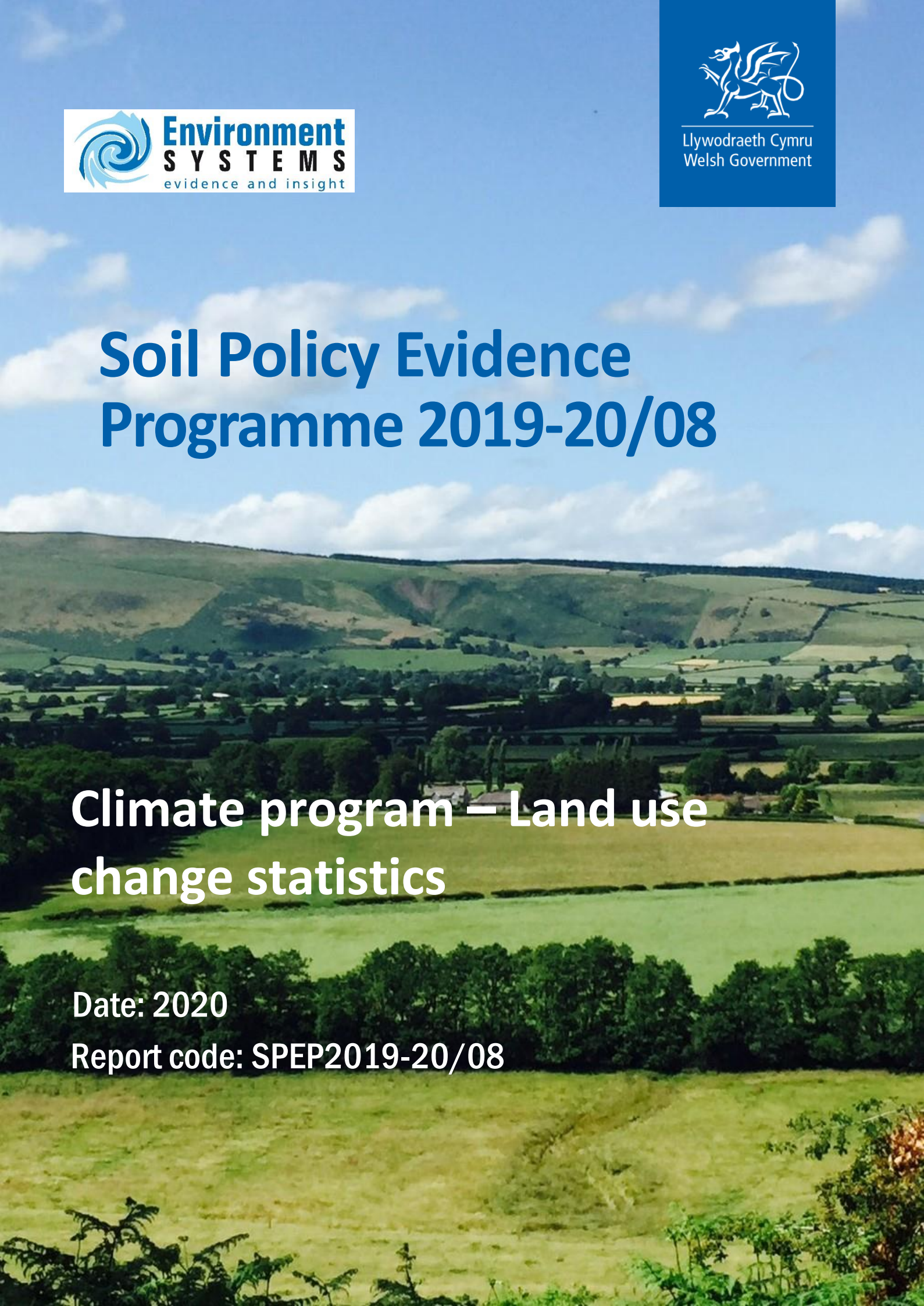


Environment SYSTEMS evidence and insight

Llywodraeth Cymru
Welsh Government

Soil Policy Evidence Programme 2019-20/08

Climate program – Land use change statistics

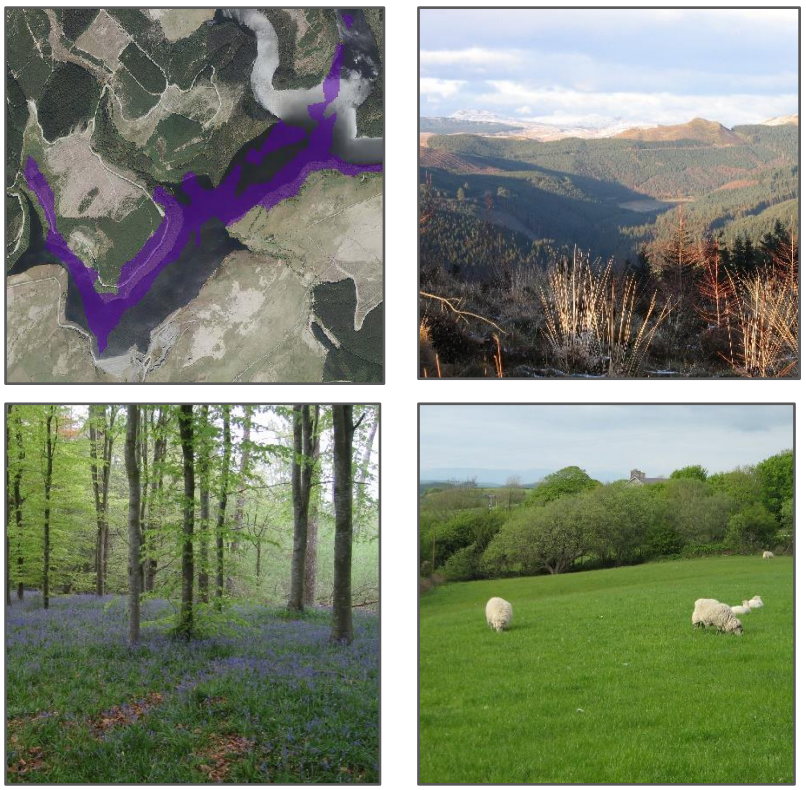
Date: 2020

Report code: SPEP2019-20/08

Environment SYSTEMS
evidence and insight

Climate program
Land use change statistics

Final report



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Llywodraeth Cynulliad Cymru
Welsh Assembly Government

CSCP – Land use change statistics

Submitted to:

Welsh Government
Soil Policy & Agricultural Land Use Planning Unit
Land, Nature and Forestry Division
Department for Environment, Energy & Rural Affairs

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1 Introduction

Land use has historically been subjected to fast rates of change, particularly throughout the last century. How agriculture is carried out is one of the most important drivers for land use change, as innovations in agricultural production drive large scale changes in farming practices; for example, the development of the combine harvester dramatically changed the sizes of fields. This issue was discussed during the project CAPABILITY, SUITABILITY AND CLIMATE PROGRAMME, CSCP09 (Welsh Government, 2019a; Bell *et al.*, 2020a; Bell *et al.*, 2020b), a joint project between Welsh Government, ADAS, Cranfield, and Environment Systems Ltd (ESL). As a project extension, ESL was commissioned by Welsh Government to investigate how these patterns manifested in Wales, both to better understand current land use and to inform potential ways towards more sustainable agricultural practice in line with Wales' sustainability goals and the Well-being of Future Generations (Wales) Act 2015.

1.1 Project aims and objectives

This project aims to investigate overall changes in land cover in Wales by initially summarising total landcover of each class in the 1930 Dudley Stamp maps and then comparing them to the most recent Phase 1 habitat classification of Wales. The focus of this comparative analysis are areas classified as either orchards or woodlands in the Dudley Stamp maps. Additionally, with a focus on changes to agricultural land use specifically, the project aims to analyse the Arable classes of both the Dudley Stamp map and the Phase 1 map with regards to their distribution amongst ALC (Agricultural Land Classification) grades.

This document contains the accompanying report to the Excel Spreadsheet WG_CSCP_LandUseChangeStatistics.xlsx; the spreadsheet contains all hectarage summaries produced during this project.

