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Applying ALC Data for Modelling Suitability for Ecological Restoration

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Capability, Suitability and Climate Programme

This project is led by Welsh Government Land, Nature and Forestry Division with partners Environment Systems Limited, RSK ADAS Limited and Cranfield University.

Report prepared by:
Dr Gemma Bell CEnv, MCIEEM
Elsa-Kristin Naumann
Dr Katie Medcalf CEnv, MCIEEM

Environment Systems Ltd.
09 Cefn Llan Science Park
Aberystwyth
Ceredigion
SY23 3AH

Tel: +44 (0)1970 626688
www.envsys.co.uk

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Executive summary

This report describes the wider application of the Version 2 Predictive Agricultural Land Classification (ALC) dataset and supporting data, for modelling: agricultural flood risk; areas suitable for and requiring irrigation; and areas suitable for ecological restoration. The resulting models were created as 50 m resolution raster datasets, covering the whole of Wales.

This work forms part of a wider three-year project which is led by Welsh Government and includes Environment Systems, Cranfield University and ADAS. The project forms part of the Welsh Government climate change mitigation and adaptation plans (Welsh Government, 2019). Previous project reporting (Bell *et al.,* 2020) described the use of ALC data for modelling land suitability for 118 crops under present day conditions, and under nine projected climate change scenarios.

The first section of this report describes the outcomes of investigations into the use of Natural Resources Wales FRAW flood risk data for creating a spatial dataset to define areas of agricultural flood risk, graded according to ALC criteria. The dataset was successfully used to define the extent and distribution of Best and Most Versatile land in relation to both summer and winter flood risk. Data gaps prevented definition of the lowest ALC grade areas, subject to highest flood risk (grade 5 for winter flood risk, and grade 4 for summer flood risk). Partial definition was possible for land graded as 4 for winter flood risk, and 3b for summer flood risk.

The second section of the report describes investigations into the use of the Version 2 Predictive ALC data for modelling irrigation requirement for sensitive crops. The initial focus of the work was for modelling land suitability for irrigation. However, following a review of the outputs by soil and crop specialists, it was felt that the definition of suitability did not sufficiently distinguish between physical suitability of the land, and the level of derived benefits gained from irrigation. The level of derived benefits varies according to soil type, location, and crop. As a result, the rulebase was revised, and the final models focussed on irrigation requirement, using five specific crops; potato, sessile oak, Sitka spruce, strawberry, and wheat.

The revised models focused on ALC drought data, where each ALC grade was assessed in terms of likely irrigation need, for each of the crops. ALC slope data was then added to identify areas where slopes are too steep to enable irrigation. The resulting models showed areas with soils that currently do not generally require irrigation; areas where the crops may experience drought, and may therefore require irrigation; and areas that are highly likely to experience significant droughtiness, and will require irrigation. Areas likely to require irrigation have been divided into steep and shallow slopes, to identify places where irrigation may be physically possible.

The models show very limited areas requiring irrigation for the five sample crops, at the present time. However, drought is predicted to become a much more significant factor over large parts of Wales in the near future, due to climate change. Future work would benefit from repeating the analysis using future scenario data; this would reveal a greater area of soils at risk of droughtiness, and provide a rapid assessment of which of these areas could be irrigated to benefit target crops. Further such analyses would benefit from the availability of gridded monthly rainfall data.

The final section of this report describes investigations into the use of suitability scoring of ALC and supporting datasets to model ecological suitability for habitat restoration, with a focus on blanket bog habitat. The study used ALC, habitat, rainfall and soil data, all of which were classified into areas suitable, of limited suitability, and unsuitable for restoration of blanket bog. The study did not consider the appropriateness of restoring areas to blanket bog; merely whether biophysical conditions would facilitate this. The analysis was carried out for present day conditions, and predicted conditions in 2080, based on the UKCP18 2080M climate change scenario.

The resulting models showed a reduction in areas suitable for restoration to blanket bog between the present day and 2080. These changes were found to be driven by changes in climate, soil wetness, soil droughtiness, and annual average rainfall, with the upland fringe and parts of eastern Wales in particular becoming too dry to support blanket bog habitat.

The ecological suitability maps can be analysed in conjunction with habitat network connectivity data in order to identify areas where restoration could increase habitat resilience, through improving ecological connectivity. The methodology could also be applied to suitability modelling for other habitat types.

Contents

Introduction

This report forms part of a wider three-year project which is led by Welsh Government and includes Environment Systems, Cranfield University and ADAS (*Figure 1*). The project forms part of the Welsh Government climate change mitigation and adaptation plans (Welsh Government, 2019). Previous project reporting (Bell *et al.*, 2020) described the use of Agricultural Land Classification (ALC) data for modelling land suitability for 118 crops under present day conditions, and under nine projected climate change scenarios.

