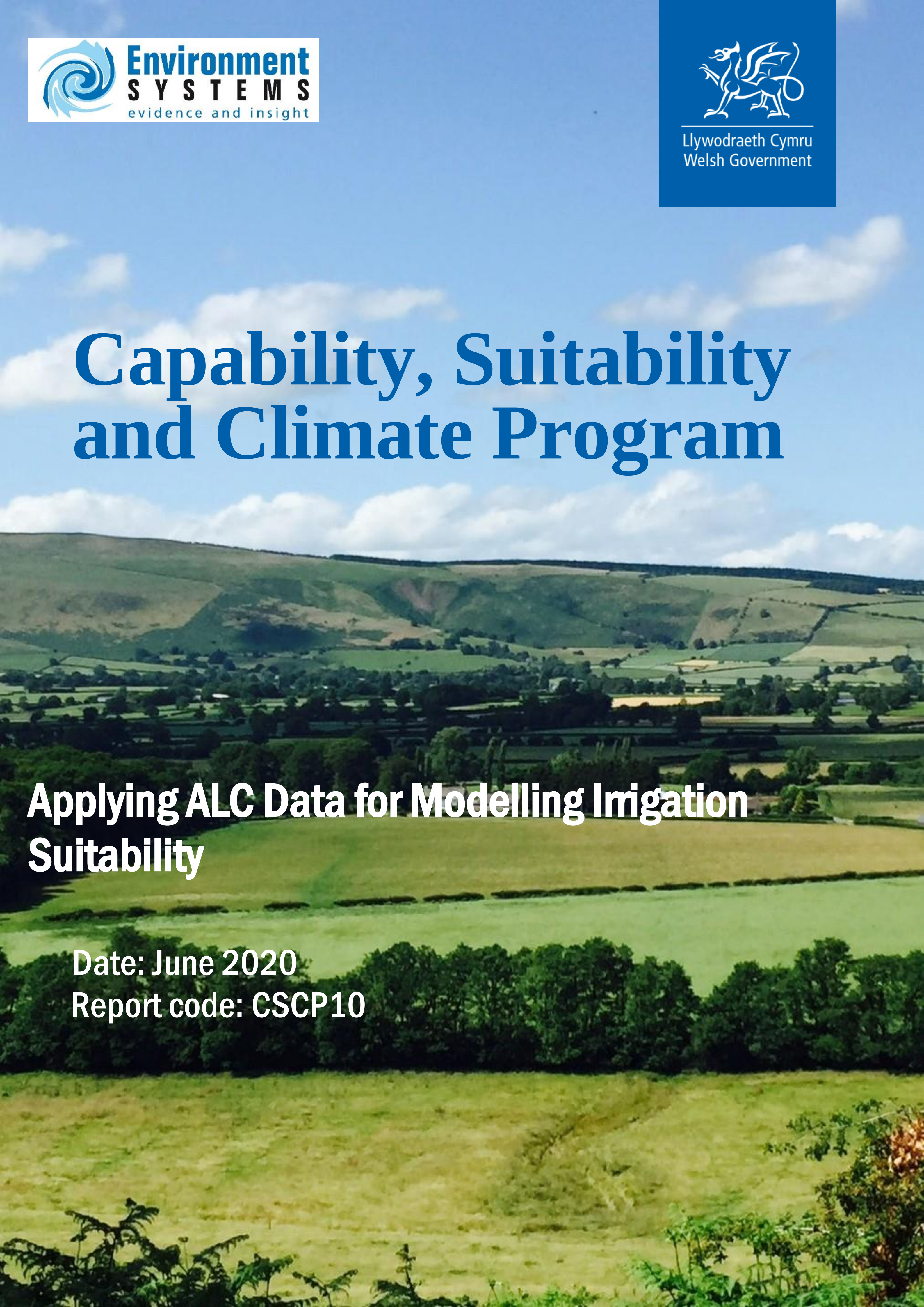

Environment SYSTEMS evidence and insight

Llywodraeth Cymru
Welsh Government

Capability, Suitability and Climate Program

Applying ALC Data for Modelling Irrigation Suitability

Date: June 2020
Report code: CSCP10

Capability, Suitability and Climate Program: Applying ALC Data for Modelling Irrigation Suitability

Report: CSCP10

Final report




August 2021
Version No. 1.00

Submitted to:

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

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

Acknowledgements
The project has been supported through the European Agricultural Fund for Rural Development (EAFRD) from the Welsh Government Rural Communities - Rural Development Programme 2014-2020, led by James Cooke, Arwel Williams and Ian Rugg.