2 Methods

2.1 Data used

2.1.1 Digital land utilisation survey (Dudley Stamp maps)

The Dudley Stamp maps provide a pre-war land survey (1933-1949) for the whole of Wales and, in 2011, have been scanned and digitised at a resolution of 1 km (DEFRA, 2011). The map classifies landcover into 8 classes: Rough Grazing, Urban, Water, Arable, Suburban, Pasture, Woodland, and Orchard. The digitisation effort was taken to provide a landcover map that can be used as a pre intensification baseline regarding agriculture; this is the function this dataset has in this project.

2.1.2 Habitat Inventory for Wales

The Habitat Inventory for Wales is the most recent national landcover dataset for Wales. The data is a remote sensing-based augmentation of the original Phase 1 terrestrial habitat survey of Wales, a programme of field recording carried out between 1979 and 1997. The remote sensing work was carried out in 2010, based on satellite imagery collected between 2003 and 2006 (Lucas et al., 2011).

2.1.3 Agricultural Land Classification for Wales

The Agricultural Land Classification system forms part of the planning system in England and Wales; it classifies the land in five categories based on biophysical assessments of versatility and suitability for growing crops. The first version of the ALC was generated between 1967 and 1974 under the name Provisional Agricultural Land Classification Map (Welsh Government, 2017). This data was superseded in 2017, when Welsh Government launched the Predictive Agricultural Land Classification Map, which has been further updated between 2018 and 2020 (MAFF, 1988; Welsh Government, 2019b).

2.2 Data processing

Processing for this project was carried out using GeoTIFFs, EPSG: 27700, at 10 m pixel size (0.01 ha pixels). Each class in the input datasets was assigned a unique identifier value (UID), which was used for rasterization. For temporal comparison of the datasets, overlie analysis between raster datasets was carried out using additive raster maths. The datasets combined were:

- Phase 1 habitat data and Dudley Stamp habitat data
- Phase 1 habitat data and Predictive Agricultural Land Classification
- Dudley Stamp habitat data and Predictive Agricultural Land Classification

For each of the output rasters, raster attribute tables (RATs) were created, listing all pixel values and their respective pixel counts. This information was used to derive area coverage information for individual classes / class combinations, e.g. the total area classified as "Wood" in the Dudley Stamp map, as well as the total area that was classified as "Wood" in the Dudley Stamp map and is classified as "A1.1.1" (Broadleaved forest) and the more recent Phase 1 data. The same calculation was used to identify how agricultural land is distributed amongst ALC grades, using the "Arable" class from the Dudley Stamp map and the Phase 1 data, respectively.

For additional change analysis, all class combinations between Dudley Stamp classes "Wood" or "Orchard" and the Phase 1 classes were manually assessed with regards to whether this is likely to represent a change in land cover. For example, pixels classified as "Wood" under Dudley Stamp, but as "Urban" in Phase 1 have likely changed land cover, whilst those classified as "A1.1.1" in Phase 1 are likely to have remained woodland.

3 Results

All results from the project are provided to Welsh Government as an Excel file (Appendix 1). (WG_CSCP_LandUseChangeStatistics.xlsx). The sheets contained therein are detailed in Appendix A.

3.1 1930 land cover

Table 1: Land cover in Wales, 1930

Dudley Stamp class	Area coverage (ha)	Area coverage (%)
Arable	186481.57	7.85
Grass	838433.26	35.31
Orchard	1187.29	0.05
Rough Grazing	767446.17	32.32
Suburban	61088.25	2.57
Urban	46699.73	1.97
Water	333692.48	14.05
Wood	139477.86	5.87
Total	2374506.61	100.00

Land cover in Wales in 1930, according to the Dudley Stamps data, was heavily weighted towards grassland, with the classes "Grass" and "Rough Grazing" combined accounting for nearly 70% of land cover (Table 1). Both "Wood" (~6%) and "Arable" (~8%) were only present in few parts of the country at the time.

