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The Implications of Climate Change on Land Capability for Agriculture

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Environment – Land Use and Rural Stewardship
PROGRAMME 3

The Implications of Climate Change on Land Capability for Agriculture: Results from a Pilot study

Contents

Forweword

This report presents the highlights from a pilot study investigating climate change and land capability for agriculture. Research is ongoing therefore the results are provided as indicative information that may be subject to further refinement. The report also provides the findings from a stakeholder workshop that considered the implications of this research.

Our aim is to encourage further dialogue on the links between the research and the implementation of climate change, land use, food and soils policy. We hope that the information will therefore provide a stimulus and a broader context for these important issues, and in particular to inform the Scottish Government's Land Use Summit.

This publication and the associated workshop were facilitated by Knowledge Exchange funding provided to the Macaulay Institute by the Scottish Government. The core research is funded by the Environment - Land Use and Rural Stewardship programme (www.programme3.net) of the Scottish Government's Rural and Environment Research and Analysis Directorate (RERAD).

Environment – Land Use and Rural Stewardship PROGRAMMES

Executive Summary

1. Land Capability for Agriculture (LCA) is a classification system for grading the agricultural quality of land based upon physical limitations: climate, soil and topography.

2. The LCA system has been widely adopted and used in Scotland by planners, land managers and other stakeholders. The three highest categories are defined in agricultural terms as ‘prime land’.

3. The currently published information on LCA was developed in the 1970s and early 1980s based upon average climate data from 1958-1978.

4. Analysis of more recent climate data (1981-2000) shows some subtle changes in the LCA, with a small increase in areas of prime land in eastern Scotland.

5. The LCA climate parameters were projected into the future using the national (UKCIP02) climate change scenarios. The future projections imply that climate constraints for many areas of southern and eastern Scotland will be relaxed, but wetness remains the key constraint in western Scotland.

6. The climate information was combined with soil and topographic constraints to give a preliminary indication of likely future changes in LCA across Scotland. This suggests a significant expansion in prime land in eastern and southern Scotland. For the 2050s Medium High Emissions UKCIP02 scenario, the area of prime land is indicated to be about three times its current extent.

7. The combined analysis also indicates that climate change in some upland areas will bring a shift from land that is capable only of providing rough grazing (class 6) to land that could be potentially improved (class 5 or higher).

8. The complexity and variability of future soil-climate interactions has meant that they have not been included in this study and they remain a major source of uncertainty. These can have an impact on land management through factors such as trafficability and drought risk.

9. The future climate projections would suggest that by the latter half of this century, a fundamental change in agricultural management would be required, possibly requiring a transition towards new farming systems for some areas.

10. This pilot study has identified scope for a reappraisal and revision of the original LCA in order to continue to meet user needs into the future.

11. The key role of LCA in both spatial planning and land management practice means that it could act as an important tool for scoping and implementing climate change adaptation strategies.

12. A Stakeholder Workshop was held on 29th April, 2008 to discuss the implications of this study.

13. Stakeholders supported the concept of a revised LCA, but also suggested that it should retain the same general framework as the original, possibly with a reappraisal of excessive soil moisture deficits which may become an increasing issue for some areas.

14. The workshop identified a broader land use agenda around the ‘land capability’ concept. In addition to agriculture (food and fibre), the concept also has relevance to other important ecosystem services. Climate change could potentially have major repercussions for many of these healthy landscape functions, including their biodiversity and soil carbon stocks.

1. Introduction

Land Capability for Agriculture (LCA) identifies the potential to use an area of land for different agricultural systems or management practices. It provides a standard classification system that has gained wide acceptance across a range of users, including planners, land managers and valuation agents. The LCA classification is based upon intrinsic physical limitations of the land (climate, soils and topography) that cannot be removed or ameliorated by reasonable management. These underlying factors therefore constrain how the land is used for agricultural purposes. Higher-grade land has more options for use, and therefore greater flexibility, as it also has the potential to be used as specified for any of the lower classes.

This publication is the result of a pilot study into the implications of climate change on the LCA system in Scotland. This work has involved an analysis of both climate change occurring in recent decades, and projected climate changes into the future. As climate is often one of the key constraints on how land is used, a changing climate can introduce potential new opportunities or risks that can modify land-use options. Exploring these issues with a land capability approach therefore emphasises the practical implications of climate change on land-use potential for a wide range of stakeholders. By considering the range of options as they extend into the future, the information can become a key step in planning adaptation responses to climate change.

2. Scotland's Changing Climate

Some climate attributes are particularly important for ecological functioning (e.g. the growing season) and for land use management activities (e.g. the period of access to the land). These attributes may be combined and mapped to indicate bioclimatic regions, in order to understand the geographic relationships between climate, land use and habitats. In the early 1970s, the Macaulay Institute produced an assessment of climatic conditions in Scotland through a series of these maps. As an introduction to climate change, we can update one of these maps, using a similar combination of warmth (accumulated temperature) and wetness (potential moisture deficit) that was originally used for the original LCA and now also used in our revised method (section 4).

Figure 1 shows that some subtle but important changes have occurred in recent decades. Regions classified as 'cold-wet' have decreased whilst 'mild-wet' regions have increased, with some even becoming 'mild-very wet' in the west. By contrast, in the east, a new 'warm-dry' region has developed in the Lothians. The changes for the 2050s future scenario are much more pronounced. The west continues to comprise mainly 'mild-wet' regions, with most of the 'cold-wet' regions lost from the uplands. In the east, the 'warm-dry' region has considerably expanded, and also includes new regions in SW Scotland.