Underpinning the crop suitability modelling was the Version 2 Predictive ALC dataset (Keay, 2020a), Natural Resources Wales Flood Risk Assessment Wales (FRAW) data (NRW, 2019), and additional models of frost, wind and salt spray risk, in order to consider the most important biophysical factors influencing suitability for growing crops. This report considers parallel work streams under the same project, to investigate other potential applications of these new and updated datasets; specifically relating to agricultural flood risk, irrigation suitability, and ecological suitability modelling.

The first section of this report describes the outcomes of investigations into use of FRAW data for creating a spatial dataset to define areas of agricultural flood risk, graded using ALC criteria, and to map the extent and distribution of the different land grades.

The second section of this report describes investigations into use of the Version 2 Predictive ALC data for modelling irrigation suitability.

The final section of this report describes investigations into the use of ALC and supporting datasets to model ecological suitability for habitat restoration, with a focus on blanket bog habitat.

All resulting models were created as 50 m resolution raster datasets, covering the whole of Wales.

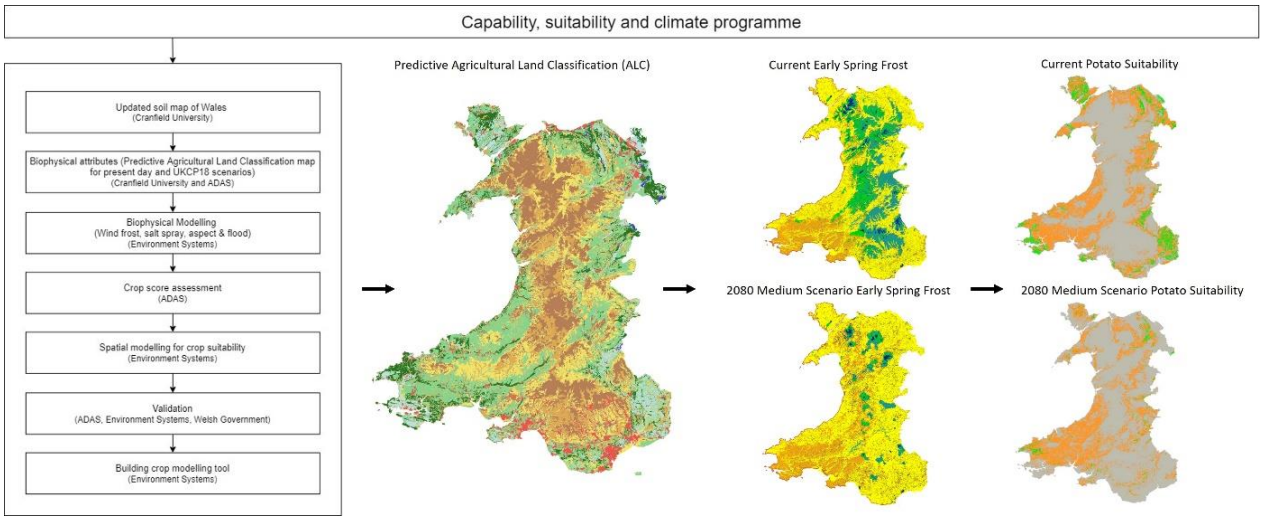

Figure 1: Stages of crop suitability modelling under the Capability, Suitability and Climate Programme

1. Ecological suitability modelling: suitability for restoration of blanket bog

1.1 Background

The capacity for ALC data to be applied to crop suitability modelling has been well-established (Bell *et al.,* 2020). However, the same methodology, focussed on the Version 2 Predictive ALC data for Wales, could also have a wide range of environmental and conservation applications, given that habitats are either directly (in the case of terrestrial habitats) or indirectly (freshwater and marine) affected by soil properties and management.

ADAS (2019) conducted a scoping study to explore whether the new ALC data could be applied to modelling suitability for restoration or creation of priority habitats in Wales, in order to identify optimal locations for land use change to support biodiversity and other environmental objectives.

The scoping study identified environmental requirements for many priority habitats; many of the environmental requirements could be linked to the ALC data or readily available supporting datasets (e.g. rainfall, slope). However, some data gaps remained (e.g. habitat tolerance thresholds in relation to soil nutrient status, and availability of appropriate soil nutrient data). Furthermore, during ALC assessments a standard level of management on mainly annual crops is assumed. The effect of management for habitats is much more complex and unpredictable, even given optimal biophysical suitability.

Therefore, the Capability, Suitability and Climate project commissioned a pilot study of ALC-based suitability modelling in the context of habitat restoration. The study considered two date/time scenarios: the present day, and the 2080 medium Representative Concentration Pathway climate change scenario based in UKCP18.

Blanket bog was chosen as the habitat to trial the methodology on, for the following reasons:

- The habitat is very important for biodiversity and ecosystem service delivery, particularly with regards to natural flood management and carbon storage for climate resilience;
- The habitat as a whole depends on a relatively narrow set of biophysical conditions to establish and function successfully.
- The biophysical conditions required to support this habitat type have been well-studied, and as such the tolerance thresholds for each factor can be defined with a relatively high level of confidence.
- Datasets were available for modelling many of the key environmental factors.
- Blanket bog is a habitat that is likely to face niche squeeze under climate change due to its restricted geographic distribution, and predicted changes in rainfall and temperature patterns; this could have strong implications for the long-term viability of blanket bog in many locations.