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.

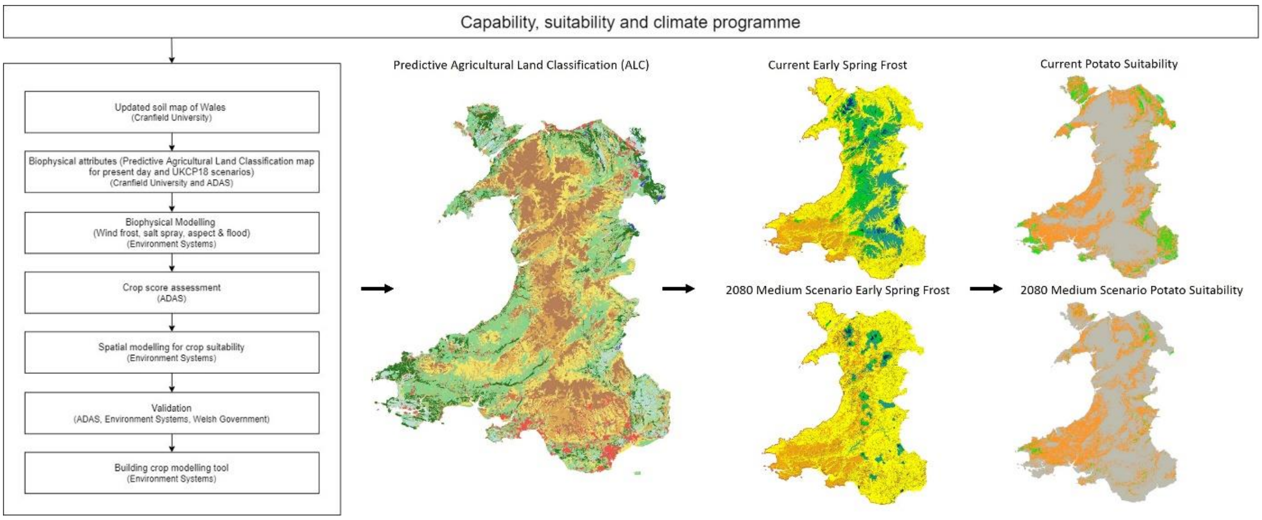

Figure 1: Stages of crop suitability modelling under the Capability, Suitability and Climate Programme

1. Irrigation requirement for sensitive crops

1.1 Background

The Predictive ALC dataset is an all-Wales, 50 m raster dataset providing information on a range of soil and climatic properties, graded according to standard ALC methodology (MAFF, 1988). The land grades for the individual properties are combined to provide an overall land grade for each pixel, representing the overall quality of land for agricultural purposes.

The ALC grading process assumes a 'good' standard of farm management, and one of the assumptions in this respect is that crops and soils requiring irrigation will be irrigated. Despite use of irrigation for ALC grading having been removed from use criteria since 1997, it is an important aspect to review, as future increases in droughtiness are likely to occur. Irrigation potential not having previously been spatially modelled leaves a data gap in our ability to assess land capability at a national scale. Suitability for irrigation can be defined as the cost-effectiveness of installing and applying irrigation, considering the level of improvement in soil condition/crop yield gained.