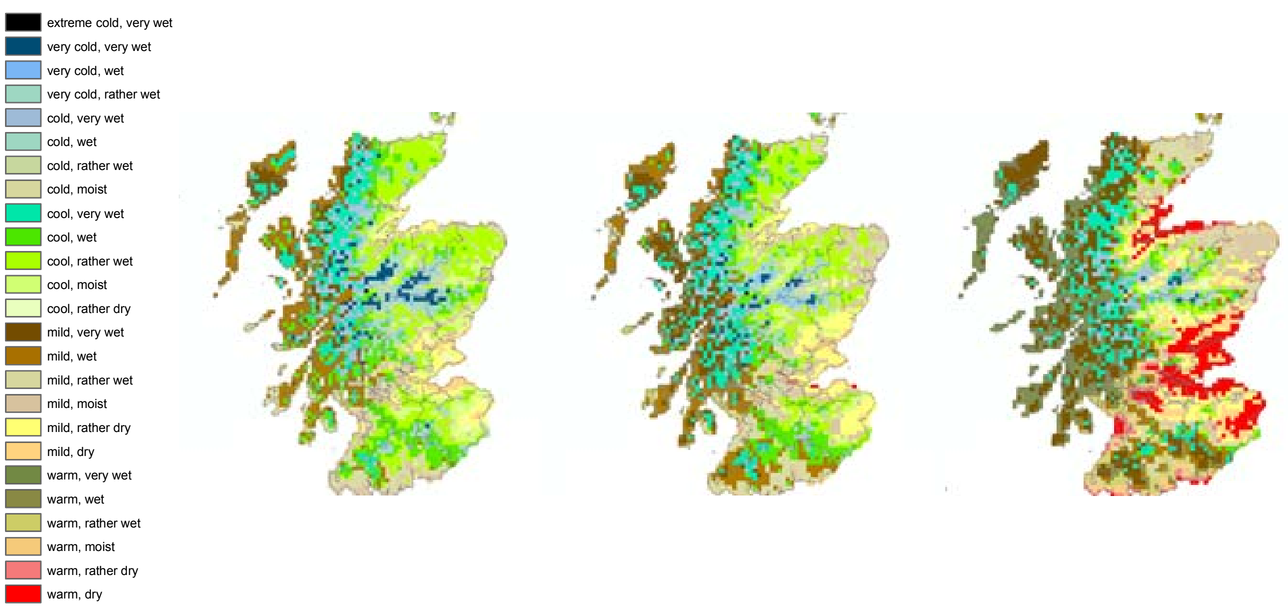


Figure 1. The Bioclimate regions of Scotland (a) 1961-1980 (b) 1981-2000 (c) 2050s [UKCIP02 Medium-High Emissions Scenarios]

3. Land Capability for Agriculture (LCA)

The LCA classification in Scotland[1] is based primarily on climate constraints (Figure 2), a number of soil properties (e.g. depth and stoniness), wetness, erosion risk, variability, and slope. The original LCA was based upon historic climate data from 1958-1978. Seven main classes are defined with additional divisions (Table 1). There are a number of important assumptions that underpin the classification:

- it is principally designed to assess the quality of land for agriculture
- is based largely on physical characteristics and the degree to which they limit agricultural flexibility
- it does not group land according to its most profitable use
- it assumes a satisfactory level of management
- it does not include location, farm structure and condition or access to markets, and therefore these criteria do not influence grading

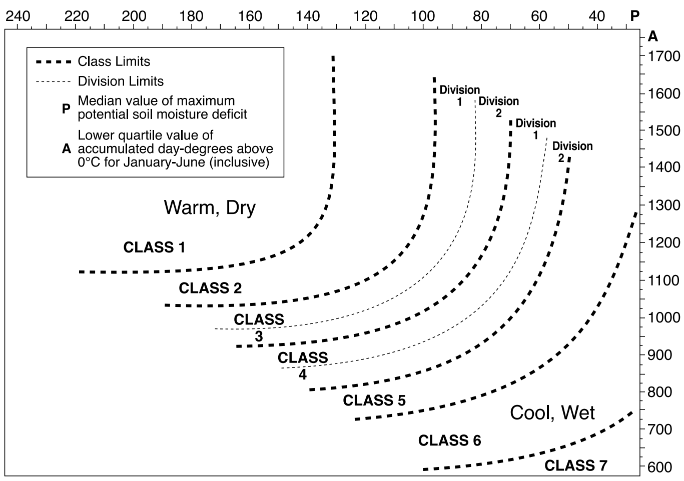


Figure 2. The two-parameter climate classification used in the LCA

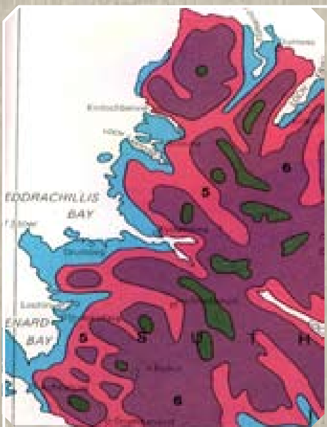
Class	Category	Climate Limitations	Land use
Class 1	Prime	None or very minor	Very wide range of crops with consistently high yields
Class 2	Prime	Minor	Wide range of crops, except those harvested in winter
Class 3_1	Prime	Moderate	Moderate range of crops, with good yields for some (cereals and grass) and moderate yields for others (potatoes, field beans, other vegetables)
Class 3_2	Non-Prime	Moderate	Moderate range of crops, with average production, but potentially high yields of barley, oats and grass
Class 4_1	Non-Prime	Moderately-severe	Narrow of crops, especially grass due to high yields but harvesting may be restricted
Class 4_2	Non-Prime	Moderately-severe	Narrow range of crops, especially grass due to high yields but harvesting may be severely restricted
Class 5	Non-Prime	Severe	Improved grassland, with mechanical intervention possible to allow seeding, rotavation or ploughing
Class 6	Non-Prime	Very Severe	Rough grazing pasture only
Class 7	Non-Prime	Extremely Severe	Very limited agricultural value

Table 1: The main classes used in the LCA system and those classified as 'Prime' agricultural land.

[1] Bibby JS, Douglas HA, Thomasson AJ, Robertson JD 1991 Land Capability Classification for Agriculture. Macaulay Institute, Aberdeen.

In national planning guidelines, land classified as 'prime' has had a presumption against development, although this was relaxed in 2002. The objective basis of LCA has also been used to suggest a potentially more robust procedure for identifying areas in the Less Favoured Areas Support Scheme (LFASS)[1].

In some areas of Scotland, the over-riding influence of climatic variables on land capability is very clear. By contrast, there are other areas where, irrespective of climate, land capability is restricted due to the severity and permanence of the other limitations. Good examples of these are NW Scotland (Figure 3) and Orkney (Figure 4). Climate limitations are similar in these two areas, but the gently sloping, non-rocky Orkney landscape with mineral soils affords many more agricultural opportunities than the very rocky NW Scotland landscape dominated by shallow or wet organic-rich soils.

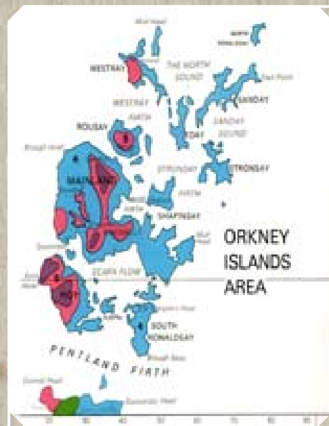


LCA Climate Guidelines: mainly class 4-6

Full LCA shows mainly class 6

Typical landscape

Figure 3. Sutherland (NW Scotland)



LCA Climate Guidelines: class 4-6

Full LCA also shows class 4-6

Typical landscape

Figure 4. Orkney

[1] Wright I, Birnie RV, Malcolm A, Towers W, McKeen M 2006 The Potential Use of Land Capability for Agriculture for Determining Support to Disadvantaged Areas of Scotland. Macaulay Institute, Aberdeen.

