Programme Area: Bioenergy

Project: Refining Estimates of Land for Biomass

Title: Final Project Report (D9)

Abstract:

This is the final report from the RELB Project. This report includes updated version of previously submitted intermediate deliverables (D1, D2, D4, D5 report and D6). This D9 report details the findings from the RELB work packages:

Review of existing studies – a review of past estimates in the literature of land availability for new perennial energy crops and new Short Rotation Forestry production in the UK and Europe;

Desk and Field studies – report of and findings from the validation exercises carried out;

Mini case studies – individual reports on the three 50x50 km cells assessed in the field study;

Opportunities and barriers – report of desk study undertaken to understand why bioenergy crop production does not currently utilise the 'available' land and to identify opportunities to increase planting;

Final summary and conclusions

For a less detailed version of this report, the reader should see deliverable D10 which is provided in PowerPoint format.

Context:

Many significant pieces of work have been undertaken to assess UK "2nd generation" bioenergy feedstock production potential. The RELB project was undertaken to help refine and sense-check these existing estimates, including the ETI's own in-house modelling assumptions, in order to understand what further 'correction factors' (if any) may need to be applied to adjust existing estimates. In addition, the project aimed to better understand the process for converting land to 2nd generation bioenergy feedstocks and the impact planting these feedstocks could have on farm businesses. The RELB project had four distinct work packages:

1. A review of latest theoretical estimates of land available for biomass production in the UK and Europe.
2. A desk study to identify additional constraint layers which could be used to refine the ETI's own in-house land availability constraint masks. The suitability of these additional constraint layers was tested through field surveys.
3. A review of the steps and agencies involved in land use change to bioenergy crops and forestry.
4. Case studies of three farmers who have planted bioenergy crops, focusing on the financial and food production impacts of their decision.

Refining Estimates of Land for Biomass

Final Project Report

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Executive Summary

Overview

Bioenergy is considered to be an important potential component of the UK's future energy mix. The sustainable production of bioenergy crops has the potential to store carbon and reduce greenhouse gas (GHG) emissions, compared to the use of fossil fuels. The Energy Technologies Institute (ETI) has undertaken previous work to model the likely contribution, types and locations of domestic and imported bioenergy sources to the UK's energy system out to 2050. This work involved the development of the Bioenergy Value Chain Model (BVCM) based on underlying land estimates using various UKERC constraint masks. This project aimed to refine the current estimates of UK land available for bioenergy crop production through desk and field based research, focusing on Miscanthus, Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF).

The work is reported in four main chapters, plus an introduction and final summary;

1. **Introduction**
2. **A review of existing studies.** This provides context for the land estimates provided by BVCM and for the field and desk studies. It comprised an assessment of recent UK and European land predavailability estimates for energy crops and SRF, in the near-term, and further in the future. It identified the strengths and weaknesses of the different approaches utilised by the studies, and provided ranges of land area estimates.
3. **Refining the estimates of land availability.** ETI selected 5 example 50 km x 50 km cells from the BVCM model which were potentially suitable for bioenergy crop production. Initial desk analysis was used to identify sub-cells for the field survey and then the results of the field survey were used to compare to the desk study. Therefore this work area was divided into two separate work packages;
    - **Field survey** – 10% of available 1 km x 1 km sub-cells were selected at random from within three of the 50 km x 50 km cells used in the desk study for ground-truthing in the field.
    - **Desk study** – The desk study focused on 5 example 50 km x 50 km cells to calculate the impact of adding additional GIS data sets to those already used in UKERC 9w. The changes in availability were validated by analysing the difference between the desk study results and those identified in the field survey.
4. **Review of processes to convert land to bioenergy crops.** This looked at the steps and agencies required to convert land to bioenergy production providing information about the various considerations that need to be made prior to planting a bioenergy crop.
5. **Review of opportunities and barriers.** This section focuses on identifying some of the barriers to increasing bioenergy crop plantings and some of the opportunities there are available to increase bioenergy crop plantings.
6. **Final summary and conclusions**

Review of existing studies

A review was conducted of existing estimates of land availability for new perennial energy crops and new SRF production in the UK and Europe. Currently in the UK, 51 kha of land is used for growing bioenergy (0.8% of arable land), of which ~**10.3 kha** is used to grow perennial energy crops and SRF. In the European Union (EU), 5,506 kha of land is used for growing bioenergy (3.2% of arable land), of which at least ~**105 kha** is used to grow perennial energy crops and SRF.

In total 46 peer-reviewed academic and grey literature studies published between 2003 and 2015 were identified and characterised in terms of key assumptions, data sets used, and strengths and weaknesses. Methods used to calculate estimates include demand-led scenarios, land-balance modelling, GIS constraint mapping, economic optimisation, agent-based simulation and farmer surveys. Each of these approaches provides insights on some aspect of future deployment. Demand-led studies are typically too removed from the reality of today to provide much insight; they only describe what might be needed, not how or where it can be achieved. Land-balance models are also very sensitive to simple parameters describing complex phenomenon such as future yield growth and dietary trends. Consequently, they are best used for scenario analysis and need to be used with caution. On the other hand, GIS models tend to be able to address focused questions, providing detailed scenarios for land use that can be investigated empirically. Their limitation is that they can only simplistically address competition between demands on land (if at all) and they are not a predictive tool. Agent-based simulation is a new sophisticated method of modelling uptake and farmer experience across geographies, explicitly considering the "chicken and egg" problem of getting farmers to plant before a local conversion plant is built (and vice versa), but is computationally expensive and sensitive to the parameterisation of human interactions. Farmer surveys provide an empirical snapshot of current sentiment, but, again, it is not straightforward to extrapolate from stated opinions to willingness to invest across a country.

The findings for each UK and EU study are summarised in Section 2.2.3 and Section 2.2.4 respectively. Each study was critically examined and relevant information about land areas extracted and analysed. Land area estimates are compared, and common assumptions and methodologies discussed – see Section 2.3. Results show that in the near-term (up to ~2020) the UK land area available for energy crops is estimated to be between **7 kha and 1,723 kha**. The bottom of this range represents an historic area of energy crops planted; the top end corresponds to a demand-led scenario in which the entirety of UK's 2020 bioenergy target under the EU Renewable Energy Directive (based on National Renewable Action Plan projections) is met from domestic production. The majority of high near-term estimates, however, match closely to the area formerly used for 'set-aside' in the UK (1988-2008). It is notable that many recent studies still trace their underlying data back to older studies that included set-aside in their derivation – i.e. are likely to be too optimistic about land availability. There are exceptions though, with new study designs involving agent-based modelling and farmer surveys recently published, taking a more cautious, bottom-up approach to land availability.

In the longer term (until ~2050 and beyond), the UK range of estimates increases to between **99 kha and 9,086 kha**. The lowest future numbers have very constrained energy crop planting rates (assuming little progress in the industry), whereas the numbers at the top end do not consider food competition and are often calculated as the first step in a GIS analysis before developing more highly constrained scenarios.

Fewer studies have looked specifically at land availability for SRF in the UK, and these all assume planting on rough grazing or low quality permanent grassland. The ranges found **are 0 to 2,498 kha** in the near-term, and **0 to 4,131 kha** in the longer-term – noting that any biomass production from these areas would require planting ~20 years prior to first harvest. We also note that there is a lack of SRF estimates at EU level, as available studies are generally less granular than UK studies.

EU study estimates for bioenergy crop land area availabilities indicate a range of **940 to 25,217 kha** in the near-term, based on conservative inventories, or optimistic demand-led projections (which coincidentally turn out to use an area close to the EU's past maximum set-aside levels). In the longer term, **1,640 to 108,200 kha** might be available in the EU, based on conservative macro-economic modelling, or optimistic food intensification assumptions in a land-balance model.

The Chapter concludes with a summary of findings and observations in Section 2.4. We have highlighted the high level of overlap between studies, and occurrences of repeated meta-analyses. In the UK at least, a new resource inventory (similar to ADAS, 2008) is needed that reflects the current agricultural reality. The tension with food remains unresolved in many studies, particularly regarding the quality of land used. New work by Alexander et al. (2014) shows land availability as a function of willingness to pay for bioenergy, based on farm profitability and innovation diffusion. The inference is that competition with food and other uses cannot be avoided, hence achieving significant domestic planting of energy crops will depend on positive education campaigns, and users offering farmers a high enough price to make growing energy crops a significantly more attractive option than their current land use.

Most studies assume that food crop yields increase over time and that this automatically releases land for energy crops and other uses – although we note there is no database of uneconomic land locations, nor any certainty that this land will be used for energy crops. Key barriers include proximity to markets and reliance on decisions of thousands of individual farmers. Only one model (Biomass Futures 2012a) describes a reduction of land availability in the future (in 2030 compared to 2020), this result is attributed to increasing demand for arable land, but as the model is not publically available nor explained in detail, the underlying drivers behind this result cannot be examined.

Another key point is that any model can very quickly become out-dated by macro-economic volatility, such as changes in food and energy prices, policy change, notably Common Agricultural Policy (CAP) reform and bioenergy support levels. Indeed the macro-economic outlook today is rather different to the period when many of the studies were conducted. In particular, the UK energy crop sector is currently stagnant, and with SRF yet to progress beyond trials.

The differing contexts, methodologies, data and assumptions of the studies analysed in this Chapter indicate a very broad range of estimates of land availability, both in the UK and Europe. The studies use different methodologies and the resulting values often cannot be directly compared with each other. however, they do allow identification of the key drivers and sensitivities (such as population growth, diet and food crop yields), and from this there is certainly a credible range of estimates within which the future for the energy crop and SRF sectors may lie, provided that policy, markets and crop technology are all developed and supported.

Refining estimates

The ETI's Bioenergy Value Chain Model (BVCM) currently uses national land estimates based on various constraint maps developed through the UKERC Spatial Mapping Project. This project builds on one of those constraint maps, UKERC 9w, to refine the current estimates of available UK land for the production of 2nd generation (2G) energy crops[1]. The objective was to analyse the impact of adding additional datasets to BVCM assumptions on land availability for 2G energy crops using GIS analysis and the results of a field survey.

ETI identified five 50 km x 50 km cells (cells) for assessment in the desk-based study, based on the potential for bioenergy crop production, three of which were also selected for field survey. The cells were divided up into 1 km x 1 km sub-cells (sub-cells), each designated either 'available' or 'unavailable' based on the coverage of the constraint layers used in the mask (at 100m resolution). A range of datasets in addition to the original UKERC 9w mask were reviewed and considered for use in a new

[1] 2nd generation energy crops are biofuel or biomass feedstocks that are not also food crops. In the UK 2G crops include short rotation coppice/ forestry and Miscanthus grasses

provisional mask. Selected datasets were added to the original UKERC 9w mask to reclassify the sub-cells as either 'available' or 'unavailable'. The provisional mask resulted in a land availability estimate of 6,852 km^2 for the five study cells, a reduction of 25% compared to the 9,136 km^2 estimated using UKERC 9w.

Field survey

In order to validate land areas estimates calculated using the UKERC 9w masks and additional GIS data layers applied to the cells, a series of field surveys were carried out. These surveys aimed to ground-truth the theoretical estimates and provide a sample of real data for comparison.

The field survey was carried out in three different 50 km x 50 km cells; cell 019 in Kent and Sussex, cell 046 in Leicestershire and Northamptonshire and cell 100 in Dumfries and Galloway. GIS layers using UKERC 9w and a number of additional masks were used to identify the 'available' and 'newly unavailable' 1 km x 1 km sub-cells in each cell. From these 'available' and 'newly unavailable' sub-cells a random selection (using random number generation) of survey cells was made, selecting 10% (minimum 200) of the sub-cells for inclusion in the survey. An additional 50 cells were selected as backups in case the planned sub-cells could not be assessed due to access or visibility challenges.

Each of the surveyors was provided with a data template listing a range of land types and features. They then had to identify what proportion of the sub-cell contained each land type and note whether certain features such as utility poles, livestock and access roads were present. At the end of the template the available land area was added together to give an initial estimate of whether the sub-cell was available. The surveyor then also noted whether or not they thought that the sub-cell was available or unavailable, giving a reason if their view differed from that indicated by the initial land area estimate.

All the surveyors were provided with training, including a worked example of how to complete the template, examples of different features and land use types to look out for. They then used a series of printed Ordnance Survey maps to locate the sub-cells and undertake the survey. Where visibility was good surveyors could use one or two view points, but in situations where visibility was poor multiple viewpoints were required to increase the proportion of the sub-cell that could be assessed. Despite this, surveyors were only able to assess an average of 88% of each sub-cell, with greater visibility problems observed in cell 046, due to high hedges surrounding a large proportion of fields and obscuring views. Where visibility was just 50-60% of the sub-cell, mapping information and satellite imagery were used to help refine estimates.

Whilst data was being collected, consistency was ensured through regular communication with the surveyors identifying challenges, discussing them and sharing conclusions. Data was also uploaded at the end of each day and checked through to ensure that any differences between surveyors were picked up, discussed and corrected, if they were not justified by differences in terrain.

Following completion of the data collection, the data was collated into a Microsoft Excel spreadsheet for analysis. Where there were unknown areas of the sub-cell, these were allocated pro rata based on the known areas to calculate a final land area forecast. This land area forecast was compared with the surveyor forecast of sub-cell availability. In total 610 sub-cells were surveyed; for 93% of these the land area forecast agreed with the surveyor forecast. In the majority of the cases where there were discrepancies between land area forecasts and surveyor forecasts, the surveyor had looked at the mapping information and any satellite imagery and considered that a pro rata allocation of the unknown land was not correct. There were three sub-cells in cell 019 where the surveyor considered that the sub-cells were not available because of other reasons; the presence of large areas of garden, a vineyard and equestrian use. In cell 100 there were four sub-cells that the surveyor considered were too steep for any sort of energy crop production, even though the basic land types were 'available'.

Desk study

Results of the provisional mask were compared with the results of the field survey to determine (i) if there were any other constraints for which spatial data were available that could be used to improve the provisional mask by excluding additional areas of land; (ii) if there were any constraints included in the provisional mask that should be removed because they are excluding areas of land that should be available and (iii) if there were any constraints included in the provisional mask that could not be identified by the field survey. The relative effect that each constraint had was also assessed by removing each one in turn from the provisional mask and comparing the results from logistic regression analyses, with the field survey classification as the dependent variable.

The comparison of results from the desk study and field survey and the outcomes of the statistical analyses were consolidated to make an additional assessment of the strengths and weaknesses of potential constraint data layers in light of the results, and recommendations made on which layers should be included in the final mask for each surveyed cell. The constraint layers that were recommended for inclusion were;

(i) altitude >300 m – even though exclusion improved the match with the field survey results, high altitude is an absolute constraint that can be measured accurately from the dataset used;

(ii) land with highest agricultural productivity (grade 1) – this constraint could not be assessed in field survey, but at the present time the highest grade land is likely to be reserved for other crops;

(iii) buildings and water bodies – the dataset used identified additional constrained areas compared to UKERC 9w;

(iv) BAP priority habitats – there is good evidence that these areas would not be suitable for planting, supported by results of the field survey;

(v) semi-natural woodland – unlikely to be felled for planting and supported by results of field survey;

(vi) historic parks and gardens – historic and cultural value of this land makes it unlikely that it would be used for planting.

The constraint layer for environmental stewardship options (which was included in the provisional mask) was not recommended for inclusion in the final mask as it is not being a permanent constraint; for example land can come out of stewardship as incentives for farmers change. The final mask resulted in a land availability estimate of 7,701 km^2 for the five study cells, a reduction of 16% compared to the 9,136 km^2 estimated using UKERC 9w.

Investigations into the reasons for mismatches between the desk study and field survey gave a good insight into where there were gaps in the desk study constraints. These gaps included private gardens, golf courses, quarries, roads, car parks and playing fields. Datasets that would fill some of these gaps were identified and included highly detailed land cover mapping such as Ordnance Survey MasterMap and the GeoInformation Group's UKLand dataset; however, the costs of these datasets are high.

The study would have benefited from a larger selection of cells on which to test the different constraint layers. It was however able to identify that a single 'correction factor' could not be applied to every cell, since the percentage decrease in sub-cell availability was not consistent between study cells. Consideration was given to the possibility of applying a correction factor to a typology, but this is not advised due to the small sample, the inability to assess all of the constraints in all cells, and the fact that the range of typologies were not fully represented in the study sample. The conclusion of this study is that the extrapolation of the findings in this study to the rest of the UK will require a GIS analysis using all of the chosen constraint datasets. Equivalent datasets would need to be sought for Wales and Northern Ireland and further assessment would also be required for considering the use of any new datasets.

Mini case studies

A series of mini case studies were prepared for each of the cells that was assessed in the field survey. These case studies highlight the variability across the country and the need for a specific study for each cell. This is highlighted first by the difference in extent in the final mask across each of the cells; with availability of 41%, 78% and 41% in cell 19, cell 46 and cell 100 respectively. Differences are further highlighted by the likelihood layers that have been examined. While the differences in the number of available sub-cells within a flood risk area are low between cells 19 and 46 (27 and 33 respectively), the differences in the number of available sub-cells within a NVZ are high; ranging from 288 in cell 100 to 1,937 in cell 46. There is also a large difference in the number of available sub-cells in water stressed areas; 109 in cell 46 and 535 in cell 19. These differences highlight the need for masks which are spatially derived, and how it isn't possible to provide a uniform mask correction that can be applied for the country.

Opportunities and barriers

A desk study was undertaken to understand why bioenergy crop production does not currently utilise the 'available' land and to identify opportunities to increase planting. Firstly we considered the steps and agencies required for a farmer or landowner to convert land to energy crops such as Miscanthus and short rotation coppice (SRC) or Short Rotation Forestry (SRF), and the government bodies involved. This was followed by an assessment of the barriers and opportunities that these processes bring for converting land to energy crops or SRF.

Before a farmer can plant bioenergy crops they need to determine if an Environmental Impact Assessment (EIA) is required, consult their Local Authority (LA) and other affected stakeholders (such as utility companies) and ensure that they comply with other environmental legislation and planning regulations (if necessary). It is also crucial that they understand the impact of making changes to their land in relation to the rules of the Common Agricultural Policy (CAP) and ensure that the crop can meet the sustainability requirements of financial incentives for renewable energy (such as the Renewables Obligation - RO, Renewable Heat Incentive - RHI and Contracts for Difference - CfDs).

Potential barriers to development of a vibrant sector include lack of information provision and awareness, access to finance, too much regulation, access to markets, and the practicalities of energy crops and silviculture. Information can be obtained from official growers' guidelines and from various other internet and industry sources with up to date information available for Miscanthus and SRF. There are regular events and open days on energy crops, often held by membership organisations, but actual training courses are rare. The private sector can provide advice, although this comes at a fee. Cashflow is a challenge despite the attractive long term revenue profile, because of the high establishment costs of energy crops.

The closure of the Energy Crops Scheme (ECS), , the lack of financial incentives in Common Agricultural Policy (CAP) greening, the high cost of some machinery and unfavourable tax treatment exacerbate the problem. The RHI currently creates incentives for those who also invest in energy generation, but compliance with air quality and sustainable sourcing criteria is expensive, creating a regulatory burden on the whole industry. Furthermore, there is uncertainty about the future of the RHI post March 2016. Afforestation by planting SRF is more tax-efficient and can be incentivised through woodland creation grants under agri-environment schemes. However, budgetary and spatial targeting constraints mean that plantation forests on an economic scale are less likely. Other issues include a lack of long term, secure markets, insufficient economies of scale, and lack of infrastructure or energy crop specific funding to set up supply chains.

There is also a perception issue: farmers indicate indifference towards energy crops and woodland creation, citing issues such as impact on land quality, lack of appropriate machinery, long term commitment, time to return, and profitability. The absence of a clear policy framework has also failed to inspire confidence, so growers lack financial incentives whilst end-users face regulatory hurdles. Without a significant change in approach the amount of new energy crops planted will be limited.

A number of opportunities for progress have been considered. One possibility would be to deliver funding and support for developing bioenergy supply chains through local or regional enterprise agencies e.g. Local Enterprise Partnerships (LEPs)[2] in England. This would provide a wider perspective with a focus on socioeconomic benefits and a wider range of environmental benefits, including flood mitigation. Other suggestions include: incentivising bioenergy crops under CAP greening requirements; setting up a levy body for the sector; developing a Miscanthus standard; more research on herbicides; updating official guidance; and targeting woodland creation more effectively. A full review of these opportunities is recommended.

Overall conclusion

The main objective of this work was to review the basis for estimating land availability for bioenergy crops from previous studies in the UK and Europe and to truth-test the BVCM as a basis for identifying appropriate land in the UK.

Research studies identify numerous methods for estimating land availability, including land-balance modelling, GIS constraint modelling, economic optimisation, agent-based modelling and farmer surveys. It is important to recognise, however, that none of these methods can be considered a predictive or forecasting tool. However, the studies collected do allow identification of the key drivers and sensitivities, and from this there is certainly a credible range of estimates within which the future for the energy crop and SRF sectors may lie – provided the policy, markets and crop technology are all developed and supported. Estimates of UK land area available for energy crops in published research indicate a huge range from just under the current baseline of 10.3 kha (Defra 2014) to 1,723 kha in the near-term, to 99 – 9,086 kha for energy crops and 0 – 4,131 kha available for SRF planting in the longer-term.

These estimates suggest that availability of suitable land is not a primary barrier, but indicate that targeting of the most suitable land is important to help drive uptake. GIS based assessments provide a snapshot of how much land is hypothetically available for energy crops after excluded land areas are removed. Lovett et al (2014) used planting grant data from Natural England to show that only 83% of planted UK energy crops lie within areas modelled by the GIS masks as potentially suitable, underlining the importance of market factors and real world decision making, compared to just relying on GIS approaches.

One of the key limitations of these GIS studies is the lack of validation through the use of 'ground-truthing'. The use of outputs from a field survey provided an opportunity to test the impact of the inclusion of additional datasets to the UKERC 9w mask on BVCM predictions of land availability. The final mask was chosen based on the results of the regression analyses and the analysis of reasons for discrepancies between field survey and desk study results.

[2] Local Enterprise Partnerships are local business led partnerships between local authorities and businesses in England which help set local economic priorities and undertake activities to drive economic growth and the creation of local jobs. See http://www.lepnetwork.net/

Across the five cells included in the study, the estimated available land was 9,136 km^2 (74%) with the UKERC 9w mask; this was reduced to 7,701 km^2 (62%) with the final desk study mask. Due to the small sample size and the variability in landscape and dataset availability across the UK, the predictive capability of the final mask cannot be assessed for the whole range of landscapes and constraints that occur in the UK. We therefore conclude that a UK-wide correction factor cannot be applied. Creation of a mask using the recommended datasets at UK scale would enable a national estimate to be produced, although the associated level of uncertainty would not be known. The inclusion of a field survey in this study has been fundamental in providing both a means for testing the strength of the inclusion of each dataset, and also in the identification of 'gaps' in methodologies. It is therefore recommended that any further study include a field survey or 'ground-truthing' method to test the legitimacy of using the recommended mask in other cells.

Ultimately, the area available for energy crops depends on how competing demands for land are prioritised now and in the future. Social, technological, economic, environmental and political factors affect this prioritisation. Set against the complexity of attempting to determine a normative "best use" of land, the questions that bioenergy crop assessments can effectively tackle are comparatively simplistic.

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1 Introduction

Bioenergy is considered to be an important potential component of the UK's future energy mix. The sustainable production of bioenergy crops has the potential to store carbon and reduce greenhouse gas (GHG) emissions, compared to the use of fossil fuels. The Energy Technologies Institute (ETI) has undertaken previous work to model the likely contribution, types and locations of domestic and imported bioenergy sources to the UK's energy system out to 2050. This work involved the development of the Bioenergy Value Chain Model (BVCM) based on underlying land estimates using various UKERC constraints mask[3]. This project aimed to refine the current estimates of UK land available for bioenergy crop production through desk and field based research, focusing on Miscanthus, Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF).

The objectives of this project were;

Objective 1 - To review existing estimates of land availability for new 2G bioenergy crop and new SRF production in the UK and Europe, highlighting key assumptions, data sets used, plus strengths and weaknesses of each of the studies reviewed**.**

Objective 2 - To analyse the impact on land availability for 2G feedstocks of adding additional datasets to existing BVCM assumptions using GIS analysis and (following WP3) the results of WP3.

Objective 3 - To carry out a field survey to "ground truth" desk-based estimates from WP2.

Objective 4 – To update existing ETI document with information about steps and agencies involved when converting existing land to biomass production, along with relevant barriers and opportunities for improvement.

Objective 5 – To collate all findings to provide a critique of theoretical, desk-based and field-based assessments of UK land available for bioenergy crop production.

In order to achieve this the work was split into four chapters, plus and introduction and conclusions. These chapters are all reported below under the following structure;

1. **Introduction**
2. A **review of existing studies** – This work provides context for the land estimates provided by BVCM and for the field survey and desk study. This work package assessed recent UK and European land availability estimates from a range of authors. It identified the strengths and weaknesses of the different approaches used, and provided ranges of land area estimates.
3. **Refining the estimates of land availability** – An initial assessment was done to identify 5 example 50 km x 50 km cells to use as the basis for this work. These cells corresponded with areas highlighted in the BVCM model as being potentially suitable for bioenergy crop production. There was an initial piece of desk work to identify sub-cells for use in the field survey and then the results of the field survey were used to compare to the desk study. Therefore this work is area was divided into two separate work packages;
    - **Field survey** – Using a random selection of 1 km x 1km sub-cells from within three of the cells used in the desk study the field survey aimed to provide some ground truthing of the estimates calculated in the desk study.

[3] UK Energy Research Centre (UKERC)

- **Desk study** – The desk study used 5 example 50 km x 50 km cells to calculate the impact of adding additional GIS data sets to those already used in UKERC 9w. The changes in availability were validated by analysing the difference between the desk study results and those identified in the field survey.

4. **Review of processes to convert land to bioenergy crops.** This looked at the steps and agencies required to convert land to bioenergy production providing information about the various considerations that need to be made prior to planting a bioenergy crop.
5. **Review of opportunities and barriers.** This section focuses on identifying some of the barriers to increasing bioenergy crop plantings and some of the opportunities there are available to increase bioenergy crop plantings.
6. **Final summary and conclusions**

2 Review of existing studies

Over the last three decades there has been resurgent interest in modern applications of bioenergy. This interest has been driven by concerns about energy security, increasing prices of fossil fuels, and climate change, as well as new opportunities for bio-based chemicals. Underpinning this interest is the expectation that sufficient quantities of biomass will be available to address these concerns, to make a material difference, and to support new industries.

The aim of this Chapter is to review estimates of land availability for new perennial energy crops and new Short Rotation Forestry production in the UK and Europe. These estimates are obtained from a detailed review of studies published in the academic and grey literature between 2003 and 2015. Each of the studies that contained new analysis or novel interpretations of prior work was examined in detail and the land area estimates identified. A summary of these estimates is presented in this Chapter to enable the findings from the desk study and field survey of the RELB project to be set in context. This Chapter also highlights major assumptions and datasets used, identifies the key insights that can be gained from each of the studies reviewed, and draws conclusions on overall strengths and weaknesses.

The scope is limited to current land availability estimates. Studies published from 2003 onwards are included, to ensure analysis of the reports which informed the UK's 2007 biomass strategy (DECC, Defra & DfT, 2012). Studies published prior to 2003 have had less influence on the recent debate about land availability and are considered less reliable (e.g. because significant amounts of set-aside[4] land still existed pre-2008). Where studies include estimates of land that might be available in the future, these have also been analysed to provide further valuable context and points for comparison alongside nearer-term estimates. Notably, some studies present numbers that can only be interpreted as future values.

The biomass resources in scope of this Chapter are perennial energy crops, e.g. Miscanthus, Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) only – existing forestry and food crops are out of scope. For example, whilst many studies assume existing agricultural land can be converted to Miscanthus, we are only gathering estimates on the land areas available for Miscanthus – we are not

[4] **Set-aside** was a European policy to reduce the production of arable crops, introduced in 1988. Farmers in the scheme agreed to set-aside (that is to stop using for any kind of agricultural production) a percentage (originally at least 20%) of their land they had been using for growing agricultural crops (HMRC: http://www.hmrc.gov.uk/manuals/ihtmanual/ihtm24064.htm). Set-aside was suspended in 2008

gathering estimates on, say, the total land available for wheat production. Units throughout are given in thousand hectares (kha).

2.1 Current land area growing energy crops

A useful starting point when examining and discussing the amount of land available for growing new perennial energy crops and SRF is to quantify the current land areas planted with these bioenergy resources.

The most comprehensive and recent report on the land areas used for growing bioenergy crops in the UK is provided by Defra (2014). This annual report aggregates and analyses statistics from a range of sources, including The June Survey of Agriculture and Horticulture, Renewable Transport Fuels Obligation data and the Renewable Energy STATistics (RESTATS) Questionnaire. The estimates of crop areas include oilseed rape (OSR), sugar beet, wheat, maize, Miscanthus and SRC; error bars for this data are typically less than 10%, although data are usually 1-1.5 years behind reality.

According to Defra (2014), the area of agricultural land in the UK used for bioenergy in 2013 was estimated to be 51 kha[5]. This area equates to approximately 0.8% of all arable land. Just over 80% (42 kha) of this land was used to produce biofuel crops (oilseed rape, sugar beet and wheat) for the UK road transport market. Miscanthus was grown on around **7.1 kha** of land in England, and SRC (willow & poplar) grown on around **2.7 kha** of land in England. Industry estimates included in the E4tech (2013) report also identify an additional **0.5 kha** of SRC currently grown in Scotland, Wales and Northern Ireland. Defra data also gives historical crop areas from previous years; it shows that Miscanthus areas are on an apparent downward trend (and SRC areas roughly static), with the new areas planted in 2014 and 2015 likely to be much smaller than previous year following the closure of the Energy Crop Scheme 2 (Natural England, 2014). However, the apparent decrease in area must be treated with caution as it may still be attributed to the sampling variation in the survey.

There is no official information on the current EU land area for growing energy crops or SRF (such as through EUROSTAT); however a few studies have attempted to quantify ranges by gathering together piecemeal information on individual Member States. The Biomass Futures (2012a) report, for example, estimates that bioenergy cropping, on average, took place on **5,506 kha** of EU agricultural land during 2006 - 2008. This amounts to 3.2% of the total EU arable area. The majority of this land is being used to produce biofuels, growing rapeseed, sunflower, wheat, barley, sugar beet, and maize for anaerobic digestion (AD). Biomass Futures (2012a) also estimated that **19.5 kha** was cultivated with Reed Canary Grass (mainly in Finland), and 38.3 kha of Miscanthus (mainly in the UK, Poland and Italy), although this report cites a UK Miscanthus area estimate of 13.5 kha which is now known to be too high. Adjusting for this, the total Miscanthus area in Europe today might be closer to **31.9 kha**. The Biomass Futures data for SRC (28.5 kha of willow and 6.5 kha of poplar) has been superseded by a more recent AEBIOM (2011) report, which states that **30 – 36 kha** of willow has been planted, and **14 kha** of poplar within the EU. These AEBIOM data are likely to be more accurate, as Biomass Futures data are older and only considered a subset of 18 EU countries for which they managed to obtain information.

Data on SRF is more limited than for energy crops. There is no reliable or centralised information available on UK or European SRF areas, as these are not currently distinguished from existing forestry data. UK experience is limited to past field trials, with less than **0.1 kha** estimated as planted

[5] Note that this figure does not include the 29.4kha of maize grown for use in AD, and also does not include the 2% of cereal straw used for bioenergy purposes.

(Forestry Commission, 2010). European experience seems to be mainly focused on Eucalyptus in Spain, with up to 140 kha planted for industrial pulping (but presumed to be long rotation, not SRF), but only **6.7 kha** known to be planted by Energia & Celulosa (ENCE) on an intensive basis (RISI, 2013; Ruiz & López, 2010). Other EU information on SRF areas is similarly old, anecdotal or unclear.

A summary of the "best available" estimated values for current perennial energy crop and SRF areas growing in the UK and EU is shown in Table 1.

Table 1: Best available estimates for land areas growing perennial energy crops in 2015

kha	Miscanthus and other energy grasses	SRC willow and poplar	SRF
UK	7.1	3.2	< 0.1
EU (including UK)	51.4	47.0	> 6.7

2.2 Review of studies

2.2.1 Introduction to land availability study methodologies

Before proceeding to discuss the specifics of the UK and EU studies reviewed in this project, it is useful to briefly introduce the principal methodologies used to calculate land potential estimates and some of the terminology used to describe them.

Numerous assessments of land availability have been undertaken at national, regional and global scales. A common feature of these assessments is that the availability of land is discussed in terms of a hierarchy of potentials: theoretical > technical/geographic > economic > realistic/implementable (see Table 2 for definitions). Caution is required, however, as these terms are not always used consistently or defined in a way that makes cross comparison straightforward. Constraints on land use (described in terms of environmental, biophysical, or economic limitations) are incorporated into the majority of studies, but may also be applied at different levels of the hierarchy.

Table 2: The biomass resource potential hierarchy

Level	Definition
Theoretical / ultimate potential	The amount of biomass that could grow annually, limited by fundamental physical and biological barriers. May change if conditions change, for example, due to climate change
Technical / geographical potential	All that can be collected from the theoretical potential (taking into account ecological constraints, agro technological restraints, topographic problems etc.). May change as technology advances. May also be defined as the proportion of the theoretical potential that is not limited by the demand for land for food, housing, etc
Economic potential	All biomass available up to a specified price level (taking into account the price elasticity of competitors in the market). Highly variable as economic conditions may change dramatically over time. May be difficult to calculate as markets may be imperfect, or may not exist
Realistic / Implementation potential	All biomass available without inducing negative social or social economic impacts. May be estimated using *recoverability fraction* or *accessibility* multipliers reflecting expert judgement about the maximum rates of exploitation, and ramp-up

(Adapted from Slade, 2011; Smeets, et al., 2006; Fischer and Schrattenholzer, 2001)

The amount of land available for energy crops depends on competing uses. The area required to meet national bioenergy (or climate) goals depends on the quality of land used and the crop yields that can be achieved.

Land (and biomass) potential estimates are often classified in the literature as either ***demand driven*** or ***resource driven*** according to the calculation methodology used. Demand driven studies seek to address questions such as:

- How much land would be required to provide [X] million tonnes of biomass?
- Given a target of [Y] hectares of land, what might be the least environmentally damaging, or most economically advantageous locations for new production?

Resource driven studies, in contrast, seek to compile an inventory of biomass resources, including the different land classes and areas on which energy crops might be grown. Typical questions these studies seek to address include:

- How much land might NOT be needed for competing uses (e.g. food) now and in the future?
- Where is land located that might NOT be constrained by existing planning requirements?
- What proportion of farmers might be willing to consider energy crops?

Hybrid approaches, however, are frequently found, for example a study may start with a land inventory and overlay this with a demand driven scenario analysis.

Resource driven studies range from simple calculations based on expert judgement and extrapolation of land use trends, to GIS mapping and sophisticated land-balance models. On this spectrum, the majority of UK focused studies adopt a simple calculation approach. There is considerable overlap, however, with European focused studies where the use of aggregate land balance models and integrated assessment models is more prevalent.

One of the most important analytical approaches, and one that underpins many estimates of future land availability, is land-balance modelling. An illustrative dynamic land-balance model is shown in Figure 1. This particular model developed by Fischer et al. (2007)[6] defines land available for energy crops as the land remaining after the area needed for food, feed and livestock, urban development, and set-aside for nature conservation is excluded. The land balance approach can integrate information from a diverse range of sources such as the Food and Agriculture Organisation's (FAO) databases and demand predictions for energy, food, timber and other land-based products to provide an estimate of land available now and in the future.

The results, however, are only as good as the scenarios used to drive the model. Because many of the variables are uncertain (e.g. dietary trends) or subjective (e.g. the desirable level of food self-sufficiency), a wide range of plausible outputs can be produced. Variables such as rates of crop yield improvement are particularly problematic to anticipate as small changes make a big difference when compounded over multiple years. Economic assumptions may also be explicit, or implicit; for example, implicit in the expectation of future yield increases is the assumption that it will be economic to invest in crop research and farm extension services. Land balance models can be applied at scales ranging from countries to administrative districts (e.g. NUTS2 regions), but the results described in the literature are usually presented at an aggregate level.

[6] This model was developed under the EU-FP7 REFUEL project and informs a number of key UK studies including E4tech (2009), AEA (2011), E4tech (2011), DECC, Defra & DfT (2012).

