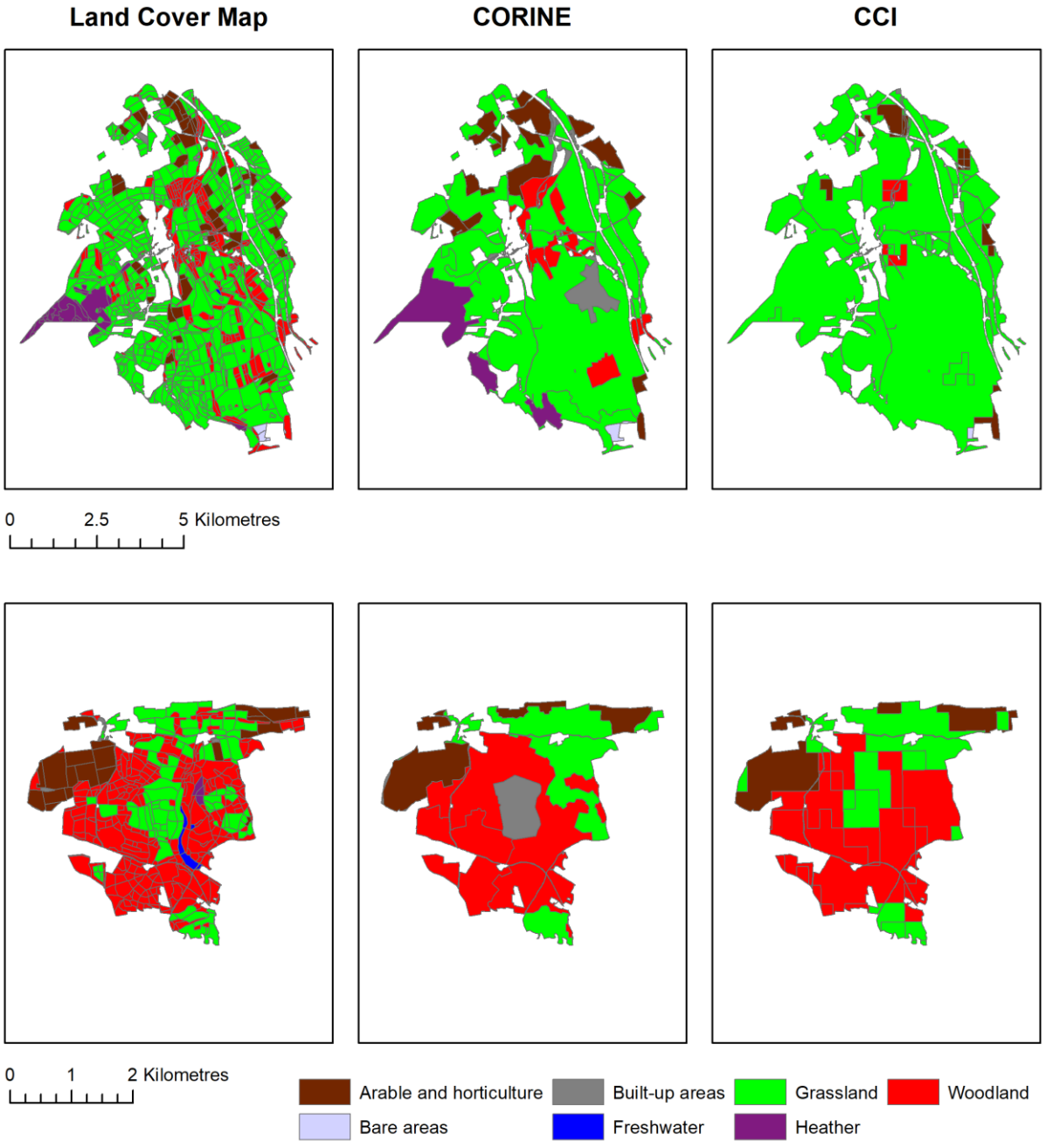

Figure 2 Land cover maps, using the harmonised classification scheme, for Site C (top) and Site E (bottom).

3.2. Monetary ecosystem service valuations

Annual ecosystem service valuations (**Figure 3**) range from £33,110 per annum (Site D using CORINE and CCI) to £1,264,299 per annum (Site B, using CORINE).