3.2 Change analysis between Dudley Stamp classes and Phase 1 habitats

A temporal comparison between the Dudley Stamp map and more recent Phase 1 data shows that most orchards appear to have been converted to different types of land cover (Table 2), most commonly to classes Improved grassland (phase 1 habitat code B4) (554.3 ha), Arable (phase 1 habitat code J1.1) (255.34 ha), and Urban and built (phase 1 habitat code J3.6) (106.91 ha) (see supplementary project data, excel file WG_CSCP_LandUseChangeStatistics.xlsx); together, these three classes account for ~77% of change away from orchard. Based on this analysis, only ~18% of orchards appear to have been retained. However, this value is to be treated with caution, as orchards are not specifically identified in the updated Phase 1 data. Any class change from orchard to a class containing trees was considered likely to have remained orchard, while classes that are noticeably different from orchards, particularly in remote sensing terms, were considered to likely represent an actual, on the ground change (e.g. orchard to urban). Changes that are unlikely to actually have occurred from an ecological and/or land use perspective were marked as "likely artefactual", such as a change from orchard to blanket bog.

Of the Dudley Stamp class "Wood", ~58% are likely to have remained unchanged (Table 2); these predominantly fall into the Phase 1 classes semi-natural broadleaved woodland, A1.1.1, and planted broadleaved woodland,A1.2.2. As the Dudley Stamp data does not distinguish between deciduous and coniferous woodland, an assessment concerning change from broadleaved to coniferous woodland types cannot be made, any Phase 1 woodland is presumed to represent no change. The ~39% of woodland now falling into non-woodland Phase 1 classes are spread over 26 habitats, with Improved grassland (B4) covering by far the largest extent (52.8% of change recorded), with the second most common change being to Arable (J.1.1) and accounting ~11.7% of change.

Full summaries of overlap between Dudley Stamp classes and Phase 1 classes can be found in the supplementary project material (see supplementary project data, excel file WG_CSCP_LandUseChangeStatistics.xlsx).

Table 2: Change analysis between Dudley Stamp classes "Orchard" and "Wood" and Phase 1 habitat types

Type of change	"Orchard" to Phase 1 habitats		"Wood" to Phase 1 habitats	
Probable change	960.21 ha	80.87 %	54722.96 ha	39.23 %
Likely no change	212.19 ha	17.87 %	80710.74 ha	57.87 %
Likely artefactual	14.89 ha	1.25 %	4044.16 ha	2.90 %

3.3 Distribution of arable land between ALC grades

Between the 1930 Dudley Stamps map and the 2016 Phase 1 data, arable land increased by ~4% (~7800 ha). The distribution of the existing arable land within the ALC grades also shifted (Table 3), with an increase of arable production in land of grades 1, 2, and 3a, and a decrease in grades 3b, 4, and 5. The majority of arable production occurs in land of grades 3a and 3b (~60% total), whereas only very little occurs on grades 1 and 5. However, this is partly driven by the land composition in Wales, where only ~0.27% of land fall into grade 1, which is likely the main reason that most arable production by hectarage takes place in grades 2 and 3.

Table 3: Distribution of arable land between ALC grades

Habitat (Data source)	Units	ALC Grade 1	ALC Grade 2	ALC Grade 3a	ALC Grade 3b	ALC Grade 4	ALC Grade 5
Arable (Dudley Stamp)	**ha**	571.36	25129.33	35946.42	76824.85	41188.18	10816.76
	%	0.30	13.19	18.87	40.33	21.62	5.68
	% of grade used for agriculture	**10.22**	**16.68**	**16.46**	**13.51**	**8.09**	**1.72**
Arable (J1.1, Phase 1)	**ha**	1316.57	33093.91	41182.07	78120.92	36400.37	8196.65
	%	0.66	16.69	20.77	39.39	18.36	4.13
	% of grade used for agriculture	**23.55**	**21.96**	**18.85**	**13.74**	**7.15**	**1.31**

4 Interpretation

4.1 Dudley Stamp map and Phase 1 habitats

The change analysis from orchards in 1930 to more recent Phase 1 data indicates that orchards have become much less prevalent in Wales, with a reduction in area of over 80%. The three most common Phase 1 habitats covering ground that was classified as orchard in 1930 are Improved grassland (B4), Arable (J1.1), and Buildings (J3.6), all of which are very unlikely to still contain orchards, as the characteristics of these classes are distinctly different from orchards in remote sensing terms. For some Dudley Stamp – Phase 1 combinations, thematical differences in resolution (see section 4.1.2) between the two maps make a clear assessment of change vs. no change difficult.