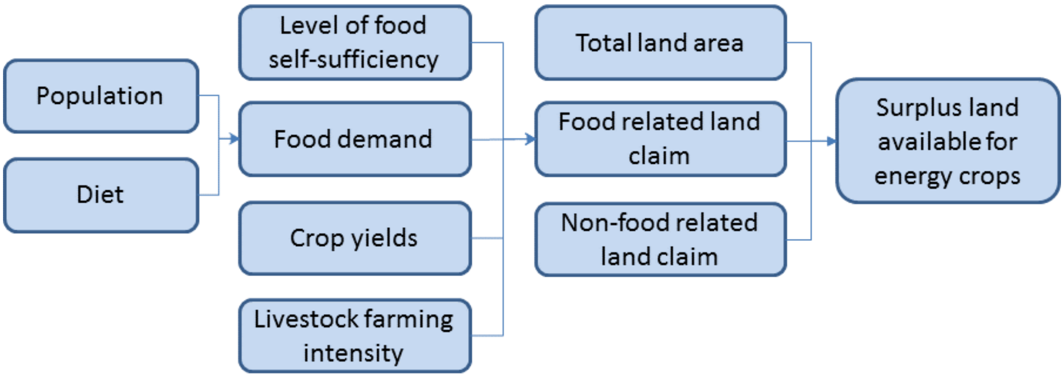

Figure 1: Variables affecting land availability in a typical land balance model (Adapted from Fischer et al. 2007)

A greater level of spatial resolution can be provided using GIS models, but these approaches typically only provide a snapshot of how much land is hypothetically available, or suitable, for energy crops after excluded land areas are removed. Although it should be noted that the constraint masks describing excluded land have become increasingly sophisticated. There is also considerable overlap with other modelling approaches, as GIS land use databases provide an important input into more aggregated land balance models.

Meta-analysis studies are also prevalent in the literature. These studies re-examine prior analysis, often re-evaluating constraints on land use to develop new scenarios. All the UK Government reports (Defra, 2007; DECC, Defra & DfT, 2012), for example, can be considered meta-analyses (as can this report).

Economic modelling of energy crop production in competition with food crops has been undertaken, but these studies are limited in number and sophistication (see Sherrington & Moran 2010).

Finally, two approaches that have only been applied in the UK in the last three years are agent based simulation (Alexander et al., 2013), and farmers surveys (Wilson et al., 2014; Glitheroe et al., 2013). Agent based simulations explore the rate of potential up-take of energy crops given assumptions about farmer and power plant investor behaviour in response to demand led economic scenarios. Farmer surveys seek to identify a representative sample of farmers and estimate their willingness to consider energy crops.

These approaches all shed light on different aspects of energy crops future deployment, but none can be considered a predictive or forecasting tool.

2.2.2 Identification and characterisation of studies

After literature research and a cross-referencing exercise, 46 studies were identified as being in scope and relevant for examination. This set of studies consists of:

- 25 studies with UK land availability data. These are identified and characterised in Table 3, and analysed in Table 4
- 16 studies with EU land availability data (including 5 studies with UK data). These are identified and characterised in Table 5, and analysed in Table 6

- 5 studies that were rejected for further analysis, as they either only provided data on current areas grown, did not provide any data points (e.g. only reviewing methods), or were only using hypothetical land scenarios for illustration purposes only. The reasons for exclusion are briefly discussed below:
    - Verkerk (2011) - Focus on existing forest resources, not new land areas.
    - Slade (2010) - Meta-analysis, with studies all re-examined in this report.
    - Aylott (2008) - Hypothetical UK scenario intended for illustrative purposes only.
    - Jackson (2008) - Focus on tranquillity mapping, no estimate of land available.
    - McKay (2003) - Focus on existing forest resources, not new land areas.

2.2.3 Review of UK studies

All the results from the studies identified were critically analysed in terms of the modelling technique, key assumptions, reliability of data as well as strengths and weaknesses. Links between different studies were also identified. A few of the studies are focused on energy crop production potentials, and hence do not explicitly give the land area assumptions used – in some cases we have had to back-calculate area estimates.

Table 3 introduces those studies in scope of the UK literature research, and Table 4 presents the results of the potential bioenergy cropping areas from these studies – note that where a report describes multiple scenarios for a single year, these are shown as a range. The comparison charts in Section 2.3 show the aggregated results, with accompanying discussion.

Table 3: Identification and characterisation of UK focused studies included in this review

Reference	Title	Geographic focus (timeframe)	Definition of potential	Focus / approach
Konadu et al., 2015	Land use implications of future energy system trajectories – The case of the UK 2050 Carbon Plan	UK (2010-2050)	Demand led theoretical potential	The study uses a top-down analysis of the interconnections between the land and energy systems, followed by the estimation of the area of land required to deliver the bioenergy component of the pathways under the Carbon Plan.
Alexander et al., 2014	Estimating UK perennial energy crop supply using farm-scale models with spatially disaggregated data	UK (England) (2010-2050)	Economic potential and modelled ramp-up scenarios	Agent-based model mapping the energy crop yields, gross margins and evaluating the interaction between suppliers and demand centres, with local experience and risk factors
Hastings et al., 2014	The technical potential of Great Britain to produce lingo-cellulosic biomass for bioenergy in current and future climates	UK (England, Wales, Scotland) ("current", 2020, 2030, 2050)	Theoretical potential on 8.5Mha	Spatially explicit (GIS) model identifies optimum locations for energy crops under climate driven yield scenarios.
Lovett et al., 2014	The availability of land for perennial energy crops in Great Britain	UK (2014)	Theoretical potential with constraint scenarios	Spatially explicit (GIS) inventory of UK land unaffected by planning restrictions and broad sustainability constraints.
Welfle et al., 2014a	Securing a bioenergy future without imports	UK (2015, 2020, 2030, 2050)	Technical potential with constraint scenarios	UK resource inventory using scenarios to describe main drivers of land use change. Calculates hypothetical land availability up to 2050 using simple Excel land balance model.
Welfle et al., 2014b	Increasing biomass resource availability through supply chain analysis supply chain analysis	UK (2015, 2020 ,2030, 2050)	Technical potential with constraint scenarios	Same approach as Welfle et al., 2014a. Paper aims to identify "maximum practical availability"
Wilson et al., 2014	Prospects for dedicated energy crop production and attitudes towards agricultural straw use: the case of livestock farmers	UK (England) (current)	Farmers "willingness to consider"	Survey of livestock farmers
Alexander et al., 2013	Modelling the perennial energy crop market: the role of spatial diffusion	UK (England , Wales, Scotland) (2010-2050)	Modelled ramp-up scenarios	Agent base model of farmer and power plant investor decision making using technology diffusion scenarios.
Glitheroe et al., 2013	Prospects for arable farm uptake of Short Rotation Coppice willow and Miscanthus in England	UK (England) ("current")	Farmers' "willingness to consider"	Survey of arable farmers.
Thomas et al., 2013	A GIS based assessment of bioenergy potential in England within existing energy systems	UK (England only)	Technical potential with constraint scenarios	GIS Inventory of land within 25km or 40km of sources of demand.
DECC, Defra & DfT, 2012	UK Bioenergy Strategy	UK (England and Wales only)	Near term extrapolation of established energy crop area and "future" technical potential	Meta-analysis. Aims to identify theoretical maximum land available not impinging on food production.

Reference	Title	Geographic focus (timeframe)	Definition of potential	Focus / approach
E4tech, 2011	Modes Project 1: Development of illustrative scenarios describing the quantity of different types of bioenergy potentially available to the UK transport sector in 2020, 2030 and 2050	UK and Global (2020, 2030, 2050)	Technical potential and scenario analysis	Resource inventory and scenario analysis exploring ramp-up rates and sustainability constraints.
AEA, 2011	UK and Global Bioenergy Resource	UK and Global	Technical potential with constraint scenarios	Inventory of UK biomass resources minus competing demands. Simple land balance calculation overlaid with deployment constraints.
Aylott et al., 2010	Estimating the supply of biomass from short-rotation coppice in England, given social, economic and environmental constraints to land availability.	UK (England only)	Demand led estimate overlaid on GIS technical potential model.	GIS land suitability model used to calculate area required to provide 7.5M oven dried tonnes per year of biomass.
Bauen et al., 2010	Modelling supply and demand of bioenergy from short rotation coppice and Miscanthus in the UK	UK (England and Wales only)	Cost optimal location for energy crops, given a fixed land use constraint.	Cost optimal feedstock location for Miscanthus and SRF, based on empirical yield maps (GIS) and linear programming. Exogenous land use constraint.
Sherrington & Moran 2010	Modelling farmer up take of perennial energy crops in the UK	UK	Theoretical economic-demand led potential	Linear program model of UK farm sector. Calculates theoretical uptake of energy crops at different gross margins, assuming a profit-maximising decision maker and no barriers to adoption.
Lovett et al., 2009	Land use implications of increased biomass production identified by GIS based suitability and yield mapping for Miscanthus in England	UK (England only) (2009)	Theoretical potential with constraint scenarios	Spatially explicit land resource inventory. GIS map of modelled Miscanthus yield overlaid with constraint masks to identify areas that might be suitable for Miscanthus production.
Thornley et al., 2009	Sustainability constraints on UK bioenergy development	UK (2009)	Technical potential with constraints scenarios	Meta-analysis overlaid with sustainability criteria.
E4tech, 2009	Biomass supply curves for the UK: a report for DECC	UK (2008, 2010, 2015, 2020)	Technical potential overlaid with constraints scenarios	Meta-analysis overlaid with cost and deployment scenarios to develop supply curves.
ADAS, 2008	Addressing the land use issues for non-food crops, in response to increasing fuel and energy generation opportunities	UK (2007, “future”)	Technical potential preserving current food production levels	Trend analysis and expert judgement. Current availability predicated on set-aside. Future land availability predicated on re-intensification.
Defra, 2007	UK Biomass Strategy 2007	UK (2020, future)	Demand led estimate and near term technical potential	Meta-analysis. Demand led estimate of area required to meet Road Transport Fuel Obligation (RTFO) requirement for wheat and OSR. Plus estimate of area for perennial crops based on set-aside.
Biomass Task Force, 2005	Biomass Taskforce 2005	UK (2009 and “future”)	Short term extrapolation of current planting plus future technical potential	UK resource inventory for 2005 with simplistic availability assumptions.
AEA, 2005	Renewable heat and heat from combined heat and power plant - study and analysis	UK (2010, 2015, 2020)	Technical potential	Meta-analysis. Report focuses on heat market not energy crops.

Reference	Title	Geographic focus (timeframe)	Definition of potential	Focus / approach
RCEP, 2004	Royal Commission for Environmental Pollution: Biomass as a renewable resource	UK (2020, 2050)	Demand led scenario	Top down estimate of land required to meet goals for renewable heat.
E4tech, 2003	Biomass for heat and power in the UK: a techno-economic assessment of long term potential - a report to the renewables innovation review	UK (2010, 2020)	Technical potential - constrained by deployment rates	Simple estimate predicated on set-aside area.

Table 4: Analysis of UK studies

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Konadu et al., 2015	2010 2050	Energy crops: 11.2 PAU composition & PAU yield 1,690-10,569 PAU composition & improved yield 1,487--5,833 50-50 Composition & PAU yield 1,339-8,226 50-50 Composition & increase yield 1,173-4,543	Future land area requirements out to 2050 driven by future UK bioenergy demands, using lower heating values and projected crop yields. Two main yield scenarios are assumed: Progress-as-Usual (PAU) yield scenario: assumes no significant change in current crop yields Improved yield scenario: based on DECC's projection for increases in energy crop yields of 30% by 2050. Diet composition and food imports kept at present levels. There are also two scenarios for the composition of the crops: Progress-as-Usual (PAU): assumes no change in energy crop composition from today (i.e. more Miscanthus) "50-50" scenario: assumes 50% each for Miscanthus and SRC willow, but it is unclear whether it is a split of land area, tonnage or energy produced Model allocates almost zero arable food crops for bioenergy purposes	Food production and the maintenance of ecosystem services prioritised to establish potential land stress and competition between different services. Majority of land allocated to bioenergy is improved grassland and pasture Results suggest that the land area requirements significantly exceed the UK Bioenergy Strategy's 2030 estimation of sustainable land.	DECC, Defra & DfT (2012) for UK bioenergy projections to 2050 and carbon plan pathways. Defra for agricultural statistics, Centre for Ecology & Hydrology for land cover and DUKES for the energy system.

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Alexander et al., 2014	Not stated, assumed "future"	Miscanthus: 172 SRC: 89 Total: 261	Energy crop yields taken from predicted values generated at the investigated spatial resolution. Conventional crop yields taken from observed mean regional yield data. Local optimisation based on constrained profit maximisation, innovation diffusion (experience learning) and risk aversion. Running the analysis for a range of energy crop prices allows supply curves to be generated. GAMS used as an optimisation tool.	Paper develops constraint masks based on social, environmental and economic criteria. Includes scenarios for climate change impacts on yields to 2050 – implications of climate change is to reduce the economic area of SRC, whereas the opposite is observed for Miscanthus.	Energy crop yields from Hastings et al., 2014. Area limitations criteria as in Lovett et al., 2014 and Wang et al., 2014. Market prices of Miscanthus from Sherrington & Moran, 2010.
Hastings et al., 2014	Not stated, assumed "future"	8,500	Spatially explicit (GIS) model identifies optimum locations for SRC (willow, poplar), Miscanthus, and SRF under climate driven yield scenarios. Assumes land area of 8,500 kha in all scenarios – 50% of total UK utilised agricultural area – obtained from Lovett et al. 2014.	Updates Lovett et al. 2009 to include yield maps for the major energy crops. Study explores future yields on a pre-existing estimate for land area, and does not develop a new estimate.	Lovett et al. 2009, Lovett et al. 2014, Aylott et al. 2008
Lovett et al., 2014	Not stated assumed "future"	Primary constraints only: 9,086 Primary constraints plus secondary constraint scenarios: 1,400 – 8,505	Primary constraints include: Urban areas (inc., roads, rivers, lakes), Slope, Woodland, Natural habitats, Woodland, High organic soils, Designated areas, Cultural heritage. Secondary constraints include: Landscape naturalness; Protected areas (Area of Outstanding Beauty, Environmentally Sensitive Area, National parks). Scenarios also consider excluding Agricultural land classifications Grades 1-3 land.	GIS model identifies the maximum possible land area not affected by constraint masks in 2014. Asserts that areas for energy crops cited as policy aspirations in the 2012 UK bioenergy strategy (930-3630kha) are not contradicted by this work (and that therefore future planting will be primarily determined by economic considerations) Scenarios imply energy crops should be located on lower grade land (class 4 or 3&4), but no explicit food constraint. Provides limited insight on feasibility of future implementation. Informed by literature only, no expert validation.	UK government databases: MAGIC, NATMAP, Land cover map 2000 (Same approach as Lovett et al, 2009 with modified constraint scenarios)

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Welfle et al., 2014a	 015 2020 2030 2050 015 2020 2030 2050	Energy crops: 468-572 564-890 1,849-2,555 5,329-7,349 SRF: 50-1107 104-2497 317-3335 305-4131	Assumes increasing crop yields free-up land for energy crops and SRF. UK land used to meet demand for food and urban development. Remainder allocated to energy crops and SRF. (Assumptions around SRF are ambiguous) Scenarios for “key drivers” (food demand, population growth) informed by literature analysis [The following conversions were used to estimate land area: average Energy crop yield 9t/ha (consistent with Defra, 2007); average SRF yield 5t/ha (consistent with ADAS, 2008)]	Identifies maximum possible land area subject to meeting food demand and other constraints. Essentially a re-interpretation of existing literature estimates with the ability to explore impact of changing key drivers of land use, and trends using a land balance approach. Paper does not include sufficient detail to correlate growth in yields to area "freed up" but some of the yield increases discussed appear large (circa 70% in staple crops by 2050). Aggregate approach no spatial or regional resolution Does not examine feasibility of future implementation. Informed by literature with limited expert validation.	Key references AEA, 2011; ADAS(2008); FAOSTAT; Smeets et al, 2006, Fischer et al. 2007 (Similar approach to Smeets et al. 2006, but with UK focus)
Welfle et al., 2014b	 2015 2020 2030 2050 2015 2020 2030 2050	Energy crops: 177 353 478 3,478 SRF: 218 364 860 396	Maintains 60% self-sufficiency ratio for UK domestic/import food production [The following conversions were used to estimate land area: average Energy crop yield 9t/ha (consistent with Defra, 2007); average SRF yield 5t/ha (consistent with ADAS, 2008)]	Same as Welfle et al, 2014a	Same as Welfle et al. 2014a

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Wilson et al., 2014	)14)14	Livestock farms only SRC: 17-55 Miscanthus: 12-44	Telephone survey of livestock farmers as part of Defra Farm Business Survey 263 respondents extrapolated to whole of England. Evaluates farmers' "willingness to consider". Stated preferences at single point in time assumed to provide indicator of potential planting area.	Concludes that constraint on energy crops will be economic, and anticipates no increase in implementation without policy support. Energy crops perceived as more difficult on marginal land and identifies that this conflicts with desire to minimise competition with food.	Defra Farm Business Survey (Similar to Glitheroe et al. 2013)
Alexander et al., 2013	 2020 2030 2041 2050 2020 2030 2040 2050	Energy crops Scenario-i: 39 236 303 244 Scenario- ii: 1,800 1,500 900 500	Two scenarios: i) low rate of farmer adoption = 2.5% of farmers willing to adopt; ii) high rate of farmer adoption = 25% of farmers willing to adopt. Farmers profit maximise, but willingness to grow energy crops affected by neighbour's behaviour. No constraints on planting capacity. Energy crop supply increases with rapid growth in demand, and decreases with conversion plant closures due to reaching end of life. Hard to validate results but model illustrates similar behaviour to growth of oilseed rape in 1970's so is considered plausible.	Powerful approach to extrapolating trends including farmer economic and risk taking behaviour. Demonstrates importance of technology diffusion and co-evolution of supply and demand. Area of energy crops in the low diffusion scenario is an order of magnitude lower than policy expectations. Potential risk of circular logic: model structure predicated on technology diffusion, and results find that diffusion is important. Acknowledges that empirical validation is not straightforward for agent based models. Model suggests that even with favourable policy support it would take ~20 years to achieve significant penetration of energy crops.	(Follows on from Sherrington & Moran, 2010)
Glitheroe et al., 2013	Not stated assum ed "futur e"	Scenario 1: 51-90 Scenario 2: 546-968	Survey of arable farmers' willingness to consider extrapolated to whole of England. Two scenarios: i) farmers willing to consider SRC allocate 9.29% of land (former set-aside proportion) ii) Farmers willing to consider SRC allocate whole farm – This is assumed to be the upper bound of what might conceivably be plausible. [Both scenarios are essentially hypothetical and so are classified as "future" in Figure 2].	A small percentage of English arable farmers indicated a willingness to consider growing energy crops (17% for Miscanthus, 12% for SRC) Survey indicated no clear links between farmer's willingness to consider and characteristics such as age etc. Policy support and extension services would be required	Defra Farm Business Survey (Similar to Wilson et al. (2014))

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Thomas et al., 2013	Not stated assumed "future"	2,522 Within 25km of demand centre: 1,998 Within 40km of demand centre 2,410	Miscanthus only. Same GIS model as Lovett, 2009 with additional constraint layer. Minimum yield of 9odt/ha assumed as cut-off for economic viability. Does not examine the implications of competing land use.	Evolution of Lovett, 2009. Shows co-location of biomass supply and demand is technically feasible to meet UK policy targets.	Lovett et al. (2009), Lovett et al. (2014), Aylott et al. (2008)
DECC, Defra & DfT, 2012	)20 Future Future Future	SRC and Miscanthus: 10-40 Max theoretical: 930-3,630 Low estimate: 620-720 High estimate: 2,430-2,800	DECC analysis using AEA (2011) model. Low estimate assumes gross margin of £241/ha. High estimate assumes gross margin of £536/ha. Food production and iLUC factors are not incorporated into the analysis. Instead the land area assessment is predicated on the AEA (2011) model assumption that only "unused or abandoned" agricultural land is made available for energy crops, This follows the ADAS (2008) assumption that food crop yield increases make land available for energy crops due to re-intensification.	Report states a high priority should be given to avoiding competition with food production, and indirect land use change compared to previous Government reports. Competition with food, and land use change impacts, however, is dealt with in the same way as prior studies: i.e. with the exogenous assumption that competition will be negligible for "unused and abandoned" land.	Based on AEA (2011) (which is derivative of ADAS (2008) and E4tech (2009)) NNFCC, Domestic Energy Crops: Potential and Constraints Review, 2012; ADAS: Carbon impacts of using biomass in bioenergy and other sectors: energy crops, 2012

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
AEA, 2011	)20)30)15)30	Energy crops: 53-655 252-1,100 SRF: 0-2 0-182	Land availability to 2020 based on an estimate of land not required for food or feed from ADAS (2008) and for 2030, an estimate of released arable as yields increase. Constraints scenarios developed from literature analysis of market, policy, technical, and infrastructure constraints and allocated to price bands using expert judgement and examination of the prices paid by competing sectors. Current land required for food production unavailable to bioenergy crops, regardless of price. Food crop yield increases make land available for energy crops. Principal constraint is planting rate. No conversion of permanent grassland for energy crops. SRF planting on rough grazing land in West, NW Scotland and upland areas of north, west and SW England. Estimate conversion of 10% permanent pasture and 20% rough grazing to SRF on permanent grassland and rough grazing (same assumption as ADAS (2008) on re-intensification of stocking).	Assessment is comprehensive, building on and elaborating the ADAS (2008) report. Transparent discussion of assumptions. Price bands are used to indicate different constraint levels. It should be noted that each price band describes a judgement about constraints, not the real-world intersection of supply and demand. I.e. the price at which constraints will be overcome is an exogenous input to the model.	ADAS (2008) (key reference for DECC, Defra & DfT (2012))
E4tech, 2011	)10)15)20)25)30)50)10)15)20)25)30)50	Energy crops: 0-9 21-45 53-134 99-355 296-902 296-1,368 SRF: 0 0-16 0-66 0-116 0-182 0-648	Maximum land area estimates from literature analysis including former set-aside, bare fallow land, and "suitable" temporary grassland. Limit on planting rates defined in terms of constraint scenarios: Easy, Medium and Hard to overcome, each scenario is allocated to a price band. Energy crop area limited by planting rate (4 kha/yr increasing 20% per annum), until max area reached. In maximum energy crop scenario all the abandoned agricultural land is planted on, plus up to 10% of temporary grassland. In minimum energy crop scenario, only land unsuitable for 1G crops is used SRF: At high prices, all barriers fall to 0% with max planting rate (10,000ha/yr reached and replanting after 20 years). At medium prices, planting rate kept at 1,000 ha/yr until 20% annual ramp-up after 2018. At low prices, 100% barriers kept as prices still insufficient to stimulate planting. Harvest 20 years after planting area	Provides scenario analysis of drivers and barriers. Total resource availability increases substantially from 2020 to 2030, as it is assumed that the planted area of energy crops expands, and land access barriers for 1G and energy crops fall	AEA (2011), ADAS (2008), REFUEL Project (Adapts and extends AEA (2011) model to 2050 ,which is based on E4tech (2009) model)

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Aylott et al., 2010	 010 010	Energy crops (SRC only): Scenario i: 800 Scenario ii & iii: 720	GIS model Identifies 7100 kha land grades-1-5 not affected by planning restrictions and excluding national parks and AONB. Demand led scenarios and yield maps used to estimate area required to grow 7.5 Modt (Million oven dried tonnes) energy crops as identified in UK renewable energy strategy (2009) Three scenarios: i) minimising competition with food - 800 kha, agricultural land grade 4 & 5 ; ii) returning a profit – 720 kha agricultural land grade 3, 4 & 5. Assumes an economic profitability threshold of 9.2odt/ha at £40/odt; iii) no displacement of land uses offering greater GHG savings – found to be consistent with scenario ii.	Spatially explicit. Highlights potential conflict between profitability and minimising competition with food. Identifies North-west and South-west England as particularly suitable for SRC.	MAGIC (Closely related to Bauen et al. (2010); similar approach to Lovett et al. (2009))
Bauen et al., 2010	 2010 030	Energy Crops: 638 1,230	Identifies 4,490 kha arable and horticultural land; plus 3,180 kha of improved grassland as the maximum area on which energy crops could be grown. Assumes: 14.2% of arable and horticultural land in 2010 27.4% of arable and horticultural land in 2030 Energy crops areas: 32-39% Miscanthus; 3.1-7.4% poplar; 54-65% willow. These percentages are derived from the EEA 2006 report by scaling the 824 kha (2010) and 1,584 kha (2030) figures for UK to the area of England and Wales. Adopts the EEA (2006) assumption that no transformation of permanent grassland into arable land will occur. Paper does not provide a scenario for improved grassland conversion. Spatial economic optimisation based on cost of production.	Limited insights on land availability – builds on EEA 2006 report. Does not examine improved grassland conversion. Demonstrates how linear programming can be used to identify cost optimal locations given an exogenous land constraint. Shows that willow is preferred crop in the wetter west and Miscanthus is the preferred crop in the dryer east.	Land cover map 2000 Aylott et al. 2008 (yield maps) (Derivative of EEA (2006))

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Sherrington & Moran, 2010	2010 2010 2010	£100/ha: 1,449 £125/ha: 2,586 £150/ha 2,900	Uses Scottish Agricultural College generic linear programming model for UK farming sector analysis. Calculates the gross margin required to motivate farmers to adopt perennial energy crops in the absence of barriers and assuming a profit maximising farmer. Aggregate model considering four generic farm types: cereal, mixed, general cropping, cattle and sheep. Three gross margin scenarios: £100/ha, £125/ha, £150/ha Limitations acknowledged include: Model does not account for changes in price as a response to increased supply, Model allows large land use changes immediately the gross margin for energy crops is higher than alternative activities. Known barriers to uptake not modelled.	Evaluates energy crops in comparison to alternatives. Shows that energy crops could be attractive in a perfect market. Miscanthus more attractive than SRC. Highlights the significance of barriers to uptake. Shows that without the barriers to adoption, farmers would adopt energy crops at a lower gross margin than they would require at present.	Defra Farm survey
E4tech, 2009	)08)10)15)20)30)08)10)15)20)30	Energy crops max available area: 634-895 675-1,044 777-1,416 879-1,661 1,083-2,534 Energy crops – planted area subject to planting constraints: 8 9 71 713 1,083-2,213	Maximum available land area from literature: REFUEL project and ADAS (2008). Energy crops (SRC and Miscanthus) located on arable and improved grassland. Principal constraint on area converted is planting rate: The 2009 planted area of 8 kha is assumed to increase by 1 kha/year in 2010, with the annual rate then doubling each year until it reaches a maximum of 150kha/year (hit in 2017), which continues until the area planted reaches the maximum land availability. Max planting rate of 150 kha/year, based on data from ADAS (2008) and communication with David Turley, CSL. Competing demand for land assumed to be supplied before any use for bioenergy. Direct competition not considered. (NB- Figure 2 shows constrained planting area to 2020 as “near term” max available area and potential planted area in 2030 shown as “future”)	Well documented and transparent assumptions based on previous literature and expert judgement. Planting rates are limited by labour and machinery, and are initially very low. Planting rates result in the energy crop potential being limited even in 2030 in all scenarios.	ADAS (2008) Calculations by D. Turley (CSL) REFUEL Project (Key source is ADAS (2008) and REFUEL project. Approach extended and adapted by AEA (2011) and E4tech (2011) reports)

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Lovett et al., 2009	Not stated assumed "future"	England - primary constraints only: 7,771 England, primary and secondary constraints, all land classes 4,720 England, primary and secondary constraints, grade-3 land only 2,783 England, primary and secondary constraints, grade-4 land only 337	GIS model in 2009. Primary constraints: Soil, Natural habitats, Woodland, Slope, Urban areas, Major rivers, Lakes, Designated areas, Cultural heritage. Secondary constraints: Landscape sensitivity (Areas of Outstanding Natural Beauty (AONB), Environmentally Sensitive Area (ESA), National parks); Permanent Grassland (assumes grassland over 5yrs old should not be ploughed up as this will release soil carbon). Land class. Miscanthus primarily replaces arable crops (winter wheat, OSR), bare fallow ground, set-aside, grassland under 5yrs old.	Miscanthus only. Shows land not affected by planning restrictions / broad sustainability constraints, where yield would be reasonable. Helps identify conflicts between optimal allocations by yield, with existing land functions. Provides retrospective analysis of Defra 2007 Biomass Strategy 350 kha figure - shows this might be achievable on grade 3&4 agricultural land. No explicit food constraint.	UK Govt. databases including MAGIC, NATMAP, Landcover map 2000
Thornley et al., 2009	)09)09	Energy crops including wheat for ethanol and OSR biodiesel: 574 SRF on contaminated land: 30	Assumes energy crops grown on lower grade arable land, constrained by the potential for conflict with food production. Simple judgement on average yields and land allocations used to generate approximate estimate for domestic energy crop production. 50% of "surplus" land is used to grow wheat for ethanol and 50% for perennial energy crops, split equally between Miscanthus and SRC. Wheat for ethanol and OSR biodiesel used to supply UK's Road Transport Fuel Obligation Area is the land assumed to be available when study was completed.	Includes 30 kha industrial contaminated land – this category not included / explicit in other studies.	Lovett et al. (2009) Defra (2007) Environment agency data on contaminated land

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
ADAS, 2008	)07 uture uture	Energy crops: 7 640 SRF: 1,827	2007 estimate is the area of energy crops grown in that year. Future estimates assumes arable farms are equipped to farm 95% following set-aside therefore 5% of arable (211 kha), plus an additional 296 kha bare fallow land, could be used for perennial crops. 133 kha Temporary grassland released through the re-intensification of beef and sheep enterprises- utilised 50% for SRC and 50% for Miscanthus. 586 kha of permanent grassland and 1,241 kha of rough grazing could be made available for SRF (1,827 kha) if stocking intensity was increased. Study includes additional 530 kha of road verges and amenity land, but this could not be used for energy crops.	Highly influential report Estimates of available area based on expert judgement and examination of historic trends predicated on former set-aside area and re-intensification of grazing.	Defra June Survey (Highly influential, cited by all subsequent UK studies)
Defra, 2007	)10 2020 2020	Wheat and OSR: 740 Energy crops: 350 Wheat, OSR, and energy crops: 1,100	Demand led estimate of the area of wheat and OSR required to meet 50% of RTFO target. Energy crops: intended to be indicative of SRC planted on 350 kha of arable and set-aside. Assumes no effect on existing markets.	Simple demand led estimate. 350 kha figure is 50% of peak set-aside from 2004 DTI Renewables Innovation Review. Cited in majority of subsequent reports.	Calculations by D. Turley, CSL (Cites EEA (2006))
Biomass Task Force, 2005	 2009 uture	Energy crops: 25 1,000	2009 estimate is short term extrapolation of expected planting rates from 2005. One third of 25 kha will be met from Miscanthus and the rest from SRC. Expectation that energy crops, particularly short rotation coppice and Miscanthus, will continue to show yield increases as new varieties are developed and commercialised	Simple estimate based on current trends No discussion of type of land to be used.	Calculations by D. Turley, CSL (cites AEA05, but figures not directly comparable)
AEA, 2005	 2010-2020	Energy crops: 456	Not explicit – land estimation peripheral to main focus of report.	Simple estimate of land area, used as an input to supply cost analysis.	Unclear – appears to be 2004 DTI renewables innovation review.

Reference	Time-frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
RCEP, 2004	)20)50	Energy crops: 1,000 5,500	Staged introduction of energy crops is envisaged: -Immediate future - energy crops utilise a relatively small proportion of set-aside land. -Short-term - area required for energy crops increases to an area equivalent to the amount of set-aside land. -Medium-term - area required for energy crops increases beyond the amount of land that is currently set-aside. -Long-term - area of land increases to be a significant proportion of total available agricultural land Assumed to be mostly grade 3, 4, 5 agricultural land	Intended to be an illustrative scenario only. Set-aside dominates near term expectations. Asserts that government policy has failed to take account of the time required to establish energy crops. Notes that co-firing is "failing to stimulate the energy crops market as intended."	Cites "Bauen 2004", but reference is ambiguous.
E4tech, 2003	)10)50	Energy crops (Miscanthus and SRC): 250 1,000	2050 energy crop area assumed to be double the set-aside area (500 kha) when report was written. This is considered: "optimistic but feasible, give the right conditions" Assumed that potential area for Miscanthus and SRC in 2050 (1,000 kha each) is mutually exclusive.	Simple estimate predicated on set-aside area.	(No references)

2.2.4 Review of EU studies

All the results from the studies identified were critically analysed in terms of the modelling technique, key assumptions, reliability of data as well as strengths and weaknesses. Links between different studies were also identified. A few of the studies are focused on energy crops' production potentials, and hence do not explicitly give the land area assumptions used – in some cases we have had to back-calculate estimates.

Table 5 introduces the EU studies in scope, and Table 6 presents the potential bioenergy cropping areas from these studies. The comparison charts in Section 2.3 show the aggregated results, with accompanying discussion.

Table 5: Identification and characterisation of EU focused studies included in this review

Reference	Title	Geographic focus (timeframe)	Definition of potential	Focus / approach
IEEP, 2014	Space for energy crops - assessing the potential contribution to Europe's energy future	EU (2010)	Technical potential of currently underused land on European farms	Trend analysis and expert judgement. Analysing current EU land statistics. Explores sustainability issues associated with increasing output.
Elbersen et al., 2013	Review of the EU bioenergy potential from a resource efficiency perspective	EU-27 (2020)	Demand led scenario analysis with sustainability constraints.	CAPRI partial equilibrium model - assumes crop yield increases free up agricultural land to meet National Renewable Energy Action Plans (NREAP) targets.
Scarlat et al., 2013	Possible impact of 2020 bioenergy targets on European Union land use. A scenario-based assessment from national renewable energy action plans proposals	EU (2020)	Demand-led calculation. Land area required to meet the NREAP targets under different scenarios.	Quantification of the impact of 2020 bioenergy targets on the land use in the EU, based on the projections of NREAPs.
Bentsen & Felby, 2012	Biomass for energy in the European Union - a review of bioenergy resource assessments	EU-25 (2000-2100)	Theoretical, technical, economical and "sustainable" potential with implementations constraints	Meta-analysis: summary of biomass for bioenergy resources on a European level based on a literature review.
Biomass Futures, 2012a	Atlas of EU biomass potentials: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources	EU-27 including UK (2020, 2030)	Hybrid demand driven study overlaid with technical, economic and sustainability resource constraints.	CAPRI partial equilibrium model, including a land-balance component, with post-hoc sustainability constraints.
Biomass Futures, 2012b	Biomass availability & supply analysis	EU (2000-2030)	Demand driven study overlaid with technical, economic and sustainability constraints.	Globiom land use model product structures
BEE, 2011	BEE - Final Report	EU-27 (>2000)	Technical and economic potential	Meta-analysis. Aiming to increase the accuracy and reliability of biomass resource assessments for energy.

Reference	Title	Geographic focus (timeframe)	Definition of potential	Focus / approach
de Wit & Faaij, 2010	European biomass resource potential and costs	EU including UK (2005 - 2030)	Technical potential assuming productivity gains	European (EU27 and Ukraine) cost and supply potential. Land balance estimation of area assuming productivity gains and a "food first paradigm".
Krasuska et al., 2010	Potential land availability for energy crops production in Europe	EU-27 (2003-2030)	Theoretical potential	Land balance approach to identify "surplus" land that could be available for non-food crops in Europe.
Ovando & Caparros, 2008	Land use and carbon mitigation in Europe: A survey of the potential of different alternatives	OECD and Eastern Europe (2005-2100)	Not defined. Potential as outlined in individual studies.	Meta-analysis. The paper surveys European studies that analyse carbon emission mitigation alternatives involving the use of land. Focus is on carbon mitigation, not land availability.
Fischer et al., 2007	Assessment of biomass potentials for biofuel feedstock production in Europe: methodology and results	EU including UK (2030)	Technical potential	Top down land balance model and inventory. Spatially explicit.
EEA, 2006	How much bioenergy can Europe produce without harming the environment	EU including UK (2010 - 2030)	Technical potential subject to "environmental compatibility" constraints	Spatially explicit, policy driven land balance model (CAPSIM).
Ericsson & Nilsson, 2006	Assessment of the potential biomass supply in Europe using a resource-focused approach	EU-27 (near-long term)	Theoretical potential	Resource inventory and simple land balance approach.
Sims et al., 2006	Energy crops: current status and future prospects	OECD and Eastern Europe (2025)	Technical potential	IMAGE integrated assessment model (which has a land balance component). IPCC scenarios.
Smeets et al., 2006	A bottom-up assessment and review of global bio-energy potentials to 2050	West and East Europe (2050)	Theoretical, technical/geographic, economic potentials.	Global resource inventory and land balance approach. EU is one of 11 world regions.
Kavalov, 2004	Biofuel potentials in the EU	EU-25 (2010)	Demand driven land use scenario	Calculates land required to meet EU policy objectives for biofuels.