Illustrations of LCA Classes

Figure 5

Class 2

Deep almost stone-free loamy soils on level terrain. Climate is the only limiting factor. *Has the potential to become Class 1 with climate change?*

Figure 6

Class 3.2

Land with grassland and cereals. *Limiting factor often climatic, but with slope, wetness and soil constraints in places. Potential to be more flexible in the future?*

Figure 7

Class 5

Current land cover is heather moorland for sporting use. *Has the physical potential now to become improved grassland but will this potential also increase in the future?*

Figure 8

Class 6

Deep blanket peat. Permanently waterlogged, acid soils. No potential for improvement and offers only poor rough grazing. *Will this land dry out seasonally with climate change and offer a higher land-use potential?*

Soil-Climate Interactions

Many Scottish agricultural soils have moderately-fine textured subsoils that prevent movement of water through them at certain times of year (Figure 9). Currently the use of many of these soils is restricted to grassland because the soil and climatic variables interact to restrict land management options.

Figure 9 (a) Land with wetness constraints from subsoil texture, leading to (b) workability problems.

In a similar fashion, sandy or gravelly soils can cause moisture stress in crops and indeed some are assessed as already having droughtiness limitations (Figure 10).

Figure 10 Land with droughtiness constraints due to sandy and gravelly soils

As the climate changes, we would expect these soil-climate interactions to change too. To evaluate this would require, however, a detailed spatial assessment, including seasonal patterns of soil moisture deficit, and the effects on different crops and land uses.

This project has not currently investigated how these dynamic climate-soil interactions will become modified under climate change. This is a complex topic but one that is important for the final LCA classification, particularly at the site level, because they identify important local issues such as accessibility, erosion and potential leaching of pollutants.

4. The Updated LCA Method

The original LCA was based upon detailed fieldwork and subsequently mapped by manual methods. This project aimed to develop an updated digital method that could replicate the key features of the original in a robust format. To achieve this, climate, soils and topographic datasets were interpolated and integrated using digital procedures in a Geographical Information System (GIS)[1].

The following datasets were used:

(i) Climate observations 1961-2005 from the UK Met Office, using both station data and the 5km UKCIP gridded data (NB: wind data only available for 1969-2005). To analyse long-term average change, data were grouped into periods for 1961-1980 and 1981-2000.

(ii) Future climate projections derived from the national (UKCIP02) climate change scenarios[2]

(iii) Soils of Scotland map data (1:250,000 scale)

(iv) Topographic map data (1:50,000 scale)

Climate data were classified for recent and future periods using the conventional LCA parameters (Figure 2). This information was then combined with the constraints imposed by soils and topography so that the final class for an area was the highest that could be attained across ALL constraints.

Particular emphasis has been placed upon potential changes in LCA 'prime' land. For this classification, the following soil and topographic constraints were applied to remove unsuitable areas from the final maps.

1. Topography. Slopes above 7°, which tend to impose restrictions on the use of machinery and constrain options.
2. Soil depth. Soils with an effective rooting depth less than 45cm due either to bedrock or impenetrable subsoil.
3. Soil wetness. Some soils have intrinsic soil moisture retention properties that would prevent them ever becoming 'prime' land. Whilst most of these are highly organic uncultivated soils (including blanket peat) some poorly drained mineral soils (wetness class IV in the Soil Survey of Scotland) are also excluded.
4. Soil pattern. Some areas of land are inherently variable in quality, for example, where the intricate pattern of freely and poorly drained soils make their integrated management very difficult.
5. Soil stoniness. Some soils, for example those developed on fluvioglacial gravels, are inherently stony: a 35% maximum stoniness criteria was applied.

NOTE:

(1) The constraints do not include dynamic change in soil-climate interactions (e.g. change in organic matter content). This could affect soil wetness, droughtiness and erosion risk and related factors such as workability, trafficability and poaching risk.

(2) Shetland and northern Orkney have not been included in the main analysis because of more limited climate data.

[1] Further details are available in: Brown I, Towers W, Rivington M, Black HIJ (in press) Influence of climate change on agricultural land-use potential: adapting and updating the land capability system for Scotland. Climate Research

[2] Hulme M and others (2002) Climate change scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre, UK.

5. Indicative Maps

Between the periods 1961-1980 and 1981-2000 (Figure 11) there has been a small increase in the area of LCA 'prime' land for E Scotland. This is due both to the rise in temperatures in recent decades and also because some areas in the east have become drier.