1.2 Methodology

The ecological suitability modelling followed the same processing steps as crop suitability modelling (Bell *et al.,* 2020). The input biophysical datasets used are shown in *Table 1*. Soil of Wales, ALC and UKCP18-derived data were provided by project partners ADAS and Cranfield University (Keay, 2020abc).

The choice of input datasets, and suitability scores applied, were based on information within the scoping study, which defined threshold values for: annual rainfall; mean annual maximum air temperature; gradient; altitude; soil pH; topsoil texture; and ALC soil wetness class.

The datasets identified by the scoping study were considered sufficient to model suitability for blanket bog in the present day. However, the altitude and rainfall parameters were considered less suitable for modelling the future scenario.

Although UKCP18 climate change models predict that annual average rainfall (AAR) will remain consistent under future scenarios, the distribution of the rainfall is predicted to significantly change towards episodes of higher-intensity rainfall, broken up by longer dry periods.

This trend raises the possibility of blanket bogs becoming subject to summer drought stress, which could threaten the long-term viability of the habitat in some locations. Similarly, as temperature patterns change, the altitudinal niche of blanket bog habitat may change in the future, with lower-altitude areas becoming less suitable. For this reason, the ALC drought and climate datasets were incorporated into the models.

The ALC drought gradings are based on the average soil moisture balances for two reference crops; winter wheat and maincrop potatoes. Blanket bog plant species are morphologically and physiologically adapted to survival in waterlogged conditions; therefore their moisture balance values should not be considered comparable to those of the reference crops. However, the dataset can be used to assess the relative suitability of soil conditions for supporting blanket bog species and peat formation. For example, ALC drought grade 1 describes land where both wheat and potato retain a positive moisture balance (i.e. no drought stress), whereas under land grade 3a both crops experience a negative moisture balance; the negative moisture balance becomes more severe (denoting increasing drought stress) for these crops under drought grades 3b, and 4.

The scoping study identified wet modified bog and areas with young or felled conifers as the habitats with greatest potential for restoration to blanket bog. However, the spatial modelling included additional habitat types with more limited restoration potential, in order to provide a complete analysis of the distribution of potential restoration sites.

The modelling considered whether it was biophysically and technologically possible for a habitat type to be restored to blanket bog within a reasonable timeframe. It did not consider whether restoration from a particular habitat type was appropriate, as this factor is often determined on a case-by-case basis, requiring a full cost-benefit analysis.

For example, wet modified bog would provide the least challenge to restoration efforts, and was therefore scored as suitable. Areas of wet heath could also be restored to blanket bog with relative ease, and have also been scored as suitable. The modelling does not consider the appropriateness of transforming one priority

habitat type to another; it considers whether the biophysical conditions exist for it to be possible.

Conversely, improved grassland would provide significant challenges to restoration, such as remediating soil nutrient loading and the effects of artificial drainage; such activity is technically possible, but would be expensive and take many years for the restoration goal to be reached. As a result, this habitat type was scored as limited suitability. Arable areas were considered too modified to allow successful restoration, and were scored Unsuitable.

The Soils of Wales dataset was used to identify topsoil textures, and also to model typical pH values for each soil series; pH values for topsoil under 'other land uses' (i.e. uses other than arable, ley or permanent grassland) were joined to the Soils of Wales Shapefile.

Soil phosphorus content was identified as an important limiting factor in the restoration potential for blanket bog, therefore the first iteration of the models incorporated gridded phosphorus data from the Advanced Soil Geochemical Atlas of England and Wales (soil sample data interpolated to a 1km grid). The data were calibrated against mapped areas of bog, semi-improved grassland and improved grassland to identify threshold values for suitable, limited suitability and unsuitable areas. However, the spatial resolution of the data was found to be too coarse to significantly influence the suitability models; a comparison of models produced with and without the phosphorus data were almost identical. Therefore, the phosphorus dataset was not used in the production of the final iteration of the models.

For environmental factors modelled from ALC data, separate datasets were available for the present day and 2080M scenario, with the exception of slope, which is not expected to change (Keay, 2020ab). However, for the other factors (habitat, pH, topsoil texture, elevation), no climate change scenario data were available; in these cases, the same datasets were used to model the factor for both the present day and 2080M scenario.