Table 6: Analysis of EU studies

Study label	Time frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
IEEP, 2014	2010 2010	Existing biofuel crop area: 3,200 "New" energy crops: 1,350	Critical assessment of current land use statistics and recent trends. Focuses on land that is currently within the official agricultural area, land that in the recent past has ceased to be cultivated or has been unsuitable for cultivation New land area excludes land currently used for crops, fodder, or under a farm environment agreement.	Pessimistic assessment compared to other studies. Excludes yield increases leading to land release. Notes that "underused" land cannot easily be identified in EU stats. Asserts that "majority of the data sources available at the pan-EU level lack the specificity, focus and rigour on which to determine accurately the numbers on which to base policy"	LUCAS land cover data; EU Farm Structure Survey (Eurostat); JRC (comparable approach to UK ADAS (2008) Study)
Elbersen et al., 2013	2020 2020 2020	Total land for energy crops: 7,095 10,890 16,782	Uses CAPRI (common agricultural policy regional impact assessment model) partial equilibrium model to estimate land required to meet EU 2020 targets. Yield increases assumed to release agricultural land Scenarios include price, yield, and GHG efficiency constraints	Closely related to Biomass Futures project. Rather impenetrable study. Difficult to identify assumptions. No constraint on planting rates. Assumes energy crops will compete with food production.	Closely related to Biomass Futures (2012a)
Scarlat et al., 2013	2020 2020 2020 2020	EU: Inc. credit for co-products: 8,771-14,950 Excl. credit for co-products: 13,529-25,217 UK: Inc. credit for co-products: 7-975 Excl. credit for co-products: 7-1723	Quantifies land use impacts of EU 2020 bioenergy targets. The increased demand from biofuels would lead to an increased generation of co-products. The co-products from biofuel production are used for feed instead of conventional fodder, reducing to some extent the impact on land use. NREAPs do not specify where imports come from. Therefore likely to underestimate EU production if trade between EU countries counted as imported. UK: (UK figures are approximate (estimated from chart) – lowest estimate assumed to be 7kha.)	Scenario analysis based on NREAP projections made by Member States. Describes plausible land use demand scenarios.	

Study label	Time frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Bentsen & Felby, 2012	2000-2010 2100	4,000-20,000 25,000-45,000	Literature review of biomass/bioenergy resources on global and European level.	Asserts that further development of harmonised and transparent assessment methodologies is required. Argues emphasis must be put on increasing the production of biomass per unit of land.	Various studies. For land area in particular Ovando & Caparros (2008) and AEBIOM (2011)
Biomass Futures, 2012a	 2020 2030 2020 2030	EU: Perennial crops: 18,357-21,726 16,105-18,793 UK: Perennial crops: 1,021-1,091 314-718	Scenario driven study. Assumes land released as a result of policy reform will make land available for energy crops. Energy crops allowed to compete with food, but some sustainability constraints on environmental impact. Two scenarios: reference and sustainability. To determine the final perennial crop mix in the reference scenario priority was given to the cheapest crop mix per region. In the sustainability scenario the crops with the highest mitigation potential were selected, with cost level as secondary selection criterion. The final perennial crop mix fits with the soil and climate characteristics per region.	Complex model. Not clear how results about land availability should be interpreted. Unlike all other studies, future land availability is found to decrease. This is as a result of increased demand for arable land in 2030.	CAPRI model results, OECD-FAO projections of agricultural prices, population and welfare developments. Demand projections come from EC4MACS project for the reference scenario 2020, PRIMES for the reference scenario 2030.
Biomass Futures, 2012b	 2020 2030	SRC: 940 1,640	Same as BEE (2011) and BIomassFutures (2012a) Globiom macro-economic model, hence different model assumptions to CAPRI, and global trade instead of EU policy focus This report introduces the approach and assumptions that are used to assess spatially explicit biomass supply and associated impacts of increased biomass use on biophysical and economic indicators	Complex analytical approach that models competition between feedstocks, to estimate an economic potential. Provides values for total cropland but does not state the proportion dedicated to energy crops. Therefore the only values that can be extracted from this study are for SRC, which is for an unknown reason modelled separately.	Globiom model, BEE (2011), Biomass Futures (2012a)

Study label	Time frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
BEE, 2011	2000-2009 2010-2019 2020-2029 2030-2039 >2050	13,000-17,000 13,000-32,000 19,000-53,000 20,000-71,000 108,000	The BEE project set out to harmonise methodologies to improve the consistency, accuracy and reliability. Results from various studies were calibrated to minimise the influence of different geographical coverage. A database of 250 bioenergy potential assessments was compiled, out of which 28 studies were selected for detailed analysis. The studies were chosen so that they cover the variability found in literature with respect to the type of biomass, type of potential and the approach and methodology. BEE published a handbook to promote harmonisation.	High quality and comprehensive review. Attributes variation between studies to: • Ambiguous and inconsistent definitions of resource potential • Lack of consistent and detailed data on land productivity • Ambiguous and varying methods and assumptions.	Relevant inputs: de Wit & Faaij (2010), EEA (2006), EEA (2007), Ericsson & Nilsson (2006), Fischer at al. (2007)
de Wit & Faaij, 2010	2010-2030 2030	EU: 41,000--104,000 UK: 1,529	Uses a top down land balance methodology, spatially disaggregated at NUTS2 level. Assumes modernization of the agriculture sector in the Central and Eastern European Countries (CEEC) is driven by increased access to financial support enabled by the accession of the CEEC to the EU. Assumes EU maintains food self-sufficiency ratios. Energy crops include: Miscanthus, willow and eucalyptus. Intensification scenarios are ambitious so although estimate is given for 2010-2030 period they are judged to be "future" scenarios	Main driver for freeing up arable land is the intensification of food crop production. Majority of potential is located in the CEEC. Cautions that intensification may be associated with soil degradation and loss of biodiversity.	Cultivation costs: various literature Land and Fertilizer costs: Eurostat database Labour costs: Labourstat database (Presents the results of the EUFP7 REFUEL project)
Krasuska et al., 2010	2007 2020 2030	13,200 20,500 26,200	Bottom-up approach based on land balance / allocation model to calculated surplus land. Food and feed production has a priority; Modelling approach relies on agricultural production parameters and population food demand, which economic variables such as energy prices, foreign exchange (FX), macroeconomic performance and trade among different regions and countries are taken as constant. Assumes annual yield increases of 0.8% p.a. for all crops except maize (0.4%pa)	Transparent study with clear assumptions. Agriculture productivity and changes in population are the most important parameters. Land potentially available for non-food crops comprises (1) current fallow land, (2) land cultivated currently with energy crops, and (3) surplus land released from food/fodder crops calculated as an outcome of the land allocation modelling (mostly arable). Spatially explicit at NUTS2 level.	Main data sources are EUROSTAT and FAOSTAT databases Data on current energy crops cultivation areas come from European Biomass Association data on population prospects derived from the UN Land balance model from RENEW and 4FCrops projects.

Study label	Time frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Ovando & Caparros, 2008	2010-2030 2050	7,800 - 21,500 16,000-101,000	Aggregation of studies grouped by broad time ranges Results from the following models were used: CAPSIM, B-UM, RF, IMAGE 2.2, QUICKSCAN Scenarios used: Bioenergy production compatible with environmental protection, Current and optimal technical potentials, Five land use and energy crop yield scenarios, IPCC/SRES, Four animal production system scenarios	Literature review, no new insight on land availability.	Data sourced from the following: EEA (2006), Kavalov (2004), Ericsson & Nilsson (2006), Sims et al. (2006), Smeets et al. (2006)
Fischer et al., 2007	2030 2030	EU: 68,500-101,100 UK: 1,100	Assumes EU27 will maintain current (period 2000-02) level of self-sufficiency for food, feed crops and livestock. Area includes arable and grassland released as a result of future consumption changes and yield increases.	Top-down land-balance model and inventory, current land uses modelled using GIS land resource database. Spatially explicit at NUTS2 level. UK included as a single data point.	CORINE land cover database Eurostat database for land use statistics IUCN-WCMC protected areas inventory European Soil Database (ESDB)
EEA, 2006	2010 2020 2030 2010 2020 2030	EU-22: 14,665 21,000 25,167 UK: 824 1,118 1,584	CAPSIM partial equilibrium model used to calculate land released as a result of CAP reform, and top down assumptions about economic activity. Main drivers for land release are policy reform, yield improvement, and displacement of export crops with energy crops owing to oil price increases and carbon prices (Germany and France only) Assumes self-sufficiency rates of food supply in the EU-25 should be ensured while direct and indirect subsidised exports are gradually phased out. Disregards the effect of competition between bioenergy and food production for domestic food supply. Assumes 30% target for "environmentally oriented farming" in high natural value areas. General assumption that no additional pressures on biodiversity, soil and water resources are exerted compared to a development without increased bioenergy production. 6Mha grassland released in EU due to CAP reform, but assumes this will not be converted to energy crops owing to release of soil carbon and loss of biodiversity	Asserts that from an environmental perspective it is best to use arable land for energy crops, but this has greatest impact on food production. Highly influential study, but a bit of a black box. For instance it is not clear what yield trends are assumed.	Models: Capsim, Primes, Efiscen, HEKTOR

Study label	Time frame	Estimated land availability (kha)	Key assumptions	Insights and limitations	Main inputs (Links to other studies)
Ericsson & Nilsson, 2006	Near-term Med-term Long-term	15,500 38,800 108,200	3 land use scenarios: • 10% of the arable land (equivalent to EU set-aside) • Maintaining the EU15 ratio of utilized arable land at (0.18 ha/capita) post EU enlargement in 2004 – this implies 25% set-aside • Assuming 0.24ha per capita land required. Majority of remaining land available for energy crops – with constraint that max 50% permanent pasture can be converted.	Simple land balance approach with optimistic assumptions predicated on EU set-aside. Highly aggregate approach.	FAOSTAT, EUROSTAT
Sims et al., 2006	2025	7,780-21,507	Projected land availability globally (including EU) using the IMAGE2.2 model. The land sub-model of IMAGE is a land balance method that estimates land availability on the basis of projected population, diets, and yields. Values for main parameters not explicit in paper but they follow the IPCC narratives (A1-strong globalisation; A2-Heterogeneous world self-reliance, B1- environmental and social focus; B2- local solutions, intermediate levels of economic development.	Sophisticated model, but a simple estimate. No spatial resolution.	IPCC (2000), IMAGE 2.2, Strengers et al. (2004)
Smeets et al., 2006	2050 2050	Sys1/2 scenario 16,000-38,000 Sys3/4 scenario 73,000-101,000	Develops bottom up land balance model (QUICKSCAN). Land for energy crops becomes available as yields increase. Assumptions range from ambitious (Sys1/2 scenario) to the extremely ambitious (Sys3/4 scenario) Global crop yields in 2050 are at least 2.9 x yields in 1998 in the most pessimistic scenario. Spatially explicit by 11 world regions.	The optimistic assumptions are extremely implausible, including landless animal production and "super high" yield increases. Most useful to consider this study a sensitivity analysis on drivers of land use change. E.g. consumption of animal products Demonstrates a major problem with land balance models, in that what seem to be modest changes in assumption can give extreme results when compounded over long periods of time.	QUICKSCAN model, FAOSTAT, UNDP, IFPRI
Kavalov, 2004	2010	6,427-22,742	Explores scenarios for supplying 2-5.75% EU transport fuels (directive 2003/30/EC) with biofuel with new accession countries and candidate accession countries.	The study is over 10 years old, and only provides values for 2010. Interesting for comparison, but further analysis does not bring much new, as macro and policy conditions very different today in EU (including having the Renewable Energy Directive since 2009).	IPTS studies

2.3 Comparison of land area estimates

The range of land availability estimates for perennial energy crops and SRF in the UK and EU is shown in Figure 2, Figure 3 and Figure 4, and discussed further below. In each chart, the studies are ordered from oldest on the left to most recent on the right. Each pair of red and blue vertical bars represents the range of estimates reported in a single study. Triangles represent land areas corresponding to specific scenarios or quoted data points[7]. Blue triangles describe highly constrained estimates that studies state or imply are plausible within the near term[8] (taken to be 5-10 years of when each study was completed). These near-term estimates are typically constrained by land areas perceived as easy targets (set-aside), the size of the existing energy crop industry and planting rates, plus assumptions that little yield improvement in food production is realisable on such short time scales – i.e. land for food production remains protected. In contrast, red triangles describe more futuristic estimates with fewer constraints, in most cases 11-60 years into the future, but all requiring far more stretching assumptions about shifting land use, planting rate, food yield improvements and increasing food demand.

2.3.1 Land available in the UK for energy crops

Near-term potential estimates for perennial energy crops in the UK range from 7-1,723 kha (as shown in blue). The bottom of this range corresponds to the actual area of energy crops grown in 2007 (ADAS, 2008). The top end of this range corresponds to a demand led scenario in which the entirety of UK's 2020 bioenergy target under the EU Renewable Energy Directive (based on National Renewable Action Plan projections) is met from domestic production. . It is not coincidental that the upper end of many of the near-term – blue – estimates corresponds well with the UK's maximum set-aside area (which peaked at 800 kha in 2001), as the vast majority of *near-term* estimates directly or indirectly cite set-aside areas in their derivation. Even after set-aside was removed in 2008, most subsequent *near-term* estimates can still be traced back to earlier studies that reference the set-aside area. The recent exceptions are Wilson et al. (2014), Glitheroe et al. (2013), Alexander et al. (2013) and Alexander et al. (2014). The first two of these extrapolate the results of farmer surveys conducted in parallel with the Defra Farm Business Survey; whereas the two studies by Alexander model the implications of hypothetical farmer and power plant investor behaviour in response to economic incentives.

Future potential estimates range from 99 - 9,086 kha. The bottom of this range corresponds to the assumption that energy crop deployment is severely limited by planting rates between now and 2025 (E4tech, 2011). The top of this range represents the maximum possible area of Great Britain on which energy crops might conceivably be planted, calculated using GIS and assuming a limited land exclusion mask (Lovett et al., 2014). Explicit in the derivation of this figure is the assumption that no land is reserved for food production, but Lovett et al. (2014) in no way suggest that this data point represents a plausible estimate for future energy crop planting – rather it should be interpreted as a methodological first step towards developing more highly constrained land use masks. Other studies at the top end adopting a similar GIS approach include Lovett et al. (2009), Aylott et al. (2010), Thomas et al. (2013), and Hastings et al. (2014). The methodological rationale for including unconstrained estimates in each of these studies is the same. High estimates, however, can also be the result of land-balance modelling

[7] All available data points are included in Figures 2,3,4, but, for clarity, where a study describes multiple scenarios for a single year these are shown as a range in Tables 4 and 6.

[8] This division into "near-term" and "future" reflects our assessment of what the original study intended to communicate. Because of the range of different methods used, this categorisation should be interpreted as indicative rather than absolute.

using optimistic scenarios about food yield improvements to free up lots of land, such as in Welfle et al. (2014a & b).

Future land area estimates in all studies reflect different constraint scenarios. There are, however, a number of common themes: Most studies assume that food crop yields will increase, thereby releasing land for energy crops and other uses; likewise, most studies assume that the provision of food will be prioritised[9]. Studies prior to 2008 assume that energy crops will be located on arable and temporary grassland areas, thereby minimising the environmental and biodiversity impact. Later studies, however, give greater emphasis to planting on lower grade agricultural land in order to minimise competition with food – despite the reality that current UK energy crops are grown mainly on Grade 2 and 3 arable lands[10]. One of the interesting results of recent analysis has been to highlight the tension between economic viability (which favours planting on good quality land) and minimising competition with food (which favours planting on marginal land) (Wilson et al., 2014).

A report that has been particularly influential in the UK context is ADAS (2008). This examines historic land use trends in the UK and uses expert judgement to estimate the proportion of different land classes that might be made available in the future. Assumptions are predicated on the former arable set-aside area and re-intensification of grazing. In common with the other resource inventories, it is assumed that the dedication of land to energy crops should not impinge upon the production of food. This report is one of the key references for all subsequent UK studies, and can be considered the archetypal UK resource inventory. It also demonstrates that once published, estimates for land availability have a long half-life in the academic literature.

UK land potential estimates are also included in EU focused studies, usually as a single data point or limited range. Influential studies include EEA (2006), Fischer et al. (2007), and de Wit & Faaij (2010)[11]. These studies use top down land balance models to calculate land available given constrained scenarios for future consumption changes and food yield increases. Although the results are presented at a highly aggregate level these studies set the boundary conditions for subsequent UK focused scenario analysis (E4tech, 2009; AEA, 2011).

For those UK land availability scenarios which are identified as *technical resource potentials overlaid with constraints,* the majority of constraint scenarios limit the proportion of land available by defining categories of land as unavailable or by prioritising competing land uses. An alternative approach is to constrain the rate at which energy crops might be planted. The E4tech (2009) report, for instance, considers a scenario where the annual planting rate for energy crops doubles each year from 2010 onwards[12]. Potential rates of deployment are also more explicitly explored using agent based simulation (Alexander et al., 2014), however the number of studies using this approach is limited, and there is limited empirical validation for the farmer behaviour assumed.

[9] The Lovett et al. (2009) and Lovett et al. (2014) studies do not include an explicit area constraint for food production, but it is implicit in their scenarios that limit the energy crop area to lower grade agricultural land.

[10] Lovett et al. (2009), for example, retrospectively shows that the target for 350 kha of energy crops outlined in the UK 2007 Biomass Strategy could be achieved with minimal impacts on food security if the 350 kha comprised grade 3/4 agricultural land and was planted with Miscanthus

[11] The de Wit & Faaij (2010) study combines land availability estimates with spatially explicit yield maps to estimate bioenergy potentials at the NUTS2 level.

[12] Later E4tech (2013) work for the ETI considers that the net annual planting rate in the UK could be negative (likely reflective of the current situation), static, or grow at 30% to 50% each year, after demonstration activities, depending on the policy environment.

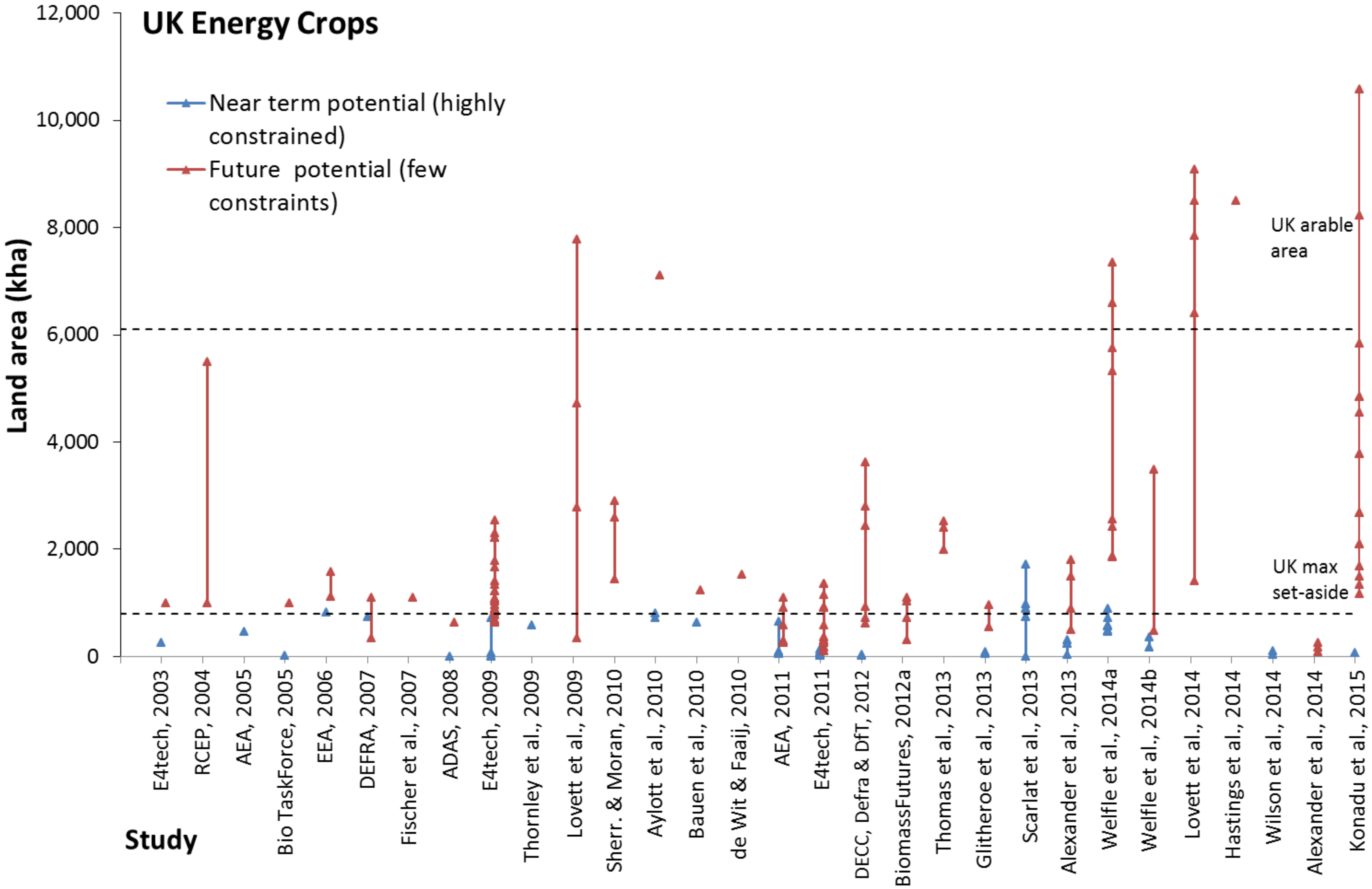

Figure 2: Ranges for the potential UK land area dedicated to perennial energy crops

GIS modelling has emerged as an important strand of analysis in the UK over the last eight years and has become increasingly sophisticated – see for example the studies by Aylott et al. (2010), Lovett et al. (2009), Lovett et al. (2014), Thomas et al. (2013) and Hastings et al. (2014). Building on a simple land exclusion analysis this series of studies has examined yield constraints, environmental constraints, demand constraints, and the potential impact of climate change on yields. This analysis identifies the optimum location of energy crops from a 'cost of production' or environmental perspective, but the constraint on the total land available given competing uses remains exogenous to the model. In other words, these models identify where in the UK energy crop production may be most economic or most desirable from an environmental perspective, but not where the market will dictate that production will occur given competing demands on land. Lovett et al (2014) also uses data from Natural England to show that only 83% of planted UK energy crops lie within areas modelled as potentially suitable (with 17% of sites modelled as unsuitable), underlining the importance of market factors and real world decision making, compared to just relying on GIS approaches.

Economic potential estimates are explored using a number of different strategies. The three closely related studies – E4tech (2011), AEA (2011) and E4tech (2009) – use price bands to indicate a hypothetical price at which deployment constraints are assumed to be overcome. It is important to note, however, that each price band reflects expert judgement rather than the intersection of supply and demand. These studies highlight the difficulty in developing *economic potential* estimates where markets do not yet exist. The study by Sherrington & Moran (2010) is the only one to directly model the competition between food and energy crops using a linear programming model of the UK farming sector, but as the authors acknowledge, the assumptions that farmers are profit maximising and that no market barriers exist is a significant limitation. Alexander et al. (2013; 2014) also uses farm level economics as a determinant of farmer behaviour.

2.3.2 Land available in the UK for SRF

Only four studies explicitly identify land available for SRF (ADAS, 2008; Thornley et al, 2009; AEA, 2011; E4Tech, 2011). The land area estimates in these studies are generally low compared to energy crops, with values ranging from 0 kha in 2015 (AEA, 2011) to between 0-1,827 kha in the long term (ADAS, 2008; AEA, 2011). All assume that SRF would be allocated to rough grazing and low quality permanent grassland. The conversion of this land, however, is considered undesirable owing to the release of soil carbon and loss of biodiversity (EEA, 2006). It is also noted that if a major effort to plant SRF had been undertaken in 2010, the first harvest would not be until 2030 at the earliest, and so would be economically unattractive in many cases (ADAS, 2008; E4tech, 2011). A further two studies (Welfle et al 2014a; Welfle et al 2014b) which use a simple UK focused land balance model to estimate potential land availability identify large areas of land (50-2,497 kha by 2020, and 304-4,131 kha by 2050) that could be available for "dedicated forest resources" – although it is not clear if this is equivalent to SRF on previously un-forested land.

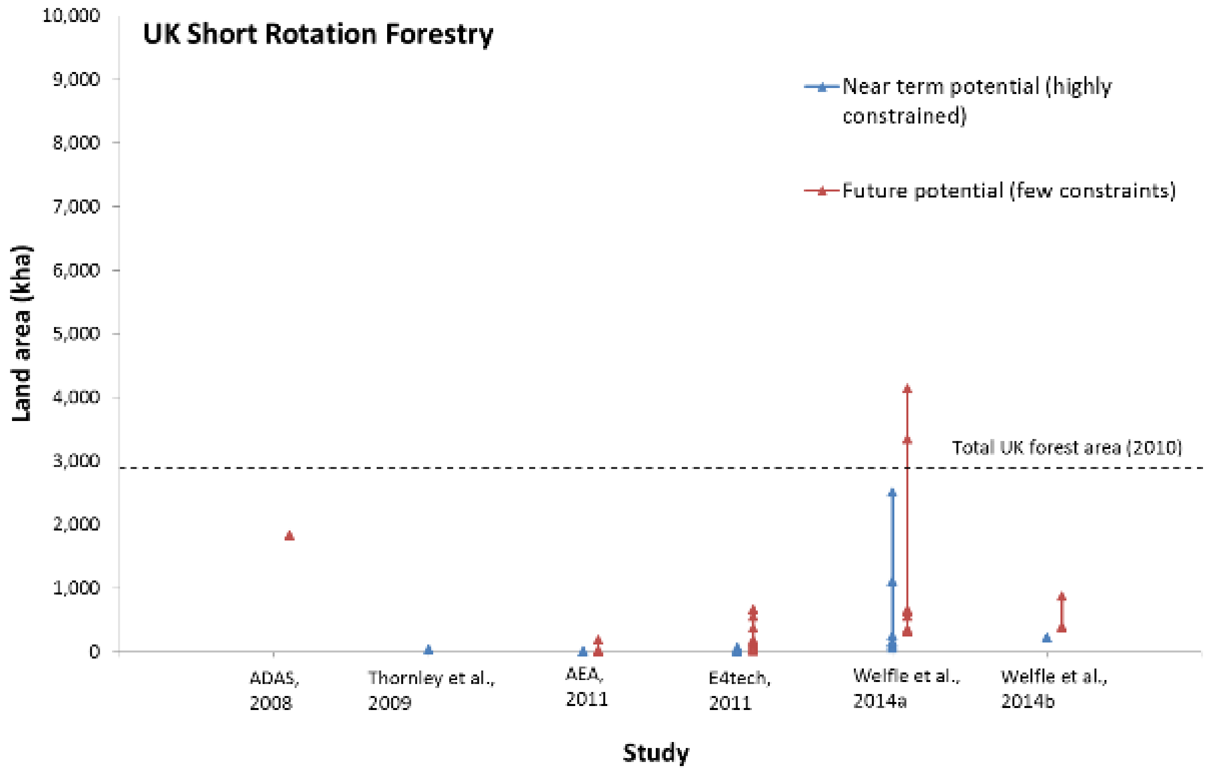

Figure 3: Ranges for the potential UK land area dedicated to short rotation forestry

2.3.3 Land available in the EU for energy crops

The range of estimates for the available area for growing energy crops in the EU is shown in Figure 4. Of the sixteen studies shown, three describe demand led calculations (Elbersen et al., 2013; Scarlat et al., 2013; Kavalov, 2004), three describe detailed meta-analyses and re-interpretations of prior work (BEE, 2011; Bentsen & Felby, 2012; Ovando & Caparros, 2008[13]), and the remaining ten present novel resource driven assessments. With the exception of the study by IEEP (2014), the principal focus of all these resource driven studies is on the long term future technical potential. There is no chart for EU SRF potentials as the EU studies do not differentiate between land available for energy crops and short rotation forestry.

For comparison, the reference line on the chart is the EU-28 arable area, given that pasture land is usually neglected/omitted (EEA, 2006).

[13] These studies are frequently cited in subsequent reports but simply collate previous land estimates and so are not discussed further here.

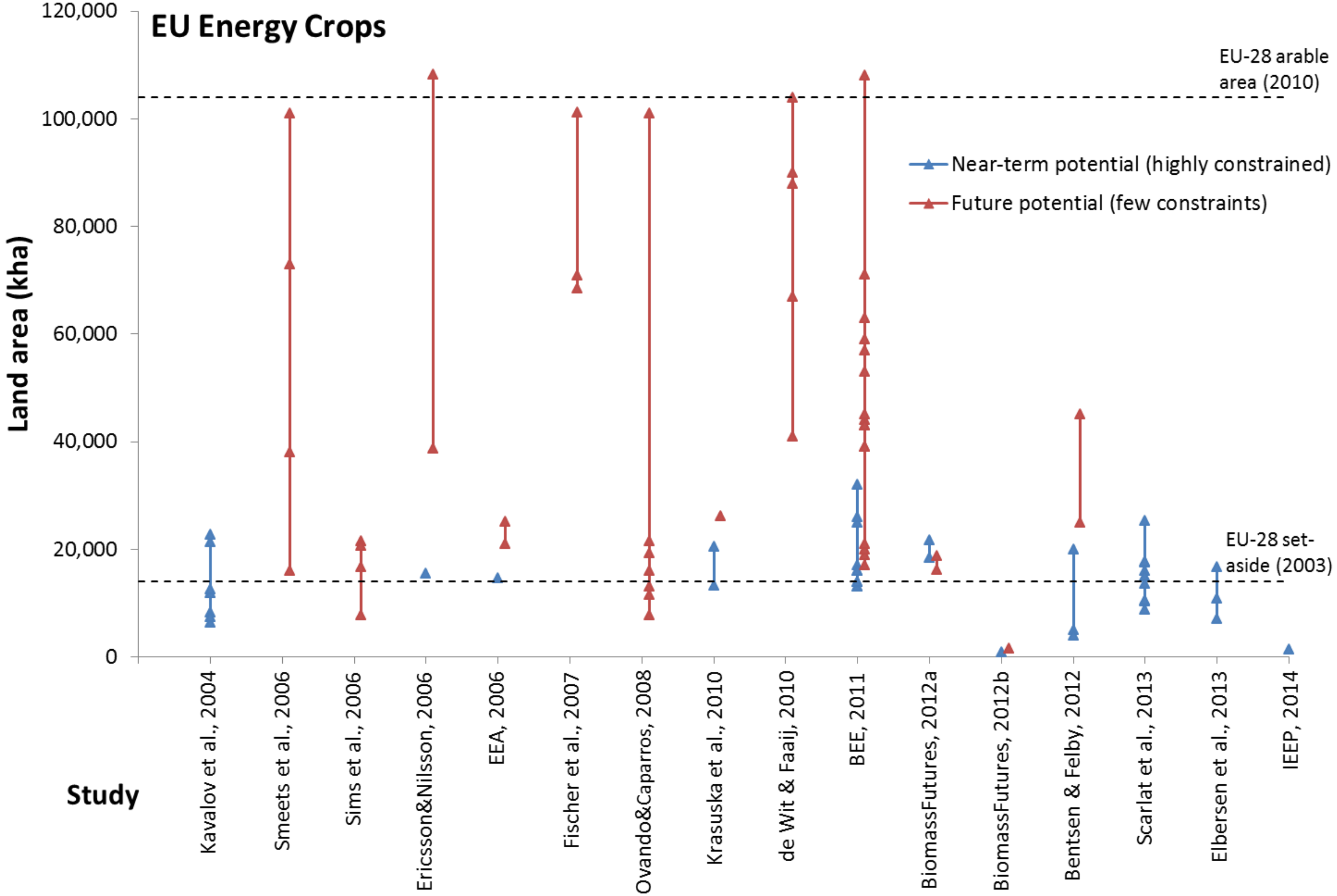

Figure 4: Ranges for the potential EU land area dedicated to perennial energy crops

Excluding the review studies, nine resource focused and demand driven studies describe *near-term* estimates (IEEP, 2014; Elberson et al, 2013; Scarlat et al, 2013;Biomass Futures, 2012a; Biomass Futures, 2012b; Krasuska et al., 2010; Ericsson & Nilsson, 2006; EEA 2006; Kavalov et al, 2004) ranging from 940 kha to 25,217 kha. The bottom of this range comes from the BiomassFutures (2012b) study, which describes an economic potential for SRC only. Interestingly, this value is not dissimilar to a conservative estimate for how much additional land might be available in 2010 (1,350 kha) described by the IEEP (2014) study and estimated via a critical examination of recent trends[14]. The top of this range is the result of a demand driven scenario that estimates the area required to meet NREAP targets in 2020 with reduced biofuel imports into the EU (Scarlat et al, 2013). This is also comparable to the estimate of 22,742 kha described in the Kavalov (2004) study and arrived at through a similar demand-led study, which assumed that the EU will reach its transport biofuel targets without importing any bioenergy resources. The value of 15,500 kha shown by Ericsson & Nilsson (2006) comes from a simple assumption that 10% of EU arable land could be made available for energy crops (an area reflecting historic set-aside policy[15]) (Ericsson & Nilsson, 2006).

Future potential estimates range from 1,640 kha to 108,200 kha. The lowest value again corresponds to an SRC only estimate by Biomass Futures (2012b). The next lowest estimate (7,780 kha) corresponds to an estimate made using the IMAGE2.2 integrated assessment model using IPCC scenarios for diets, population growth, and technological progress (Sims et al., 2006); the assumed rates of crop yield growth however, are not explicit. The upper estimate represents an area greater than the total arable area in the EU28 countries and represents a very simplistic calculation that assumes the per capita land area required to feed the EU population can be limited to 0.24 ha (Ericsson & Nilsson, 2006).

Although a range of models are used, all the EU *resource-focused* estimates are derived using variations on a basic land balance approach i.e. it is typically assumed that food crop yields will increase faster than food demand grows, such that a fraction of the currently utilised agricultural area will become available for energy crops. Food production is prioritised (for instance by maintaining the national food self-sufficiency ratio) and assumed not to compete with energy production. Environmental limits are imposed using constraint scenarios. The exception to this generalisation is the analysis undertaken as part of the Biomass Futures project using the CAPRI model (BiomassFutures, 2012a). This approach appears to allow food and energy crops to compete on price in order to meet modelled demand targets, however the model is essentially a black box and the assumptions underpinning the analysis are highly opaque. A unique feature of the Biomass Futures (2012a) results compared to other studies, however, is that the range of estimates for 2030 (18,357-21,726 kha) is lower than the range of estimates for 2020 (16,105-18,793 kha). This is attributed to increased demand for arable land in 2030.

The four *resource driven* studies that present the largest range are: Smeets et al. (2006), Ericsson & Nilsson (2006), Fischer et al. (2007), and de Witt and Faaij (2010). The main insight obtained from these studies is that land balance models are extremely sensitive to the choice of scenario parameters for crop yields, diets, and population. Although these models effectively demonstrate what might ultimately be possible, it is notable that none of the studies appears to evaluate the plausible rate of land conversion. It can also be argued that they do not reflect the complexity of managing the transition to a situation where energy crops occupy a significant proportion of European land.

[14] The 1,350 kha estimate in IEEP (2014) describes land over and above the existing area used for first generation biofuel crops. This estimate is not predicated on land becoming available as crop yields increase in the future. Methodologically, it is comparable to the ADAS (2008) UK study: i.e. taking an inventory approach.

[15] Prior to the accession of the CEEC countries. Whereas most UK near-term estimates can be traced back to the former UK set-aside area, it is not immediately apparent that this is the case for all EU near-term estimates.

2.4 Conclusions

This report describes estimates of land availability for new perennial energy crops and new SRF production in the UK and Europe found in 46 peer-reviewed academic and grey literature studies published between 2003 and 2015. A summary of the resulting ranges are presented in Table 7. Methods used to calculate estimates include land-balance modelling, GIS constraint mapping, economic optimisation, agent-based simulation and farmer surveys. The general trend is that EU studies tend to be more aggregate, and the UK studies more granular, as shown by the lack of SRF estimates at EU level.