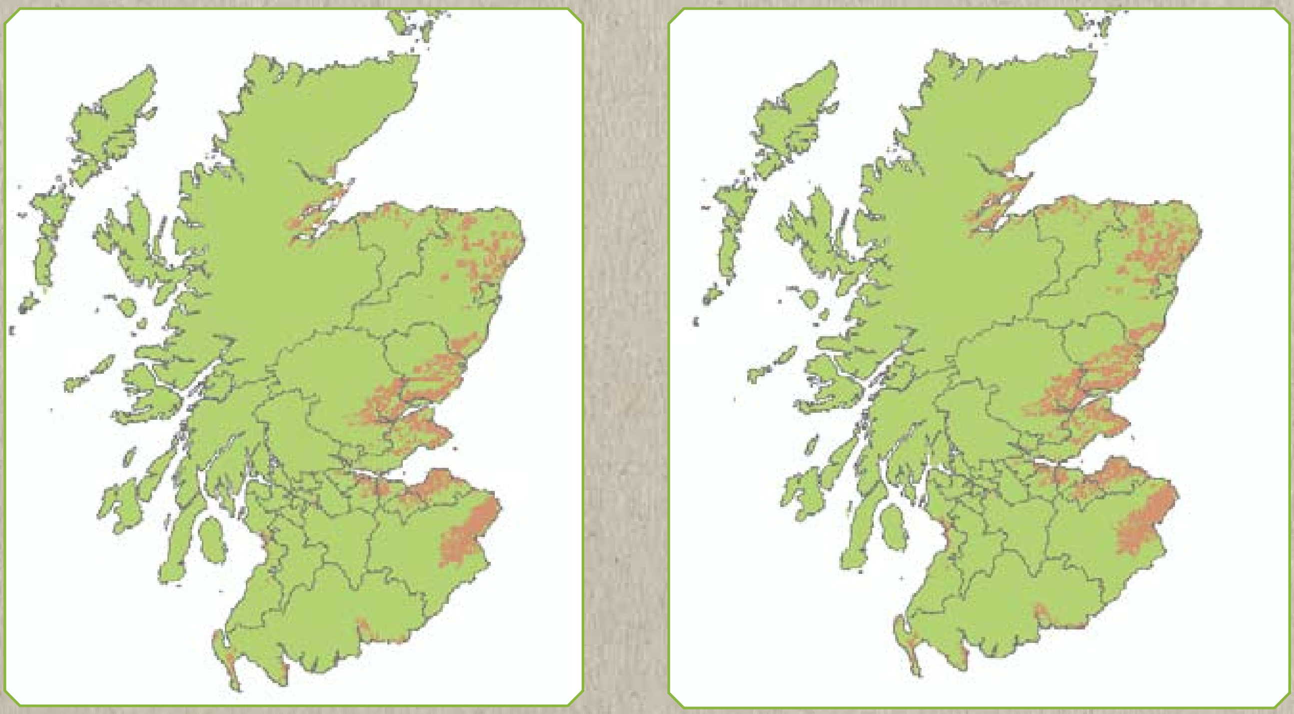


Figure 11 LCA 'Prime' land classified for (a) 1961-1980 (b) 1981-2000

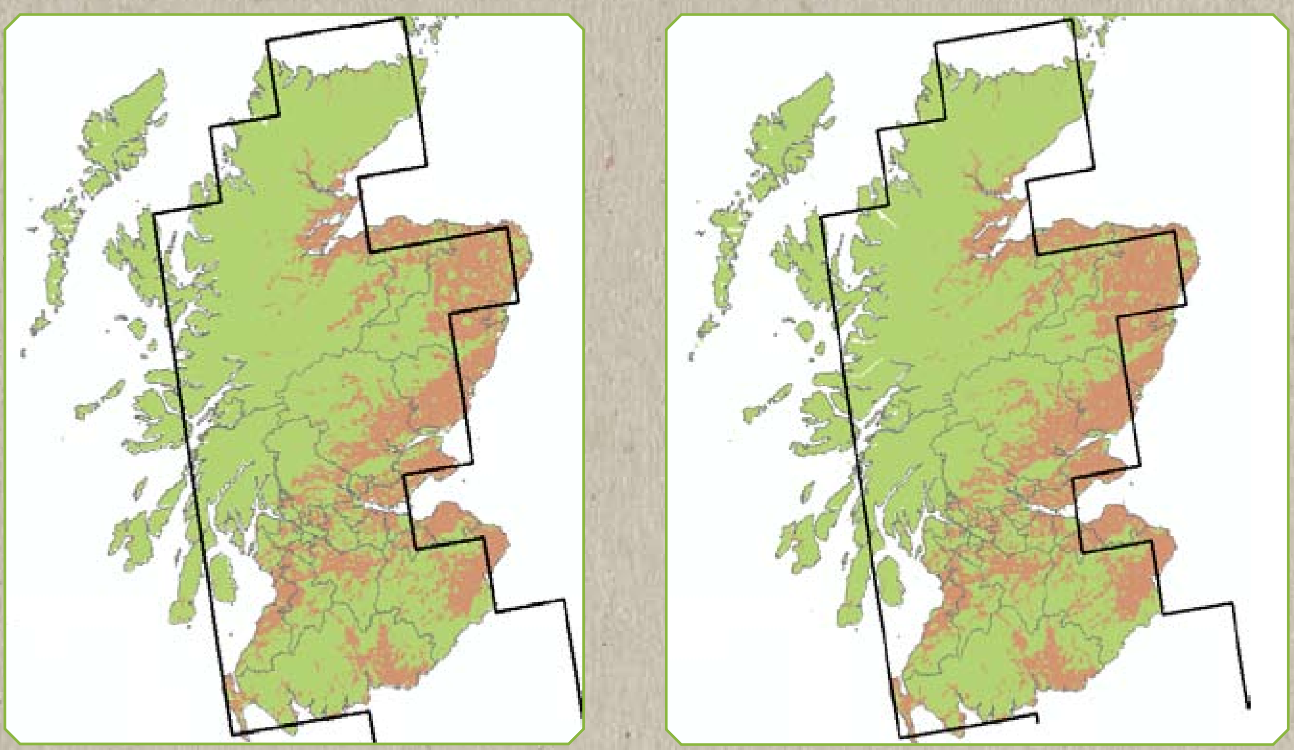


Figure 12 LCA 'Prime' land classified for the 2050s (a) UKCIP02 Low Emissions Scenario (b) UKCIP02 Medium-High Emissions Scenario. Bold line indicates climate model 'land' area.

Using the future climate projections, the area of 'prime' land increases significantly (Figure 12), with the changes mainly in E Scotland and SW Scotland. The indicative results are very similar for each of the UKCIP02 emissions scenarios as changes in greenhouse gas emissions take a few decades before they can significantly change the climate; by 2050 the differences between the scenarios are just starting to have an influence.

Figure 13 shows the projected changes for the 'Medium-High' scenario using the full LCA classification, compared to the currently published version. Again, this indicates the potential for large areas of land to move to a higher class. This finding applies both to 'prime' land and also to the potential for unimproved class 6 land to become class 5 or higher (Table 2).

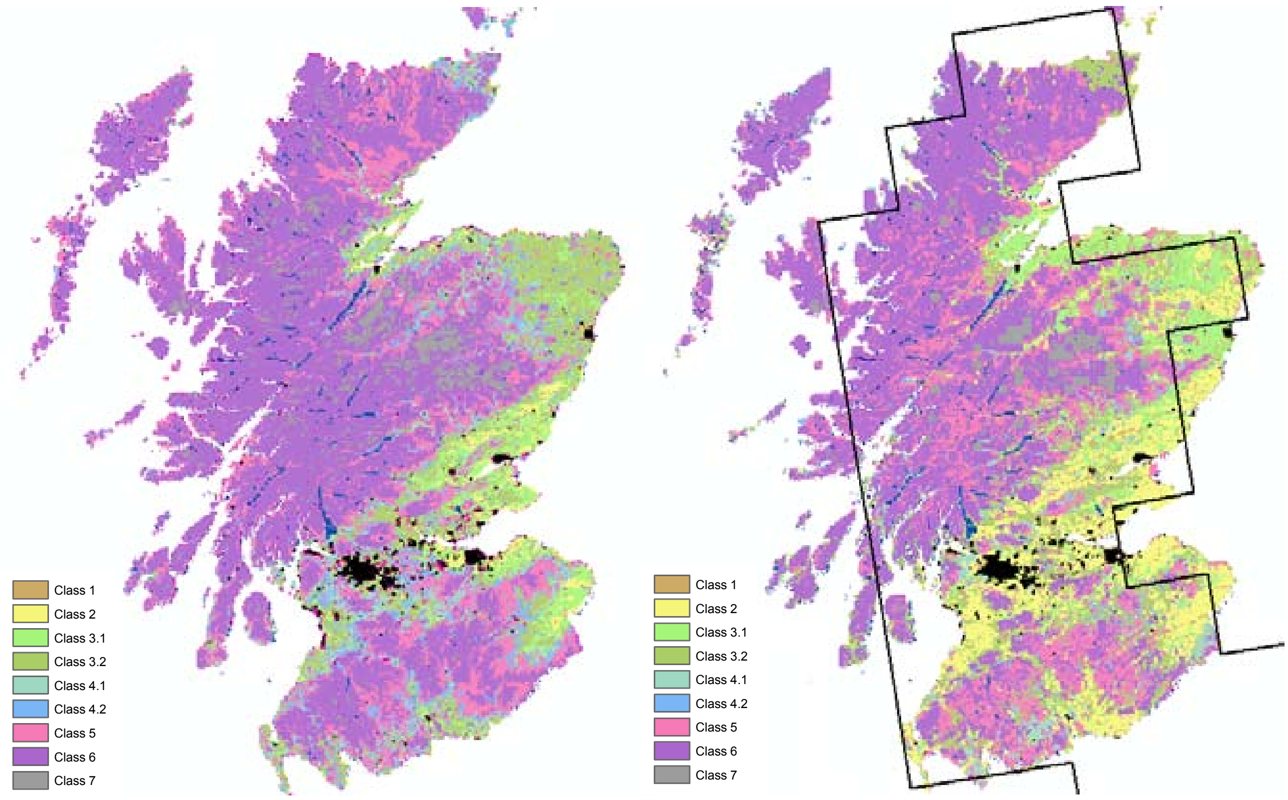


Figure 13 A comparison of (a) the original LCA with (b) the 2050 Med-High Emissions scenario