Table 1: Datasets used for blanket bog suitability modelling

Biophysical factor	Description of biophysical factor	Data used for 2080M scenario	Classes
Elevation	Elevation above sea level; blanket bogs are found at their greatest extent on upland plateaux.	Same dataset used for PD and 2080M models.	Continuous data showing elevation in m: >250m – Suitable <250m - Unsuitable
Slope	ALC factor; steeper slopes shed water and inhibit deep peat formation.	Same dataset used for PD and 2080M models.	ALC grades 1 – 5: 1-3b – Suitable 4-5 - Unsuitable
Wetness	ALC factor; considers the susceptibility of soil to waterlogging.	2080M ALC wetness UKCP18.	ALC grades 1 – 5: 1-3b – Unsuitable 4 – Limited 5 - Suitable
Average Rainfall	Average annual rainfall; blanket bog is an ombrotrophic habitat requiring high soil moisture levels.	UKCP18 data for 2080M.	Continuous data recording average rainfall in mm: >1200 mm – Suitable <1200 mm - Unsuitable
Drought	ALC factor; considers the susceptibility of soil to drought during the growing season.	2080M ALC Drought.	ALC grades 1 – 4: 1 – Suitable 2-4 - Unsuitable
Climate	ALC factor; considers AAR and AT0. Blanket bog is found in cooler, wetter environments.	2080M ALC Climate.	ALC grades 1 – 5: 1 – Unsuitable 2-3b – Limited 4-5 Suitable
Organic content of soil	Topsoil texture and organic content derived from Soils of Wales. Blanket bog develops on peat.	Same dataset used for PD and 2080M models.	All combinations of topsoil texture class and organic status: Peat soil – Suitable Peaty organic topsoil – Limited Mineral – Unsuitable
pH of soil	pH levels of the soil; typical pH values for Soils of Wales soil classes. Blanket bog is a low-pH habitat.	Same dataset used for PD and 2080M models.	Continuous data recording pH value for each soil type: <4.5 - Suitable 4.5-5.5 - Limited >5.5 - Unsuitable

Biophysical factor	Description of biophysical factor	Data used for 2080M scenario	Classes
Current habitat	Current land cover (Phase 1 habitat map of Wales); influences whether the area can technically be restored to blanket bog.	Same dataset used for PD and 2080M models.	All Phase 1 habitats in Wales: A4, A4.1, A4.2, A4.3, B1.1, B1.2, B5, B5.1, B5.2,, C1.1, D1.1, D2, D3, D4, D5, D6, D7, E1.7, E1.8, E2, E2.1, E4 – Suitable A1.1.2, A1.2.2, A1.3.2, A2.1, B4, B6 – Limited E1.6.1, E1.6.2, E3, E3.1, E3.1.1, E3.2, E3.2.1, E3.3, E3.3.1 – Unsuitable (existing bog/mire habitat) Other habitats - Unsuitable

1.3 Results and discussion

The maps of overall biophysical suitability for restoration to blanket bog for the present day and under the 2080M Representative Concentration Pathway scenario are shown in *Figure 2*.

In the suitability models, five of the individual input factors are identical for the present day and 2080M scenario: elevation, slope, organic content, pH and habitat type. The remaining four factors drive the differences between the present day and 2080M scenarios: AAR; ALC wetness; ALC climate; and ALC drought (*Figure 3-Figure 6*).

The AAR and wetness factors drive very subtle differences in the suitability models, with the 2080M model showing areas becoming downgraded from limited to unsuitable in east and south Wales, and downgrading from suitable to limited in parts of west Wales. These changes are for the most part, small-scale.

For the climate and drought factors, due to uncertainty regarding the impact of individual ALC grades on blanket bog habitat, these factors were scored conservatively in order to avoid over-classifying areas as being unsuitable; this precaution resulted in several ALC climate grades being classified as limited, rather than unsuitable. Scored in this way the ALC climate and drought factors show large areas of suitable or limited suitability land in the present day, but considerable contraction of suitable and limited suitability areas by 2080 (*Figure 5-Figure 6*).

These suitability maps can be analysed in conjunction with habitat network connectivity data in order to identify areas where restoration could increase habitat resilience through improving ecological connectivity. However, a comparison of

suitability in the present day against suitability under the 2080M scenario can also inform an assessment of habitat resilience in a particular location. In addition to overall suitability, the data can be queried at the pixel scale to identify suitability for each individual factor, and the total number of limiting or unsuitable factors; this information can be used to further analyse resilience and prioritise activities for restoration and conservation.

This task focussed on modelling suitability for restoring blanket bog, but the methodology could also be applied to modelling suitability for restoring other habitat types. However, modelling the requirements of different habitats will require different combinations of input datasets, and some habitats are likely to require greater focus on the requirements of key individual species, rather than production of a single generic model for the broad habitat type.