Table 7: Summary of land area ranges that may be suitable for energy crops and short rotation forestry (SRF)

Area	Near-term (kha)		Long-term (kha)	
	Min	Max	Min	Max
UK Energy crops	7	1,723	99	9,086
UK SRF	0	2,498	0	4,131
EU Energy Crops	940	25,217	1,640	108,200

Particularly in the case of the UK, it is apparent that many estimates are ultimately calculated from the historic UK set-aside area. There is also a high level of linkage between the studies, and in a few cases this leads to recent meta-analyses using values from earlier meta-analyses (this applies to both UK and EU set of studies). In the current UK situation where set-aside no longer exists, any new calculation would likely have to take a much lower starting position. It also follows that in the absence of new empirical and modelling work, further meta-analysis may be of limited value.

The key challenge that many of the studies seek to investigate remains the bioenergy dilemma of food versus fuel. Many studies identify the tension between growing energy crops on high quality land – which is preferable economically and often environmentally (in terms of biodiversity and impacts on soil carbon (ADAS, 2008; Rowe, 2009)) – and growing energy crops on lower grade land – which is preferable in order to reduce competition with food. More recent studies assert that energy crops should be preferentially located on low grade land, but the current reality is that most UK energy crops have to date been grown on land grades 2 to 3.

One of the key assumptions underpinning a great many studies is that as food yields increase, land will become available for energy crops and other uses. This assertion, however, is seldom critically examined. Even with volatile macro-economic pricing, arguably the only event that had any substantial impact on EU land areas was the introduction of set-aside under the Common Agricultural Policy (CAP) following many years of overproduction and following decades' long policies of intensification. Only one study (BiomassFutures, 2012a) showed future land availability decreasing to 2030, due to additional demand for arable land taking back released land in 2020 (and further decreases under sustainability constraints). This is a markedly different result from every other study, that all assume that a longer timescale leads to more land becoming available.

Another important observation is that even if land becomes available (because it becomes uneconomic to grow food), it is uncertain that these fields will be used for growing energy crops. As well as the farmer having to decide in favour of energy crops, and possessing the knowledge to do so, such land is often available in neglected areas with difficult access and poor infrastructure. It may also be the case that the location of this land in the first instance may not be known about by anyone other than the farmer. Many EU studies show potential areas released in Eastern Europe as food yields improve, but this is far from the final markets with stronger renewables policies in Western Europe, and hence the transport would be uneconomic.

It is also important to consider how the insights provided by the different modelling techniques can be used. In general, good spatially explicit data is available (including land types, soil data, water resources, demand maps etc.) and the studies tend to make the best of it. However, there is no database of land that is underemployed, or sub-optimally exploited. Demand-led studies are typically too removed from the reality of today to provide much insight; they only describe what might be needed, not how or where it can be achieved. Land balance models are very sensitive to simple parameters describing complex phenomenon such as future yield growth and dietary trends. Consequently they are best used for scenario analysis and give very broad ranges which make it difficult to draw tangible conclusions. On the other hand, GIS models tend to be able to address focussed questions, providing detailed scenarios for land use. Their limitation is that they can only simplistically address competition between demands on land and they are not a predictive tool.

Some of the most exciting recent work takes an entirely different approach, looking at farmers as economic agents and simulating - whether land would be converted, and how information is passed between farmers (innovation diffusion). The work by Alexander et al. (2014) shows that land availability is a function of relative pricing – so the question of "how much land" is starting to turn into "how much is someone willing to pay" and "what would convince a farmer to become a grower".

The reality of today's market, however, is very different to what is considered in many of the studies. There is no more set-aside (although greening measures and ecological focus areas (EFAs) are in place), food prices have peaked and are falling, oil prices are low and volatile, and opposition to using land to grow crops for energy has been increasing (EU biofuels policy now has a % supply cap on biofuels from food crops, and some energy crops such as maize). Even the perfect model would end up being dramatically wrong 5 years later; the land system is also particularly sensitive to a few key global macro-economic drivers, and reform of policies such as CAP, which cannot be controlled even at a national level. Energy crops saw some uptake (at the rate of a few kha/yr) in both the UK and EU during the 2000's, but only when food prices were low, energy prices were high, demand-side policy for renewables was supportive, and supply-side policy was supporting establishment in several countries. Currently, in the UK, wholesale energy prices are low, renewables policy is weakening and there are no planting grants – hence there are multiple forces acting as head-winds to achieving future UK ambitions (and the sector is currently shrinking in the UK). This is also before considering the micro-economic decisions that farmers have to take to enable uptake, the variable yields and profits obtained on their farm, and the time required for ramp-up and farming success to diffuse spatially.

The differing context, methodologies, data and assumptions of the studies analysed therefore lead to the area ranges shown in this report being very large. Although many studies with a variety of data collection and manipulation methods have been investigated, and they all have different strengths and weaknesses (as discussed), the resulting values often cannot be directly compared with each other – we cannot make authoritative judgements such as "study X is too low". Overall, it can be concluded that currently the data does not exist to provide precise land area estimates (nor is it likely that the study methodologies and global drivers would ever allow this accuracy). The studies collected do allow identification of the key drivers and sensitivities, and from this there is certainly a credible range of estimates within which the future for the energy crop and SRF sectors may lie – provided the policy, markets and crop technology are all developed and supported.

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3 Refining estimates of land availability

3.1.1 Objective

To design and carry out a field survey to ground truth theoretical estimates of potentially available land for energy crop production from the desk based study.

To analyse the impact of adding additional datasets to BVCM assumptions on land availability for 2G energy crops using GIS analysis and the results of the field survey.

This report aims to provide the following;

- Information on the additional datasets applied to the UKERC 9w mask, including their strengths and weaknesses
- Information on how the application of constraint masks was refined following a review of field survey data
- Identification of the most appropriate combination of datasets for estimating available land for 2G energy crops

3.2 Method

3.2.1 Identification of cells for analysis

Selection of study cells

A subset of five cell outputs from BVCM were identified for analysis by the ETI to represent a range of contexts for bioenergy crop production as detailed in Table 8. These are cell numbers 019, 040, 046, 072 and 100. Three of these (019, 046 & 100) were selected as preferable for further field (Figure 5.

Table 8: Land area statistics (from Corine) for 50 km study cells

without (None) and with (UKERC 9w) constraint mask applied and the ETI's reason for the preference for analysis in the study

Cell	Arable (None) (ha)	Grass (None) (ha)	Forest (None) (ha)	Arable (9w) (ha)	Grass (9w) (ha)	Forest (9w) (ha)	Suggested Analysis	Reason
19	54,529	120,547	32,341	43,841	72,749	22,137	Desk and field survey	BVCM Miscanthus and SRF preference area. Water stressed area.
40	183,740	30,569	3,551	175,021	25,920	3,320	Desk study only	BVCM Miscanthus and SRF preference area. On edge of water stressed zone.
46	128,138	66,795	2,612	120,732	61,608	2,454	Desk and field survey	BVCM Miscanthus and SRF preference area. Area with current energy crop production
72	202,484	12,599	2,587	178,354	9,857	2,293	Desk study only	BVCM Miscanthus and SRF preference area. Area with current energy crop production
100	24,900	130,030	45,570	20,258	63,305	34,510	Desk and field survey	BVCM SRC Willow preference

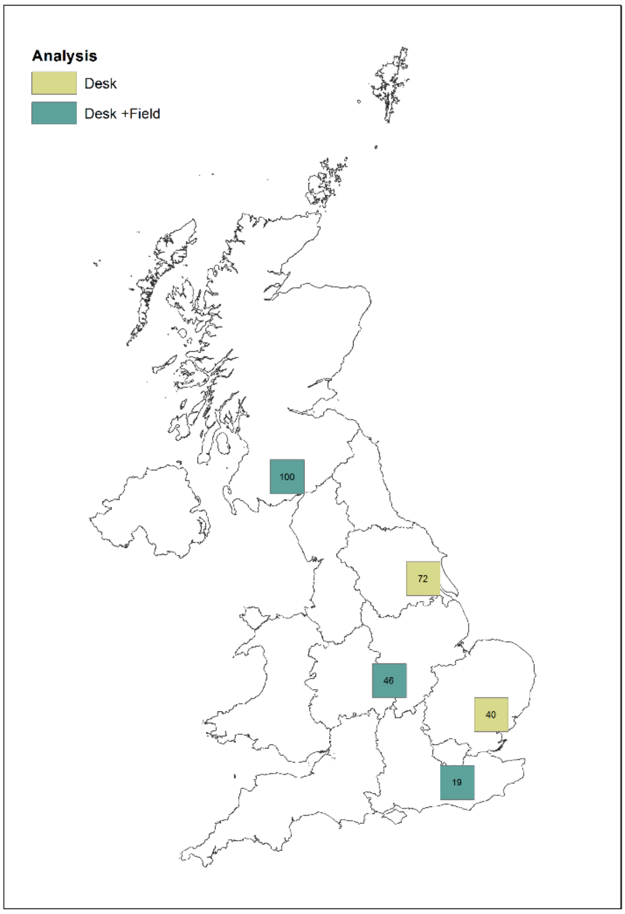


Figure 5: Locations of study cells and the type of analysis to be performed for each

Addressing the issue of cell misalignment

The cells and sub-cells used within the BVCM are offset from the Ordnance Survey (OS) grid by 400m north and 300m west, due to the original yield map data collected by the BVCM partners. This is not a large offset at the cell level, but at the scale of the sub-cell it is significant. For consistency with the original 100m constraint mask and for the purpose of field survey, the OS grid cells were used for analysis. Following analysis and translation of results to the 1 km OS grid, the BVCM sub-cells were matched to their nearest OS grid cell using a GIS process. This is consistent with the methodology used in the original BVCM project (R. Taylor pers. comm.).

Selection of sub-cells for field survey

The UKERC 9w constraint mask at sub-cell level was used to identify sub-cells that were deemed ‘available’. First, a pool of 250 ‘available’ sub-cells within each study cell were selected using a random number generator. The survey sample (10% of ‘available’ sub-cells in each study cell) was then selected at random from this pool. The remainder of the original 250 selected sub-cells were reserved for back-up survey in case any of the survey sub-cells were inaccessible. For a full description of the field survey methodology, please refer to report D5.

The original sample selection had to be completed prior to the identification of the ‘newly unavailable’ sub-cells (these are the sub-cells that are available under UKERC 9w, but unavailable under the new mask). due to delays in accessing the UKERC 9w 100m raster layers. Therefore, a cross check was done after cell selection was completed to ensure that sufficient ‘newly unavailable’ sub-cells were included in the survey sample.

Table 9: Number of 'available' and 'newly unavailable' sub-cells in cell and survey sample

Cell	Available sub-cells under UKERC 9w	Newly unavailable sub-cells under additional constraint mask	Available sub-cells under additional constraint mask	Number of sub-cells surveyed	Of which: 'available' under additional constraint mask	Of which: 'newly unavailable under additional constraint mask
Cell 019	1565	696	869	206	126	80
Cell 046	2053	280	1773	202	181	21
Cell 100	1320	318	1002	202	156	46

The randomly selected cells used in the field survey were chosen after the available squares had been identified using the UKERC 9w mask and are visible outlined in red on the overview maps for each of the 50 km x 50 km cells in Appendix 2.1 – Sub-cells surveyed.

Unique identification

To enable the 1 km x 1 km sub-cells to be easily identified by the surveyors on the ground a unique code was used. This code consisted of the; 50 km x 50 km cell number, followed by count to the right (easting), followed by count to the top (northing) with the easting and northing being numbered from 01-50 starting in the bottom left hand corner of the 50 km x 50 km cell. This gave a unique 7 digit code for each sub-cell. E.g. 046-11-02 is the M40/A46 junction near Warwick. These cell references were included on the Excel recording template as unique identifiers for each data set. They were then cross referenced with the GIS data to ensure consistency and comparability between the two data sets.

Access to sub-cell

A sub-cell was deemed to be inaccessible if there was no public right of way on or within view of the sub-cell, or if motor vehicle access was not possible within 1 km of the sub-cell. Where the only access to the sub-cell was on a motorway or other main road where it was unsafe to stop and park up a vehicle the cell was also deemed to be inaccessible. In addition there were a number of sub-cells that were accessible, but the visibility from the access point(s) was insufficient to see more than 50% of the sub-cell (e.g. due to tall hedges) these sub-cells were also excluded from the survey. Where the sub-cell was not surveyed it was coded un-surveyed and the reason was noted on the data recording sheets. The nearest backup sub-cell for that location was then assessed instead.

3.2.2 Approach to sub-cell assessment

The survey method was the optimum choice of design that allowed for the collection of relevant quantifiable and qualitative data over as many of the selected cells as possible, with the time and resources available and without the need to gain permissive access over the land parcels in question.

The selected survey sub-cells were printed out onto digital maps at 1:25000 scale, with the boundaries of the survey square clearly marked for the surveyor – the surveyor was not aware as to whether or not the sub-cell was deemed to be 'available' or 'newly unavailable'. Working through the list of 1 km randomly selected sub-cells, the surveyor determined from the 1:25000 map a prominent point, or up to 3 points, at which to survey and record as much of the 1 km sub-cell as possible. The surveyor then visibly assessed each sub-cell, completing a survey template (see appendix 2.3) to answer and identify a select number of parameters that determined what percentage of the sub-cell being viewed is potentially available for the growing of energy crops.

Land was deemed available if it was not in a residential or built up area, the land type was arable or other cropping, improved grassland, scrub, plantation (broadleaved / coniferous) or was already growing energy crops, access was possible with large machinery and haulage vehicles, there were no steep slopes or gradients (excess of 7°) or immoveable features already present on the area such as solar panels or wind turbines and land was not under water at the time of survey.

The sub-cell was deemed to be unavailable if more than 50% of the land area was deemed unavailable through not matching with the above or, it was deemed inaccessible or where the woodlands present in the sub-cell were thought to be a protected habitat i.e. Caledonian Pine Forest, Lowland Beech and Yew, Wet Woodland or Upland Oak woodlands.

Where a visual assessment of more than 50% of the sub-cell was not possible the cell was discarded and the next back-up sub-cell was surveyed in its place.

For each sub-cell the following steps were taken;

- Consider the most appropriate and methodical route to survey the chosen cells.
- Identify assessment point or points and note grid reference on the Excel template (If there was no road or track from which to view the sub-cell and no access points visible on the map the sub-cell was discarded and marked as inaccessible with a reason).
- Travel to sub-cell (if all assessment points proved to be unsafe, busy road/ dual carriageway with no safe stopping points the sub-cell was discarded and marked as inaccessible with reason, then the appropriate backup sub-cell was selected and assessed in its place).
- Complete Excel template from one or more assessment points dependent on visibility, but only filling in one column per sub-cell.
- Mark on a printed map the cell code on the 1 km square being assessed and with an **x** location of assessment, and with a **p**, for where photos were taken, if more than one assessment point.
- Take photographs - details below.

Photographs

The most appropriate assessment point for taking photos was identified, favouring the one with best visibility of the whole sub-cell. In order to help identify the photographs in the future the first photograph taken at each location was of the map with the written features marked as above, then where practical four other photographs were taken in the order North, East, South and West from the assessment point. If a particular direction was out of the sub-cell (i.e. assessment point was on the boundary) then a blank photo (of hand or lens cap) was taken to ensure that there were the correct number of images for each sub-cell (five photographs in total).

In order for ETI to be able to make use of the photographs in the future and identify which cells they were from it was important that the photographs were saved in a way such that they can be recovered.

- Surveyors recorded data in the template in the order that they assessed the sub-cells, therefore the order of the photographs taken was the same order as that used in the assessment of the sub-cells.
- The surveyor always took five photographs in the order map (to cross reference with data), north, east, south and west (or thereabouts).

- Each day's photographs were saved in a new folder labelled with the 50 km x 50 km grid cell number, the surveyor's name and the date – this will allow the photographs to be associated with the cells assessed by that surveyor on that date. E.g. Cell019_SoniaBrunton_240815.

Data capture and saving documents

Data captured on the Excel spreadsheet was downloaded at the end of each day's surveying and stored on a removable device.

At the end of each day's surveying, or as soon as an internet connection was available, all documents and photograph folders were uploaded to the SharePoint/LAN. Where the number and size of photos was too large these were saved in appropriately named folders to a removable device and sent to a central location.

3.2.3 Training of field surveyors

A training session was provided to ensure all surveyors had knowledge of the background to the survey and understood the outcome requirements of the field survey and techniques applied. A risk assessment document and health and safety document were sent to all surveyors before the survey started to ensure good safety procedures were in place and clear to each surveyor, a return statement of having read the documents was returned to the field survey leader. Steps were taken to ensure that the field surveyors were aware of the risks of lone working, including provision of a PowerPoint training course that highlighted risks. Surveyors were offered the option of using a remote worker alarm if they felt any of the areas that they were working in were high risk. Each surveyor was sent the relevant documents including the 'Field survey plan', health and safety reporting procedures, equipment list, maps and Excel recording forms, prior to the training taking place.

The training consisted of working through an example of how a sub-cell should be assessed using images of the sub-cell. A step by step approach was to be taken going through the Excel sheet questionnaire and interpretations for the wording of each question was made clear as to the approach to take to ensure consistency in recording land use and estimating size of fields with percentage cover. To visually estimate field size an example was suggested that an international rugby field is very close to 1 ha in size and the green area inside a 400 m running track at a sports stadium is just over 1 ha (1.12 ha). Surveyors were also told to use the detail provided on the maps to help them determine what proportion of the sub-cell each feature occupied. Where visibility of the sub-cells was borderline 50-60% of cell visible, e.g. due to tall hedges, surveyors used Google satellite images to identify whether the land they were unable to see clearly was likely to be available or not. To help visually assess the angle of a slope a diagram of each category was attached to the questionnaire, together with photos and descriptions of some of the habitats that need recording.

Ensuring consistency

Each surveyor was contacted by the field survey leader individually following the first day's surveying to clarify any challenges raised, discuss discrepancies or questions that had arisen once out in the field. As each surveyor uploaded the day's data to the SharePoint, the data file was quality checked by the field survey leader, and any unusual patterns were picked up and queried as the project progressed to ensure that the assessments for each surveyor were as consistent as possible with the other surveyors. A proportion of the data was cross referenced against the field maps and satellite imagery and any anomalies were discussed with the individual surveyor. Where information from discussion with one surveyor was thought to be relevant for recording consistency, this was conveyed immediately to all surveyors. A briefing session was under taken at the end of the first week's surveying, to feed back any challenges and ensure that surveyors were capturing data consistently.

3.2.4 Understanding cell estimates at a local scale

The UKERC 9w constraint mask at sub-cell resolution was used to provide initial estimates of land availability for each study cell. Maps were also produced showing the distribution of available sub-cells within each study cell.

By not disaggregating this mask, a significant amount of the uncertainty (and potential inaccuracy) in the estimates from this project's GIS analysis and the comparison to the field survey could not be examined. This is because the UKERC 9w mask is being taken as being completely accurate with no uncertainties, despite only matching with 83% of the currently planted energy crops (Lovett et al., 2014). The received mask data provided no indication of which of its sub-layers is the most important.

3.2.5 Initial estimates of land availability using additional data layers

There are a number of constraints or factors that may influence the likelihood of land being available for energy crop production over and above those that are included in the UKERC 9w mask. These can be classified into two types. The first type we have termed 'constraint layers'. These are areas of land that constrain the planting of energy crops and can be represented by spatial datasets that have sufficiently fine resolution for them to be applied directly as masks. The second type we have termed 'likelihood layers'. These are attributes of the land that may influence a decision to plant energy crops on that land but are not necessarily constraints to planting. These cannot be applied directly as masks since they do not constrain planting, but could potentially be used to target planting.

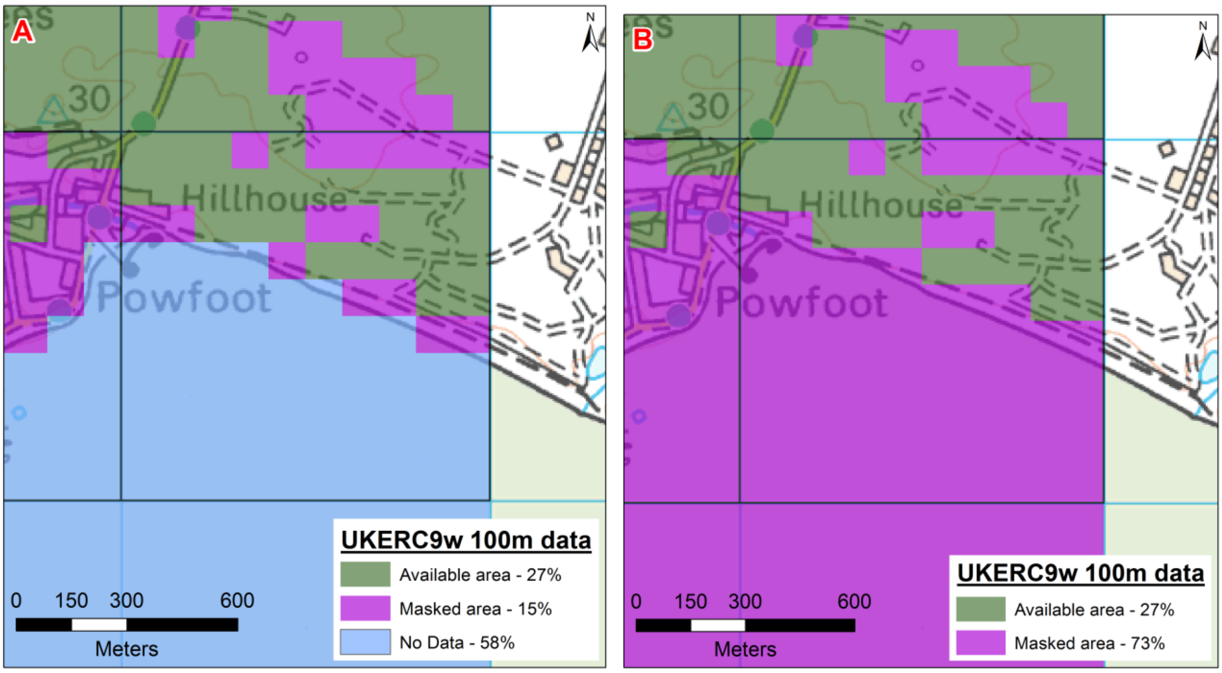
National spatial datasets that best represent these constraint or likelihood layers were identified and licencing terms reviewed. The evidence for considering usage of each of these datasets and the methodology for creating the data layer (if applicable) are detailed below for each constraint or likelihood. Each dataset was assessed for its suitability for inclusion in the analysis.

Choice and creation of constraint data layers

The methodology for creating the additional mask layers and the individual constraint layers was the same as that used to create the original UKERC constraint layers. Depending on the type of dataset used (vector or raster), the data was converted into individual raster layers with 100m cell size. The values of the raster were either; 0, where none or majority of the 100m cell was not covered by the constraint; or 1, where the majority of the cell was covered by the constraint.

1.1.1.1.1 UKERC 9w constraint mask

The UKERC 9w mask was used as the baseline constraint and was not disaggregated. The 100m raster



version of the mask was used to identify those areas within a sub-cell that had already been excluded due to a constraint so that the impact of adding further constraint layers could be assessed. During this process it was discovered that a small proportion of the 100m raster cells in the UKERC 9w mask were classed as 'NoData', particularly where they covered water bodies. This can have an impact on the classification of a sub-cell as available or unavailable. For example, if a large proportion of the sub-cell is covered by 'NoData', only the remaining area was assessed for percentage mask coverage to create the original BVCM masks (Figure 6). Since the 'NoData' areas cannot be planted with energy crops (usually because they represent water bodies), this led to an overestimate in the land available for planting at the sub-cell level. We have therefore taken the decision to reclassify 'NoData' cells in the 100m UKERC 9w mask as 'unavailable'.

Figure 6: Example of where 'No Data' affects sub-cell classification;

A) Available area is greater than masked area, sub-cell is classed as available;

B) 'No Data' is reclassified to 'Masked', sub-cell is now classed as unavailable

1.1.1.1.2 Altitude

Trials on SRC growth at various altitudes were undertaken by IBERS at Aberystwyth to see the differences in yield between varieties planted at 0, 32, 225 and 296 metres above sea level (Hinton Jones & Valentine, 2008). The yields at sea level were 25% better than at 296 metres, however the yields at this height were still acceptable for the best varieties. There has not been much work done on Miscanthus growth at altitude, but planting Miscanthus in Wales (especially at altitude) requires a film covering for establishment to protect from frost (M. Hinton Jones pers. comm.).

Based on this evidence, the Ordnance Survey Terrain 50 elevation dataset was used to exclude any areas above 300m as a barrier to the growth of SRC and Miscanthus.

1.1.1.1.3 Agricultural land productivity

One of the greatest barriers to planting energy crops is currently the profitability of conventional crop production in comparison to the energy crops, particularly on high grade agricultural land (Lindegaard et al., 2015). The Agricultural Land Classification (ALC) in England and Wales, and the Land Capability for Agriculture (LCA) in Scotland classify land by its likely productivity based on various climate, soil and site-specific parameters. Land grades 1 & 2 are the 'best and most versatile' for crop production. This potential constraint was considered as a proxy for food vs. fuel (i.e. the argument that the best land should be reserved for food production), however there have been Energy Crop Scheme (ECS) plantings of energy crops on grade 1 & 2 land in the past (determined by overlaying GIS data of ECS plantings onto ALC map). If financial incentives are introduced for growing energy crops, these areas may be considered in the future.

Based on this evidence, the ALC and LCA spatial datasets were used to exclude any Grade 1 land, although it should be noted that this is not an absolute constraint. These are the only spatial datasets available that show land capability.

1.1.1.1.4 Soil parameters

The Teagasc SRC best practice guidelines (Teagasc, 2015) state;

"Most agricultural soils with pH in the range 5.6 -7.5 will produce satisfactory coppice growth. However, light sandy soils, particularly in drier areas, will have a problem with moisture availability and highly organic or peaty soils should be avoided as initial weed control, which is vital, will be extremely difficult.

Medium to heavy clay-loams with good aeration and moisture retention are ideal, although they must have a capability of allowing a minimum cultivation depth of 200-250mm to facilitate mechanical planting."

The Teagasc Miscanthus best practice guidelines (Teagasc; AFBI, 2015) state;

"Miscanthus has been reported growing, and producing high or reasonable yields on a wide range of soils, from sands to high organic matter soils. It is also tolerant of a wide range of pH, but the optimum is between pH 5.5 and 7.5. Miscanthus is harvested in the winter or early spring and therefore it is essential that the site does not get excessively waterlogged during this period, as this may limit accessibility for harvesting machinery and cause damage to the soil structure. Growing Miscanthus on heavy clay soils in certain circumstances should therefore be avoided."

Based on this evidence, soils that are of a very high clay content (>60%[16]) were excluded using the Joint Research Council's dataset 'European Topsoil Physical Properties' at 500m resolution. This soils dataset was chosen as it is freely available and at a high spatial resolution. Further analysis could include an analysis of soil workability, which depends on the interactions between climate and soil physical properties, however this analysis would require considerable additional time and data.

1.1.1.1.5 Buildings and water bodies

A more recent Ordnance Survey dataset (VectorMap District) to that used in UKERC 9w was used to exclude additional buildings and water bodies that were missed by the original UKERC 9w mask. This is the most comprehensive vector dataset that is freely available.

1.1.1.1.6 Biodiversity Action Plan Priority Habitats

The Priority Habitats Inventory (PHI) administered by Natural England currently identifies areas of many habitats listed as Priorities for action under Biodiversity 2020[17]. Biodiversity 2020 is a national strategy for England's wildlife and ecosystem services that describes what is needed to halt biodiversity loss by 2020. This includes quality goals for priority habitat and SSSIs. Natural England consider that it would be appropriate to exclude all mapped Biodiversity Action Plan (BAP) priority habitat (PH) areas from energy crop planting (A. Cooke pers. comm.) due to the influence of this strategy.

There are, however, some caveats in the PHI that should be considered when potentially using as a constraint layer;

- It does not include most freshwater PH (e.g. lakes, ponds and rivers), nor woodland, pasture and parkland etc. Water bodies are excluded in UKERC 9w and woodland and parkland are covered by other data layers (see sub-sections on semi-natural woodland and parks & gardens), therefore this was not considered to have a substantial impact on the robustness of the constraint layer.
- It maps deciduous woodland as a broad habitat, which encompasses a wider range of deciduous woodland than the PH nested within the broad habitat. Deciduous woodland is unlikely to be felled for energy crop planting (see sub-section on semi-natural woodland), therefore this was considered acceptable for inclusion in the constraint layer.
- It maps selected additional habitats that are not PHs (i.e. Grass Moorland and Good Quality Semi-Improved Grassland) that are of interest to Natural England in the context of potential for restoration to PH types or for their actual or potential contribution to ecological networks. Biodiversity 2020 aims to increase the area of PH and improve habitat connectivity, therefore

[16] No UK reference available, but work in Canada indicates that soils with more than 60% clay become difficult to work.
[17] https://www.gov.uk/government/publications/biodiversity-2020-a-strategy-for-england-s-wildlife-and-ecosystem-services

these areas of interest are unlikely to be consented for the planting of energy crops. The decision was therefore taken to include these in the constraint layer.

- Some areas are mapped as 'No Main Habitat but Additional Habitat Present'. This is an artefact of the mapping process whereby a priority habitat feature is believed to occupy part of a polygon but at less than 50% coverage. This was considered to be acceptable for inclusion in the constraint layer to provide a conservative estimate rather than missing areas of PH.

The PHI is a simplified representation of the distribution that is not 100% complete, since it is largely a reflection of past survey effort, agri-environment delivery and designation of special sites. The version used in this project is a beta version that is expected to be updated before the end of 2015. The updated version should be used in a national constraint layer if recommended for inclusion in the final mask.

Even though BAP priority habitats exist in Scotland, to date there has not been a complete inventory of their locations published, and those habitats that have had their extents mapped do not have associated GIS data available.

All mapped areas in the PHI for England were excluded, under the assumption that land mapped as non-priority habitat or no main habitat may be subject to other regulation (e.g. EIA of uncultivated land). This decision was taken based on informed consideration of the caveats and advice from Natural England.

1.1.1.1.7 Semi-natural woodland

There is unlikely to be planting of energy crops in semi-natural woodland (whether PH or not) due to the requirement for felling before planting can take place (K. Lindegaard pers. comm.). All areas of ancient woodland (in addition to PH woodland) were therefore excluded using the Ancient Woodland Inventory for England and the Ancient and Semi-natural woodland inventories for Scotland. The Forestry Commission's National Forest Inventory was considered for use, but it does not distinguish between semi-natural woodland and plantations and was therefore not considered suitable for identifying 'available' vs 'unavailable' land.

1.1.1.1.8 Parks & gardens of special historic interest

There are GIS-based registers of historic parks and gardens of special historic interest for both England and Scotland. These are gardens, grounds and other planned open spaces, with a focus on 'designated' landscapes. They are assessed to be of particular significance in reflecting the landscaping fashions of the past and are a 'cherished' asset. Although in some cases parts of the grounds are used for agriculture, it is unlikely that areas of land would be converted for the growth of energy crops as protection of these designed historic landscapes is encouraged by Historic England and Historic Scotland, and energy crop planting would spoil their character. There are equivalent GIS datasets for England and Scotland.

1.1.1.1.9 Environmental Stewardship options

Environmental land management schemes provide funding for farmers and land managers who deliver benefits for wildlife, improve water quality and create woodland. They are delivered under the EU's Common Agricultural Policy (CAP). New schemes will be brought in from 2016 under the new CAP, but there are still large areas of farmland that are being managed under the old schemes. In England, these are 'Environmental Stewardship' and 'classic Countryside Stewardship'.

Any of the permanent grassland options in English environmental land management schemes state 'do not plough, cultivate or re-seed'. This is the case for all permanent grassland, not just important habitats. There are requirements for options on arable land that state what type of crop the middle of the field has to have, such as conservation headlands, over-wintered stubbles and fallow plots for ground-nesting birds. Most of these options are rotational so there would be a requirement for an agreement holder to maintain a minimum area of arable land to fulfil the annual requirement for the option.

On this basis, the option directories for Environmental Stewardship and classic Countryside Stewardship schemes in England were consulted and each option code assigned a flag if it would not allow the planting of energy crops. These included all of the area-based options in Higher Level Stewardship and a large proportion of the area-based options in Entry Level Stewardship and classic Countryside Stewardship (Appendix 3.1). Spatial data on the locations of these options were available from Natural England. There is no equivalent spatial dataset for Scottish environmental land management schemes (as far as we are aware), therefore this was not done for Scotland.

1.1.1.1.10 Water stressed areas

Energy crops, particularly Short Rotation Coppice (SRC), have a greater water requirement than conventional crops. Landowners must obtain a licence from the Environment Agency to abstract >20m^3 of water for irrigation in a single day under the Cross Compliance verifiable standards for England (GAEC 18). Even if crops are not irrigated, the growth of large areas high yielding energy crops may affect the local water table. Areas of limited water availability may therefore constrain the planting of large areas of SRC and a constraint data layer was created based on this assumption.

The Environment Agency has a dataset on water resource availability and reliability mapped to Water Framework Directive (WFD) Cycle 2 catchment boundaries. Each catchment is colour coded by its water resource availability, with red representing water not available for licencing. These are waterbodies where flows are below the indicative flow requirement to support Good Ecological Status (as required by the WFD). Catchments are also coded by resource reliability, with categories for the percentage of the time additional consumptive resource may be available.

Catchments that were coded 'red' for water resource availability and in the lower 30% for flow reliability (worst case) were selected for potential use as a constraint layer. The constraint has a particularly large coverage in areas of Eastern England.

1.1.1.1.11 Visibility

Miscanthus and SRC have the potential to obscure views and influence landscape character, however there is no formal requirement to consult with neighbours about the restriction of views before planting an energy crop (Lindegaard et al., 2015). Consideration was given to the possibility of excluding areas of land that were above a certain visibility threshold using Ordnance Survey Terrain 5 elevation data in a viewshed analysis. The decision was taken not to do this due to the large amount of processing required and the associated data costs for a constraint of likely low importance, especially given that a landscape constraint is included in the UKERC 9w mask, based on naturalness scores.

1.1.1.1.12 Historic Environment records (HERs)

Under cross compliance rules (GAEC 7e), when planting crops farmers need to ensure that they are not causing harm to scheduled ancient monuments. In addition to scheduled monuments, there is a national network of local HERs that provide information relating to the archaeology and historic built environment of a defined geographic area. These records would provide further information on un-designated local archaeological sites and finds, historic buildings and historic landscapes. However, if there are no scheduled monuments on a farmer's land then they don't need any further planning permission to plant energy crops. Scheduled monuments are already included in the original UKERC masks. Furthermore, there are over 85 HERs in England which are maintained and managed by local authorities. This would have incurred a lot of additional time and expense to the project in identifying all the relevant authorities and requesting the data therefore the decision was taken not to include these datasets.

Assessment of impacts of each constraint layer

In order to assess the impact of each constraint in turn, the constraint raster was added to the original UKERC 9w mask. This was then converted to the sub-cell level to identify how many additional sub-cells were excluded/masked per study cell as a result of using the additional constraint. The impact of all of the constraints combined (preliminary mask) on sub-cell availability was also calculated.

Choice and creation of 'Likelihood' data layers

The possible likelihood variables were assessed in conjunction with knowledge of the available spatial data layers that best represent them. Since the objective of this project is to refine estimates of land availability for the planting of energy crops, and these variables represent likelihoods rather than constraints, they cannot be used for this purpose. We have, however, provided evidence and descriptive statistics for completeness and for possible use in future work.

1.1.1.1.13 Flood risk

Planting energy crops on flood plains could have benefits that outweigh even woodland planting, due to the increased water uptake, fast growth of the crops and the increase in surface roughness to slow the flow of water (Nisbet et al., 2011). A variable to represent flood risk was created by calculating the proportion of the remaining available land area within each sub-cell (after application of the UKERC 9w mask at 100m grid resolution) that was in a flood risk area, as defined by the Environment Agency's flood risk map.

Flood data for Scotland was sought from SEPA, however only responsible authorities and partner organisations are provided with access to the data for the purpose of flood risk management planning.

1.1.1.1.14 Nitrate vulnerability

Planting energy crops in Nitrate Vulnerable Zones (NVZs) would be beneficial due to the lower applications of fertilisers compared to conventional crops and the barrier that they provide to the delivery of pollutants to water courses (Lindegaard et al., 2015). A variable to represent nitrate vulnerability was created by calculating the proportion of the remaining available land area within each sub-cell (after application of the UKERC 9w mask at 100m grid resolution) that was in an NVZ, as defined by Defra's NVZ map.

1.1.1.1.15 Land tenancy

Farmers that rent land are less likely to plant energy crops due to the long-term land-use change commitment that is required (Eves, et al., 2014). Defra's June Survey of Agriculture results at county level (highest level of spatial disaggregation readily available) were used to calculate the proportion of the farmed land area within a county that was rented. Each sub-cell was assigned the value for the county in which the majority of its land area fell.