	Class 1	Class 2	Class 3_1	Class 3_2	Class 4_1	Class 4_2	Class 5	Class 6	Class 7
Published LCA	42	1092	3331	7322	3603	4484	13528	37454	2502
2050s Med-High Scenario	690	8981	5376	7989	1625	1417	13624	29993	1516

Table 2 Summary of area (km^2) per LCA class for the published version and a future 2050s projection.

NOTE:
The UKCIP02 climate scenarios are based on climate models from the Hadley Centre (UK Met Office). Future climate projections have a degree of uncertainty depending on the climate parameter (for example, rainfall is more uncertain than temperature), and other climate models sometimes imply different geographical patterns of change.
Further information on this issue will be provided in the forthcoming UKCIP08 climate scenarios
www.ukcip.org.uk

6. Yearly Variability

The LCA system is based on long-term climate averages, but yearly variations in weather conditions are just as important for land managers. This yearly variability is not included in the current LCA, and the metrics are designed to exclude the effects of extreme years (good or bad). But should we seek to include more information on this variability, especially if it is changing? As Figure 14 shows for all of Scotland, there can be large changes from year-to-year together with sequences of good or bad years.

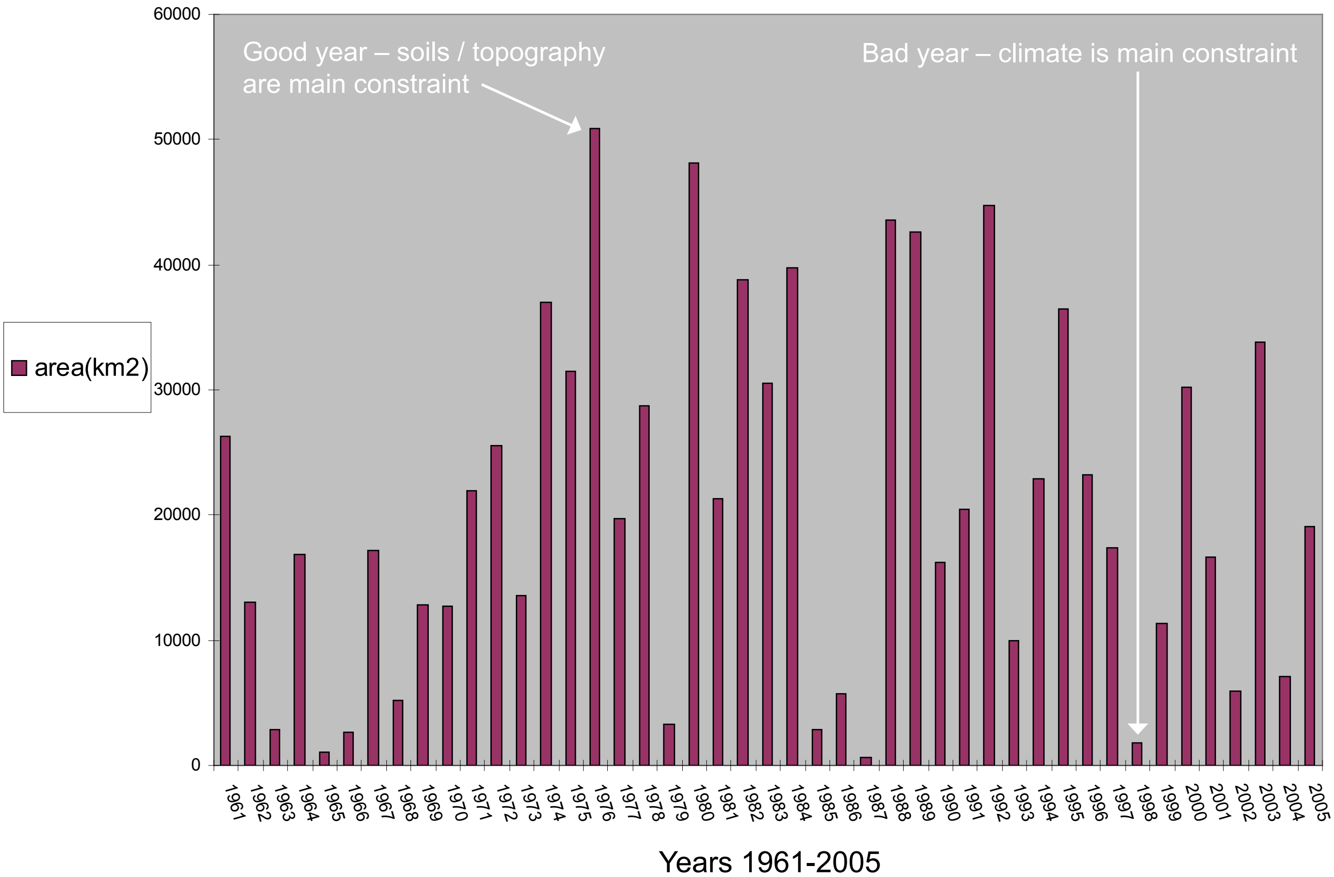


Figure 14. Total area of 'prime' land (climate variables only) for all Scotland on a yearly basis 1961-2005. Further work is exploring the influence of this variability on crop and grass yields.

7. Changes at Specific Sites

The original LCA work included estimations of the climatic constraint parameters at 233 meteorological stations within the UK. We can therefore use the same procedures to investigate both yearly variability and long-term trends for particular locations, including future scenarios.

Past trends and yearly variability:
Plotting the two primary climate parameters for 1961-80 and 1981-2000 can show how changes have occurred at key sites (Aberdeen and Auchencruive: Figures 15 and 16). Aberdeen has become warmer and drier in that time period, whilst Auchincruive (Ayrshire) has changed very little, with a slight warming. However, the metrics used for the LCA (quartiles and median values) may be considered not to capture the extremities of the yearly variation.

Future projections:

By plotting the climate parameters for individual years for the past and projected future climate (Figure 17), we can see how these constraints may change the LCA class in the future (in isolation from the other constraints).

NOTE:

These estimates of future daily weather data are for the 2070-2100 period and are downscaled to each specific site to indicate the direction of the future change shift.

