CCC land use project

September 2017

Introduction

This paper describes work that the Committee on Climate Change and the Adaptation Sub-Committee have done in relation to the future use of land.

Non-developed land is one of our key resources. It provides a wide range of goods and services, such as food, timber, clean water, energy, wildlife habitats, carbon storage, flood management as well as green spaces important for our physical and mental health and other recreation activities.

Choices on how non-developed land is used and managed have a significant influence on key CCC and ASC objectives: reducing greenhouse gas (GHG) emissions and preparing for the impacts of climate change:

- For mitigation, we have estimated the contribution the two land based sectors (agriculture and land use, land use change and forestry) can make in helping to meet the UK's 2050 emissions reduction target.
- For adaptation, the ASC assesses the level of preparedness to climate change in England across a range of uses and related services, including agriculture, forestry, biodiversity, and flooding and water management.
- Looking further ahead, land will play a crucial role in helping meet the Paris Agreement's ambitious target for net zero global emissions in the second half of this century, given its current uniqueness amongst all sectors to remove carbon dioxide from the atmosphere.

It is against this background that we have started to explore how the use and management of land could deliver deeper emissions cuts and increased GHG removals in the UK agriculture and LULUCF sectors to 2050 and beyond. We are also interested in how the choices made affect the resilience of relevant sectors to future climate change.

The first part of the CCC land use project was published in 2016. We are now publishing a second piece of work undertaken by a consortium led by the Environmental Change Institute (ECI) at Oxford University. This paper presents the main findings from that work, and concludes with an overview of the next steps for the project.

1. Phase one

In the initial phase of this work, we commissioned ADAS to review the evidence base on the drivers of land use at the local and national levels, and to identify relevant metrics and indicators required to monitor changes in land use and land use management, spatially and through time. They also provided a review of the capability of existing land allocation models and their ability to assess the impacts of land use change, with the aim of identifying models that could potentially be useful for us in modelling future land use scenarios.

A key part of this first phase, and with the Paris Agreement setting the context, was to identify potential land use pathways to achieve net zero emissions in the UK agricultural and LULUCF sectors beyond 2050. This was explored in a workshop with key specialists in the agriculture, forestry, land use modelling and ecosystem services sectors. This identified four pathways to deliver deeper emissions reduction:

- **Improved technological efficiency of agriculture** (e.g. improved yields, crops with lower fertiliser requirements);
- **Multi-functional land-use** (e.g. permacultures, agro-forestry);
- **Increasing carbon sinks** (e.g. afforestation and peatland restoration); and
- **Diet change** (primarily reducing consumption of carbon-intensive red meats).

The report by ADAS and the write-up of the workshop are published on the CCC website[1].

2. Phase two

Objectives and framework

For the second part of the project we wanted to quantify the impacts of potential pathways (some of which were identified at the workshop) that could:

- Maximise reductions in emissions and increase sequestration in the UK agriculture and LULUCF sectors, consistent with reaching net negative emissions in the second half of the century.
- Take account of the need to prepare for the impacts of climate change and ensure the future land uses are resilient to the effects of climate warming projections under a 2°C and 4°C world.