1.1.1.1.16 Pollinator density

Willows produce lots of nectar and pollen in the early months of the year (Lindegaard et al., 2015). This could potentially help rebuild populations of pollinators. Energy crop planting (particularly SRC willow) in areas of low pollinator density may therefore provide additional environmental benefits. Outputs of species distribution models for crop pollination were provided for the project by Polce and the Insect Pollinators Initiative (Polce et al., 2013). However, this dataset was restricted to areas of the country where beans are grown, since this was the primary research purpose, and therefore lacked national coverage. The dataset could therefore not be used for this project.

1.1.1.1.17 Field size

Smaller field sizes could deter planting of energy crops due to difficulties in harvesting small plots. Conversely, large fields are perhaps more suited to large-scale food crop production and there is currently a trend towards hand harvesting of smaller fields (K. Lindegaard pers. comm.). Larger fields are more economically viable to harvest with large machinery, but research and development on new machinery that could harvest small, odd-shaped fields is underway. There is therefore no clear evidence base that field size could indicate the likelihood of planting and the decision was taken not to include field size in the analysis.

1.1.1.1.18 Areas of rapid land-use change

The Land Use and Land Cover Survey (LUCAS) is a survey carried out every three years across the European Union. It estimates the area occupied by different land use/ cover types on the basis of sampling points that are re-visited. This dataset was considered for use in this project to identify areas of the landscape that are changing most rapidly and where it was hypothesised to be less likely that energy crop plantings would result in unwelcome changes in landscape character. Outside of constraints already presented (including those contained in UKERC 9w relating to landscape) there is no evidence to suggest that the rate of change of land use within an area has any impact on the ability or decision to plant energy crops. Furthermore, the local planning system does not cover the impacts of planting bioenergy crops on the character of the local landscape. This dataset was therefore not considered further in the analysis.

1.1.1.1.19 Local Planning

Consideration was given to the use of planning studies from local authorities, which may give information on local schemes or incentives in place for the planting of energy crops (e.g. the East Midlands Forestry Micro-enterprise Grant, now closed to new applicants). According to the Biomass Energy Centre[18], there are currently no local schemes for energy crop production. Given that gathering information from the multiple local authorities in the study cells would have required a large amount of effort and the low likelihood of any local schemes or incentives being in existence, it was concluded that local planning studies would not be sourced for use in this project.

3.2.6 Final evaluation of datasets and estimates

Comparison of sub-cell classification from desk study and field survey

The results of the field survey (final result of surveyor opinion of availability of a sub-cell) were used to calculate the numbers of sub-cells that matched and mismatched with the desk study in their classifications of available or unavailable. This made the assumption that the field surveyor makes a perfect assessment of land availability, which of course in practice is not the case. It was therefore important to investigate the reasons for discrepancies to see if there were any regularly occurring explanations for why differences were being seen and whether or not these could be addressed. For each sub-cell that had a mismatch in classification between the field and the desk study, the surveyor's assessment of the cell was consulted to see if the reason for the difference could be identified. The reason was recorded in a spreadsheet.

[18] http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,15133&_dad=portal&_schema=portal

The results of this analysis were used to determine (i) if there were any other constraints for which spatial data were available that could be used to improve the provisional mask by excluding additional areas of land; (ii) if there were any constraints included in the provisional mask that should be removed because they are excluding areas of land that should be available and (iii) if there were any constraints included in the provisional mask that could not be identified by field survey.

Prediction of surveyed sub-cell unavailability using statistical models

To formalise the prediction of surveyed sub-cell unavailability using the constraint data layers and to help identify the relative contribution of different data layers, statistical models were used.

Logistic regression models (with a separate model for each 50 km cell) were built to predict the suitability of sub-cells (only those available following application of the UKERC 9w mask) for the planting of bioenergy crops based on survey results. The dependent variable was the sub-cell availability determined by the field survey (surveyor's opinion), where 0 represented sub-cells that were ≥50% available, and 1 represented sub-cells that were <50% available. The independent variable was the sub-cell availability based on various combinations of constraint layers (masks), where 0 represented sub-cells that were masked by ≤50% and 1 represented sub-cells that were masked by >50%. Constraint layers used in the new mask could not be included in the model independently of one another (nor independently of the UKERC 9w mask) due to the geographical overlap between layers. The effect that each one of them had on the model performance was therefore assessed by removing each one in turn from the new mask and comparing the results based on Akaike's Information Criterion (AIC) and graphs of odds ratios and their confidence intervals. The use of these statistics is explained more fully in section 3.4.3.

A final mask was chosen based on the results of the logistic regression analyses and the analysis of reasons for discrepancies between field survey and desk study results (see section 3.4.3).

Creation of cell typology and prediction of sub-cell availability

A separate analysis was carried out for each surveyed cell due to the differences in land character and coverage of constraint layers. To enable these models to be applied to other cells in BVCM, a simple typology was created based on the relative proportions of each of the land cover summaries for areas outside of the UKERC 9w mask in Figure 7 and the digital terrain model shown in Table 10, with the aim being that it could be applied to all cells in the UK if necessary.

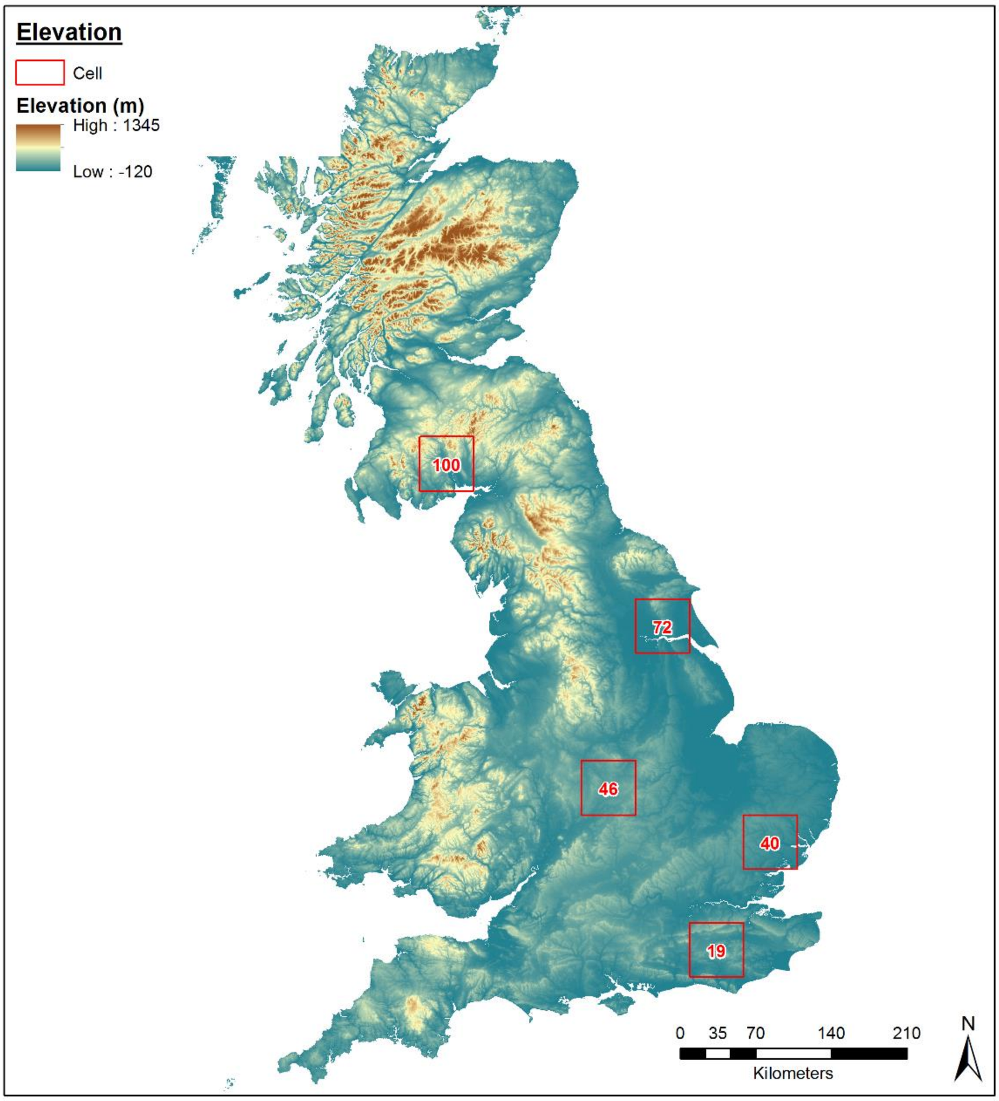


Figure 7: Digital Elevation Model of the UK and the location of the five cells included in the desk study

Each of the five study cells was assigned a simple typology as shown in Table 10. The Joint Nature Conservancy Council's (JNCC) distinction between upland and lowland for classification of semi-natural habitats is based on the upper limits of agricultural enclosure (250-400m altitude). A threshold of >250m for the classification of upland was therefore used. Upland cells are unlikely to be dominated by intensive agriculture, and therefore upland was not split into sub-categories. If this typology were to be applied to other UK cells, all cells would have to be constrained to their closest typology.

Table 10: Typologies and their application to study cells

Typology	Definition	Cell numbers
lowland mixed	Majority of land below 250m. >15% arable, >15% grassland, >15% forest.	**019**
lowland arable	Majority of land below 250m. >70% arable, <15% grassland, <15% forest.	**040, 072**
lowland forest	Majority of land below 250m. >70% forest, <15% grassland, <15% arable	
lowland grassland	Majority of land below 250m. >70% grassland <15% arable, <15% forest.	
lowland arable and grassland	Majority of land below 250m. >15% arable, >15% grassland; <15% forest.	**046**
upland	Majority of land above 250m.	**100**

3.3 Field survey results

3.3.1 Cell 019 – Kent and Sussex

Number of cells surveyed

In total 206 sub-cells were surveyed. There were 13 of the 200 originally selected sub-cells that were not surveyed, with back-up sub-cells being selected in their place. The main reason for failing to survey was that it was not possible to see more than 50% of the cell due to no access (12 sub-cells) and a lack of safe places to stop and stand (1 sub-cell) (Table 11).

Table 11: Cell 019 Total number of sub-cells surveyed and number of cells not surveyed including reason for not surveying.

Why were cells not assessed?		Number of cells
Surveyed		206
Not surveyed. Of which:		13
No safe place to stand and survey		1
Not able to see >50% of the cell		12
Weather restrictions (fog, low cloud etc.)		0
Other		0

On average of the sub-cells assessed the surveyors were able to assess 96% of the 1 km x 1 km sub-cell, although this ranged from 65% to 100%. The unknown area was proportionally allocated to 'available' and 'unavailable' based on proportions identified in the visible portion of the sub-cell.

Land use

Average land use was calculated by taking the proportion of the visible part of the sub-cell in each land use and adding the unknown part of the sub-cell pro rata. The predominant land use category in cell 019 was improved grassland (27% - range 0%-90%), closely followed by arable (19% - range 0%-80%) both of which were deemed to be 'available' (Figure 8). On average the field survey indicated that based on land type 51% of the land in the surveyed cells was available for energy crop production. The remaining unavailable land included semi-natural habitats of semi-natural broadleaved woodland (12% - range 0%-80%), semi-natural grassland (9% - range 0%-92%) and semi-natural mixed woodland (6% - range 0%-98%). Buildings and including residential and industrial amounted to 9% of land area with various other land uses accounting for less than 3% of land use each.

Fields sizes were of medium size 3-6 ha dominant in 106 sub-cells, fields of less than 1 ha were dominant in just 1 sub-cell, fields of 1-3 ha dominated in 22 sub-cells and fields of more than 6 ha were dominant in 71 sub-cells and the remaining six sub-cells had no dominant field size as they were dominated by thick woodland (semi natural mixed).

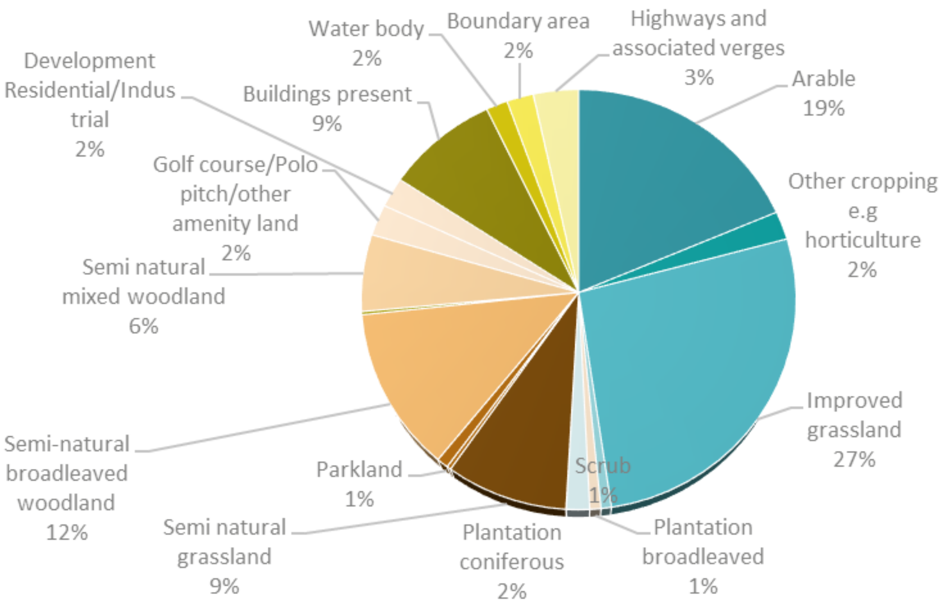


Figure 8: Cell 019 - Summary of land use (based on the visible portion of sub-cells)

Blue areas (arable, horticulture, improved grassland, scrub and plantation coniferous) deemed to be 'available' and other coloured areas (all other land uses) deemed to be 'unavailable'.

Improved grassland was the dominant land use which meant that there were livestock present in 82% of the sub-cells, with sheep the dominant species in 28% of sub-cells, horses dominant in 27% and cattle dominant in 22% with other species in 4% of sub-cells.

Topography and slope

Of the sub-cells assessed 57 were considered to have complex topography with varied elevations and slopes, whilst the remainder were considered to have simple topography, with uniform elevations and slopes. Of the sub-cells assessed the majority (194 sub-cells) were considered to have slopes suitable for both short rotation forestry (SRF) and Miscanthus, with an additional 11 sub-cells deemed to have steep slope only suitable for SRF and not Miscanthus, whilst 1 sub-cell was deemed to be too steep for any energy crops to be grown and harvested (Figure 9). Where cells had complex topography the dominant slope was selected when allocating the slope.

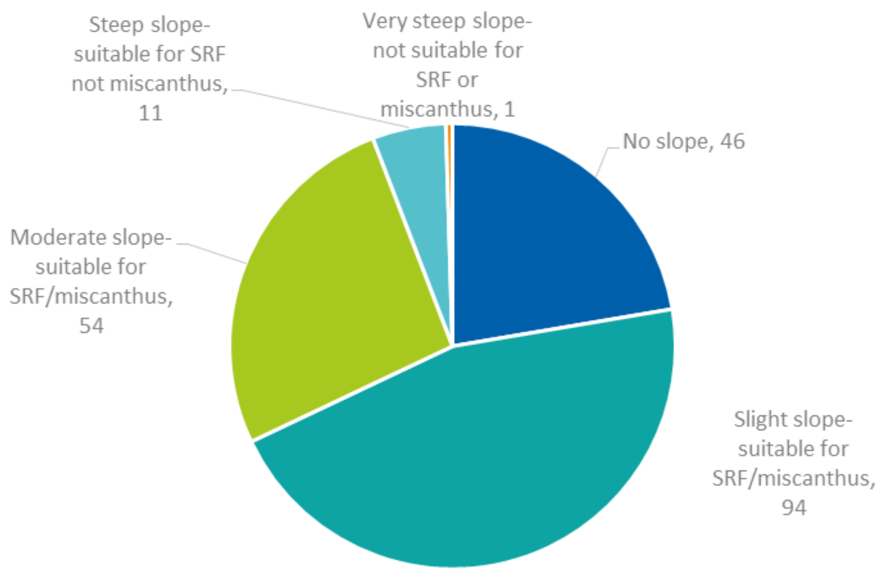


Figure 9: Cell 019 - Typical slope in sub-cells assessed

Other features

There were a range of other features present in the sub-cells. Utility pylons were present in 115 sub-cells, there were public rights of way in 201 sub-cells and scattered trees in 127 sub-cells. Evidence of waterlogging was identified in 49 sub-cells. However, it was only considered that these other features impacted on the availability of the whole sub-cell in nine of the sub-cells assessed (Figure 10). The features that impacted on availability were;

- The presence of horses & utility poles
- Scattered trees and public right of way (8 cells)

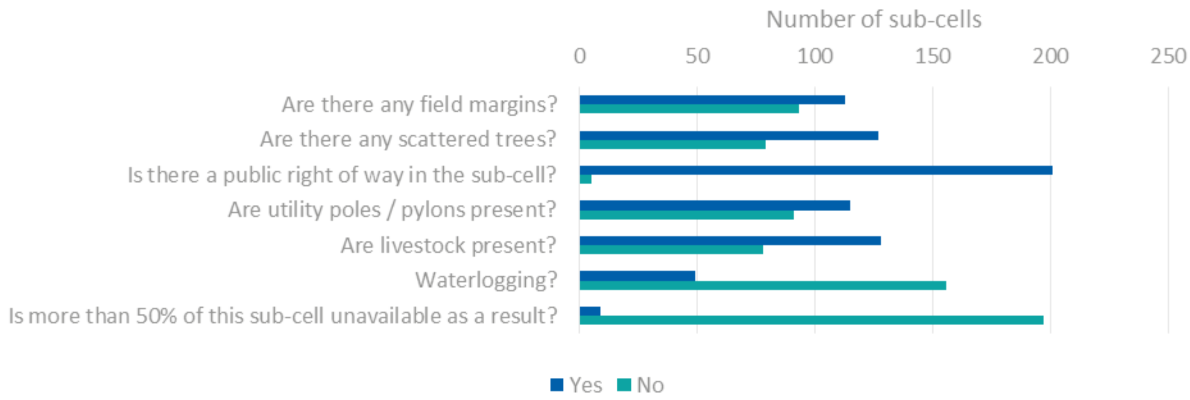


Figure 10: Cell 019 - Presence (yes) or absence (no) of other features in sub-cells and the impact on availability.

Access

Of the sub-cells assessed the majority had good access, with all 206 sub-cells having roads or tracks within 1 km of the sub-cell boundary, of these 13 were near a motorway junction, 104 were adjacent to A roads and 141 were adjacent to a B road with some cells having access to more than one type of road. There were, however, 23 sub-cells that had bridges or weight limits to contend with making access more challenging (Figure 11), although in no sub-cells was this considered sufficient to make the sub-cell 'unavailable'.

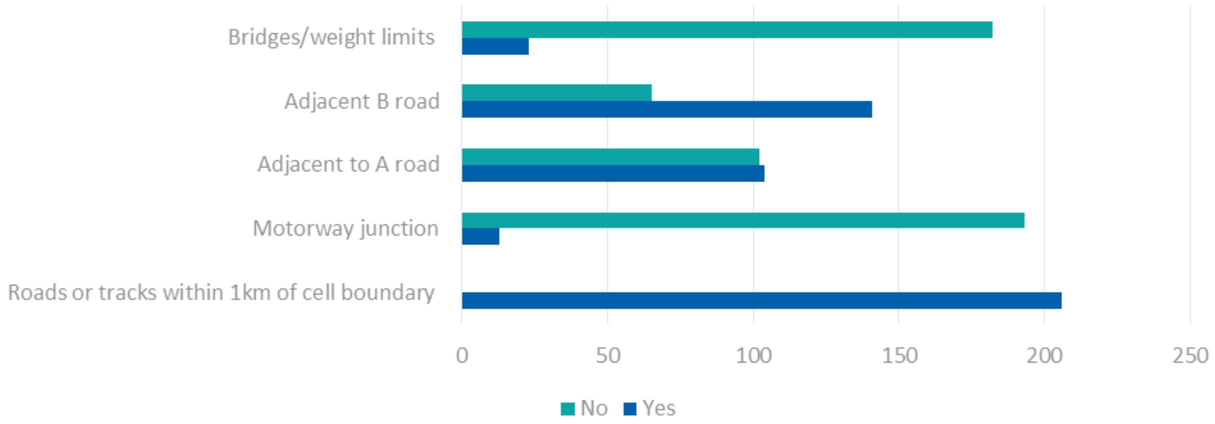


Figure 11: Cell 019 – Access - presence (yes) or absence (no) of road features in sub-cells

Availability of sub-cells

According to the original mapping based on the UKERC 9w mask, all 206 of the assessed cells were available/suitable for energy crop production. When the additional mask was applied in the desk study this indicated that 80 of the sub-cells actually surveyed were newly unavailable. Based on land area (with unknown area applied pro rata) the surveyors identified 106 cells to be available and 100 to be unavailable, however based on the surveyor's opinion there were 121 cells available and 85 unavailable. The surveyor agreed with the land area forecast on 185 of the sub-cells surveyed (Table 12).

Table 12: Cell 019 – Comparison of the surveyor forecast with the land use forecast (adjusted to include the unknown areas pro rata) – identification of available vs unavailable land.

Land use (applied pro rata) Surveyor view	Available	Unavailable	Total
Available	103	18	121
Unavailable	3	82	85
Total	106	100	206

There were 18 sub-cells where the surveyor thought that the cell was available, but the estimated area of available land indicated that they were not in fact available. There were nine of these sub-cells where the available land area was between 45% and 50% of the sub-cell area when the pro rata application of unknown land was applied, most were just 2% of less below the cut off threshold. In these cases the surveyor appears to have taken a pragmatic approach to deciding that the land was available. The remaining sub-cells the surveyor indicated that although they could not clearly see the unknown land they thought based on the maps and glimpses of the land that the majority of it was available (predominantly improved grassland), and therefore the proportion of land available would be higher than a pro rata calculation implies.

There were three sub-cells where the land area estimates indicated that the land was available, but the surveyor indicated that the land was not. The reasons these were marked as unavailable by the surveyors included;

- the inclusion of gardens to a hotel and land in front of a large manor house,
- the horticultural use being a vineyard – which was considered unlikely to be removed for bioenergy production,
- grass land used for equestrian use and therefore considered unlikely to change use to bioenergy.

The alignment of the field survey results with the desk study results is discusses in section 3.4.3.

3.3.2 Cell 046 –Leicestershire and Northamptonshire

Number of cells surveyed

In total 202 sub-cells were surveyed. There were 27 of the 200 originally selected sub-cells that were not surveyed, with back-up sub-cells being selected in their place. The main reason for failing to survey was that it was not possible to see more than 50% of the cell, due to topography and presence of tall thick hedges (21 sub-cells), a lack of safe places to stop and stand (1 sub-cells) and no road access within the sub-cell (5 sub-cells – other) also prevented surveying (Table 13).

Table 13: Cell 046 Total number of sub-cells surveyed and number of cells not surveyed including reason for not surveying.

Why were cells not assessed?	Number of cells
Surveyed	202
Not surveyed. Of which:	27
No safe place to stand and survey	1
Not able to see >50% of the cell	21
Weather restrictions (fog, low cloud etc.)	0
Other	5

On average of the sub-cells assessed the surveyors were able to assess 79% of the 1 km x 1 km sub-cell, although this ranged from 55% to 100%. The unknown area was proportionally allocated to 'available' and 'unavailable' based on proportions identified in the visible portion of the sub-cell.

Land use

Average land use was calculated by taking the proportion of the visible part of the sub-cell in each land use and adding the unknown part of the sub-cell pro rata. The predominant land use category in cell 046 was arable (49% - range 0%-93%) followed by improved grassland (25% - range 0%-71%) both of which are deemed to be 'available' (Figure 5). On average the field survey indicated that based on land type 75% of the land in the surveyed cells was available for energy crop production. The remaining unavailable land included semi-natural habitats of semi-natural broadleaved woodland (4% - range 0%-80%), semi-natural grassland (1% - range 0%-41%) and water bodies (1% - range 0%-15%), highways and associated verges 4%, development (residential or industrial) 6%, with various other land uses accounting for less than 3% of land use each.

Fields sizes ranged from small to medium sized, with fields of 3-6 ha dominant in 82 sub-cells, fields of 1-3 ha were dominant in 63 sub-cells and fields of <1 ha dominant in 3 sub-cells. Fields larger than 6 ha dominated in 51 of the sub-cells. There were three sub-cells for which there was no dominant field size one was dominated by parkland, another by residential or industrial developments and the third was broad-leaved woodland.

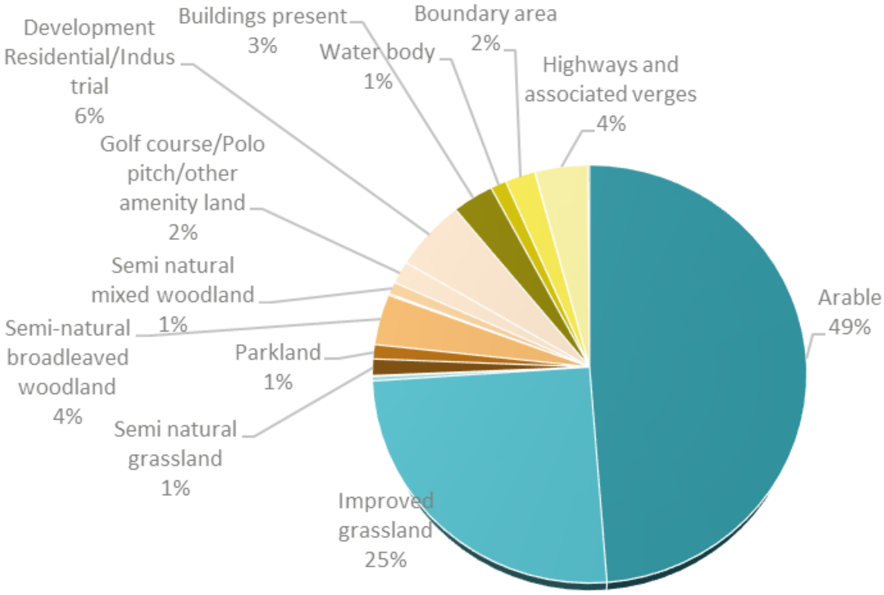


Figure 12: Cell 046 – Summary of land use (based on the visible portion of sub-cells)

– Blue areas (arable and improved grassland) deemed to be 'available' and all other colours (all other land uses) deemed to be 'unavailable'.

With improved grassland identified as a dominant land use, there were livestock present in 69% of the sub-cells, with sheep the dominant species in 40% of sub-cells, cattle dominant in 18% and horses dominant in 10% with poultry present in only 1 % of sub-cells.

Topography and slope

Of the sub-cells assessed 29 were considered to have complex topography with varied elevations and slopes whilst the remainder were considered to have simple topography, with uniform elevations and slopes. Of the sub-cells assessed the majority (200 sub-cells) were considered to have slopes suitable for both short rotation forestry (SRF) and Miscanthus, with an additional 2 sub-cells deemed to have steep slopes only suitable for SRF and not Miscanthus (Figure 13), where cells had complex topography the dominant slope was selected when allocating the slope.

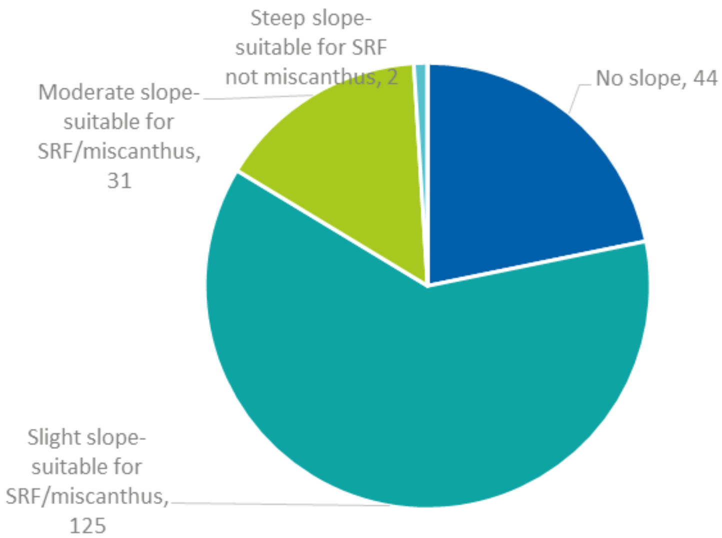


Figure 13: Cell 046 – Typical slope in sub-cells assessed

Other features

There were a range of other features present in the sub-cells. Utility pylons were present in 99 sub-cells, there were public rights of way in 175 sub-cells and scattered trees in 160 sub-cells. Evidence of waterlogging was identified in three sub-cells. However, it was only considered that these other features impacted on the availability of the whole sub-cell in eight of the sub-cells assessed (Figure 14). The reasons for cells being deemed unavailable were;

- The presence of scattered trees combined with a public right of way (6 cells)
- The presence of horses (equine use), combined with utility poles, scattered trees and a public right of way (2 cells)

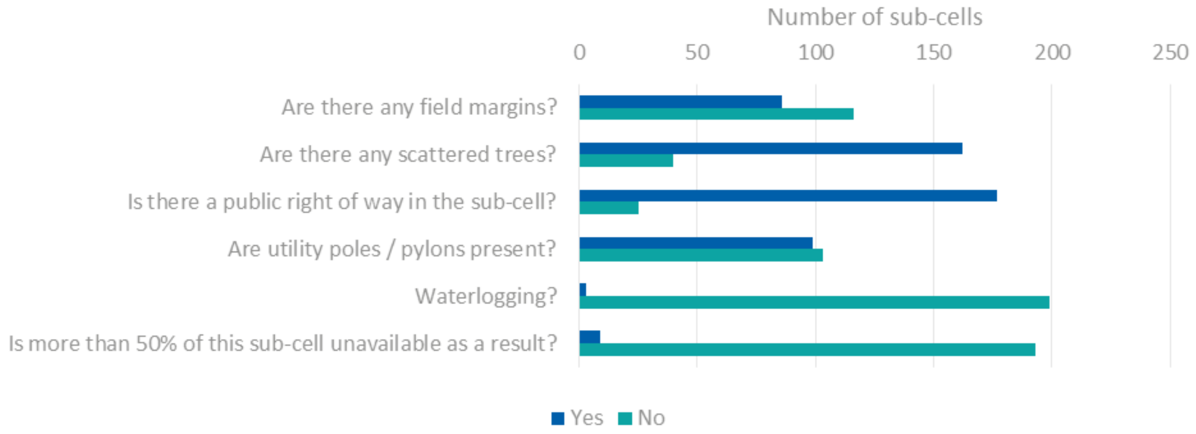


Figure 14: Cell 046 – Presence (yes) or absence (no) of other features in sub-cells and the impact on availability.

Access

All of the sub-cells assessed had good access, each having roads or tracks within one kilometre of the sub-cell boundary, of these 23 were near a motorway junction, 92 were adjacent to A roads and 90 were adjacent to a B road, the rest had access along minor roads. There were, however, 32 sub-cells that had bridges or weight limits to contend with making access more challenging (Figure 15), although no cells were specifically marked as 'unavailable' due to access issues.

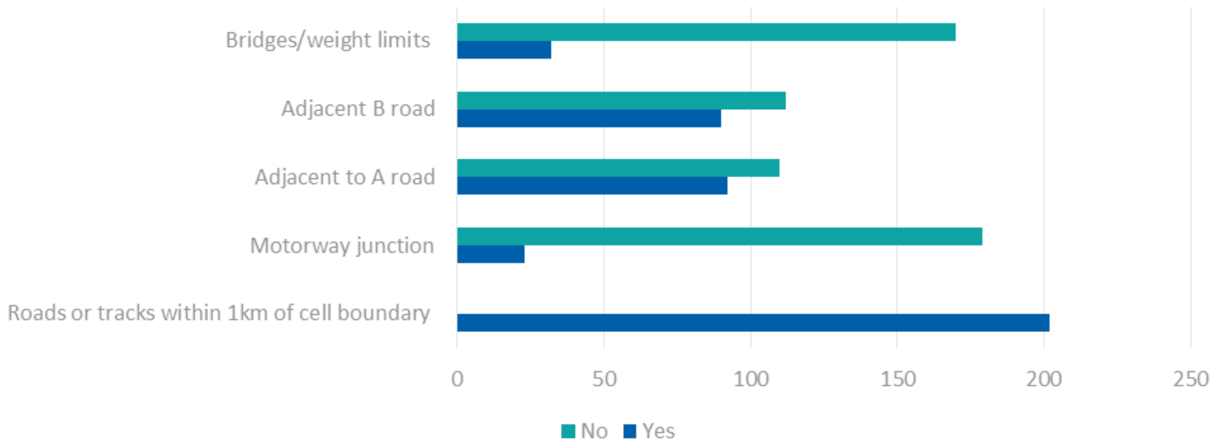


Figure 15: Cell 046 – Access - presence (yes) or absence (no) of road features in sub-cells

Availability of sub-cells

According to the original mapping based on the UKERC 9w mask, all 202 of the assessed cells were available/suitable for energy crop production. When the additional masks were applied this indicated that 21 of the sub-cells actually surveyed were 'newly unavailable'. Of the 202 sub-cells assessed in cell 46, there were 37 which were completely visible to the surveyor using one or more vantage point, the remainder of the cells had at least part of the sub-cell that was not visible to the surveyor – marked as unknown. This unknown area was applied pro rata to the known portion of the sub-cell to increase the land area estimates up to 100% of the total cell. Based on land area (with the unknown area of the sub-cell applied pro rata to the known proportions) the surveyors identified 171 cells to be available and 31 to be unavailable, however based on the surveyor's opinion there were 179 cells available and 23 unavailable. The surveyor forecast agreed with the land area forecast on 194 of the sub-cells surveyed. There were no sub-cells where the land area forecast overestimated available land compared to that of the surveyor forecast, but there were eight sub-cells where the land area forecast was under estimating that of the surveyor.

Table 14: Comparison of the surveyor forecast with the land use forecast (adjusted to include the unknown areas pro rata) – identification of available vs unavailable land.

Land use (applied pro rata) Surveyor forecast	Available	Unavailable	Total
Available	171	8	179
Unavailable	0	23	23
Total	171	31	202

There were 8 sub-cells where the surveyor thought that the cell was available, but the estimated area of available land indicated that they were not in fact available. In all eight of these sub-cells the surveyor indicated that although they could not clearly see the unknown land they thought based on the maps, aerial photography and glimpses of the land that the majority of it was available (predominantly improved grassland), and therefore the proportion of land available would be higher than a pro rata calculation implies. There were no instances where the survey indicated that the land was not available when the land area estimates indicated that it was.

The alignment between the field survey estimates and the desk study estimates is discussed in section 3.4.3.

3.3.3 Cell 100 – Dumfries and Galloway

Number of cells surveyed

In total 202 sub-cells were surveyed. There were 27 of the 200 originally selected sub-cells that were not surveyed, with back-up sub-cells being selected in their place. The main reason for failing to survey was that it was not possible to see more than 50% of the cell, due to slope and presence of tall vegetation (18 sub-cells), although poor visibility due to weather (6 sub-cells), a lack of safe places to stop and stand (2 sub-cells) and no access to a wind farm (1 sub-cell – other) also prevented surveying (Table 15).

Table 15: Cell 100 - Total number of sub-cells surveyed and number of cells not surveyed including reason for not surveying.

Why were cells not assessed?	Number of cells
Surveyed	202
Not survey. Of which:	27
No safe place to stand and survey	2
Not able to see >50% of the cell	18
Weather restrictions (fog, low cloud etc.)	6
Other	1

On average, of the sub-cells assessed, the surveyors were able to assess 88% of the 1 km x 1 km sub-cell, although this ranged from 50% to 100%. The unknown area was proportionally allocated to 'available' and 'unavailable' based on proportions identified in the visible portion of the sub-cell.

Land use

Average land use was calculated by taking the proportion of the visible part of the sub-cell in each land use and adding the unknown part of the sub-cell pro rata. The predominant land use category in cell 100 was improved grassland (39% - range 0%-83%) closely followed by coniferous plantation (32% - range 0%-99%) both of which were deemed to be 'available' land use types (Figure 16). On average the field survey indicated that based on land type 76% of the land in the surveyed cells was available for energy crop production. The remaining unavailable land included semi-natural habitats of moorland (5% - range 0%-50%), semi-natural broadleaved woodland (4% - range 0%-35%) and water bodies (3% - range 0%-21%) with various other land uses accounting for less than 3% of land use each.