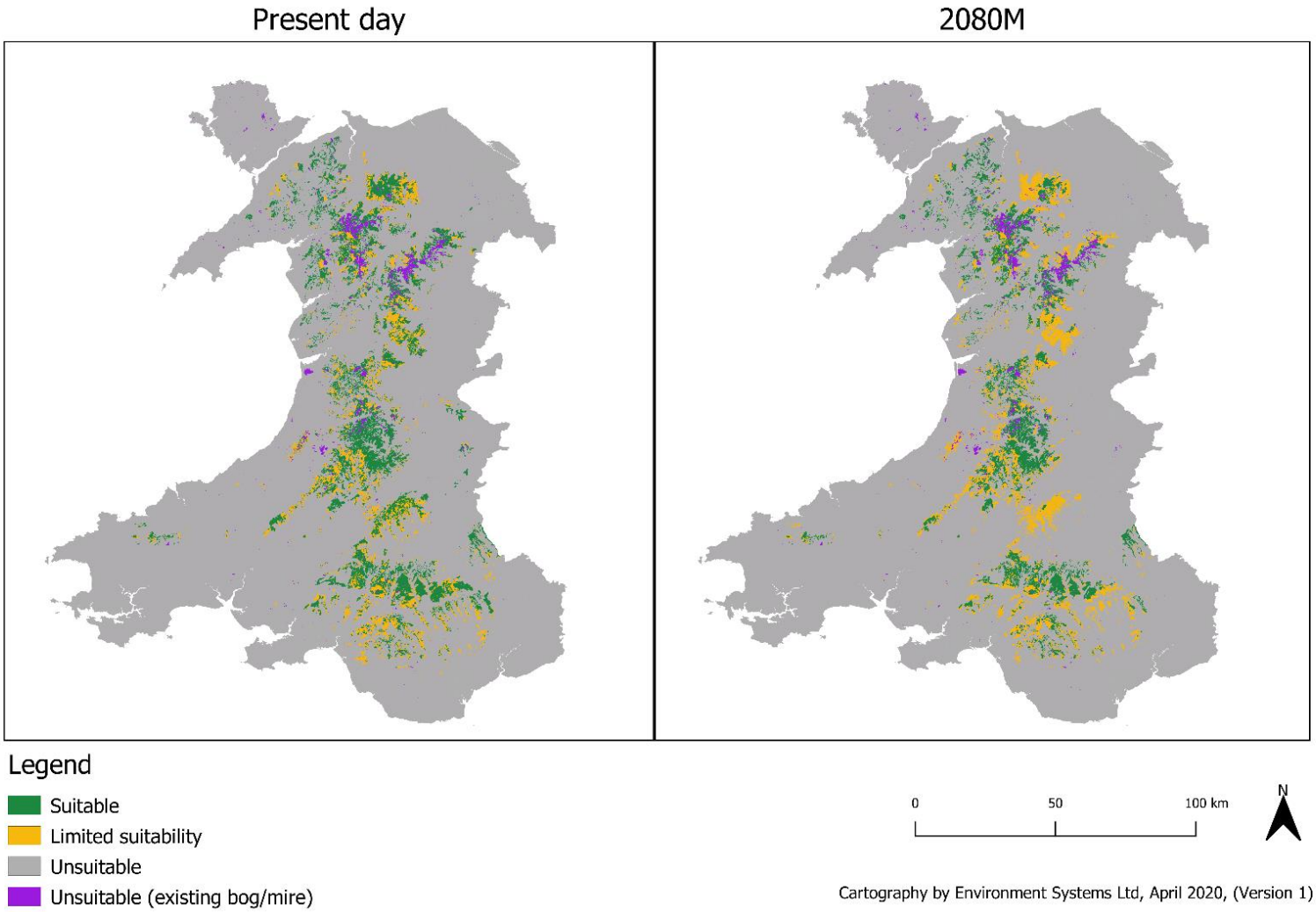

Figure 2: Overall biophysical suitability of land for restoration to blanket bog, through combination of nine individual factors: present day and 2080 medium Representative Concentration Pathway climate change scenario.