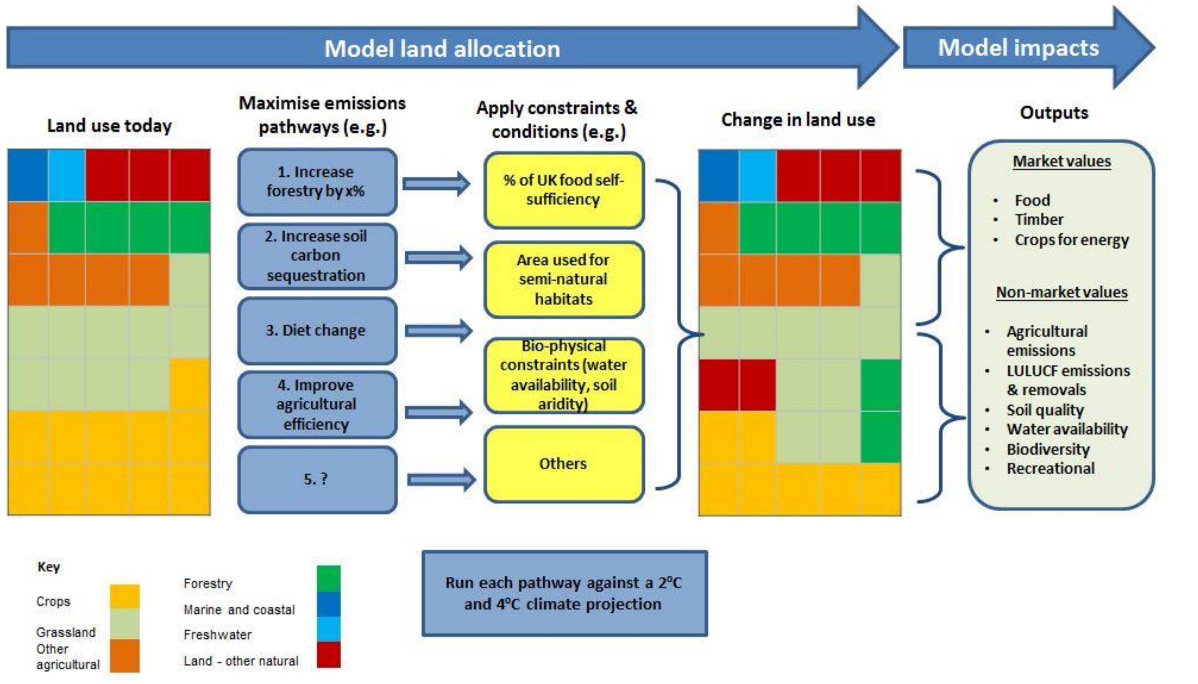
As part of this work, we also wanted to understand the potential trade-offs and synergies between land uses that deliver emissions reductions and other benefits or costs (e.g. on food production).

The ADAS study identified different models and analytical frameworks that we could use in thinking about these issues. These largely focussed on existing integrated models of current land use and drivers. By setting an objective function that could be tested in the

[1] ADAS (2016) *'UK land use projections and the implications for climate change mitigation and adaptation'*

future, applying a series of constraints to avoid unintended consequences and adverse outcomes, and using known relationships between different market drivers, the intention was that the model would be able to run different scenarios and output information on a number of key metrics. Figure 1 illustrates the modelling approach.

Figure 1. Illustrative land use modelling framework



Source: CCC (2016)

The project

We commissioned a consortium comprising Cranfield University, University of Edinburgh, Centre for Ecology and Hydrology and led by the Environmental Change Institute (Oxford University) to undertake the work using their Integrated Assessment Platform 2 (IAP2) model.

Because of the challenging and ambitious nature of the project, we asked the consortium to complete a pilot piece of work in order to demonstrate that its modelling approach could meet all our requirements. Specifically, we wanted to test the capability of the IAP2 model to ensure that it could deliver a range of relevant outputs important for the project (including GHG emissions by source and gas and resilience indicators relevant for the ASC).

This stage of the project focused on modelling two scenarios:

- A mitigation scenario based on the central abatement scenario developed by the CCC for the fifth carbon budget (2028-32)2. This comprised emissions reductions in agriculture largely through changes in farming practices for crops and livestock and afforestation rates of around 15,000/ha annually by 2030 in the UK.

- A hypothetical adaptation scenario was tested that maximises land use change and management options to benefit biodiversity for the 2050 time period.

We appointed a group of experts with expertise in agricultural emissions, soils, forestry and land use modelling to peer review some aspects of the modelling.