The level of gains achieved from irrigation depend firstly on the starting condition of the soil. Crops grown on soil types that retain moisture within their pore structure, and which are located in areas receiving ample rainfall, are unlikely to benefit from irrigation. Conversely, soils that do not retain moisture well, or that are located in areas receiving low summer rainfall, could be much more productive if irrigation is applied, to stop crops experiencing moisture deficits. However, for extremely droughty soils it may be too expensive to apply the level of irrigation required to support certain crops. Similarly, steep slopes present mechanical challenges, and decrease the relative gains of irrigation through runoff losses, making irrigation an unviable solution.

The Version 2 Predictive ALC dataset contains detailed soil property information that could be used to inform models of irrigation requirement. The purpose of this task was to test the applicability of this dataset to modelling suitability for irrigation across Wales under present day conditions. Assessment of existing water resources, and modelling capacity for additional water storage resources, was beyond the scope of this task.

1.2 Methodology

The irrigation suitability models followed a three-stage process; initial model development, panel review of the draft models, followed by methodological revisions and production of the final models.

The initial model applied a rulebase using eight factors, chosen for their influence on soil moisture retention and benefits derived from irrigation, described in *Table 1*. All datasets were derived from the Version 2 Predictive ALC. Categories within the datasets were scored as 'suitable' if the categories were deemed suitable for irrigation; 'limited suitability' if the categories represented areas where irrigation may be more difficult or provide less benefit; or 'unsuitable' if irrigation would not be possible or required.

Table 1: Initial rulebase for production of irrigation suitability model

Factor	Reason for inclusion
ALC Depth	Different crops have different rooting depths. Many crops have a rooting depth of 50-150 cm, but some tolerate depths of 20-30 cm. Irrigation would not be beneficial if soils are too shallow to support the crop.
ALC Drought	Soils that do not experience droughtiness are unlikely to benefit from irrigation. Soils of moderate droughtiness are likely to benefit from irrigation. It may not be cost-effective to irrigate extremely drought-susceptible soils.
ALC Rock	There is no soil present in rocky areas.
ALC Slope	Irrigation is only mechanically possible on shallower slopes.
ALC Stones	A high stone content reduces the water holding capacity of soil. However, high stone content can also increase resistance to soil erosion.
ALC Wetness	Wetter soils are less likely to require irrigation; crops will not benefit from irrigation.
Field capacity days (FCD)	Irrigation has less benefit in areas with higher FCD.
Depth to semi-permeable layer (DSP)	Shallow DSP soils are likely to be wetter, although is generally possible to plough out SPL up to a depth of 35cm.

The first draft irrigation suitability models were reviewed by Welsh Government and ADAS crop experts. It was felt that the initial model did not sufficiently differentiate between suitability for irrigation, and the relative benefits gained from irrigation (irrigation requirement). Furthermore, it was felt that the spatial datasets modelling FCD and SPL were too coarse for continued inclusion in the analysis. The panel agreed that the model should be revised to focus on identifying areas that would benefit the most from receiving irrigation.

Accordingly, the second iteration of the irrigation models used a simplified rulebase, focussing on the level of droughtiness likely to be experienced by crops. Five specific crops were used as examples: wheat, potato, strawberry, sessile oak and Sitka spruce. This method used the Version 2 Predictive ALC drought grades and the corresponding crop suitability scores for each grade; this information had been developed as part of the wider crop suitability modelling task, and is reported on separately (Bell *et al.*, 2020).

The ALC grades for drought had been scored as either 'suitable', 'limited suitability', or 'unsuitable', for each of the five crops; these scores were combined with ALC slope data to classify land that will not need, may need, and will definitely need irrigation, and on which slope category the land lies. A slope threshold of seven degrees (ALC grade 3a) was used to define areas where irrigation is practically feasible. The combined rulebase is shown in *Table* 2.

Suitable areas were interpreted as being areas where irrigation would not be needed, as drought stress is not predicted to occur for the crop in question under the present-day climate.

Unsuitable areas were interpreted as being areas where irrigation would definitely be needed, although in practice the level of moisture deficit is likely to be so high that irrigation would not be economically viable.

Limited suitability areas were interpreted as areas where crop cultivation is possible; droughtiness is expected to have an impact, but mitigation could be possible.