Fields sizes were large, with fields of more than 6 ha dominant in 104 sub-cells, fields of 3-6 ha were dominant in 67 sub-cells, and there were 22 sub-cells where no clear boundaries were seen due to large stands of coniferous plantation. In the remaining 9 sub-cells field size averages 1-3 ha.

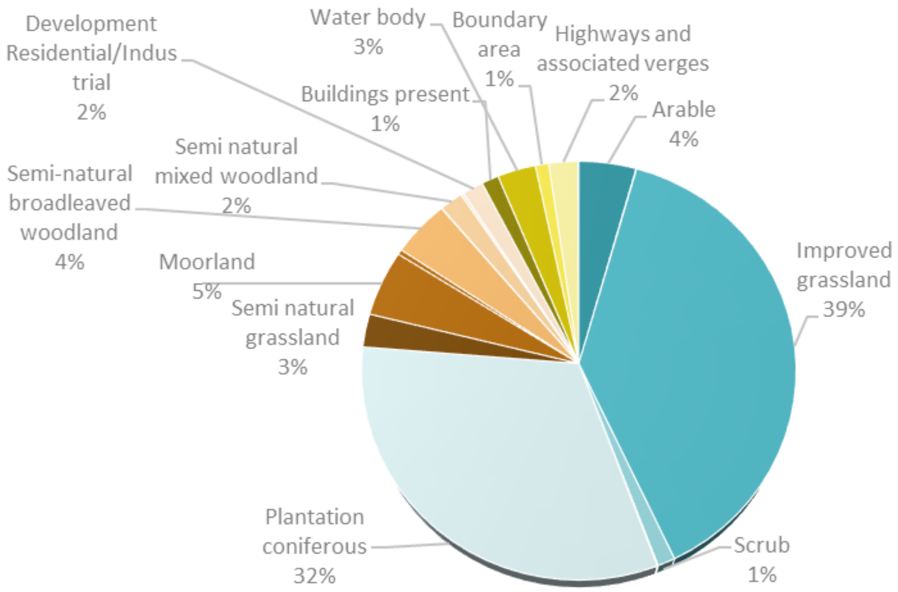


Figure 16: Cell 100 – Summary of land use (based on the visible portion of sub-cells)

– Blue areas (arable, improved grassland, scrub and plantation coniferous) deemed to be 'available' and all other colours (all other land uses) deemed to be 'unavailable'.

The large area of grassland, especially improved grassland meant that there were livestock present in 60% of the sub-cells, with cattle the dominant species in 35% of sub-cells, sheep dominant in 23% and horses dominant in 2%.

Topography and slope

Of the sub-cells assessed 60 were considered to have complex topography with varied elevations and slopes whilst the remainder were considered to have simple topography, with uniform elevations and slopes. Of the sub-cells assessed the majority (162 sub-cells) were considered to have slopes suitable for both short rotation forestry (SRF) and Miscanthus, with an additional 30 sub-cells deemed to have steep slopes only suitable for SRF and not Miscanthus, whilst 10 sub-cells were deemed to be too steep for any energy crops to be grown and harvested (Figure 17), where cells had complex topography the dominant slope was selected when allocating the slope.

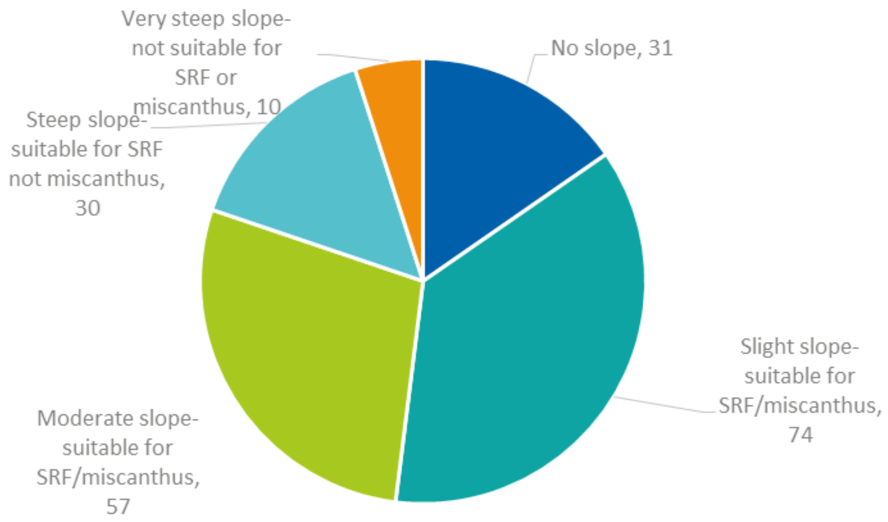


Figure 17: Cell 100 – Typical slope in sub-cells assessed (number of cells given after label)

Other features

There were a range of other features present in the sub-cells. Utility pylons were present in 93 sub-cells, there were public rights of way in 63 sub-cells and scattered trees in 37 sub-cells. Evidence of waterlogging was identified in 44 sub-cells. However, it was only considered that these other features impacted on the availability of the whole sub-cell in four of the sub-cells assessed (Figure 18). The causes for cells being unavailable were;

- A combination of waterlogging and utility poles – 2 sub-cells
- The presence of horses (equine use) – 2 sub-cells

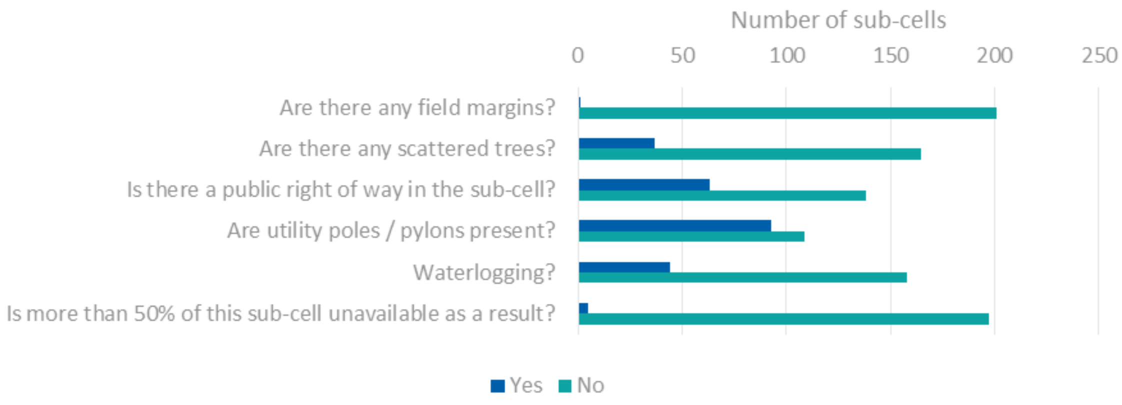


Figure 18: Cell 100 – Presence (yes) or absence (no) of other features in sub-cells and the impact on availability.

Access

Of the sub-cells assessed the majority had good access, with 198 sub-cells having roads or tracks within one kilometre of the sub-cell boundary, of these 1 was near a motorway junction, 54 were adjacent to A roads and 45 were adjacent to a B road, the remaining 98 cells had minor roads that enabled access. There were three sub-cells that had no public roads through or near them, but they did have forestry tracks leading up to them. There were, however, 36 sub-cells that had bridges or weight limits to contend with making access more challenging (Figure 19), although no cells were considered to be 'unavailable' due to access issues.

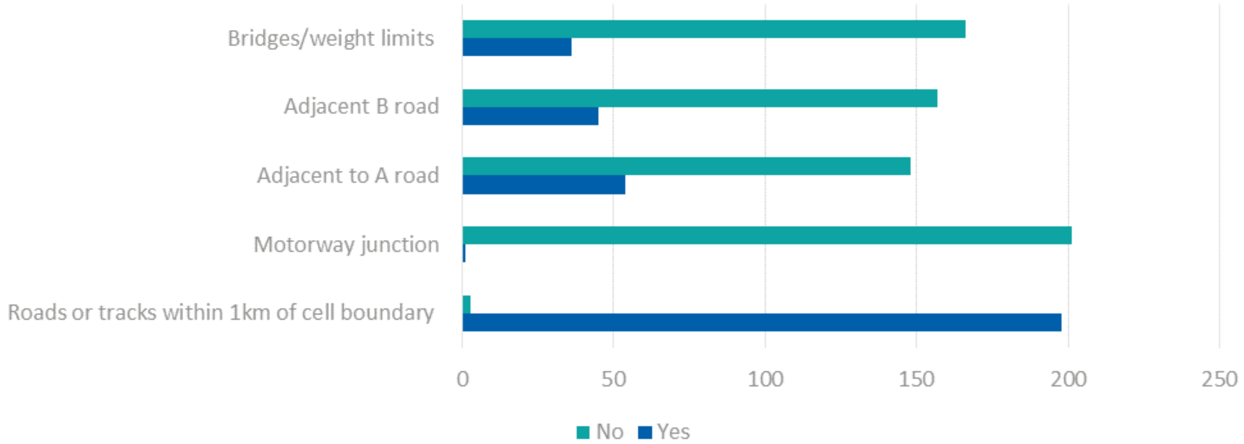


Figure 19: Cell 100 – Access - presence (yes) or absence (no) of road features in sub-cells

Availability of sub-cells

According to the original mapping based on the UKERC 9w mask, all 202 of the assessed cells were available/suitable for energy crop production. When the additional mask was applied in task 2.2 this indicated that 46 of the sub-cells actually surveyed were newly unavailable. The availability of sub-cells from the field survey was calculated in two ways; based purely on the land area estimates provided by the surveyors - with the unknown area applied pro rata to 'available' and 'unavailable' (*land area forecast*) and also based on the surveyor's view, which was able to account for access, difficult field shapes etc. (*surveyor forecast*). Based on land area (with the unknown area applied pro rata to 'available' and 'unavailable') the surveyors identified 181 cells to be available and 19 to be newly unavailable, however based on surveyor's opinion there were 173 cells available and 21 unavailable.

The surveyor forecast agreed with the land area forecast on 188 of the sub-cells surveyed (Table 16). There were three sub-cells where the surveyor thought that the cell was available, but the pro rata estimated area of available land indicated that they were not in fact available. Two of these cells were right on the borderline with over 48% available with pro rata inclusion of unknown land and the third had a large area (33%) of unknown land that in the surveyors view was available based on mapping and satellite images.

There were 11 sub-cells where the pro rata calculation of available land indicates that the cells should be available, but the surveyor view indicated that it was unavailable. Of those the initial land estimates (prior to the pro rata application of unknown land), indicated that seven of those sub-cells were unavailable – with the surveyor comments indicating that they thought the greater proportion of the unknown land in those sub-cells was expected to be unavailable based on mapping and satellite photography. All four of the sub-cells that had high levels of available land uses, but were considered by the surveyor to be unavailable were considered to be too steep for cost effective SRF, although some of the land was already in plantation forestry.

Table 16: Cell 100 - Comparison of the surveyor forecast with the land use forecast (adjusted to include the unknown areas pro rata) – identification of available vs unavailable land.

Land use (applied pro rata) Surveyor view	Available	Unavailable	Total
Available	170	3	173
Unavailable	11	18	29
Total	181	21	202

The comparison of the field survey results with the desk study results is provided in section 3.4.3 .

3.4 Desk study results

3.4.1 Understanding cell estimates at a local scale

A summary of the total number of sub-cells and the number of 'available' sub-cells following application of the UKERC 9w mask for each study cell is given in Table 17. Some cells have fewer than 2,500 sub-cells because they are coastal and sub-cells do not extend offshore.

Table 17: Number of sub-cells within each study cell and the number of these that are 'available' for energy crop planting following application of the UKERC 9w mask

Study Cell	Number of sub-cells	Number of 'available' sub-cells after applying UKERC 9w mask
19	2,500	1,565
40	2,453	2,199
46	2,500	2,053
72	2,412	1,999
100	2,439	1,320

3.4.2 Initial estimates of land availability using additional data layers

Constraint data layers

The constraint variables, the datasets chosen to represent these, their impact on land availability within survey cells, and an initial assessment of their strengths and weaknesses are summarised in Table 18.

Table 18: Summary table of the assessed constraints, source of data, how they were used, additional sub-cells excluded and the initially identified strengths and weaknesses of the data layers

Data layer	Source of data	Mask creation	Additional sub-cells excluded in all study cells (above UKERC 9w)	Strengths	Weaknesses
Altitude	Terrain 50 (Ordnance Survey)	Areas >300m above sea level	174	Absolute constraint Data accurate	Only Scotland cell (#100) has areas >300m Requires some GIS processing to create layer
Agricultural land productivity	ALC (Natural England) LCA (James Hutton Institute)	Grade 1 land	156	Straightforward to apply	Not an absolute constraint - if financial benefits are high enough, these areas may be planted on Datasets have not been updated in a long time
Soil Parameters	European Topsoil Physical Properties	>60% clay	0	Absolute constraint	No exclusions in study cells so validity cannot be tested
Buildings and water bodies	VectorMap District (Ordnance Survey)	Buildings, water bodies	22	Absolute constraint Accurate data	Does not include gardens and amenities Is already included in UKERC 9w, hence this is only incremental changes
BAP Priority Habitats	Priority Habitat Inventory (Natural England)	All mapped PHs	777	Straightforward to apply	Do not cover Scotland Not an absolute constraint May be inaccurate for certain habitats/ areas Subject to change
Semi-natural woodland	Ancient woodland/ semi-natural woodland inventories (Natural England/ Scottish Natural Heritage[19])	All	510	Straightforward to apply Full coverage	Does not include all semi-natural woodland in England (only ancient woodland).

[19] Copyright Scottish Natural Heritage Contains Ordnance Survey data © Crown copyright and database right 2015

Data layer	Source of data	Mask creation	Additional sub-cells excluded in all study cells (above UKERC 9w)	Strengths	Weaknesses
Parks & gardens	Historic Parks & Gardens (English Heritage)[20] Gardens & Designated Landscapes (Historic Environment Scotland)[21]	All	126	Straightforward to apply Full coverage	May not be absolute constraint
Stewardship options	Environmental Stewardship and classic Countryside Stewardship options/areas	Area based options whose prescriptions would not be compatible with the planting of energy crops	998	Spatial resolution at option scale (individual fields)	Scheme options not mapped for Scotland. Subject to change as agreements end and new agreements are entered into. Dataset not being maintained.
Water stressed areas	Water Resource Availability and Abstraction Reliability (Environment Agency)	Areas where resource availability is coded 'red' and abstraction reliability is <30%.	2,759	Straightforward to apply	Does not cover Scotland Unlikely to be an absolute constraint unless large areas are planted together

Impacts of each constraint layer

The 'provisional mask' that was created comprises UKERC 9w plus all of the constraint datasets in Table 18 with the exception of water stressed areas. The latter were not included due to the large areas that they impacted in the cells situated in the East of England combined with the limited evidence that this is an absolute constraint. A summary of the number of available sub-cells following application of the provisional mask, plus the actual and percentage decrease from UKERC 9w only is provided in Table 19.

Table 19: Summary of impacts of provisional new mask on sub-cell availability in the five study cells compared to UKERC 9w

Study Cell	Number of 'available' sub-cells after applying UKERC 9w mask	Number of 'available' sub-cells after applying provisional mask	Number of 'newly unavailable' cells	Percentage decrease in available sub-cells from UKERC 9w
19	1,565	869	696	44%
40	2,199	1,711	488	22%
46	2,053	1,773	280	14%
72	1,999	1,497	502	25%
100	1,320	1,002	318	24%

Maps showing the impact of the provisional mask in addition to UKERC 9w for each study cell are shown in Figure 20 to Figure 24.

[20] © English Heritage 2015. Contains Ordnance Survey data © Crown copyright and database right 2015, The English Heritage GIS Data contained in this material was obtained on October 2015.
[21] Contains Historic Environment Scotland and Ordnance Survey data © Historic Environment Scotland - Scottish Charity No. SC045925 © Crown copyright and database right 2015.

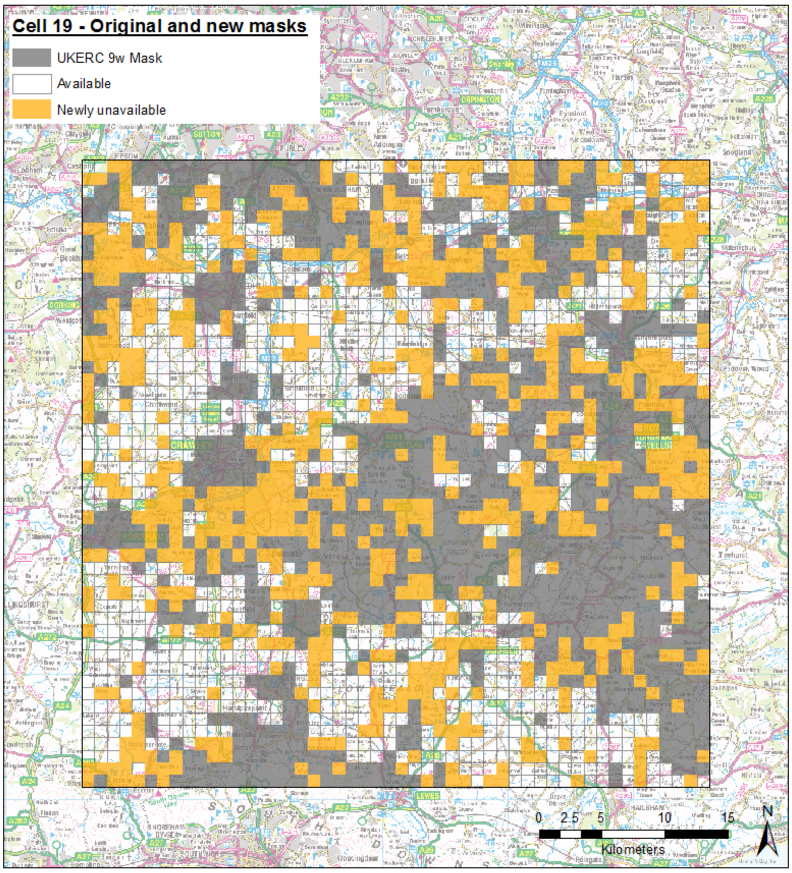


Figure 20: Impact of provisional mask (newly unavailable) on sub-cell availability in cell 19

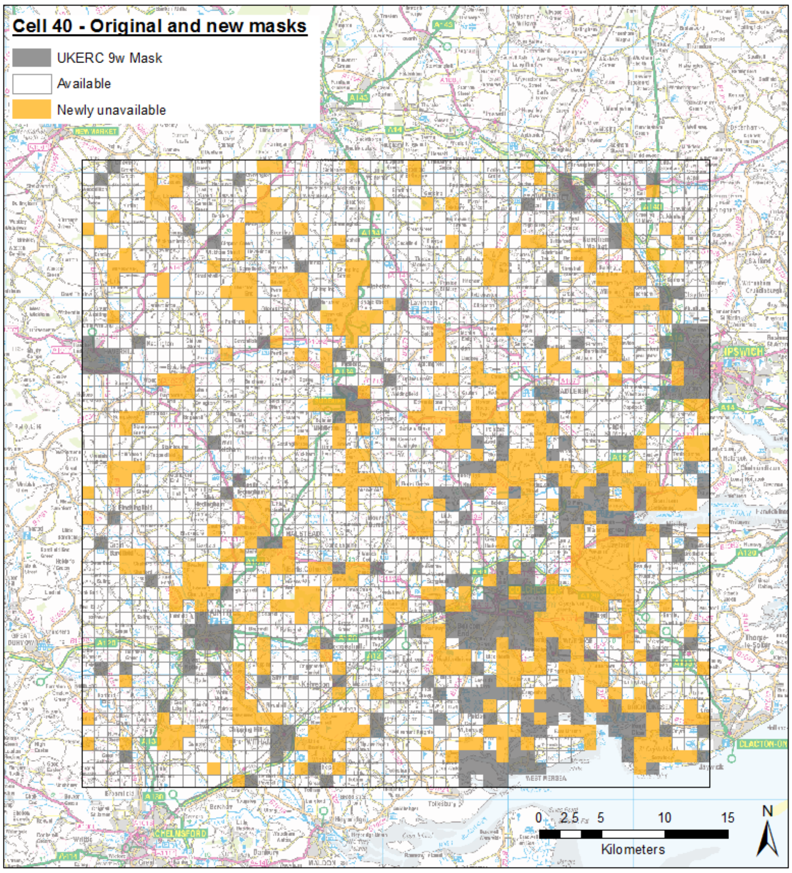


Figure 21: Impact of provisional mask (newly unavailable) on sub-cell availability in cell 40

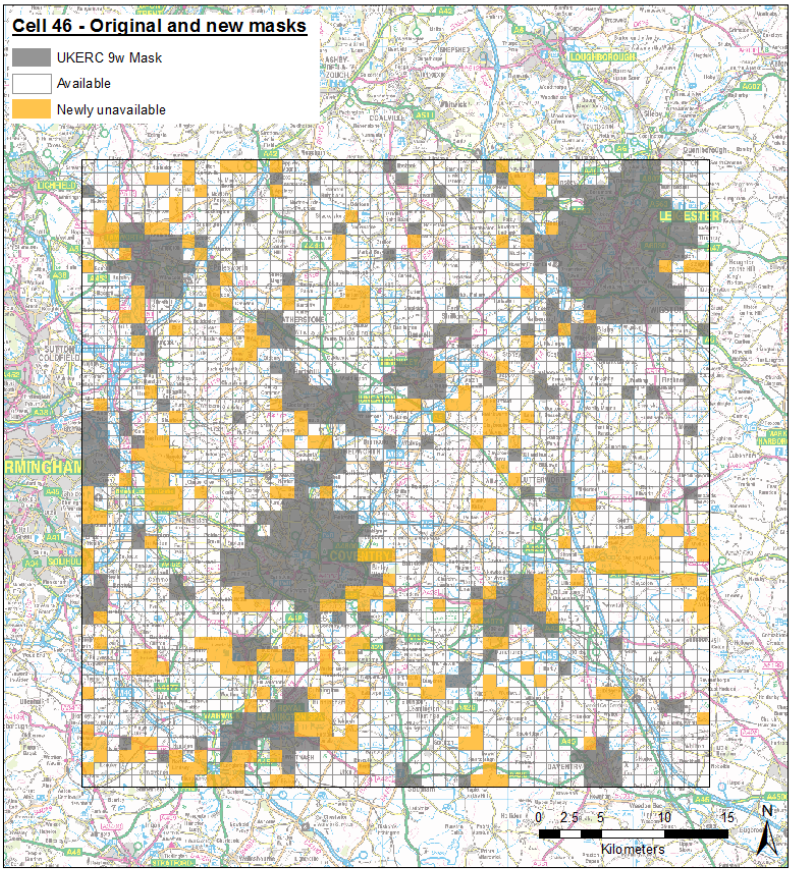


Figure 22: Impact of provisional mask (newly unavailable) on sub-cell availability in cell 46

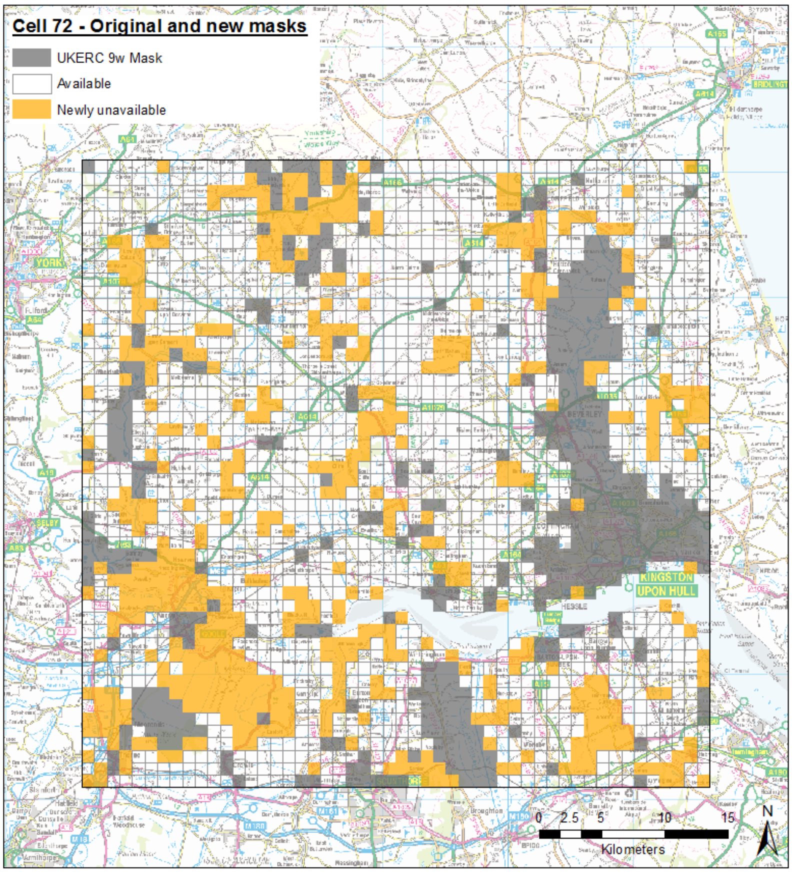


Figure 23: Impact of provisional mask (newly unavailable) on sub-cell availability in cell 72

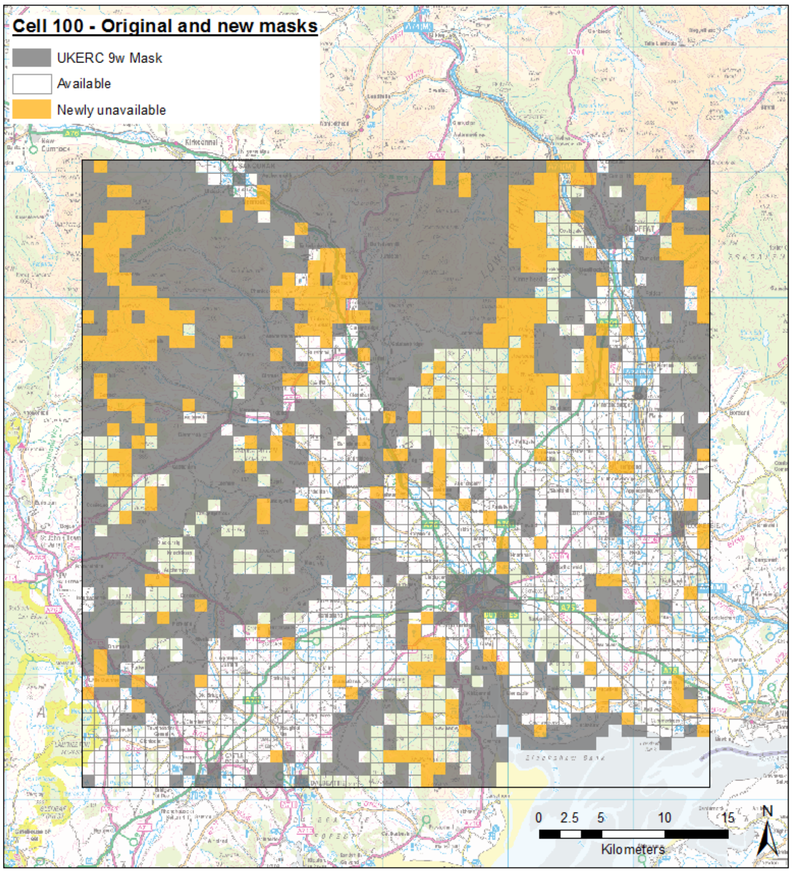


Figure 24: Impact of provisional mask (newly unavailable) on sub-cell availability in cell 100

Maps showing the impact of each constraint layer (where an impact was seen) separately on sub-cell availability in the five study cells are provided in Appendix 3.2.

Assessment of 'likelihood' data layers

A summary of the likelihood data layers used and an assessment of their strengths and weaknesses is provided in Table 20.

Table 20: Assessment of the likelihood data layers including the data source, how the variable was created and the strengths and weaknesses

Data layer	Source of data	Variable creation	Strengths	Weaknesses
Flood Risk	Flood Risk Areas (Environment Agency)	Proportion of land area outside of UKERC mask that is in flood risk area	Well defined area	Energy crop planting in flood zones may provide additional environmental benefits, but more useful as a dataset for targeting planting than assessing land availability. Scottish data not publically available
Nitrate vulnerability	Nitrate Vulnerable Zones (Defra/ Scottish Government)	Proportion of land area outside of UKERC mask that is in NVZ	Well defined areas	NVZs cover large areas of country. Energy crop planting in NVZs may provide additional environmental benefits, but more useful as a dataset for targeting planting than assessing land availability.
Land tenancy	June Survey of	Proportion of		Best spatial resolution we can get is

	Agriculture county level results (Defra/ Scottish Government)	land area rented		county level. Indicates likelihood of planting rather than land availability.

3.4.3 Final evaluation of datasets and estimates

Comparison of sub-cell availability from desk study and field survey Table 21 to Table 23 give a summary of the comparison between the provisional mask and field survey results in the number of sub-cells that had a matching classification of available or unavailable for the three surveyed cells.

Table 21: Contingency table comparing the results from the field survey and initial desk study for Cell 19

Cell 19 (number of sub-cells)		**Desk study** Unavailable	Available	**Total**
Field survey	Unavailable	48	37	**85**
	Available	32	89	**121**
	Total	**80**	**126**	**206**

Table 22: Contingency table comparing the results from the field survey and initial desk study for Cell 46

Cell 46 (number of sub-cells)		**Desk study** Unavailable	Available	**Total**
Field survey	Unavailable	8	15	**23**
	Available	13	166	**179**
	Total	**21**	**181**	**202**

Table 23: Contingency table comparing the results from the field survey and initial desk study for Cell 100

Cell 100 (number of sub-cells)		**Desk study** Unavailable	Available	**Total**
Field survey	Unavailable	7	22	**29**
	Available	39	134	**173**
	Total	**46**	**156**	**202**

Table 24 gives a summary of the most commonly occurring reasons for discrepancies between desk study and field survey results, split into (i) limitations of desk study when sub-cells were classified as available by desk study and unavailable by field survey; (ii) limitations of field survey when sub-cells were classified as available by desk study and unavailable by field survey; (iii) limitations of desk study when sub-cells were classified as unavailable by desk study and available by field survey; (iv) limitations of field survey when sub-cells were classified as unavailable by desk study and available by field survey.

For cases of type (i), the desk study was often missing features that are constraints to energy crop planting, either because a dataset to represent the constraint was not available (e.g. gardens, golf courses) or the dataset used did not capture the full extent of the constraint (Priority Habitat and ancient woodland inventories). In some sub-cells that were classified differently by desk and field survey it was found that main roads and motorways were not being excluded by the mask. This is because they are represented by linear features in the OS mapping. In some cases the land use (as opposed to the land cover) was considered a restriction; such as non-agricultural uses for managed grassland (e.g. horse paddocks). In such cases the datasets used in the desk study (or in the UKERC 9w mask) would not pick up this level of detail. In a number of cases, surveyors classified a sub-cell as unavailable even if the land area constraints did not add up to >50%. Some common reasons were limitations to accessibility in the sub-cell (e.g. pylons and terrain). Whilst slope is included as a factor in the UKERC 9w mask, summarising this to a sub-cell scale means that it does not capture complex topography or fine scale variations in slope angle that may restrict access for planting and harvesting. Other reasons included visual landscape impacts.

Table 24: Summary of main reasons for discrepancies between desk study and field survey results at a sub-cell level.

Study Cell	Primary desk study limitations where desk classed as available and field unavailable	Field survey limitations where desk classed as available and field unavailable	Primary desk study limitations where desk classed as unavailable and field available	Field survey limitations where desk classed as unavailable and field available
19	Houses and gardens not picked up by desk study Golf courses, quarries, carparks not picked up by desk study Woodland not in ancient woodland or PH inventories	Over-estimation of unavailable area by surveyors	UKERC 9w mask excluding land for unknown reason	Environmental stewardship option areas not identified PH/ ancient woodland not identified
46	Houses and gardens not picked up by desk study Golf courses, motorways/main roads, carparks not picked up by desk study	Over-estimation of unavailable area by surveyors		Environmental stewardship option areas not identified ALC Grade 1 and Parks & Gardens areas not identified
100	Woodland not in ancient woodland inventory	Over-estimation of unavailable area by surveyors Slope assessed as too steep	UKERC 9w mask excluding land for unknown reason	Land not identified as over 300m elevation Ancient woodland not identified

For cases of type (ii), the field survey was overestimating the area of constraints (compared to the extent in the spatial data layers) or judging a constraint to be over a threshold when in the desk study it was not (slope). Overestimates of the area of constrained land types could be due to land not being visible within the sub-cell (and therefore the wrong assumptions being made about the availability of non-visible areas), or the unavailable land area being close to the 50% threshold. Where the slope of the land was judged to be a constraint by the surveyor, it may be that they were overestimating the slope angle, or they were picking up finer scale topography that was not represented by summarising slope angle to a sub-cell.

For cases of type (iii), the main reason was that in some cases where UKERC 9w was excluding <50% of the cell but the additional constraints pushed it above 50% the UKERC 9w mask was deemed to be excluding too much land; the reason for which was unknown because the mask had not been disaggregated. It is possible that this was a landscape constraint.

For cases of type (iv), the field survey was not picking up areas under environmental stewardship options, which was understandable given that they are not easily identified on the ground. In some cases, areas of priority habitat and/or ancient woodland were not identified. It is not clear whether this is due to inability to distinguish certain habitats on the ground or inaccuracies in the datasets.

Having reviewed the discrepancies between the desk study and field survey, gaps and limitations of existing datasets were identified. One of the limitations of the data used was the use of open source OS data (VectorMap). Although the dataset includes buildings, it did not include any of the grounds of the buildings. This means that private land and gardens were not included. This was found to be the most common reason for discrepancies between the desk study and field survey. Figure 25 shows an example sub-cell where the desk study has designated it as available, and the field survey has designated it as unavailable. It highlights how, although areas of buildings are identified by the dataset, in many cases the source vector layer does not cover enough (the majority) of the 100m grid square to be included as part of the mask. The sub-cell in Figure 25 is also largely covered by a golf course which again has not been identified by any of the datasets used.

Figure 25: Example of a sub-cell where limitations of the data have resulted in discrepancies between the desk study and field survey

Identification of alternative data sources

Following the comparison of sub-cell availability between the desk study and field survey, alternative potential constraint datasets were identified that may be able to fill the main data gaps identified (Table 25). Many of these gaps could be addressed through the use of highly detailed land cover mapping such as OS MasterMap or UKLand map. The costs of these, however, are high. A national dataset of MasterMap would cost somewhere in the region of £4.5million per annum, whereas UKLand would cost in the region of £55,000 per annum. Additional analysis on the quality and accuracy and reliability of these datasets would need to be carried out, perhaps by purchasing a small sample and comparing with field survey findings.

Table 25: Additional potential constraint datasets and potential sources

Data set	Current limitations	Potential data sources	How would it be used
Gardens	Open source datasets only identify the extent of buildings, and not the gardens. Datasets identifying "Urban areas" only include the larger urban areas and smaller towns and villages are missed.	MasterMap (Ordnance Survey) UKLand (The GeoInformation Group)	Attributes of the MasterMap dataset include descriptions on the land surface type. Selection of "Multi Surface" features seems to pick out gardens. Dataset includes "Residential with amenities" as individual features.
Golf Courses		UKLand (The GeoInformation Group)	Dataset includes areas of "Recreational land" as individual features.
Quarries		MasterMap (Ordnance Survey) BRITPITS (British Geological Survey) UKLand (The GeoInformation Group)	Identify features of "Manmade Landforms" to pick out potential Quarries and Sand and Gravel pits. Use point data to identify quarry locations then digitize extents. Dataset includes "Mining and spoil areas" as individual features.
Roads (as polygons)	All current OpenSource datasets contain roads as polyline features	MasterMap (Ordnance Survey) Current Opensource data UKLand (The GeoInformation Group)	Identify features of "Road Or Track" or "Roadside. Use a generic buffer distance for a given road type to estimate the coverage of roads. Dataset includes "Principle Transport Roads" as individual features.
Carparks (and other manmade surfaces)	OpenSource datasets do not currently identify carparks	MasterMap UKLand (The GeoInformation Group)	Identify "Man made" land surfaces. Dataset includes "Business parks" and "Retail parks" as individual features which seem to include the carparks.
Playing fields	No datasets currently exist for England and Wales	Future greenspace map Scotland: Greenspace map UKLand	N/A Currently being sourced Dataset includes areas of "Recreational land" as individual features.