3. Modelling approach of the IAP2

The IAP2 integrates ten different models in six different sectors (agriculture, forestry, water use, urban growth, flooding and biodiversity) to explore *'what if'* scenarios of future land use in response to changes to both the climate and a range of socio-economic drivers:

- The climate projections are based on the IPCC AR5 representative concentration pathways (RCPs). For the purposes of this project, RCPs 2.6 and 4.5 were used which corresponds to an average European warming of c. 1.5°C and c. 2.0°C respectively by 2050.

- The socio-economic scenarios in the model are based on the IPCC's Shared Socio-economic Pathways (SSPs) which were downscaled from the global to the European scale. They include the main drivers of land use such as GDP, population, technological change, behavioural change and policy targets.

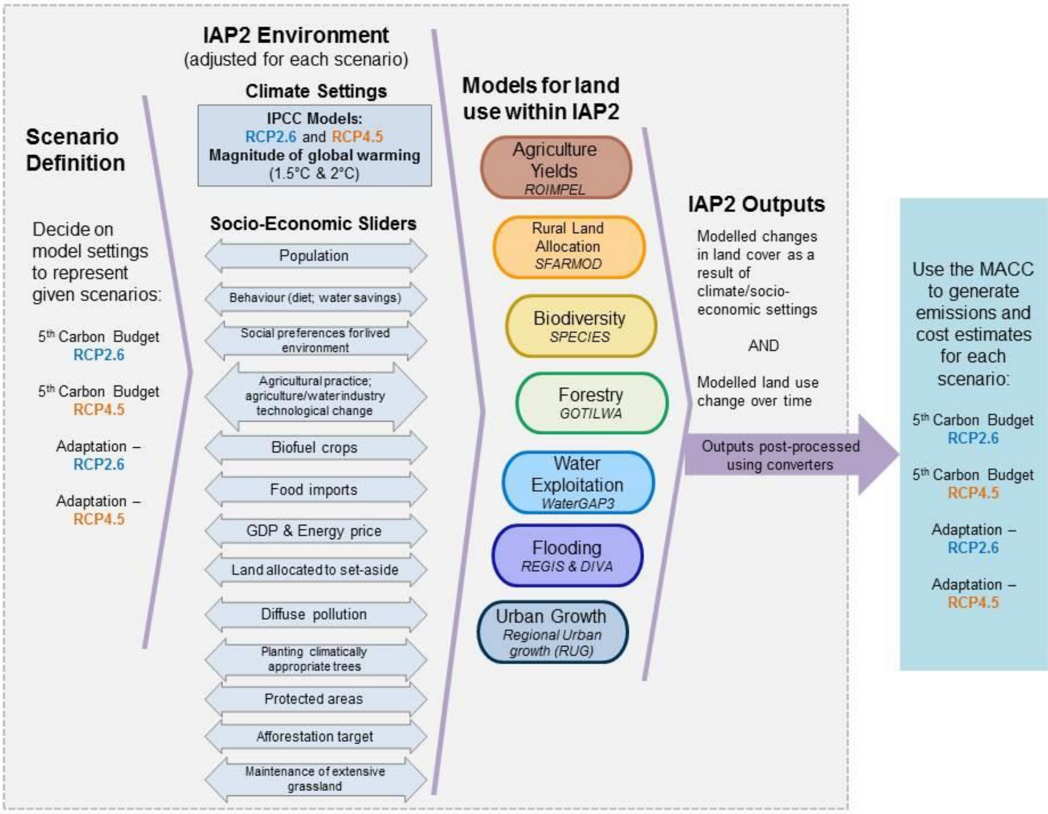
Land is allocated for a particular use on the basis of reaching specific profitability thresholds determined by the interaction of the supply of land (including biophysical properties such as climate and soil suitability) and demand for different commodities. The demand and supply functions were at the European scale. The model does not therefore take account of other factors that determine land use such as subsidy payments, historical allocations, inertia and regulations.

As the IAP2 was not designed to calculate agricultural non-CO_2 emissions, ECI used the CCC's fifth carbon budget agricultural Marginal Abatement Cost Curve (MACC) to calculate the emissions savings from the outputs produced by the IAP2.

Figure 2 provides an overview of the modelling framework used for this project.