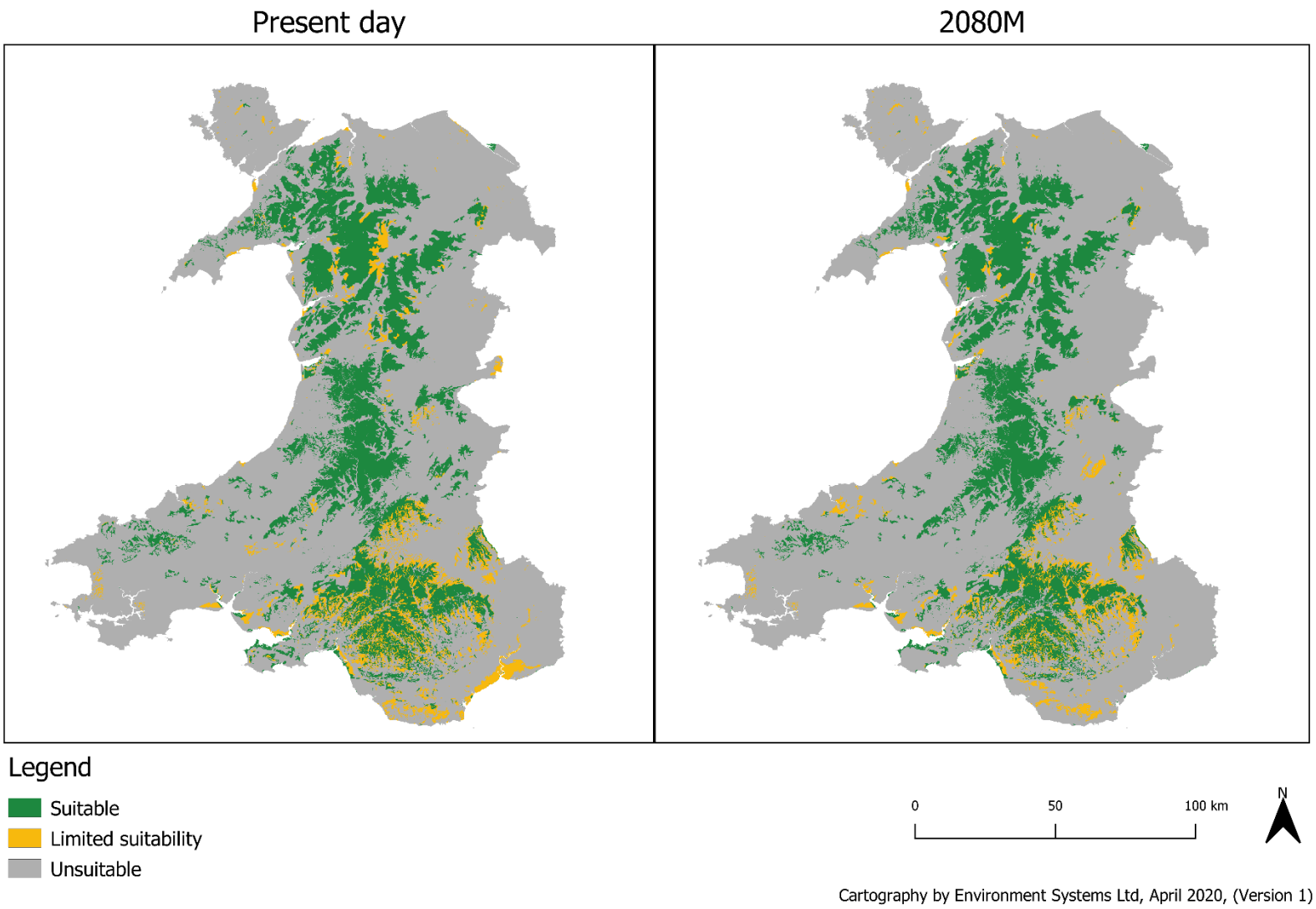

Figure 3: Individual factor suitability of land for restoration to blanket bog: ALC wetness. Present day and 2080 medium Representative Concentration Pathway climate change scenario.