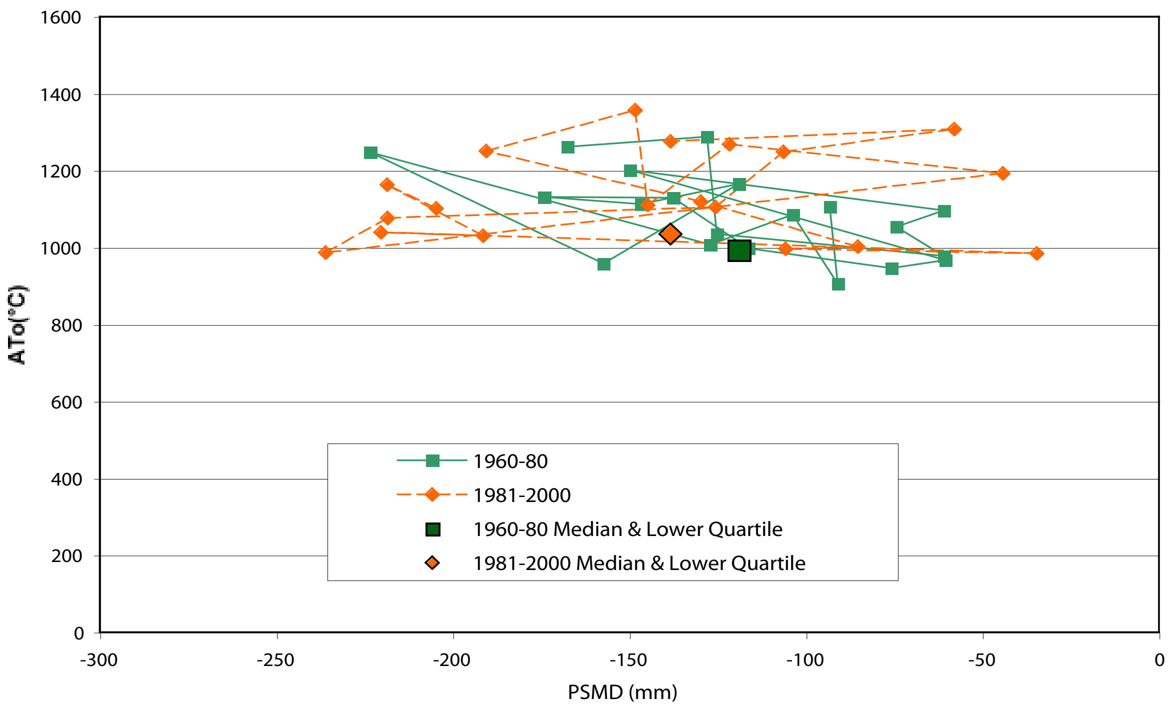


Figure 15 Recent yearly changes in LCA climate constraints for Aberdeen.

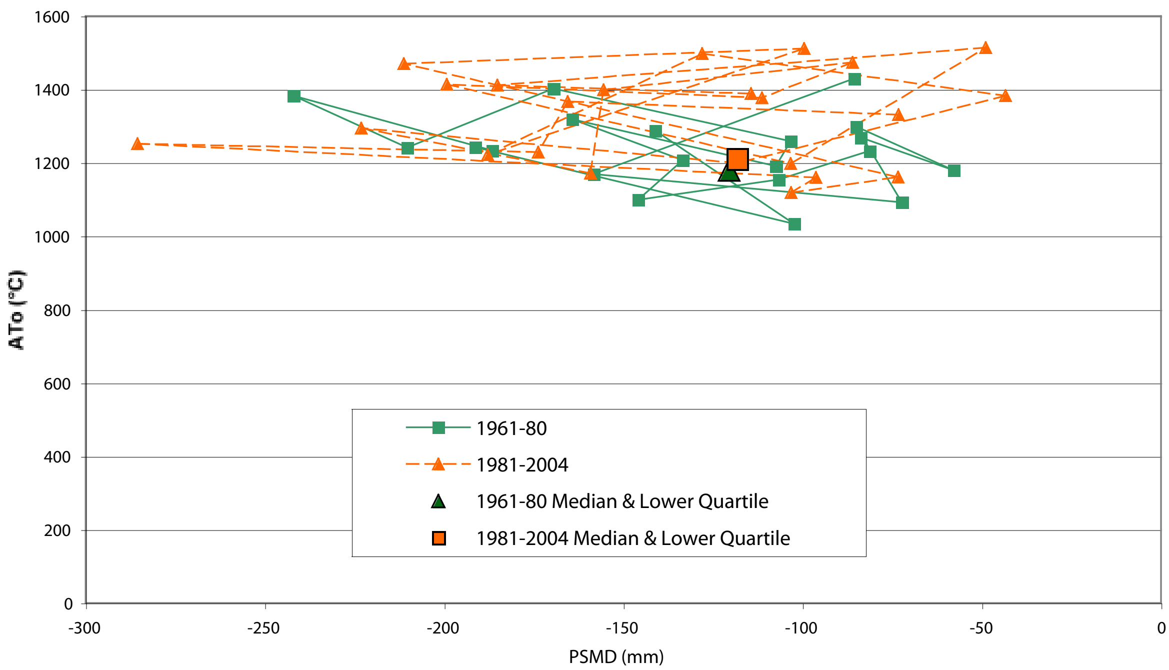


Figure 16 Recent yearly changes in the LCA climate constraints for Auchincruive (Ayrshire).

Figure 17 shows that Aberdeen, which is currently classed as LCA class 3_1, could shift its climate by 2070 into class 1, similar to parts of Cornwall now. Figure 18 indicates a similar response for Auchincruive, to a climate more characteristic of the Isle of Wight. Similar shifts have been found at all other sites investigated. These projections would suggest that a fundamental in agricultural management would be required to cope with the projected changes, possibly requiring a transition from one farming system to an entirely new one.

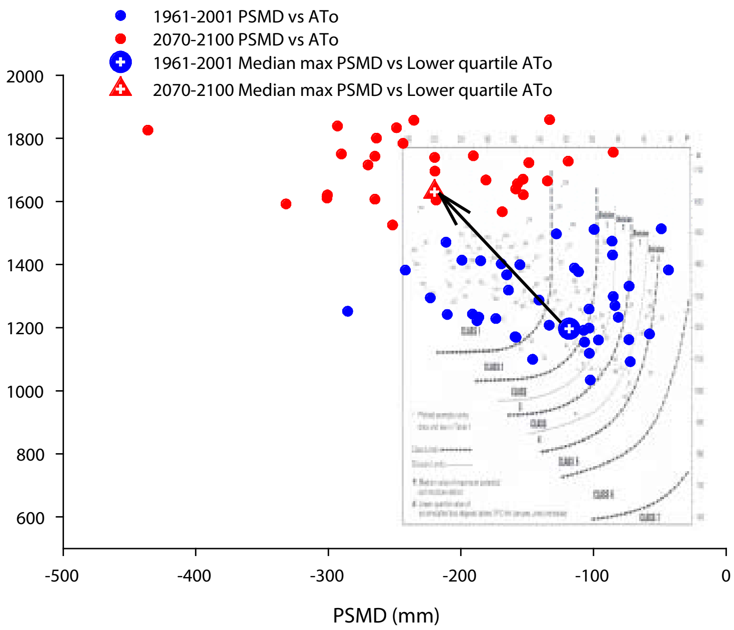


Figure 17 Climate constraints for the past climate and a future projection for Aberdeen (UKCIP02 Medium-High emissions scenario for 2070-2100 period).