[2] CCC (2015) *'Sectoral scenarios for the fifth carbon budget'*

Figure 2. Overview of the modelling framework



Source: ECI et al (2017)

4. Main results of the pilot study

(i) Establishing a baseline of current UK land use

The first task was to assess how well the IAP2 could model current land use in the UK, the results of which could then be compared with observed land use data from the Land Cover Map of Great Britain 2007 (LCMGB).

Figure 3 compares the IAP2 results with the land cover map data. It shows that while there were close matches between the two sets of results for urban areas and extensive grassland, large differences were noted for certain sectors such as forestry and arable land.

There are a number of reasons that could explain the differences in these results.

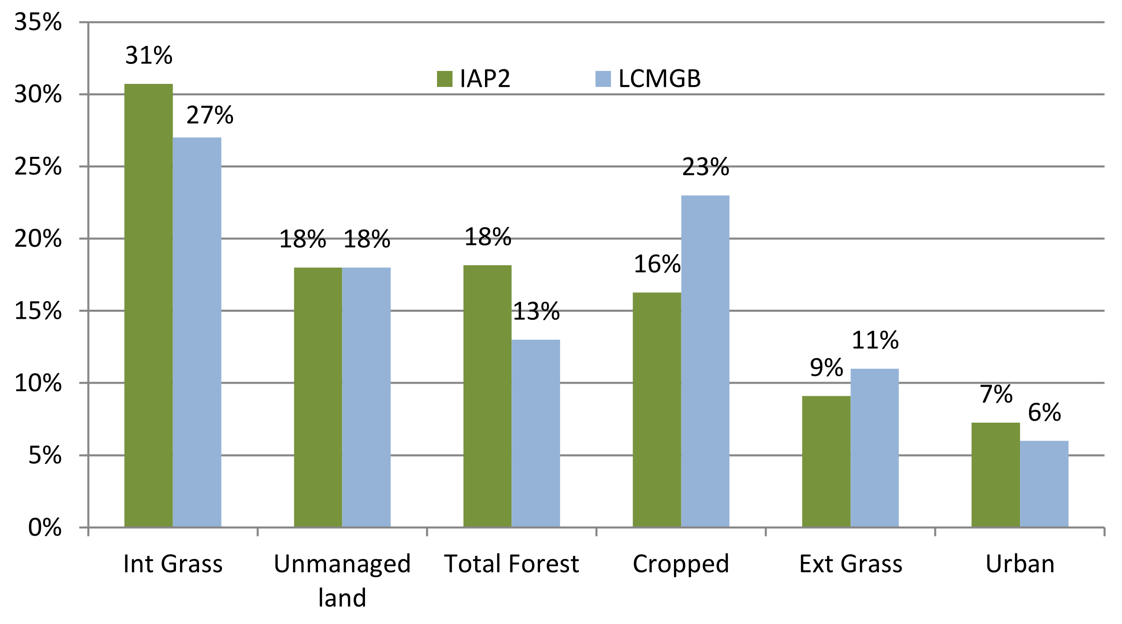
- The IAP2 optimises land allocation at the European scale based on potential profitability. The results suggest that the model found crop production to be more profitable elsewhere in Europe rather than the UK, while the opposite was found for forestry.

- The IAP2 definition of land use is slightly different to the one used in the LCMGB data set which estimated land cover.

- We know that some drivers of land use are missing from the simplified IAP2 profit function.

Nevertheless, these differences were significant enough to raise concerns, as they make it more difficult to understand fully why land is being allocated to a given use in both the baseline and different future scenarios.

Figure 3. Comparison of modelled IAP2 baseline to an observed baseline (% of UK land area)



Source: ECI et al (2017) and LCMGB (2007).

(ii) Results by 2050

Having established a modelled baseline of UK land use, we then wanted to explore how land use changed by 2050 in three distinct scenarios:

a) BAU - no change in current land use drivers

b) The fifth carbon budget mitigation scenario

c) A maximum biodiversity scenario

Each of these was run under the 1.5°C and 2°C climate warming scenarios, giving six scenarios in total.