An example is A1.2.2 (Planted coniferous woodland) – given specific ground flora conditions, the remote sensing methodology employed when updating the Phase 1 map could feasibly have classified certain configurations of orchards with a dense ground flora as Planted woodland. Similarly, the remote sensing methodology had some known confusion between hedges, scrubs, and orchards.

The woodland class, also affected by thematical differences in resolution (see section 4.1.2), displays a more varied pattern, with just over half of the land classified as woodland in 1930 still containing woodland, whereas about 40% have changed, mostly to improved grassland. However, comparing the total woodland area in Dudley Stamp (nationally only ~5.9% of land) to woodland in the Phase 1 data shows an increase in total woodland cover by about 40%. Over half of this additional woodland consists of coniferous plantations; in 1930, the vast majority of this land was used for Rough Grazing. This observed change reflects activity beginning at the end of the second world war and spanning into the 1960's, where large coniferous forests were established across Wales by the Forestry Commission in order to address a shortage of timber.

Looking at the full change matrix shows that land out of most Dudley Stamp classes has experienced some change to woodland, including >9,000 ha of conversion from Arable to Broadleaved woodland (A1.1.1), >59,000 ha from Grass to Broadleaved woodland (A1.1.1), and >33,000 ha from Rough Grazing to Broadleaved woodland (A1.1.1). Substantial amounts of conversion from Grass and Rough Grazing to other Phase 1 woodland classes were also observed, with the Phase 1 classes being Planted woodland (A1.2.2), Dense scrub (A2.1) and Felled woodland (A4.2).

The above results are affected by both spatial and thematical differences in resolution between Dudley Stamp and Phase 1 habitat data, which are further explored in section 4.1.1 and section 4.1.2, respectively.

4.1.1 Spatial resolution

Spatial resolution refers to the accuracy with which boundaries are digitised / generated and was likely less accurate in the original 1930 data than in the more recent Phase 1 data, even in the original field work effort. Some inaccuracies in the Dudley Stamp data can be seen easily in areas with gaps between polygons (Figure 1). These boundary differences are likely the reason for many Dudley/Phase 1 habitat combinations that only occur across a very small area and that appear unlikely from an ecological / land use perspective. In the change analysis, these have been marked down as "likely artefactual", and cover combinations such as a change from "Wood" in the Dudley Stamps map to hard cliff in the Phase 1 data. These types of combinations are presumed to be caused by edge effects, where a habitat boundary has been digitised in a slightly different position between the two datasets. Some combinations are likely to be a mix between actual change and this type of artefactual edge effect; here, the change from woodland to standing water is noteworthy: In one area that was manually assessed, it appears that the creation of a new reservoir makes this an actual change (Figure 2). However, in other regions the boundaries of lakes were simply digitised slightly differently between datasets.

Figure 1: Close up Dudley Stamp map, showing gap and some polygon misalignment

If more detail change analysis was to be carried out, edge effects could be minimised by clumping pixels of the same value into groups and applying a minimum mapping unit prior to area calculations; this way, very small clumps along boundaries would be excluded from further analysis.