Table 2: Final rulebase used to map areas of land suitable for irrigation

ALC drought suitability class	Slope class (7° threshold)	Irrigation suitability
Suitable	n/a	Suitable for crop without irrigation
Limited suitability	Shallow	May need irrigation (on shallow slope)
	Steep	May need irrigation (on steep slope)
Unsuitable	Shallow	Will need irrigation (on shallow slope)
	Steep	Will need irrigation (on steep slope)

1.3 Results and discussion

The final irrigation requirement models are shown in *Figure 2*. Although five crops were selected for modelling, only three unique models were produced, as potato, sessile oak and strawberry were found to have the same suitability scores for each of the ALC drought grades, highlighting a limitation in the sensitivity of the ALC drought data.

ALC drought grading criteria are based on the average moisture balances experienced by two reference crops; wheat and potato. Wheat and potato are broadly representative of a wide variety of crops with similar rooting/foliar characteristics, but other crops may nevertheless display different moisture balances under the same conditions, which could affect the accuracy of the models for non-reference crops.

The irrigation requirement maps show relatively small areas of land requiring irrigation, and not all of the areas modelled as requiring irrigation are agricultural land; some areas are designated protected sites. Wider crop suitability modelling (Bell *et al.*, 2020) found that drought is not currently a significant factor for growing crops across the majority of the land area of Wales. However, the study found that drought is likely to become a very significant limiting factor for most crops across large parts of Wales in the near future, due to climate change.

The increasing significance of the drought factor over time is highlighted in *Figure 3*. At the present time, most of the land area of Wales is suitable for growing potatoes in terms of drought susceptibility, and irrigation is not needed in these suitable areas. However, by 2080 under a medium Representative Concentration Pathway scenario, a large proportion of lowland Wales is predicted to become either limited suitability or unsuitable for growing potatoes in terms of drought; irrigation would be needed in these areas in order to support cultivation (although irrigation may not be cost-effective or mechanically possible in all of these areas).

Next steps for analysis of irrigation suitability and requirement should consider future changes to the predictive ALC that are expected to occur under climate change (Keay, 2020b). The same rulebase used in this study of present-day irrigation suitability would consider much wider land areas if applied to climate change scenarios, which contain much larger extents of limited suitability and unsuitable areas for each crop; this would give a more realistic representation of where irrigation is likely to be needed in the future, and where topography will facilitate irrigation.

The models for non-reference crops could be enhanced and differentiated from each other by conducting research to identify typical rooting depths, and moisture balance values experienced by the crops in different soil types, under different rainfall and evapotranspiration conditions.

The irrigation requirement models could also be enhanced by Incorporating monthly rainfall data, to model water availability and irrigation suitability at critical time periods in the crop growth cycle. The definition of critical periods, in terms of timing and duration of rainfall, varies between crops. For example, soft fruits tend to require irrigation during May, June and July, whereas potatoes are more likely to require irrigation throughout the growing season.