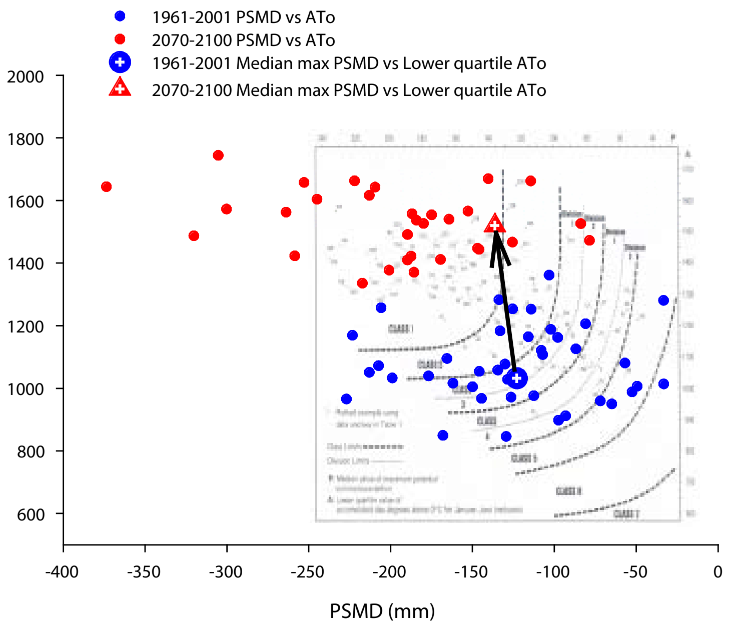


Figure 18 Climate constraints for the past climate and a future projection for Auchincruive (Ayrshire) (UKCIP02 Medium-High emissions scenario for 2070-2100). Note different PSMD scale to Figure 17

8. Summary of Stakeholder Workshop

8.1 Introduction

The purpose of the workshop was to review the existing LCA and to identify whether it remains fit for purpose for use both now and in the future. Attendees of the workshop represented stakeholders, policymakers and other key users of the LCA. They were invited to provide feedback on whether or not they felt that the current LCA is an important dataset, whether it needs updating and how it could it be improved. The workshop also featured a broad-ranging discussion on the potential implications of climate change for land capability and land use in Scotland.

8.1.1 Workshop Attendees

The following individuals and organisations took part in the workshop, together with the project team from the Macaulay Institute:

Mark Aitken, Scottish Environment Protection Agency
Donald Barrie, Glensaugh Farm (Macaulay Institute)
Antje Branding, Scottish Government (Soil Policy)
Patricia Bruneau, Scottish Natural Heritage (Soil Science)
George Corsar, Hartwood Farm (Macaulay Institute)
Jonnie Hall, National Farmers Union Scotland
Alex Harvey, UK Climate Impacts Programme
Lesley Macinnes, Historic Scotland
George Milne, National Sheep Association
Deborah Munro, Scottish Natural Heritage (Landscapes)
Peter Pitkin, Scottish Natural Heritage (Land Use)
Duncan Ray, Forest Research
Caspian Richards, Scottish Government (RERAD)
Graham Russell, Edinburgh University
Karen Smyth, Scottish Rural Property and Business Association
Stewart Snape, Forestry Commission
Ron Wilson, Hill Farmer & Edinburgh University
Geeta Wonnacott, Scottish Government (Soil Policy)
Guy Winter, Scottish Government (Climate Change)

8.1.2 Workshop Format

The workshop consisted of a morning session of presentations by the Macaulay Institute. This introduced the information presented in the previous chapters of this report, notably the current LCA data and the potential influence of climate change both at a national level and at the local level.

These were followed by a presentation from Donald Barrie, Farm Manager at Glensaugh, which is run by the Macaulay Institute as a functioning farm and research station. The aim of this presentation was to put LCA and the potential impact of climate change into context at the farm scale.

The afternoon session involved division of the attendees into three groups to discuss the following questions as well as any other general points they wished to raise:

i. Do you use the current LCA and find it useful framework?

ii. Do you think it would be useful to develop a revised version? What are the implications of climate change for Land Capability and future land use?

iii. What other information would be useful for land use planning & management – now and in the future?

iv. What do you recommend as next steps for the research and for policy guidance?

8.2 Farm level perspectives

Donald Barrie, Manager at Glensaugh Farm provided context on what the identified potential changes in climate may actually mean for land management and use.

The main points highlighted by Donald relating to the future of farming were as follows:

- Moderation of the climate will not reverse the trend of land extensification and reversion to rough grazing, because:
  i. Artificial inputs are likely to continue to increase in price; and
  ii. It will always be more worthwhile to focus costly inputs on more productive land.
- As energy costs rise and labour costs fall (relatively), livestock systems will recruit more labour and use less energy, therefore:
  i. Extensive systems will become more profitable than energy-intensive middle ground systems; and
  ii. Middle ground livestock systems could extensify due to rising input costs.
- High quality arable land will be used for the production of bulk commodity staple crops.
- Marginal hill land will benefit from a moderated climate and will be valued as a source of cheaply produced meat and wool.
- Middle ground will also benefit from a moderated climate but the level of output will no longer justify the level of inputs required to achieve economic crop yields.
- Economic constraints will tend to outweigh the benefits which accrue from climate moderation.

Figure 19. Marginal land at Glensaugh. This land was broken in when food production was a key driver, but it is expensive to maintain its levels of fertility and the output does not justify maintenance costs. It is currently reverting to rough grazing, but may have a different function in the future?

8.3 Summary of Stakeholder Responses

There was a general consensus on the points raised independently by each break-out group. The main points can be summarised as follows:

Utility of LCA

- LCA in its current state is an important tool which is widely used for a variety of purposes.
- LCA is an important tool in driving the development and implementation of strategic land use policies.
- Attendees unanimously recognised that physical land capability is not currently the primary driver of land use, but that there is a strong relationship between these issues.
- The current version of LCA was not designed to support field or farm level decisions. There was, however, limited consensus on the benefit of providing LCA at this level. Although it may be useful when considering long term decisions such as the purchase of machinery, LCA is not the key driver of short term decisions and land owners have more knowledge of their land to make decisions than could be provided by a LCA system.
- Food security is a growing priority issue. If food production becomes a policy driver the importance of LCA will increase.
- There is increased interest in horticulture, but how does this map on to the current categories? Is it appropriate to add this to the classification?