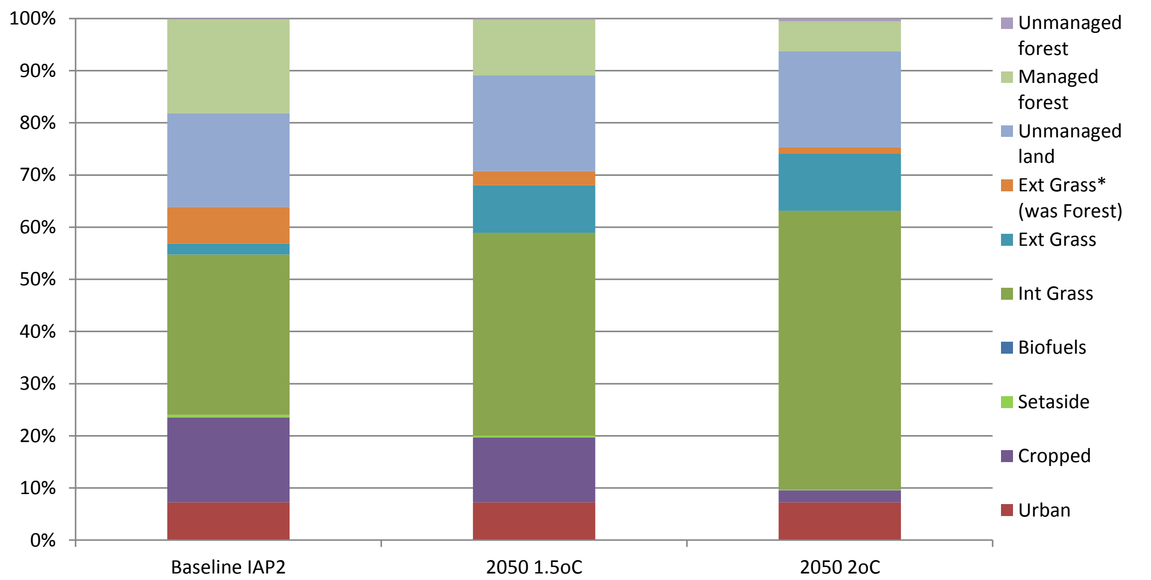
(a) Business as usual with climate warming

The results of the climate only scenarios are given in Figure 4. This shows that compared with the modelled baseline, under both climate change scenarios, the areas of intensive and extensive grassland increased, while the areas of forestry and cropland declined. In addition, food production declined under both scenarios. There are a number of reasons as to why the area of forestry might decline:

- Unfavourable climate: wetter climate favours grassland and not trees.
- Forestry is more profitable elsewhere in Europe and is therefore migrating from the UK.
- Increased timber yields in the UK due the CO_2 fertilisation effect means that less managed forest area is required to deliver the same amount of output.

Distinguishing between these, and other possible explanations was, however, difficult. This was due in part to the nature of the model and partly because land optimisation was being done at the European rather than the UK scale. Nevertheless, given that little work had been done to date to model the impact on UK land use due to climate change alone, this work may be of interest and could initiate further analysis.

Figure 4. Change in UK land use by 2050 due to climate change alone by 2050



Source: ECI et al (2017)