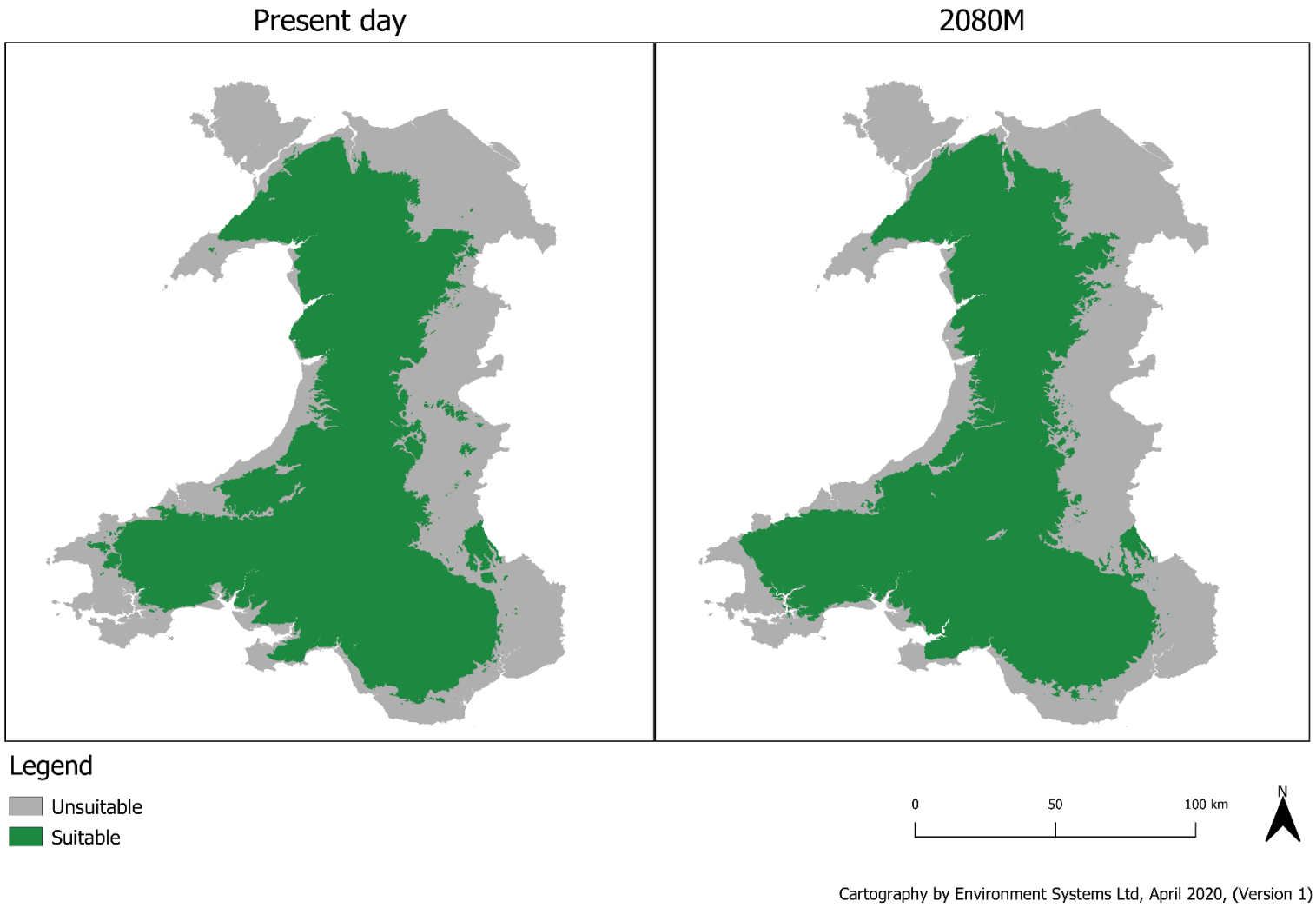

Figure 4: Individual factor suitability of land for restoration to blanket bog: Annual Average Rainfall. Present day and 2080 medium Representative Concentration Pathway climate change scenario.