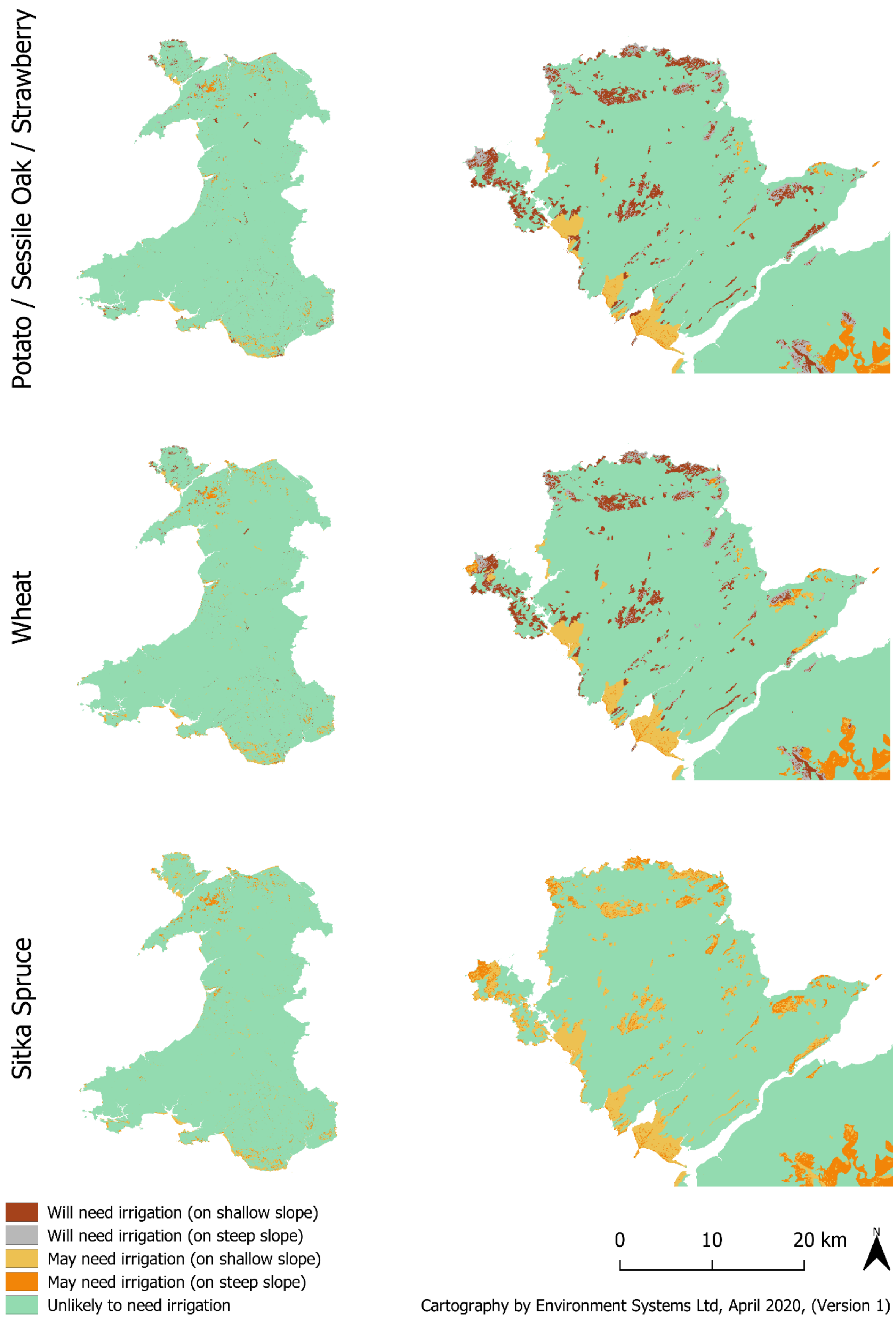

Figure 2: Irrigation requirement models based on ALC drought and slope; present day climate, highlighting Anglesey.