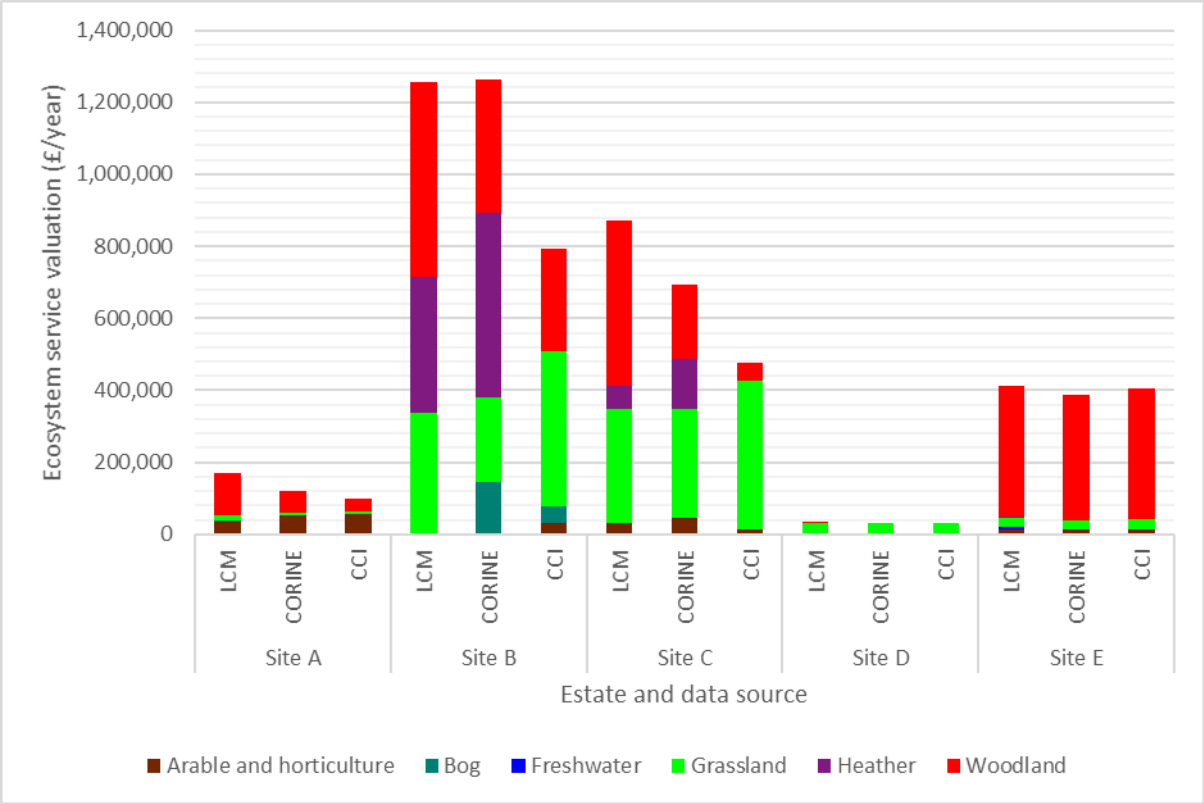

Figure 3 Ecosystem service valuations for the five sites, displayed using the common classification scheme.

4. Discussion

Using land cover data with varying spatial resolutions and disparate land cover classification systems results in variable ecosystem service valuations. LCM results in the highest valuations for all sites bar Site B. It was initially expected that this would be due to the inclusion of small but valuable features, such as ponds or boggy areas. However, these have a minor impact on overall valuations, with freshwater contributing at most 1.3% to a valuation (Site E) and bog 12% (Site B). Despite being assigned a relatively high value (£569/ha/yr and £412/ha/yr), this does not make up for their very small area.

Rather, valuations are primarily dominated by farmland (arable and grassland), which has a low valuation (£105/ha/yr) but is present in large areas, and woodland, which has the highest valuation (£738/ha/yr) and is present in moderate amounts at most sites. With LCM able to distinguish small and sinuous patches of trees, it records the greatest amount of woodland at all sites. CORINE and CCI record only the larger continuous parcels. This leads to a general trend with LCM recording more woodland and less farmland, leading to higher valuations, with the inverse being true for CCI.

The consistency between valuations produced using the three datasets varies considerably. Valuations are most variable at sites where land cover is fragmented and made up of small parcels, such as Site C, where valuations produced using LCM and CCI differ by 58%. The upland heather environment of Site B also shows variability, with 17% of the site being assigned a different land cover type in each of the three datasets. Here, 30% of the site's value as calculated using CEH LCM is due to the presence of heather. However, CCI does not contain a heather or comparable class, highlighting a problem with using a global dataset to map a quite UK specific habitat.

Site E conversely is characterised by large, continuous areas of woodland, grassland and arable, and

here the agreement between maps is surprisingly high, with just a 6% difference in valuations produced by LCM and CORINE. Similarly, Site D which is the smallest and nearly wholly pastures, saw just 7% difference. This suggests that the resolution of the land cover data required to obtain accurate valuations varies between sites.

There are uncertainties involved, especially around assumptions made during the benefit transfer process. Further work will investigate how valuations can be further improved by the introduction of additional land cover data, such as the distribution of woody linear features and hedgerows.

5. Conclusions

This work demonstrates a land cover-based approach to natural capital and ecosystem service quantification in farms and agricultural estates, showing the characteristics of the land cover data used impacts these valuations. The CEH LCM possesses the highest spatial resolution, and results in the highest valuations at all sites, primarily through the detection of larger areas of woodland. The consistency of the valuations varies with the type of land cover present at the site, and its arrangement. As well as spatial resolution, thematic resolution must also be considered, with the land *use* classes uses by CORINE and mosaic classes used by CCI making assigning these a suitable valuation problematic.

6. Acknowledgements

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Biographies

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