Revision of LCA

- Updating of the current LCA to reflect current and future predicted climate would be very useful.
- The current methodology has the advantage of being relatively simple and objective and therefore easily understood. Care must be taken to ensure this advantage is not compromised.
- Consideration of climate and soil interaction should be a key priority for future work. This should place a particular emphasis on how climate change will influence soil properties (e.g. organic matter content) and associated agricultural issues such as workability, trafficability and the risk of livestock ‘poaching’ on cultivated land.
- A new version of the LCA should be based upon an evolution of the old methodology to act as a baseline. Beyond this it would be useful to incorporate other drivers such as social, economic, policy and environmental issues.
- Planning documents look 20 to 50 years into the future therefore an updated LCA and future projects could be important for planners. Key links existed with planning protocols (e.g. SPP14 and the National Planning Framework).
- A suggested revision schedule for LCA was every 10 years (consistent with the review of baseline climate averages). Versions for different time periods could then be produced in conjunction with the current LCA (i.e. LCA, LCA 2020, LCA2030 … LCA2050).
- There is a need to consider declines in capability as land moves higher into Class 1 due to the increase in moisture deficit. This is not included in the current LCA system, but suggests that higher deficits should result in a reversal back into Class 2 or less.
- In the current LCA, the uplands are mapped at a lesser scale (1:250,000) compared to the lowlands (1:50,000). Is there a need to revisit this, at least for some areas? Previous work has shown that significant changes occur in the boundaries of the LCA classes depending on the scale at which it is drawn at.
- There was a need to consider uncertainty and climate variability, such as by the inclusion of the probability of land being in a particular class.
- A potential focus could be on ‘marginal areas’ where most change is expected to occur.
- There was continued reference to on the ground verification of LCA against actual land use. This could further verify the connection between the two aspects, identify whether any recent changes in land use have occurred, and through discussion with land owners attribute these to the different potential drivers (e.g. climate change, policy, economics). In this context, an important link would be with the Countryside Survey 2010 and other previous surveys.

Wider Issues and Implications

- An updated version of the LCA was considered by all as potentially a good tool to underpin a more objective identification of Less Favoured Areas (LFAs) within Scotland, especially in light of the Mediterranean focus of the new criteria currently promoted by the European Union. This should be pursued with the LFA Stakeholder group.
- No clear consensus emerged on the potential impact of an updated LCA on land prices. Although LCA is used to guide initial pricing, some participants indicated that local knowledge was often more crucial in deriving the final price.
- Land capability is not just an issue for agriculture and forestry, but could include biodiversity or conservation potential and other ecosystem services (e.g. soil carbon stocks). The original LCA was developed when production was the main driver, but current policy is also directed at broader environmental benefits. Targets exist for some land uses (e.g. 25% of area for forestry cover) but not for agriculture. Does this cause an imbalance?
- LCA for future predicted climates could be used to assess potential long term changes in land use, landscapes and associated issues. For example, what area of land might be ploughed under different socio-economic scenarios, with an assessment of the consequences for greenhouse gas emissions and biodiversity.
- To facilitate the production of maps with different drivers of land-use and to test land-use scenarios, it would be useful to produce interactive outputs via Geographical Information Systems as well as in hardcopy. Maps could then be customised for particular user requirements (e.g. crop varieties).
- LCA is used for research in aspects of the historic environment. It would be useful to examine changes in classification in this context and the relationship with historic land-use assessment (e.g. changes in farming composition in areas where we currently have significant historic farming continuity leading to changes in field patterns etc).
- A potential integration with other existing environmental data (e.g. flood risk maps, indicative forestry strategies) to expand the concept of 'land capability' was identified but there were also issues of scales and uncertainty to be resolved in this process. Potentially, the outcome could be a 'climate proofing' of land use policy.
- There was a requirement to be aware of, and interact with, equivalent procedures in England & Wales, and also throughout Europe, in updating the LCA system. For example, in Germany the tax system for farmers is linked to an equivalent LCA and soil quality, and includes distance to market. This would also suggest some form of co-operation and co-ordination with other partners to be useful. Similarly, the UN Food and Agriculture Organisation (FAO) are proposing a review of their guidelines on land evaluation to better account for environmental and ecosystem services.

8.4 Conclusions from the workshop

The Workshop demonstrated that LCA is an important and widely used classification and dataset and there is significant call for it to be updated to reflect current climate and potential future climate scenarios. It was considered important to produce an updated version based on the current classification system for use as a baseline. However consideration should be given to developing more complex systems which include additional drivers. To facilitate the future production of multiple end points to meet specific user requirements any new output should be made available within an interactive GIS database not just as hard copy maps.

The projected changes in land capability may not translate directly into changes in actually land use due to the influence of economic, policy and social factors on land management decisions, not just the biophysical criteria considered in the LCA classification. The system of classification is built around a concept of 'reasonable management' but this would seem to require further clarification, for example with respect to changes in the use of labour, machinery and energy.

9. Recommendations

The Land Capability for Agriculture system is sensitive to changes in climate. Results from the pilot study indicate that there have been some subtle changes since the original maps were published, notably through a small increase in 'prime' land in E Scotland. With regard to future climate change, results using the UKCIP02 scenarios imply rather larger changes due to a relaxation of climatic constraints. These changes include a further increase in 'prime' land potential, particularly in E Scotland, and that some of the land currently only capable of rough grazing (class 6) could improve in class and have additional capability.

The Stakeholder Workshop broadly supported the concept of a revised version of the LCA to incorporate and help plan for climate change in Scotland. In addition to developing more up-to-date maps, representation of future time periods could provide a valuable adaptive planning and management tool to 'climate-proof' land-use strategies on different time horizons. The new digital LCA method has many advantages over the original method in terms of efficiency, data integration and flexibility to test different land-use scenarios.

We therefore propose that there is a clear prerogative to scope out and develop a new LCA. In this context, the main recommendations are:

- A revised LCA should retain the flexibility of the original and not be too complex.
- A revised LCA should use the same methodology as the original LCA to provide a baseline against which to initiate any further changes in methods.
- Extra consideration needs to be given to those areas where soil moisture deficits may become excessive. This may require revision of the climate constraint classes (Figure 2) to reallocate excessively dry areas to a lower class.
- The LCA class should include an index of climate variability and frequency of extremes.
- Further work is required on the uncertainties of climate change, particularly relating to summer rainfall and its impact on soil moisture values. This should be developed in conjunction with the forthcoming UKCIP08 climate scenarios.
- Soil-climate interactions should be prioritized as a key next step towards a revised LCA. However, detailed site-based assessments are required to better understand the influence of soil-climate interactions, and how these may apply over the larger area.
- To develop an associated study investigating changes in land use as a comparison with changes in land capability.
- Establish links with other related work in the UK and Europe, relating both to LCA and its implications, including policy-related schemes such as the LFASS.
- Further work with farmers and land managers to understand short and long-term decision making needs related to climate change, climate variability and land capability.
- The potential for integrating the LCA with other data-sets relating to aspects of land-use or landscape (e.g. landscape character assessment; historic land-use assessment) should be explored.

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