(b) The mitigation and adaptation scenarios

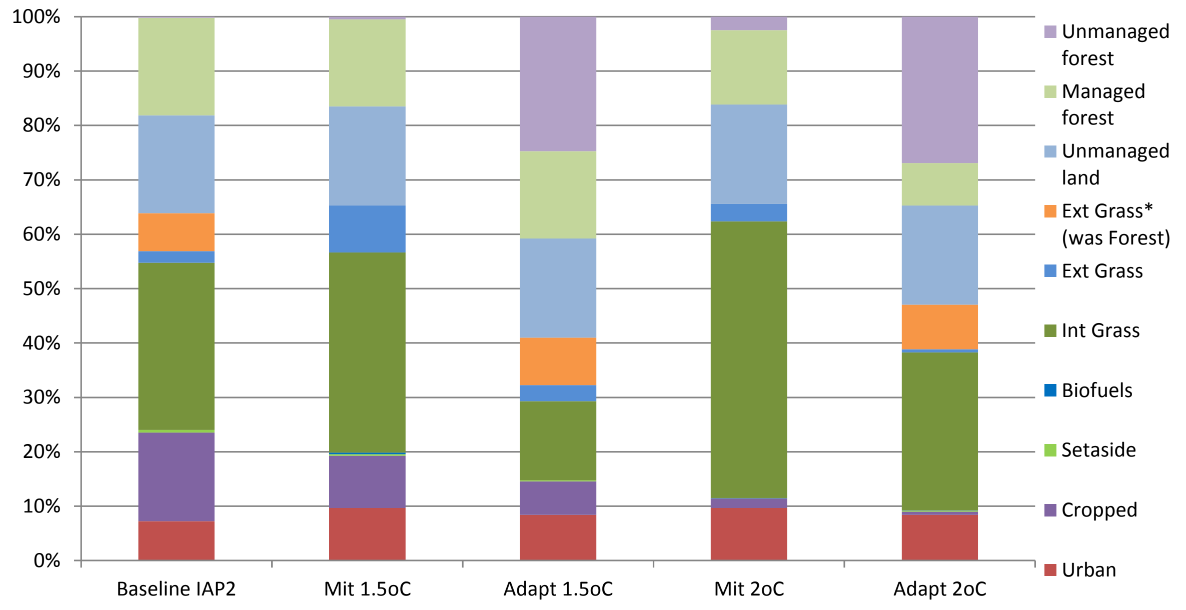
The main impact of the mitigation scenarios was to increase forestry area and reduce cropland compared with the BAU climate only scenario (Figure 5):

- The increase in afforestation to meet our fifth carbon budget assessment led to an increase in forestry area under the two mitigations scenarios by 2050 compared to the two climate only scenarios. However forestry area is less than the modelled baseline level, possibly reflecting that it is more profitable to plant trees elsewhere in Europe.

- The area of cropland reduces in the mitigation scenarios compared with the climate change only scenarios. However, food production increases due to increased yields, although this only occurs under the 1.5ºC climate warming projection.

- In the two scenarios (Adapt 1.5ºC and 2ºC) to maximise biodiversity, total forested area more than doubles compared to the baseline, while agricultural output falls as land for both crops and livestock declines. As forests tends to be more biodiverse than agricultural land, overall biodiversity increases.

Figure 5. Mitigation and adaptation scenarios under each climate change projection by 2050



Source: ECI et al (2017)

(iii) Agricultural emissions

The outputs generated by the IAP2 on agricultural land area (e.g. cropland and grassland) were input into the CCC agricultural MACC in order to quantify the impact of the mitigation and adaptation scenarios on non-CO_2 emissions.