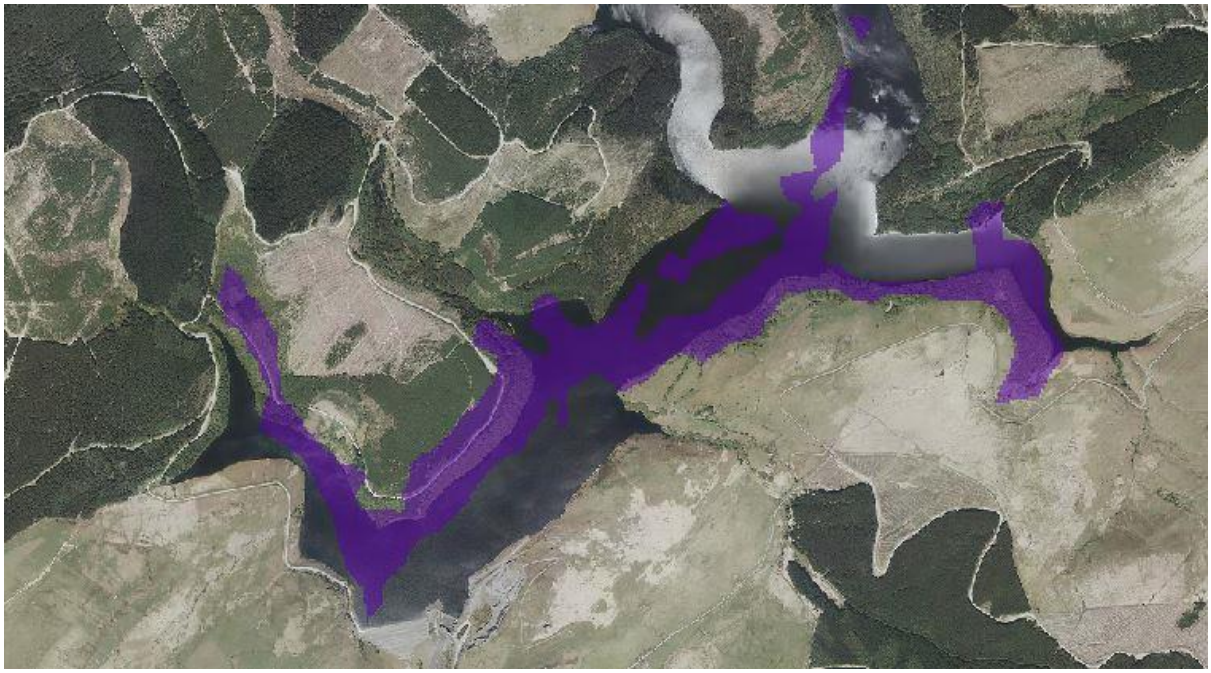

Figure 2: Aerial photograph (2014) showing a reservoir, with purple overlie highlighting areas classed as "Wood" in the Dudley Stamps map

4.1.2 Thematical resolution

Thematical resolution refers to the level of detail in the classification scheme. This level of detail differs substantially between the two datasets, with 8 classes in the Dudley Stamps map and 102 in the Phase 1 habitats data. This is the reason for the assessment of change having been carried out manually for the two Dudley Stamp classes selected for more detailed analysis; the issue was first identified looking at areas marked as arable in the Dudley Stamp map, and as Hedges in the Phase 1 data. Most likely, this does not represent a change on the ground, hedges were simply included with the arable land in the Dudley Stamps map. For the Dudley Stamp Orchard class, thematical resolution proved particularly difficult, as orchards do not have their own class in the Phase 1 data; therefore, anything that was orchard and still contains a non-coniferous tree class is presumed to have retained its orchard. For woodland, the main difficulty was in the lack of separation between deciduous and coniferous data under Dudley Stamp, making it impossible to make any statements regarding conversion from deciduous woodland to coniferous plantation, a shift that is highly consequential for biodiversity and ecosystem service generation.

4.2 Arable land and Predictive ALC (updated)

Based on the 1930 Dudley Stamp map and the more recent Phase 1 habitat data, agricultural land use in Wales has increased slightly, by ~4%, to a total of ~198,000 ha (approximately 11% of Wales). Based on the distribution between ALC grades, however, this relatively small value might be masking larger changes in how the agricultural land is distributed, seeing that agricultural land in ALC classes 1 through to

3a increased, whilst decreasing in ALC classes 3b through 5. This could indicate better targeting of agricultural land use to Best and Most Versatile land and imply increased agricultural productivity.

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Appendix A. Hectarage tables produced during this project

All results from the project have been provided to Welsh Government as an Excel file (Appendix 1). (WG_CSCP_LandUseChangeStatistics.xlsx), with the following sheets:

- D_Habitat
  - All classes: Matrix showing area covered by each Dudley Stamp class – Phase 1 class combination
  - Summarised: Matrix showing area covered be each Dudley Stamp class – Phase 1 class combination, with all B classes combined into one Grassland class
  - Change analysis between areas classed as "Orchard" in the Dudley stamps data and their nowadays Phase 1 class
  - Change analysis between areas classed as "Wood" in the Dudley stamps data and their nowadays Phase 1 class
  - Area summaries for the Dudley Stamps data
- ALC_Grade
  - Distribution of Arable class (from Dudley Stamps map and Phase 1, respectively) into ALC grades, by total hectarage as well as percentage