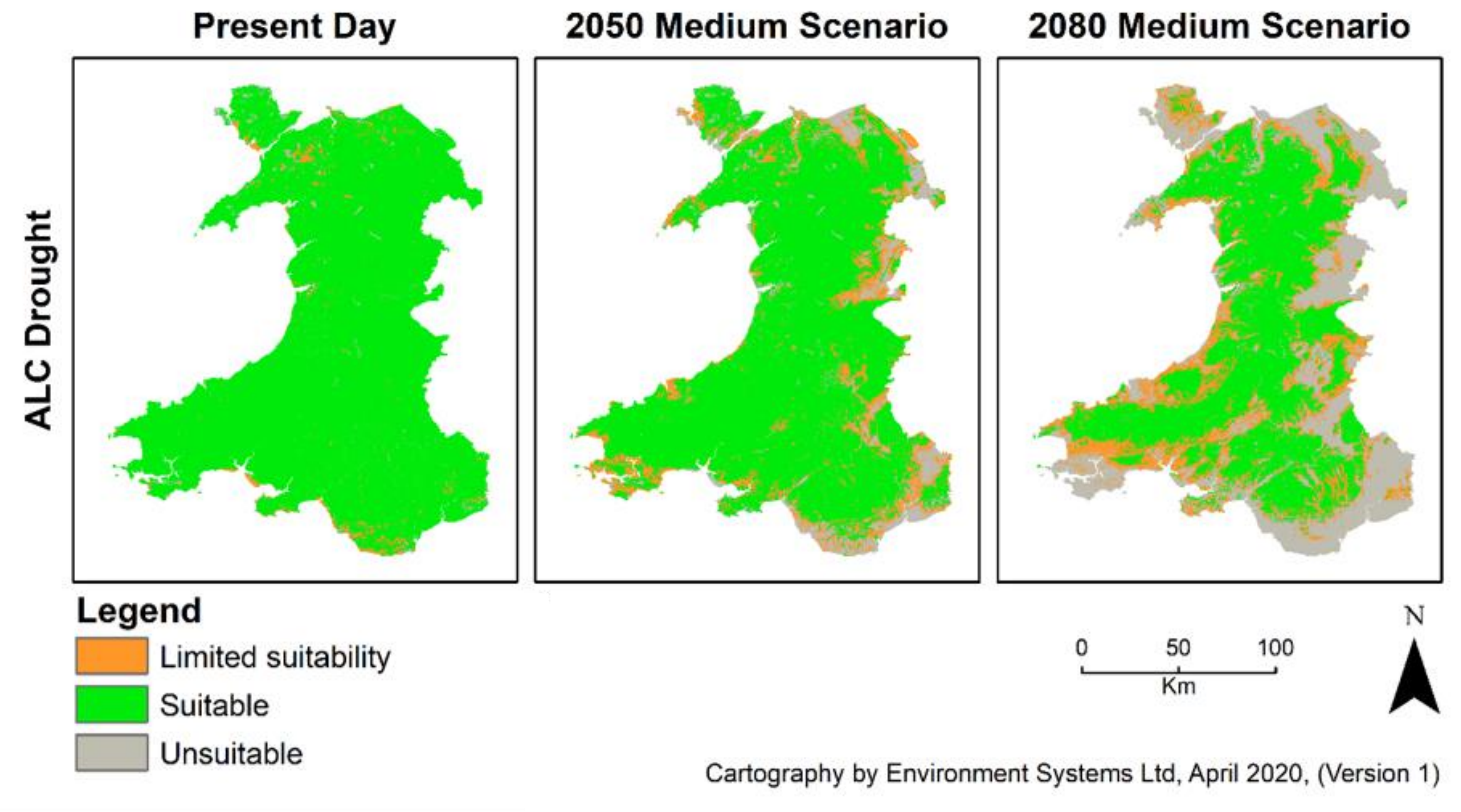

Figure 3: Changing ALC drought suitability for potato under the UKCP18 medium Representative Concentration Pathway scenario (from Bell et al., 2020)

References

ADAS (2019) Habitat Suitability Modelling Scoping Study. Report to Welsh Government.

Bell, G., Kristin-Naumann, E.-K., and Medcalf, K. (2020) Capability, Suitability and Climate Program: Application of ALC and UKCP18 Data for Modelling Crop Suitability. Report to Welsh Government.

Keay, C. (2020a) Capability, Suitability and Climate Programme Volume 3 – Predictive ALC Map of Wales v2. Report to Welsh Government.

Keay, C. (2020b) Capability, Suitability and Climate Programme. Effect of Climate Change on the predictive ALC map of Wales v2. Report to Welsh Government.

Keay, C. (2020c) Capability, Suitability and Climate Programme Volume 2 – Soils of Wales – Series Map. Report to Welsh Government.

MAFF (1988) Agricultural Land Classification of England and Wales. Revised guidelines and criteria for grading the quality of agricultural land. Ministry of Agriculture, Fisheries and Food.

NRW (2019) Flood Risk Assessment Wales. An Introduction. National Resources Wales.

Welsh Government (2019) Prosperity for All: A Climate Conscious Wales A climate change adaptation plan for Wales.