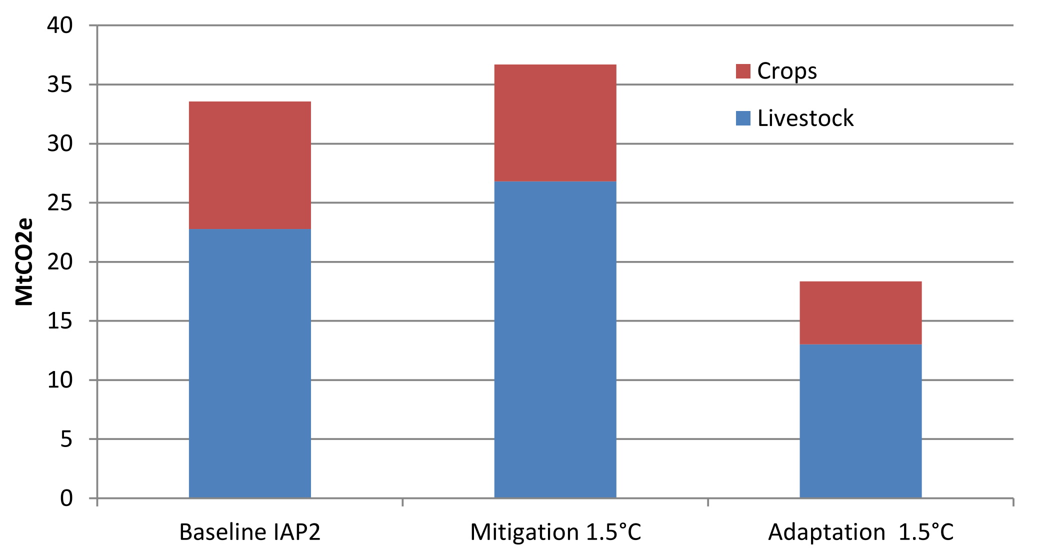
The mitigation scenario under the lower warming projection (1.5ºC), showed an increase in livestock emissions and a reduction in crop emissions relative to the baseline. In the adaptation scenario emissions from both sources declined (Figure 6):

- **Mitigation scenario:** livestock emissions increased due to the rise in grassland area, while the decline in crop area produced a corresponding fall in crop emissions. Compared to our fifth carbon budget estimates, the respective changes in land area increased the abatement potential for livestock, while reducing it for crops.

- **Adaptation scenario:** with both grassland and crop areas declining in order to benefit biodiversity, emissions from both sources were below the baseline level of emissions. This therefore reduced the overall level of abatement potential compared to fifth carbon budget estimates.

The results demonstrated that non-CO_2 emissions could be calculated by linking the IAP2 model with the CCC's Agricultural MACC. The pilot phase however was not able to demonstrate the calculation of carbon in trees and soils, important when exploring the impact of afforestation and peatland restoration. This is because the model does not currently calculate these outputs, although the modellers indicated that these could be approximated for any further work.

Figure 6. Impact of land use change on non-CO_2 agricultural emissions



Source: ECI et al (2017)

5. Conclusion and next steps

The IAP2 model produced some interesting results on potential changes to future land allocation and outputs, when considering the impact of the warming climate alone and when combined with the mitigation and adaptation scenarios. It also demonstrated that a good approximation of non-CO_2 emissions estimates could be achieved by linking the IAP2 model to the CCC MACC.

However, the integrated modelling approach also raised a number of issues. Firstly, was the difficulty in determining what was actually driving the results, which in part was due to the challenge of adapting an existing modelling framework initially designed at the European scale to suit the specific UK case and scale. Developing a specific UK version of the IAP2 was not an option given the significant work this would entail in terms of customising existing models to the UK scale, and the collection and processing of UK specific datasets to populate the models. Secondly, the IAP2 model lacked the capability to produce some key outputs important for measuring resilience, particularly on soil and habitat condition.

In view of the challenges of using an integrated modelling approach to cover both mitigation and adaptation, and in order to improve the transparency of results, the Committee decided to adopt a simplified analytical approach. We propose to undertake two studies on land use:

- Development of a calculator tool primarily aimed at assessing land uses consistent with deep emissions reduction, but including a narrative on likely resilience impacts. We are looking to adopt a simple transparent modelling tool based on bottom-up analysis to quantify the impact of a set of future land use scenarios which focus on pathways that deliver deep emissions reduction and increased sequestration. The required outputs will be limited in number and scope with the primary focus on emissions, although where possible, the impact on resilience outputs will also be considered.

- A wider cost-benefit analysis of a defined set of land use and land management scenarios that focus on increasing resilience to climate change. The findings from the first study will help inform this analysis.

A tender[3] has been issued to take forward the mitigation work. The closing date for bids is 9th October 2017.

[3] https://www.contractsfinder.service.gov.uk/Notice/cd1fa08d-fa94-40b1-9471-cddf597994f8