Having examined the main reasons for discrepancies between the desk study and field survey (in Table 24), and identified potential data sources (in Table 25), Table 26 examines the potential impact of including either the OS MasterMap dataset or UKLand dataset to provide additional constraint data.. This assumes that use of the new dataset will lead to a correct sub-cell classification of 'unavailable' to match the survey.

Table 26: Potential additional matching sub-cells as a result of including identified datasets

	Number of potential additional matching sub-cells as a result of using OS MasterMap data	Number of potential additional matching sub-cells as a result of using UKLand dataset
Cell 19	20	22
Cell 46	9	10
Cell 100	3	5

Prediction of surveyed sub-cell unavailability using statistical models

The logistic regression models used in this study output an odds ratio (OR) as one of the measures of effect size. The OR is a measure of association between the independent and dependent variables and can be explained using a two-by-two frequency table as shown in Table 27;

Table 27: Example frequency table

		Field survey	
		Unavailable	Available
Desk study	Unavailable	a	b
	Available	c	d

Where;

a = Number of sub-cells that are classified as unavailable by both desk and field survey

b = number of sub-cells that are classified as unavailable by desk study but available by field survey

c = number of sub-cells that are classified as available by desk study but unavailable by field survey

d = number of sub-cells that are classified as available by both desk and field survey

$$OR = \frac{ad}{bc}$$

Therefore the greater the odds ratio, the better the match between classifications by field survey and desk study. An odds ratio of >1 indicates a positive prediction (i.e. more matches than would be expected by chance) and an odds ratio of <1 indicates a negative prediction (i.e. more mismatches than would be expected by chance). The confidence interval (CI) (in this case 2.5 – 97.5%) is used to estimate the precision of the odds ratio, whereby a large CI indicates a low level of precision and a small CI indicates a higher level of precision.

The Akaike Information Criterion (AIC) is a measure of the relative quality of statistical models for a given set of data. The lower the AIC, the better the fit of the model.

1.1.1.1.20 Cell 19

The results of the univariate logistic regression models to predict surveyed sub-cell unavailability for cell 19 from constraint masks, removing each constraint variable in turn from the provisional mask, are shown in Table 28 and Figure 26.

Table 28: Results of univariate logistic regression analyses to predict sub-cell unavailability (as determined by ground survey) from various combinations of constraint layers (masks) for cell 19.

Cell 19		Confidence Interval (%)				
Mask	**Odds Ratio**	**2.5**	**97.5**	**AIC**	**Significance**	**Interpretation**
Provisional mask	3.63	2.02	6.63	260.74	<0.001	The likelihood that sub-cell classifications match between field and desk study using the full mask is significantly greater than expected by chance.
Without semi-natural woodland constraint	3.46	1.93	6.31	262.16	<0.001	Poorer prediction than full mask but not as poor as without PH constraint indicates that semi-natural woodland should be included in mask as second most important variable.
Without Priority Habitat constraint	2.42	1.31	4.5	271.77	<0.01	Poorest prediction indicates that priority habitat should be included in mask as most important variable (in addition to UKERC 9w).
Without buildings & water bodies constraint	3.63	2.02	6.63	260.74	<0.001	Same result as for provisional new mask indicating that coverage of this variable did not exclude any additional surveyed sub-cells therefore its impact could not be assessed.
Without parks constraint	3.79	2.1	6.95	259.59	<0.001	Better prediction than full mask indicates that parks should not be included in mask.
Without stewardship options constraint	5.17	2.75	10.02	252.66	<0.001	Better prediction than full mask indicates that stewardship options should not be included in mask.
Without land productivity constraint	3.63	2.02	6.63	261.51	<0.001	Same result as for provisional new mask indicating that coverage of this variable did not exclude any additional surveyed sub-cells therefore its impact could not be assessed.
Without stewardship options or parks constraint	5.5	2.9	10.75	252.66	<0.001	Best prediction indicating that this should be the final mask used for this cell.

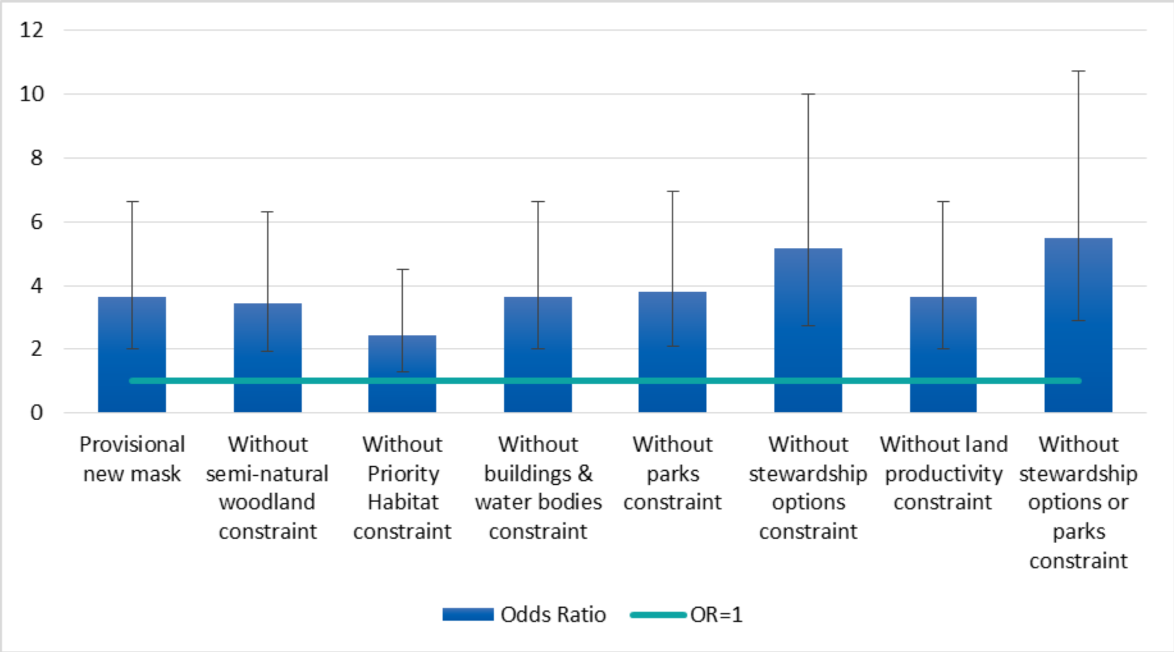


Figure 26: Comparison of odds ratios (error bars show 97.5% confidence intervals) between different masks (where unmasked sub-cell = 0 and masked sub-cell = 1) for predicting sub-cell availability (where 0 = available and 1 = unavailable) from field survey for cell 19.

The results for cell 19 indicate that the masks without the parks & gardens constraint and without the stewardship options constraint are better at predicting sub-cell unavailability as determined by field survey. For the purpose of the statistical analysis only, a mask was created that excluded both the parks and the stewardship options constraints, which subsequently gave the best result in terms of predicting results of the field survey.

1.1.1.1.21 Cell 46

The results of the univariate logistic regression models to predict surveyed sub-cell unavailability for cell 46 from constraint masks, removing each constraint variable in turn from the provisional new mask, are shown in Table 29 and Figure 27.

Table 29: Results of univariate logistic regression analyses to predict sub-cell unavailability (as determined by ground survey) from various combinations of constraint layers (masks) for cell 46.

Cell 46		**Confidence Interval (%)**				
Mask	**Odds Ratio**	2.5	97.5	AIC	Significance	Interpretation
Provisional mask	6.61	2.31	18.42	134.42	<0.001	The likelihood that sub-cell classifications match between field and desk study using the full mask is significantly greater than expected by chance.
Without semi-natural woodland constraint	5.42	1.82	15.35	137.32	<0.01	Poorer prediction than full mask but not as poor as without PH constraint indicates that semi-natural woodland should be included in mask as joint-second most important variable.
Without Priority Habitat constraint	2.03	0.43	7.05	145.06	ns	Poorest prediction indicates that priority habitat should be included in mask as most important variable (in addition to UKERC 9w).

Cell 46 Mask	Odds Ratio	Confidence Interval (%) 2.5	 97.5	AIC	Significance	Interpretation
Without buildings & water bodies constraint	5.42	1.82	15.35	137.32	<0.01	Poorer prediction than full mask but not as poor as without PH constraint indicates that additional buildings and water bodies constraints should be included in mask as joint-second most important variable.
Without parks constraint	7.2	2.49	20.38	133.65	<0.001	Better prediction than full mask indicates that parks should not be included in mask.
Without stewardship options constraint	75.69	12.42	1462.36	119.65	<0.001	Better prediction than full mask indicates that stewardship options should not be included in mask.
Without land productivity constraint	6.61	2.31	18.42	134.47	<0.001	Same result as for provisional new mask indicating that coverage of this variable did not exclude any additional surveyed sub-cells therefore its impact could not be assessed.

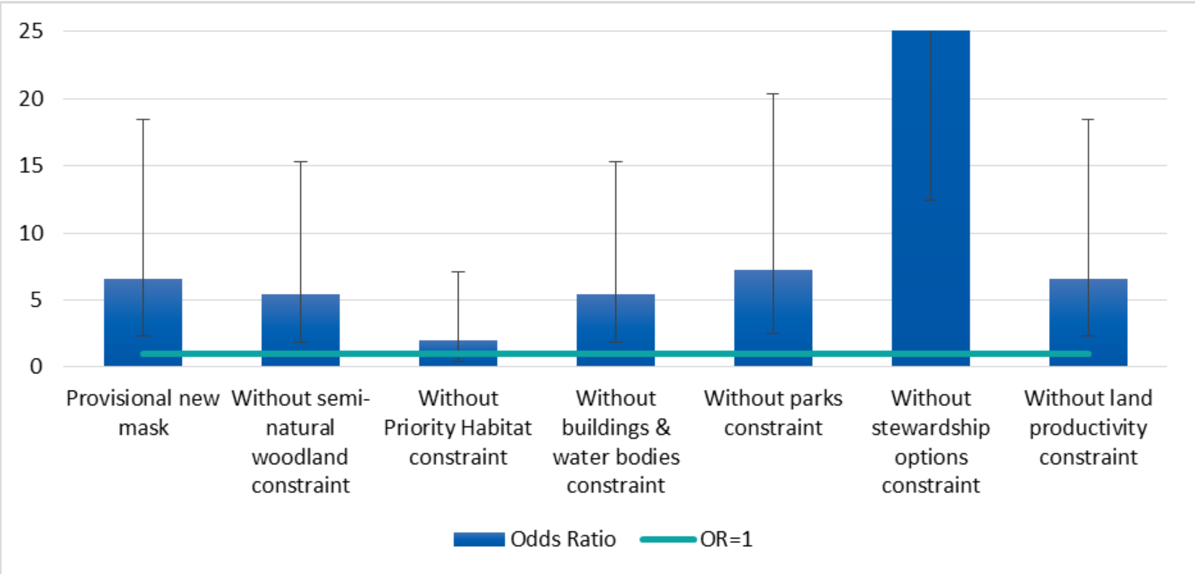


Figure 27: Comparison of odds ratios (error bars show 97.5% confidence intervals) between different masks (where unmasked sub-cell = 0 and masked sub-cell = 1) for predicting sub-cell availability (where 0 = available and 1 = unavailable) from field survey for cell 46. Y axis scale constrained due to large OR for 'without stewardship options' constraint.

The results for cell 46 indicate that the masks without the stewardship options constraint are significantly better at predicting sub-cell unavailability as determined by field survey. It was not possible to calculate an odds ratio for the mask without the parks and stewardship options constraints due to there being no sub-cells that were unavailable according to the mask and available according to the survey, but the contingency table showed it had the greatest number of matching classifications.

1.1.1.1.22 Cell 100

The results of the univariate logistic regression models to predict surveyed sub-cell unavailability for cell 100 from constraint masks, removing each constraint variable in turn from the provisional new mask, are shown in Table 30 and Figure 28.

Table 30: Results of univariate logistic regression analyses to predict sub-cell unavailability (as determined by ground survey) from various combinations of constraint layers (masks) for cell 100.

Cell 100		Confidence Interval (%)				
Mask	**Odds Ratio**	**2.5**	**97.5**	**AIC**	**Significance**	**Interpretation**
Provisional mask	1.09	0.41	2.64	170.16	ns	The likelihood that sub-cell classifications match between field and desk study using the full mask is *not* significantly greater than expected by chance.
Without semi-natural woodland constraint	0.2	0.01	1.01	166.44	ns	This mask predicts most poorly, which indicates that semi-natural woodland should be included in mask as the most important variable.
Without buildings & water bodies constraint	1.09	0.41	2.64	170.16	ns	Same result as for provisional new mask indicating that coverage of this variable did not exclude any additional surveyed sub-cells therefore its impact could not be assessed.
Without parks constraint	1.09	0.41	2.64	170.16	ns	Same result as for provisional new mask indicating that coverage of this variable did not exclude any additional surveyed sub-cells therefore its impact could not be assessed.
Without altitude constraint	3.12	1.1	8.23	165.68	<0.05	Better prediction than full mask and the only significant result indicates that altitude constraint should not be included in mask.

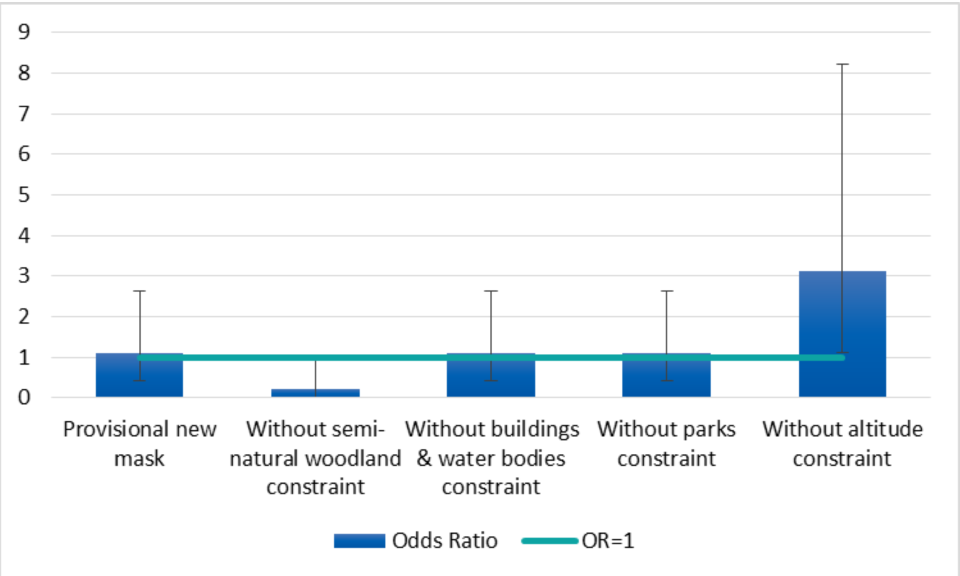


Figure 28: Comparison of odds ratios (error bars show 97.5% confidence intervals) between different masks

(where unmasked sub-cell = 0 and masked sub-cell = 1) for predicting sub-cell availability (where 0 = available and 1 = unavailable) from field survey for cell 100.

None of the masks assessed for cell 100 were good predictors of sub-cell unavailability as determined by the field survey, but the mask without the altitude constraint gave the best result.

Choice of best mask for assessing land availability for each surveyed cell

The comparison of results from desk study and field survey and the outcomes of the statistical analyses were consolidated to make an additional assessment of the strengths and weaknesses of potential constraint data layers in light of the results, and recommendations as to which layers should be included in the final mask for each surveyed cell. The occurrence of Energy Crop Scheme planting locations within these constraint layers at a national scale was also calculated to aid in the decision making process. A summary of the assessment is provided in Table 31.

Table 31: Additional strengths and weaknesses of constraint datasets identified following results of comparison with field survey findings. Also decision on whether or not to include in the final mask for each cell and the justification for the decision

Data layer	No. ECS plantings within constraint	Strengths	Weaknesses	Inclusion in final mask for cell 19	Inclusion in final mask for cell 46	Inclusion in final mask for cell 100
Altitude	1	Strong evidence that 2G crops cannot be grown above a certain altitude. Dataset used has sufficient accuracy	Was not assessed in field survey	N/A – Cell did not include areas of this constraint	N/A – Cell did not include areas of this constraint	Yes – even though exclusion improved match with field survey, altitude is an absolute constraint that can be measured accurately from the dataset used
Agricultural land productivity	28	Only variable that accounts for competition with food crops	Evidence for this being a constraint is weak Could not be assessed in field survey	Yes – Highest grade land is likely to be reserved for other crops	Yes – Highest grade land is likely to be reserved for other crops	Yes – Highest grade land is likely to be reserved for other crops
Buildings and water bodies	1	Excludes additional areas that are absolute constraints that UKERC 9w misses	Impact could not be assessed in cells 19 & 100 due to it not excluding additional surveyed sub-cells	Yes – Identifies additional constrained areas	Yes – Identifies additional constrained areas	Yes – Identifies additional constrained areas

Data layer	No. ECS plantings within constraint	Strengths	Weaknesses	Inclusion in final mask for cell 19	Inclusion in final mask for cell 46	Inclusion in final mask for cell 100
BAP Priority Habitats	75	Good evidence that these areas would not be suitable for planting Most important constraint variable in cell 19	Some PH not identified as such by field survey No data for Scotland May be inaccuracies in PH extents in datasets	Yes – Recommendation from Natural England and supported by results of field survey	Yes – Recommendation from Natural England and supported by results of field survey	N/A – Dataset not available for Scotland
Semi-natural woodland	1	Good evidence that these areas would not be suitable for planting	Some semi-natural woodland not identified as such by field survey	Yes – Areas of woodland unlikely to be felled for planting and supported by results of field survey	Yes – Areas of woodland unlikely to be felled for planting and supported by results of field survey	Yes – Areas of woodland unlikely to be felled for planting and supported by results of field survey
Parks & gardens	3	Accounts for some landscape and cultural heritage constraints	Impact could not be assessed in cell 100 due to it not excluding additional surveyed sub-cells Limited evidence that this is absolute constraint	Yes – Even though exclusion slightly improved match with field survey, there were too few additional sub-cells excluded to make a robust assessment of its importance. In addition, field survey did not always identify this land as constrained. Recommended to include as constraint due to historic and cultural value placed on the areas of land	Yes – Even though exclusion slightly improved match with field survey, there were too few additional sub-cells excluded to make a robust assessment of its importance. In addition, field survey did not always identify this land as constrained. Recommended to include as constraint due to historic and cultural value placed on the areas of land	Yes – Historic and cultural value placed on the areas of land
Stewardship options	511	Good evidence that these areas would not be suitable for planting	Could not be assessed in field survey Dataset not being maintained	No – Exclusion improves match with field survey results. Not a permanent constraint. Incentives for farmers could change	No – Exclusion improves match with field survey results. Not a permanent constraint. Incentives for farmers could change	N/A – Dataset not available for Scotland

Final prediction of sub-cell availability for all 'available' study sub-cells

The impacts of the final mask on sub-cell availability in the study cells are shown in Table 32. The percentage reduction in sub-cell availability from UKERC 9w ranges from 6% to 35% (average 17%). Relating these percentage reductions back to the proposed typology (Table 10) would help inform the decision as to whether or not a factor or factors could be applied to the original UKERC 9w mask. Using this typology, cells 40 and 72 are both lowland arable and differ by 4% in their percentage decrease in availability from UKERC 9w. The greatest decrease is seen in cell 19, which was classified as lowland mixed. The smallest decrease is seen in cell 46, which was classified as lowland grassland and arable.

Table 32: Summary of impacts of final mask on sub-cell availability in the five study cells

Study Cell	Number of 'available' sub-cells after applying UKERC 9w mask	Number of 'available' sub-cells after applying final mask	Number of 'newly unavailable' cells	Percentage decrease in available sub-cells from UKERC 9w
19	1,565	1,013	552	35%
40	2,199	2,000	199	9%
46	2,053	1,938	115	6%
72	1,999	1,748	251	13%
100	1,320	1,002	318	24%
Total	**9,136**	**7,701**	**1,435**	**16%**

The spatial distributions of the final masks in the study cells are shown in Figure 29 to Figure 33.

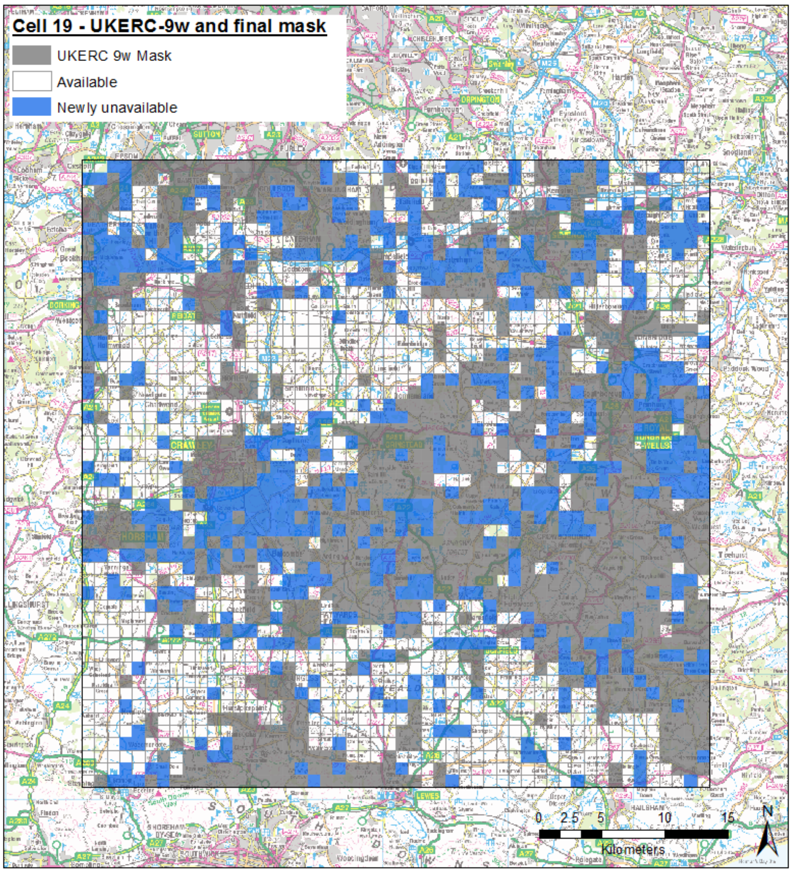


Figure 29: Impact of final mask (newly unavailable) on sub-cell availability in cell 19

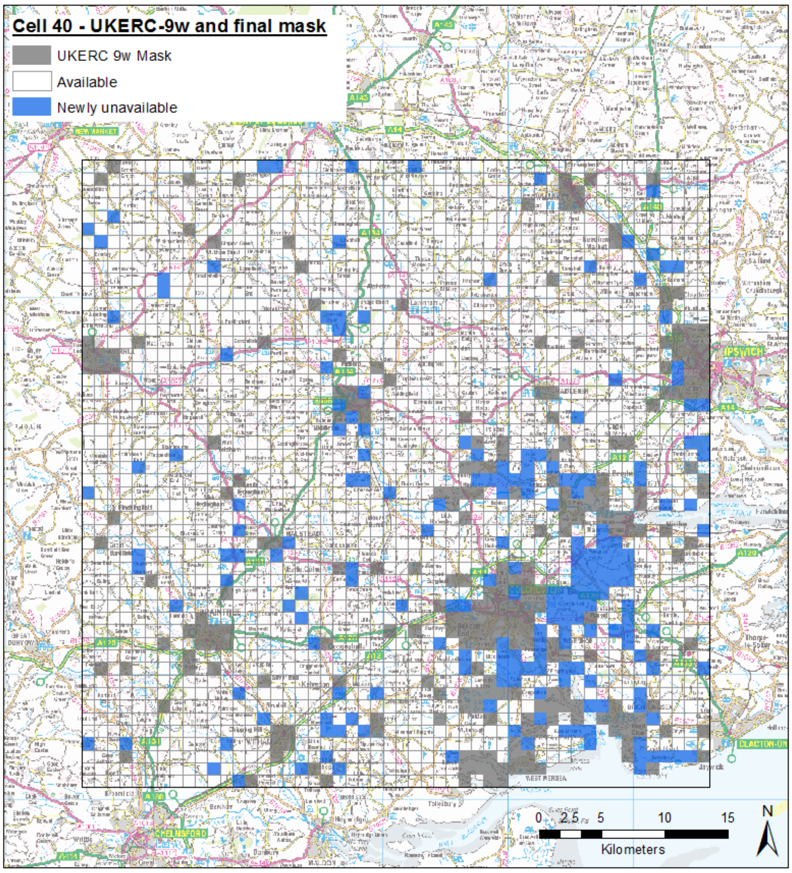


Figure 30: Impact of final mask (newly unavailable) on sub-cell availability in cell 40

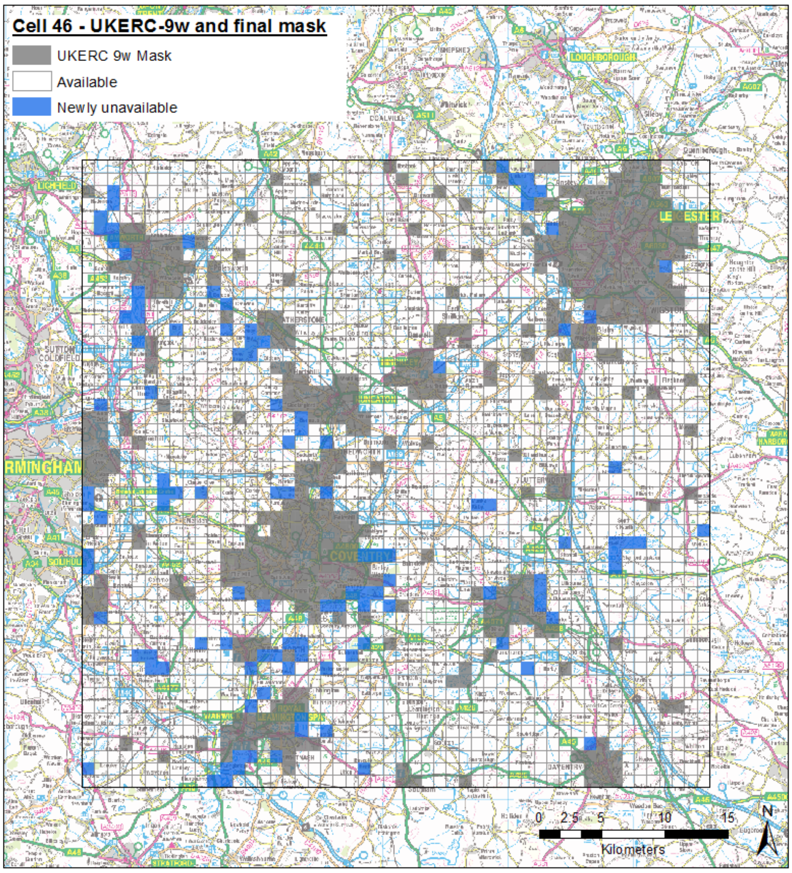


Figure 31: Impact of final mask (newly unavailable) on sub-cell availability in cell 46

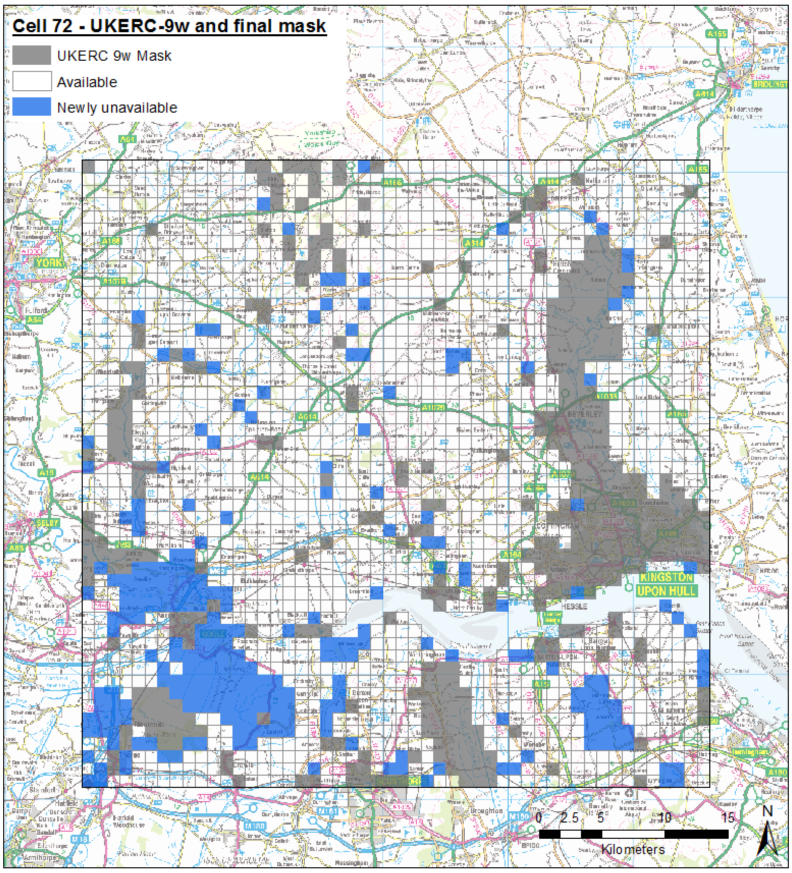


Figure 32: Impact of final mask (newly unavailable) on sub-cell availability in cell 72

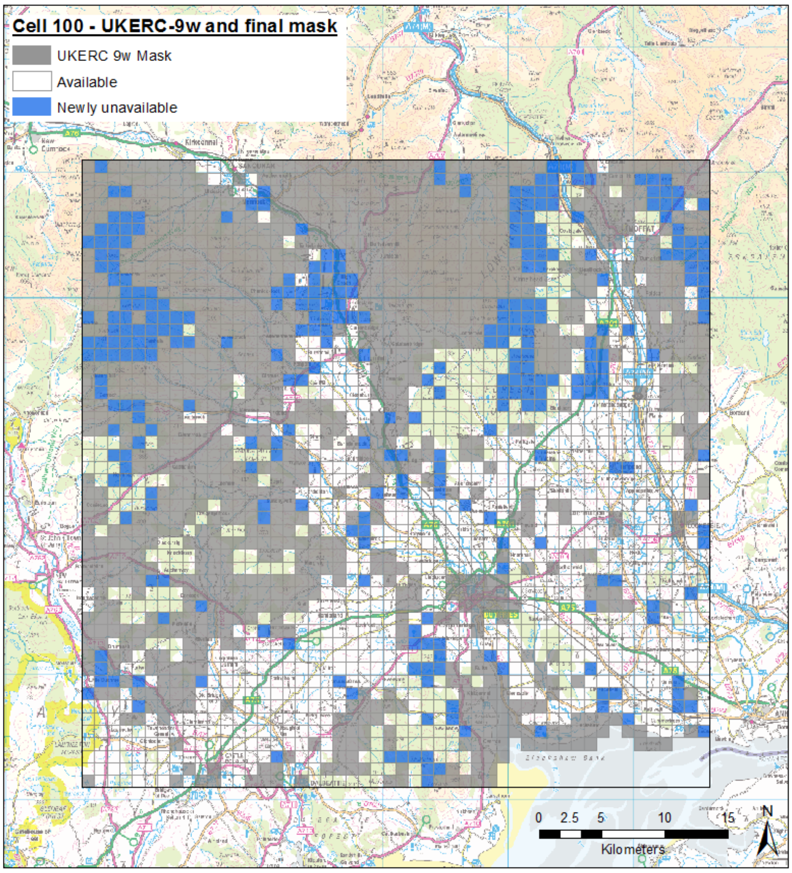


Figure 33: Impact of final mask (newly unavailable) on sub-cell availability in cell 100

Table 33 and Table 34 show the distribution of surveyed sub-cells between available and unavailable according to the final mask used in the desk study, and the field survey. A table for sub-cell 100 is not shown since it is the same as that in Table 23.

Table 33: Contingency table comparing the results from the field survey and final desk study for Cell 19

Cell 19		Desk study		
		Unavailable	Available	Total
Field survey	Unavailable	43	42	85
	Available	20	101	121
	Total	63	143	206

Table 34: Contingency table comparing the results from the field survey and final desk study for Cell 46

Cell 46		Desk study		
		Unavailable	Available	Total
Field survey	Unavailable	7	16	23
	Available	1	178	179
	Total	8	194	202

3.5 Refining estimates of land availability - Conclusion

3.5.1 Field survey conclusions

The field survey results indicates that additional information could be used to further refine the UKERC 9w to further reduce the number of 'available' sub-cells in a cell. The field survey surveyed 610 sub-cells, all of which are 'available' under the UKERC 9w mask. Of these, 137 (or 22% of surveyed sub-cells), were found to be unavailable. However, this reduction was not even across the cells; it ranged from 23 sub-cells (or 11% of surveyed sub-cells) identified as 'unavailable' by the surveyors in cell 046 to 85 sub-cells (41% of surveyed sub-cells) identified as unavailable in sub-cell 019 (Table 35).

Table 35: Summary of sub-cell availability in each of the main cells as assessed in field survey and compared to the desk study initial masks.

	Originally available – UKERC 9w (whole cell)	Newly unavailable (from desk study)	Number of sub-cells surveyed	Available according to field survey	Unavailable according to field survey	Available according to desk study	Newly unavailable according to desk study
Cell 019	1565	696	206	121	85	126	80
Cell 046	2053	280	202	179	23	181	21
Cell 100	1320	318	202	173	29	156	46

The field survey used two different approaches to calculate the 'available' land. The surveyors each completed a table setting out how much land was present of each type and this was categorised as 'available' or 'unavailable'. There was a proportion of the land that the surveyors were unable to see - the 'unknown' area. This accounted for approximately 12% of the survey area and this land was allocated pro rata to the land types accessed in the same sub-cell. This combination of the assessed land area and the allocated land area was used to calculate the 'land area forecast'. In addition, the surveyors looked at other aspects of the cell such as access, presence of scattered trees, utility poles, public rights of way or waterlogging and whether the use of the grassland was agricultural or equine. This was then used to give a surveyor view. In 567 sub cells (93%) the surveyor forecast agreed with the land area forecast, however there were 43 sub-cells were there was disagreement (Table 36).

Table 36: All cells - Comparison of the surveyor forecast with the land use forecast (adjusted to include the unknown areas pro rata) – identification of available vs unavailable land.

Land area forecast (pro rata) Surveyor forecast	Available	Unavailable	Total
Available	444	29	473
Unavailable	14	123	137
Total	458	152	610

There were 29 sub-cells (5%) where the surveyor considered that the sub-cell was available, even though the land area estimates indicated that it was unavailable. The majority of these sub-cells (18) were in cell 019. In half of these sub-cells the available land area was almost 50%, so the pro rata allocation of unknown land could easily skew the selection of available vs unavailable either way. This was also the case for two of the sub-cells in cell 100. In the other half of these sub-cells the surveyor indicated that the larger proportion on the 'unknown' land would appear to be available based on glimpses of the land through trees and through use of map information. The same justification was given for the 8 sub-cells marked as available by the surveyor in cell 046 and for one of the sub-cells in cell 100.

There were 14 cells (2%) where the surveyor thought that the cell was 'unavailable' even though the land area forecast indicated that it was 'available'. The majority of these (11 sub-cells) were in cell 100. Of these, the surveyor indicated that based on mapping and satellite photography there were seven sub-cells that appeared to have a greater amount of 'unavailable' in the 'unknown' as compared to the 'available' and therefore the pro rata allocation would over estimate the amount of 'available' land. The other four sub-cells were considered by the surveyor to be too steep for cost effective short rotation forestry to be planted, although the land was already being used for plantation forestry. Of the three sub-cells that were identified as available based on the land area forecast but unavailable by the surveyor, in cell 019, there was one that contained large areas of gardens and land belonging to a manor house, one that had a vineyard present and one that was used for equestrian purposes. There were no sub-cells identified as available in the land area forecast that the surveyors thought were unavailable in cell 046.

The difference in land use across the available cells became apparent in the survey and was notably different according to where the 50 km x 50 km cell was positioned. In the north (cell 100), improved grassland and coniferous plantations formed the dominant land use covering 71% of the land area. In cell 019 and cell 046 improved grassland and arable were the dominant land cover, with arable being more dominant in the Midlands (cell 046), with 49% arable and 25% improved pasture. This compared to the southern cell (cell 019) of which arable accounted for 19% of the total area and improved grassland 27%. The presence of livestock was recorded and results showed that horses featured more frequently in cell 019 where they were almost equal in dominance to that of sheep and cattle, whilst sheep were dominant in cell 046 and cattle in cell 100.