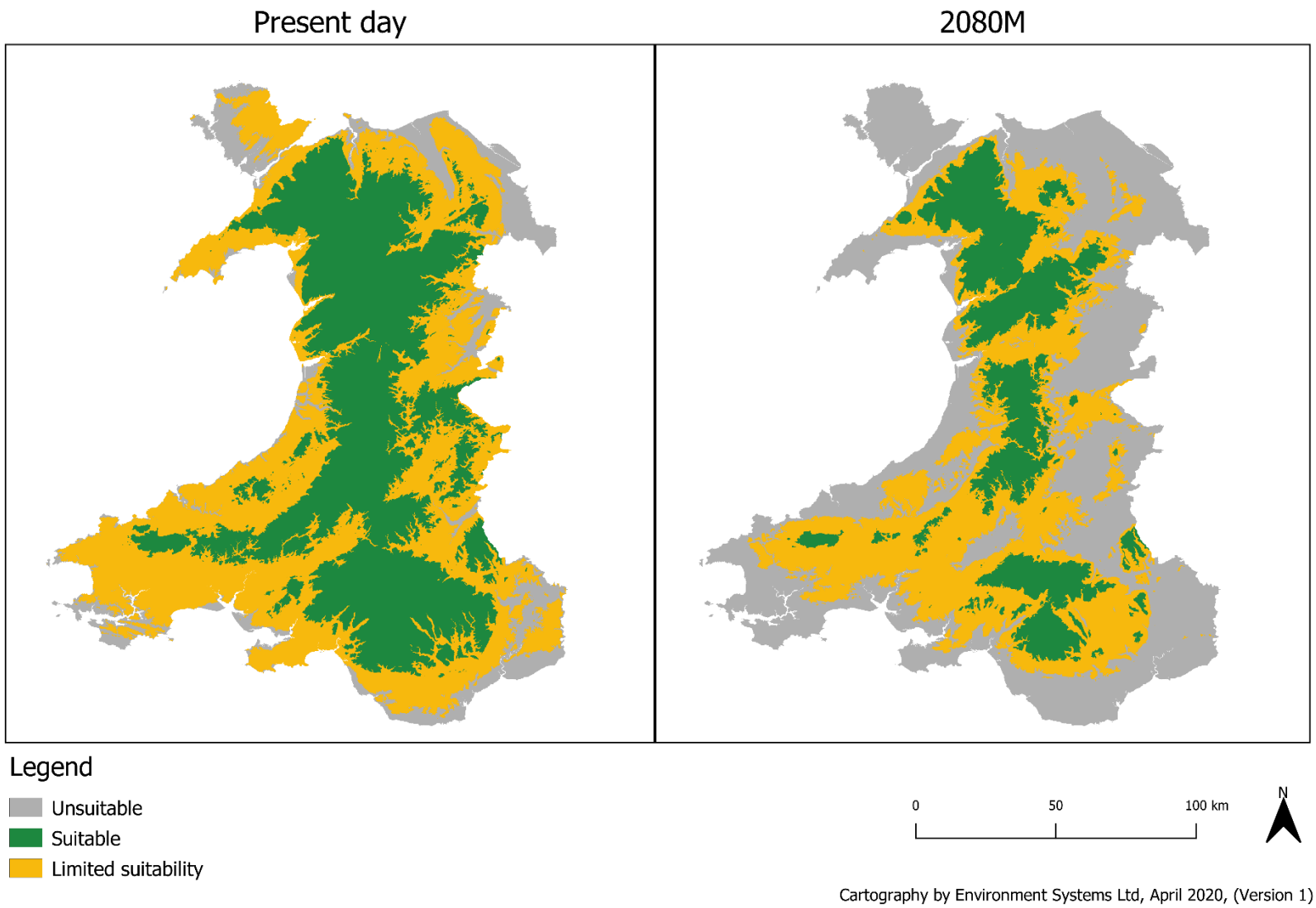

Figure 5: Individual factor suitability of land for restoration to blanket bog: ALC climate. Present day and 2080 medium Representative Concentration Pathway climate change scenario.

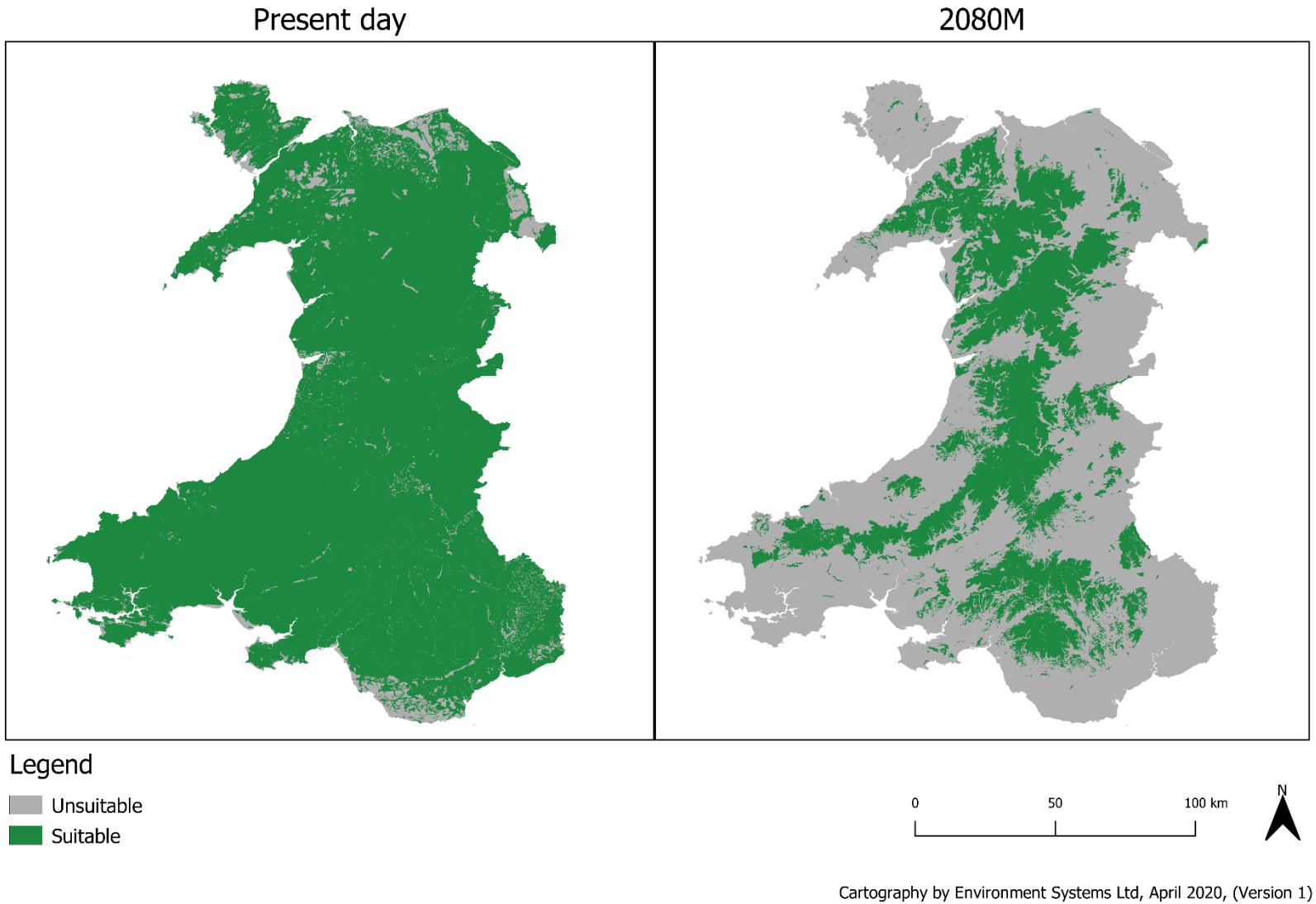

Figure 6: Individual factor suitability of land for restoration to blanket bog: ALC drought. Present day and 2080 medium Representative Concentration Pathway climate change scenario.

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