Unassessed sub-cells

There were approximately 10-12% of the planned sub-cells that could not be assessed due to access or visibility difficulties, with cells 046 and 100 more affected than cell 019. In cell 100 the challenging terrain with hidden valleys and tall trees made it most difficult to see (18 sub-cells), although low cloud did obscure views of an additional six sub-cells. In cell 046 tall hedges caused that greatest challenge with 21 sub-cells inaccessible due to obscured views. In cell 019 there were 12 sub-cells that could not be assessed due to obscured views, predominantly caused by built-up areas adjoining the main road accesses obscuring the view to the land beyond.

Topography and slope

The different cells had very different topography, with cells 019 and 046 being mostly gently rolling and most slope suitable for miscanthus production. In cell 100 the land was more undulating, with increased areas of steep slopes that were suitable only for short rotation forestry or even too steep for that.

Other features

A range of different features were detected in the field survey. Utility poles occurred in 307 sub-cells (50%), with a slightly higher proportion detected in cell 019 (115 sub-cells) compared to the other two cells. Utility poles on their own did not cause surveyors to consider that the sub-cell was unviable, but if the poles fell into an 'available' part of the sub-cell farmers would have to contact the utility companies to confirm whether their plans for bioenergy cropping would impact on the utilities and whether any mitigation was needed, e.g. leaving unplanted areas under power lines (see section 4.3.10). Public rights of way (PROW) were present in 439 of the sub-cells (72%). The highest density of PROWs were in cell 019, where almost all sub-cells contained at least one PROW, whereas in cell 100, just 31% of sub-cells had PROWs. Again these were not on their own considered to be a barrier to availability, although consideration for how to work around the public right of way enabling continuous access would need to be made in advance of planting energy crops.

There were scattered trees present in 324 sub-cells (53%), with this feature being more dominant in the lowland cells (019 and 046) than in the more heavily forested upland cell 100. In 14 sub-cells the presence of scattered trees (in combination with a right of way) were considered by the surveyor make the sub-cell unavailable.

Due to the timing of the survey, waterlogging was not easy to detect as the fieldwork was completed in early autumn, when ground conditions were generally very good. However evidence of waterlogging was detected in 85 cells (14%), but only two of those were considered (in combination with utility poles) to make the cell unavailable (these were both in cell 100). The other main feature that was reported as being a barrier to planting energy crops was the use of land for equestrian activities (horses). There were 5 sub-cells (one or two in each cell) that were considered unavailable due to proportion of the cell in equestrian use. It was considered that although must of this land may be improved pasture it was less likely to be in agricultural use, and therefore unlikely to be converted to energy crops.

Access

All of the sub-cells that were assessed as part of this project had some form of access road in or near them (this is partly as a result of the methodology that required the surveyor to use public access to complete the survey). There were just three sub-cells in cell 100 that had no public road, but these did have access via a forestry track. Road links were reasonable to most sub-cells (especially in cells 019 and 046), with A and B roads and even motorways crossing the cells and providing good road links. Although there were 98 sub-cells in cell 100 where the only access was along a minor road it was not considered that this was a barrier to cell availability. There were 91 sub-cells where at least one route through the sub-cell had weight restrictions or high restrictions on it, but in no cases were these considered to make the sub-cell unavailable due to the availability of alternative routes in and out of the sub-cell.

Advantages of the approach

The approach used for the field survey was able to access 88% of the planned sub-cells, and survey them. The selection of a backup sub-cell for every four planned sub-cells meant that where a sub-cell could not be assessed due to poor access or lack of visibility there was a preselected alternative in that area to visit in its place, minimising any surveyor bias in selecting an alternative. The use of surveyors on the ground meant that a true visual assessment of the land use as available on the day was provided. This means that any land use changes that had taken place in recent years were captured, whereas any mapping layer is only as current as its latest update, which may have been a number of years ago.

Overall a large quantity of information was recorded in the field survey, including some features (bridge/weight limits, waterlogging, livestock, scattered trees, margins, new buildings, roads and verges) that the desk study could not address when deciding if an area is potentially available or unavailable for growing bioenergy crops.

After the first day's surveying of sub-cells it became apparent that it would not be possible to record a good percentage of land cover from just one or two prominent points in the 1 km square. Instead the approach was adjusted slightly to be similar to that of a Phase 1 habitat survey, where the surveyor drove through and round the square wherever access was possible and annotated field use and habitats onto the Ordnance Survey map. Surveyors also used public footpaths to see further across a square, where these were accessible. This flexible approach to the surveying meant that improvements were made to ensure that the accuracy of assessment was as high as possible within the time and access constraints in this project.

Limitations to the approach

There were a number of limitations to the approach that mean the results from the assessment cannot be assumed to be 100% accurate. The main limitation was the requirement for good visibility of the whole of a 1 km x 1 km sub-cell. This was rarely possible from a single location, and often even with multiple locations selected it was not possible to see the whole of the sub-cell. In cell 100 the limiting factors were; no public access in or close to the cell boundary and the steep hillsides with low cloud cover causing limited visibility on some days. In cell 019 and 046 with a flatter, more undulating landscape the limiting factors included; lack of public access, residential properties lining the roads obscuring the land behind and tall, thick hedges, which made estimating land cover beyond the hedge impossible. On average across the 610 sub-cells surveyed, the surveyors were able to assess 88% of the land cover, although this ranged from 50% - 100% across the individual sub-cells.

Estimating percentage cover of different habitats within a 1 km square was challenging and some reliance on using the Ordnance Survey map was necessary to assist estimations and increase the proportion of each sub-cell that could be assessed. Field surveying was kept as consistent as possible by using the minimal number of trained surveyors in each 50 km x 50 km square and monitoring of data as soon as it was available on the SharePoint. However, it should be noted that the assessment of the proportion of available land in each category is subjective and despite using Ordnance Survey mapping to cross check and using trained surveyors that there were slight differences between the surveyors in their assessment of the percentage land use for each category.

As part of the project, photographs were taken on site. However, the need to do this with minimal labelling, whilst allowing the photographs to be allocated to the correct cell meant that there were limitations in the usefulness of the photographs. These were only taken at one point in the sub-cell, looking in four directions and therefore there was a limit to the amount of the 1 km square that was visible. One photograph taken at a number of points and recording the direction might have created a better overview of the variety of land type in each sub-cell, but this would have been more labour intensive to label and complete.

Overall conclusion

The field survey approach used in this project was able to provide ground-truthing information to support the development of more robust estimates of land availability for energy crops. The field survey results indicate that additional information could be used to further refine the BVCM model, reducing the number of 'available' sub-cells in a cell. There are certain aspects of land use that a field survey is better suited to identifying than a desk study, such as the presence of smaller features such as gardens, scattered trees, pylons that individually might not impact on land use but collectively could make sections of land less easy to utilise for biomass production. In addition the field survey was able to detect land uses such as horse pasture, which might not be distinguished in the mapping layers, but could have ownership constraints that make them less likely to be available for biomass production than improved pasture grazed by other stock. However, a field survey can only assess what is visible and barriers such as access, tall hedges, buildings along road edges or poor weather conditions can limit the proportion of the sub-cell than can physically be viewed.

3.5.2 Desk study conclusions

This study analysed the impact of adding additional datasets to BVCM assumptions on land availability for 2G energy crops using desktop GIS analysis and results of the field survey (reported separately). A three-stage approach was taken within five 50 km x 50 km study cells to achieve the objective. Firstly, possible constraints in addition to those covered by the UKERC 9w mask were identified and combined to form a new preliminary mask. Secondly, the resulting estimates of land availability at a sub-cell scale were compared to the results obtained from the field survey for a sample of sub-cells. The results of these comparisons were then used to inform the creation of a final mask that was used to estimate land availability for the five study cells.

All of the datasets that had been proposed for use in the original project outline were assessed for their merits and limitations and several were discounted at an early stage. This was either due to them being unfit for purpose, or because the data sourcing and creation of a suitable spatial data layer would have been too time consuming or expensive, and resulted in little additional benefit. Datasets that represented likelihood of planting rather than constraints to planting were discounted for use in this study as they cannot refine estimates of land availability. A preliminary mask was created from the suitable constraint layers that resulted in a revised estimate of land availability in the study cells of 6,852 km^2, compared to the 9,136 km^2 estimated using UKERC 9w (a reduction of 25%).

Comparisons between preliminary results of the desk study and the field survey made it clear that neither provided a perfect representation of land availability for energy crop planting, which was to be expected. However, investigations into the reasons for mismatches gave a good insight into where there were gaps in the desk study constraints. It is possible that some of these gaps could be filled, but this is likely to involve the use of expensive datasets. In our opinion, the benefits gained by purchase of these datasets would be outweighed by the costs. Some proxies could be used to fill some of the data gaps; for example more roads could be constrained by applying a buffer around linear road features to the average width of the road type.

The results of the statistical analyses, whilst attempting to predict an 'imperfect' dependent variable, provided a means of ranking constraints by their importance. In the England cells, priority habitats were identified as being the most important constraint, followed by semi-natural woodland. In Scotland, priority habitats have not been mapped. Attempts were made to find a proxy, but no suitable alternative was identified. Some of the constraint datasets with more limited spatial coverage could not be statistically assessed because they did not result in a change in sub-cell classification in the surveyed sub-cells.

A synthesis of these results was carried out to inform the choice of the best mask for assessing land availability. The decision was made to include all of the assessed constraint datasets in the final mask with the exception of the stewardship options. Altitude and parks & gardens were included even though the statistical analysis indicated that excluding them gave a better match with field survey results. This decision was taken because evidence from the analysis of discrepancies between desk and field survey showed that these constraints were not always identified by surveyors. Altitude is known to be an absolute constraint and parks and gardens included in the register have particular historic and landscape significance not captured by other datasets. The environmental stewardship option constraint was excluded mainly because the spatial dataset is not being maintained and the area of land under agreement is constantly changing. The estimated percentage of land under relevant stewardship options at any one time could be applied in BVCM as a percentage reduction in availability of all agricultural land as an alternative. If all datasets were available in all UK countries, we would make the recommendation that the same constraint mask is used for all cells. In reality, dataset availability is poorer for Scotland and possibly for Wales and Northern Ireland also. Application of the final mask resulted in a final estimate of land availability in the study cells of 7,701 km^2 (a reduction of 16% from the UKERC 9w mask)

An expectation of the work upon commissioning by the ETI was that it may be possible to apply a 'correction factor' to the current BVCM estimates. The conclusion reached by this study is that this is not possible due to the spatial variation in the constraint layers across the UK, and the fact that the percentage decrease in sub-cell availability was not consistent between study cells (it ranged from 6% to 35% when the final mask was applied). Consideration was given to the possibility of applying a correction factor to a typology, given that the percentage decreases in sub-cell availability were similar (within 4%) for the two cells with the same typology. However this is not advised due to the small sample, the inability to assess all of the constraints in all cells, and the fact that the range of typologies were not fully represented in the study sample.

However, the recipe for creating a constraint mask that could be applied across the UK as far as the data allows is provided as an output. This would require some GIS analysis to be performed. In practice, equivalent datasets to represent the included constraints would need to be sourced for Wales and Northern Ireland. The differences in performance of the masks between Scotland and England due to missing constraint layers in Scotland will also need to be taken into consideration.

Limitations of approach/ lessons learned

Throughout this assessment, it has been necessary to refine the methodology to overcome any limitations identified. One such limitation was the use of the original UKERC 9w mask. As well as overcoming the areas of 'no data' (discussed in section 3.2.1 Addressing the issue of cell misalignment), the mask was not disaggregated. This meant that any misclassifications of cells that occurred due to the UKERC 9w mask could not be identified.

Other limitations with datasets included the access to, or lack of datasets. Some datasets were not able to be used as licence requirements could not be met. In some cases for Scotland, equivalent datasets to those that were identified for England did not exist or were not accessible. Furthermore, where datasets were available, in some cases their impact or relevance could not be properly assessed due to their limited or patchy coverage not coinciding with surveyed sub-cells, or not resulting in a change in classification of surveyed sub-cells.

In the study, the field survey was used as a method of 'ground truthing' the results of the desk study. However the field survey was not able to provide a 'gold standard' against which to test validity of using desk study datasets. Therefore the results of the statistical analysis had to be considered in conjunction with the other evidence before a decision could be made as to inclusion and non-inclusion of constraints. Furthermore, some datasets, such as land productivity, could not be assessed for usefulness due to the variable not being identifiable on the ground, so the decision whether or not to include them in the mask was rather arbitrary. This being said, the survey was still able to identify many cases where the desk study was limited, or where additional datasets needed to be identified.

The study would also have benefited from a larger selection of cells that covered all of the typologies on which to test the different constraint layers. Ideally, at least two cells within each typology would have been required to assess whether or not a correction factor specific to a typology could be applied.

Recommendations

- Re-create a mask for England and Scotland using the constraint layers and methods described in this study and apply the same mask to all England and Scotland cells in BVCM. There is not enough evidence from this study to suggest that a typology should be used to vary the constraints included in the mask.
- Identify equivalent datasets for Wales and Northern Ireland and create a mask for these countries. Apply to Wales and Northern Ireland cells in BVCM.
- Periodically review and update constraint layers that are subject to change.
- Obtain a sample of the UKLand dataset and assess the impact of excluding recreational areas, residential areas (including garden areas) and industrial/retail areas (that would include the car parks) on the land availability.
- Consider applying the percentage of agricultural land under agri-environment scheme agreement at any one time (statistics available from devolved governments) as an overall percentage reduction in agricultural land availability in BVCM (specific to country).
- Consider the use of likelihood layers if using BVCM to target energy crop planting.

3.6 References

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4 Review of processes to convert land to bioenergy crops

4.1 Introduction

The establishment of energy crops requires a number of different steps in order to ensure that local regulations are identified, sensitive environments are protected and the requirements of any grants are met.

The steps that should be taken prior to the planting of Miscanthus, Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) are shown in the flow diagrams below – with the detailed explanation of the steps given in the following text.

In certain cases the onus is on the end user rather than the producer to demonstrate compliance with financial incentives for using bioenergy. Details of these compliance steps are also included in this report as, in many cases, the end user of the fuel is also the supplier. This is the case when a farmer intends to self-supply their own woodfuel for a biomass boiler or an on-farm combined heat and power (CHP) plant.

Figure 34: Flow charts of steps to consider prior to planting Miscanthus

– dominant pathway shown with thicker arrows, EIAs are only required in an minority of circumstances.

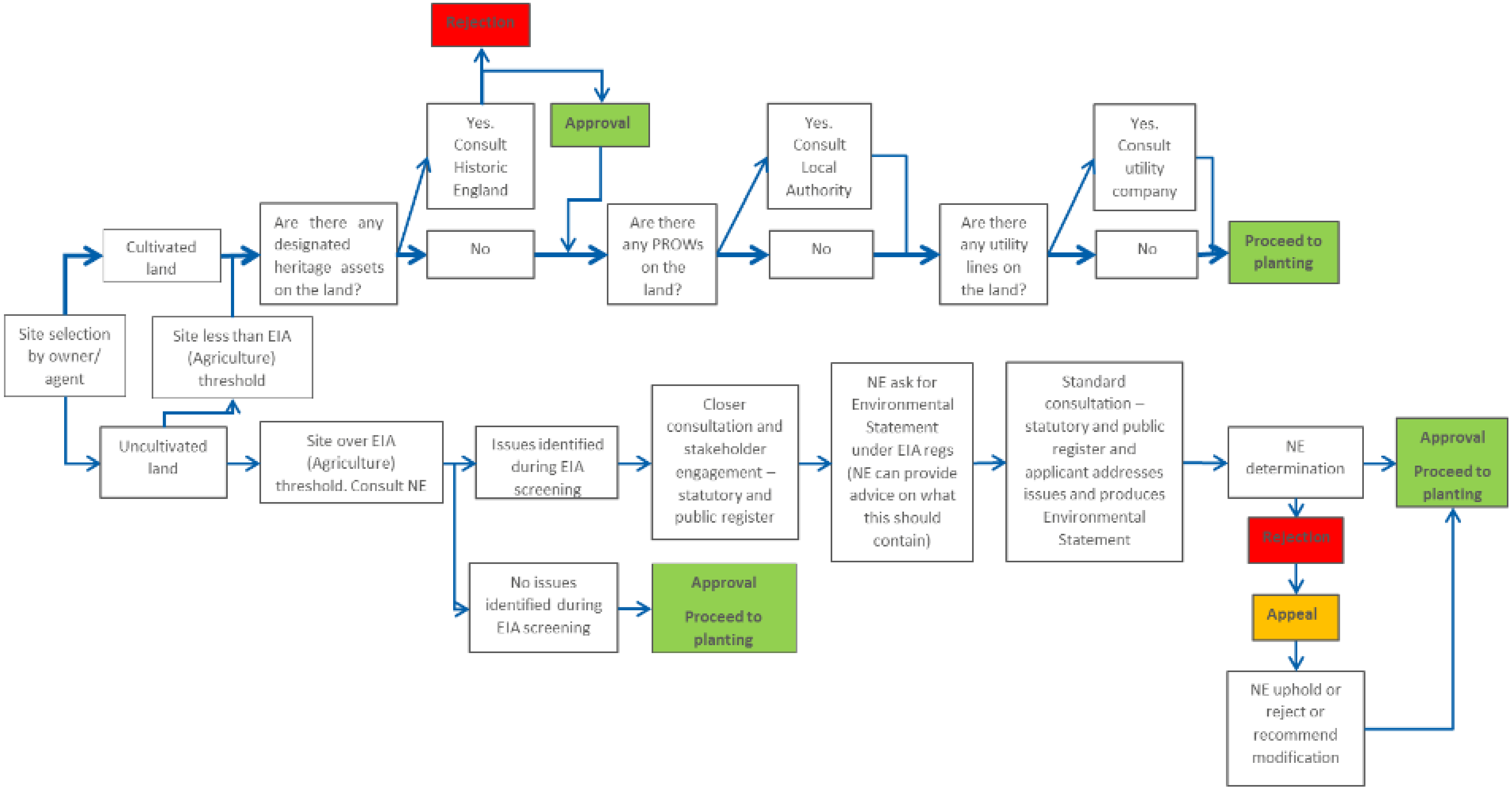
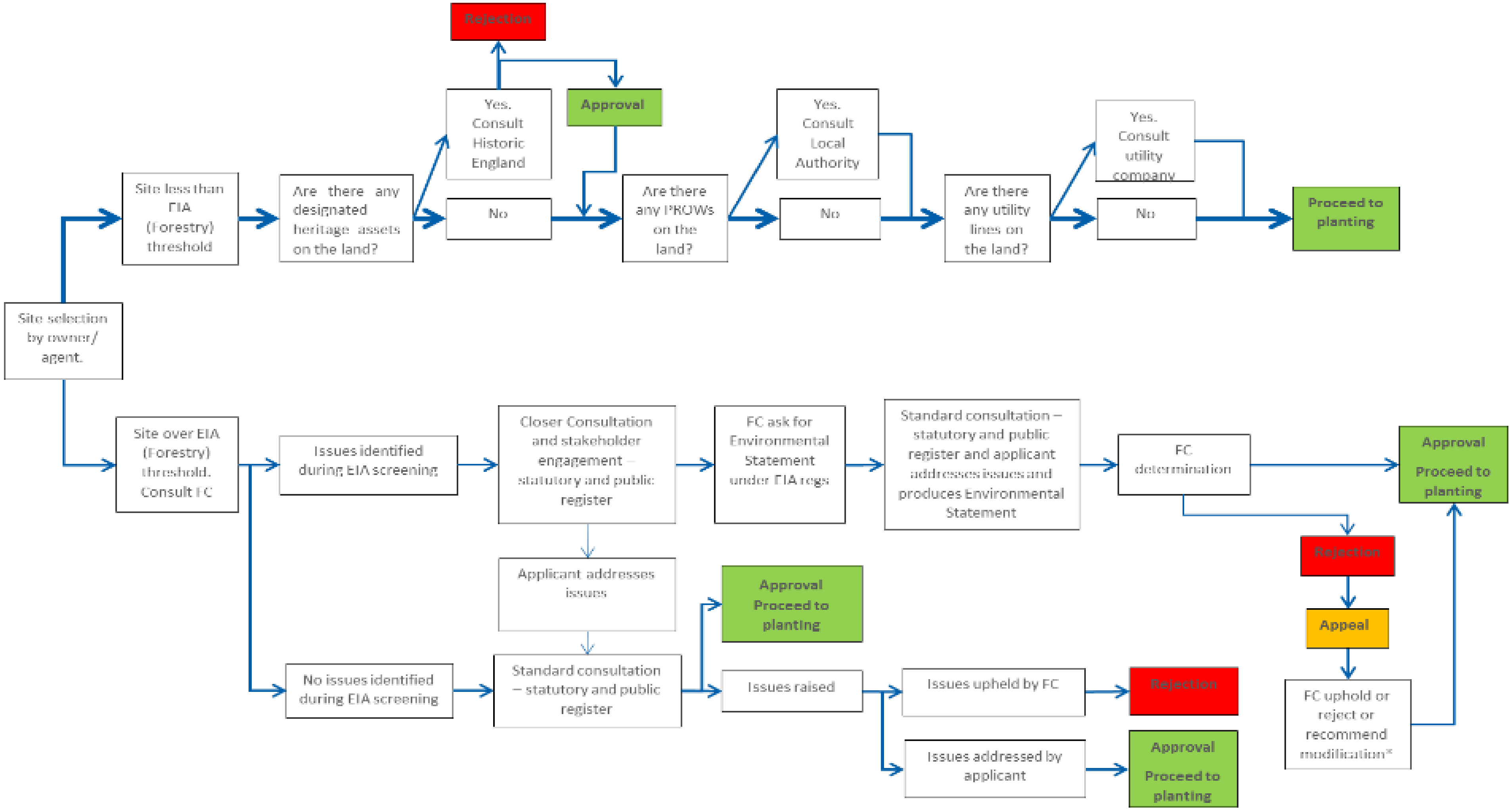


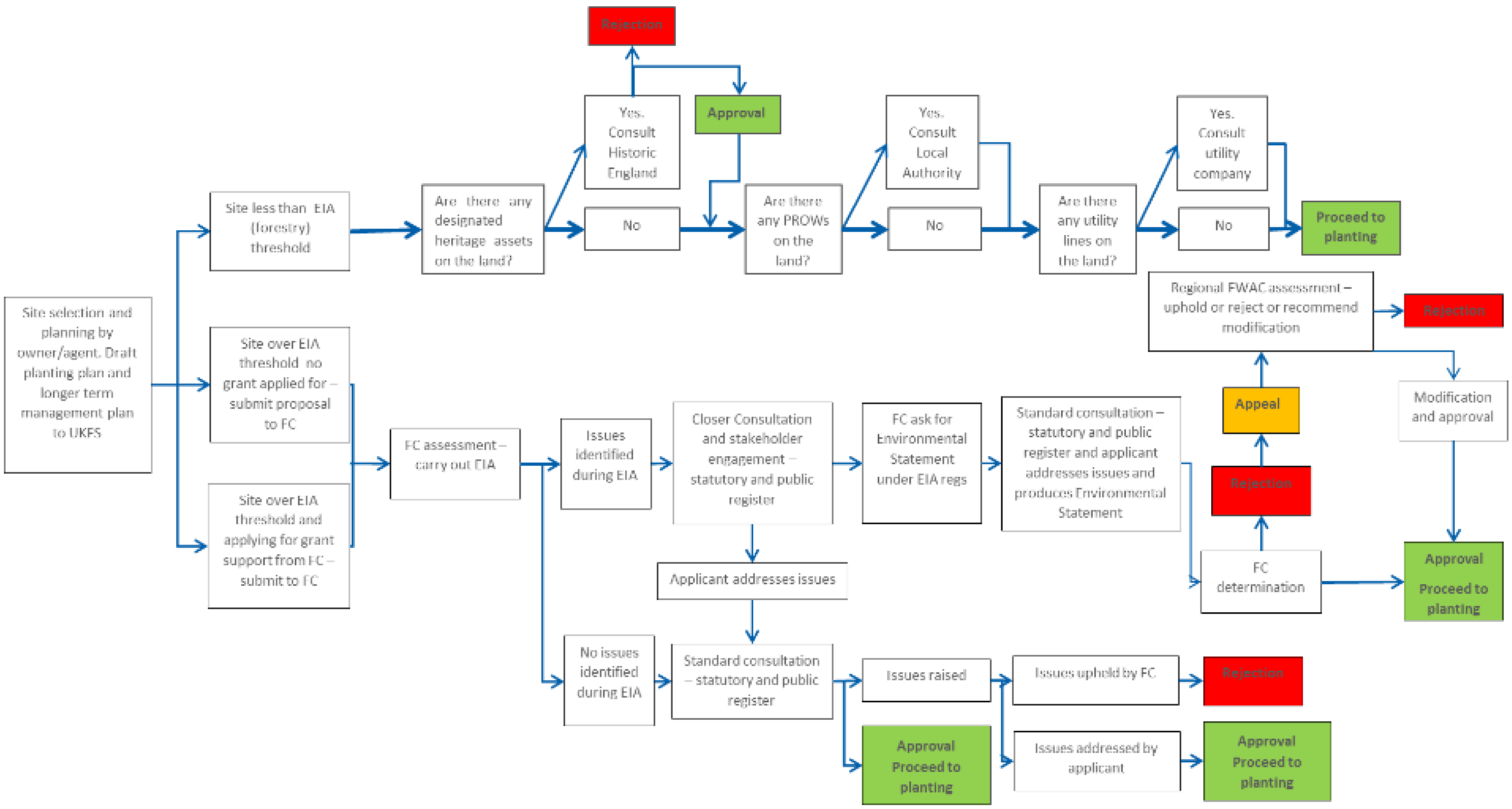
Figure 35: Flow chart of steps to consider prior to planting Short Rotation Coppice (SRC)

– dominant pathway shown with thicker arrows, EIAs are only required in an minority of circumstances.



* If the land owner wishes the land to be under a long term SRC crop (5 or more years between harvests) then a FWAC assessment is available to SRC. In this instance, the SRC would be classified as a forestry crop and not an agricultural crop and follows the same route as SRF.

Figure 36: Flow chart of steps to consider prior to new woodland creation including Short Rotation Forestry (SRF) – dominant pathway shown with thicker arrows, EIAs are only required in an minority of circumstances.



4.2 Land use change regulations

The first step that should be taken prior to converting land to energy crops is to identify if there are any regulatory requirements that need to be met in order to convert existing land to an alternative purpose. These steps include:

- Determining if an Environmental Impact Assessment (EIA) is required.
- Consulting the Local Authority (LA) and other affected stakeholders (such as utility companies).
- Complying with other environmental legislation.
- Complying with planning regulations (where necessary).

Separately, it is important to understand the impact of the land-use change on farm revenue and the requirements of the energy crop end-user, including:

- Understanding the impact of changing land use in the context of Common Agricultural Policy (CAP) and any payments the farm receives.
- Ensuring that the crop can meet the sustainability requirements of financial incentives for renewable energy (such as the Renewables Obligation, Renewable Heat Incentive and Contracts for Difference).

4.2.1 Environmental Impact Assessment (EIA)

The majority of cases the size of the planned planted areas is below that required for an EIA; 2ha for Miscanthus if it is to be planted on previously uncultivated land or 5ha for SRC and SRF. Therefore it is rare that the EIA process is required. However, details of the process are given below for completeness. There are two types of EIA relevant to energy crops: EIA (Agriculture)[22] which covers Miscanthus and EIA (Forestry)[23] which covers SRC and SRF.

EIA Agriculture

If Miscanthus or alternative arable crops are due to be grown on already cultivated agricultural land, there are no requirements on the farmer to apply for consent under the EIA regulations.

The planting of Miscanthus or arable crops may be subject to EIA (Agriculture) Regulations[24],[25],[26],[27]. These Regulations protect uncultivated land[28] and semi-natural areas[29] from being damaged by agricultural work, which could include the planting of Miscanthus or arable crops. The regulations implement the EU EIA Directive and the Habitats Directive with respect to projects involving the restructuring of rural land holdings, and projects for the use of uncultivated land and semi-natural areas for intensive agricultural purposes. The Regulations do not apply to the planting of SRC; this is covered by the Forestry Regulations (see below).

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[22] https://www.gov.uk/guidance/eia-agriculture-regulations-apply-to-make-changes-to-rural-land
[23] http://www.forestry.gov.uk/england-eia
[24] England http://www.legislation.gov.uk/uksi/2006/2522/contents/made
[25] Scotland http://www.legislation.gov.uk/ssi/2006/582/contents/made
[26] Wales http://www.legislation.gov.uk/wsi/2007/2933/contents/made
[27] Northern Ireland http://www.legislation.gov.uk/nisr/2007/421/contents/made
[28] Uncultivated land is defined in the regulations: "means land which has not been cultivated in the previous 15 years"
[29] The term 'semi-natural area' is not defined in the EIA Regulations. However, such areas will be mainly self-seeded or self-propagated vegetation which is naturally characteristic of the area. Scottish Natural Heritage determine whether land is a semi-natural area primarily by reference to the plants it supports, but will also consider a number of other factors, including the natural conditions of the area, the soil type and the degree of cultivation."

On the rare occasion where a farmer wishes to plant Miscanthus/arable crops on uncultivated land, semi-natural land or restructure a rural land holding, and the size of the development is above the relevant threshold set out in Table 37, they must apply to the statutory environment body e.g. Natural England in England for a screening decision[30].

In the case of planting Miscanthus/arable crops, the screening decision will inform the landowner whether their project is likely to have a significant effect on the environment (a 'significant project'). If a project is not deemed to be a 'significant project' then no further permissions are required and they are free to go ahead with planting. The screening decision is usually made within 7 weeks.

Where a project is deemed to be a 'significant project', the landowner must apply to Natural England for consent before proceeding with the project. The application must include an environmental statement (ES). In making their decision on the application, Natural England must not make a decision which goes against Regulations 39, 41 or 43 of the Habitats Regulations (which forbids the destruction of protected plants and animal species and their habitats). Natural England can, on request, provide the applicant with a scoping decision which provides advice on what the ES should contain. Following the submission of an environmental statement, the application and its ES is consulted on by statutory consultees and is placed on a public register. The applicant has the opportunity to address any issues for the application to proceed to approval. If issues cannot be addressed then the application can be rejected. A process is in place whereby the applicant can appeal against a rejection and NE must consider if the application can be further modified to allow it to proceed to approval. An applicant may appeal against a screening decision or a consent decision. The appeal must reach the Secretary of State for Environment Food and Rural Affairs within three months of the decision.

Any farmer who does not comply with the EIA regulations faces a fine of up to £5,000, may be asked to restore the land to its original state and their payments under the Common Agricultural Policy may be affected.

EIA Forestry

Creating new woodland and planting SRC is classified as afforestation under the EIA (Forestry) (England and Wales) Regulations 1999[31], the EIA (Forestry) Regulations (Northern Ireland) 2006[32] and the EIA (Forestry) (Scotland) Regulations 1999[33] which can also cover proposals for forest roads, quarries and deforestation. An opinion from the Forestry Commission (FC) may be required for an afforestation proposal under these regulations.

Depending on whether the proposed application exceeds EIA thresholds (see Table 1 below) the applicant should seek the opinion of the FC (National Resources Wales (NRW) in Wales and Department of Agriculture and Rural Development (DARD) in Northern Ireland) as to whether the tree/SRC planting requires FC's consent.

The FC's decision will depend on whether, in their view, the work is likely to have a significant impact on the environment. This decision is informed by gathering information from the applicant and other interested bodies and individuals through the 'screening' process. There are set area thresholds, which vary depending on whether the site to be planted is within a sensitive area, such as a National Park or Site of Special Scientific Interest (SSSI), which will help to identify if the scheme is a relevant project (Table 1). If a project is above the threshold it is considered more likely to have a significant impact and require consent. In sensitive areas the threshold for woodland creation is two hectares; a threshold of

[30] In Scotland you would apply to the Rural Payments and Inspections Directorate (SGRPID), in Wales to the Welsh Assembly divisional offices and in Northern Ireland to the NIEA.
[31] http://www.legislation.gov.uk/uksi/1999/2228/contents/made
[32] http://www.dardni.gov.uk/index/forestry/forest-environment/environmental-impact-assessments.htm
[33] http://scotland.forestry.gov.uk/supporting/grants-and-regulations/environmental-impact-assessment

five hectares applies elsewhere, except on SSSIs (and other protected sites) where there is no minimum threshold.

Where the opinion is that there is no significant impact or indeed the application is below EIA thresholds, FC's consent is not required and the applicant is able to plant the trees or SRC. The EIA Opinion is valid for five years (or a shorter period if specified). There may still be a requirement for the scheme to go through statutory consultation depending on site constraints and these would be identified by the FC and the applicant informed, however it is usual that the applicant will have considered and addressed any site constraints prior to putting a scheme forward.

Standard consent conditions as set out in the FC's EIA guidance[34] specify the date by which the applicant must start and finish the work. The start date will be no later than five years from the date of consent and the finish date will be no later than ten years from the date of consent.

Where the opinion is that there is likely to be a significant impact formal consent will be needed. The FC will advise the applicant as to whether or not an Environmental Statement (ES) is required in order to obtain consent. The ES analyses the project's significant impacts and its content is usually determined through a 'Scoping' meeting. The ES is subject to consultation with other bodies (such as Natural England and the Local Authority) and must be made available to the public for comment. Several rounds of consultation may be required if the ES requires revision. A decision whether to grant consent is made once the ES is finalised. Where consent is given it must carry conditions that define when the work takes place (start within five years of the consent and end no more than ten years after consent). Other conditions may also be applied to secure any required mitigation.

An ES would typically include the following: detailed site description, how the local community has been consulted and the outcomes, description of current land uses, flora and fauna surveys, landscape surveys, cultural heritage surveys, land use context, soil surveys and climatic factors, but in all cases would be site specific and dependent on the issues raised by FC and it's consultees.

FC must give an opinion within 28 days, where an application for an EIA opinion is made. There is no timescale for the FC to provide an opinion when they are providing this in association with an application for grant aid to support the woodland planting. In most cases it takes longer than 28 days because FC does not provide an opinion until after proposals for tree planting have been subject to the consultation requirements associated with awarding grant aid.

There is no set timescale for granting consent and the time period required to process an application for consent varies greatly depending on the impacts that require consideration. The process will always take several months and can run to years, depending on how many cycles of consultation are required.

It is worth noting that only a handful of cases go through the full EIA process, as most can be dealt with locally or be resolved quickly by applicants submitting more complete information in the early stages.

1.1.1.1.23 Consultation: new planting projects where government funding is sought

The Government provides financial support for woodland through agri-environment schemes across the UK, e.g. Countryside Stewardship (CS) in England. Funding cannot be issued until after the CS application has been available for comment on FC's public register for 28 days. This register shows:

- The location of the land affected;
- The work that is going to be carried out; and

[34] Forestry Commission (2009) Environmental Impact Assessment of Forestry Projects. Accessed online October 2015 - http://www.forestry.gov.uk/forestry/infd-6dfkbc

- The value of the grant applied for.

Members of the public can comment and raise objections to applications on this register. FC will consider all comments and where necessary may ask applicants to adjust their proposals. Once applications have been approved they'll remain on the register, so the public can see which applications will be going ahead. FC will also consult with local authorities and other statutory organisations about the impact of certain types of application.

This consultation process[35], including placing the application on the public register, consulting with the local authority and securing EIA consent (if required), must be completed before agreements can be issued. In the event that this process goes beyond 30 September each year (this being the current annual deadline for CS applications), applications will be rolled over to the following year.

For projects where no CS funding is sought there is no requirement for a scheme to be put on the FC's public register. However, if a scheme is presented to the FC and they deem an EIA to be a requirement before it is to proceed then it is put onto the FC's EIA register and the public have an opportunity to comment on it if they wish. These comments can be taken into account by the FC, or not as the case may be as part of their assessment of the scheme.

1.1.1.1.24 Dealing with an objection

If there is an objection to a scheme requesting CS funding by a consultee and these cannot be resolved locally then there is an opportunity for the objection to be considered by the regional Forestry and Woodland Advisory Committee (FWAC). The FC would in all cases try to resolve any objections before taking it to the FWAC. The long term use of the land is important in the context of the requirement for an EIA with regard to creating SRC plantations. If the land owner wishes the land to be under a long rotation SRC crop (harvested at periods of more than 5 years) then, a FWAC assessment is available to SRC should it be rejected at the application stage and an appeal is made. In this instance, the SRC would be classified as a forestry crop and not an agricultural crop and follows the same route as a standard forestry application. The land owner could of course choose for the land to remain as agricultural by harvesting the crop every 3-4 years.

1.1.1.1.25 Further steps if the applicant seeks government funding

This outline is based on the English Woodland Grant Scheme (EWGS) which ran from 2007 to 2014 and is now closed. A similar process is being developed for CS under the rules for the new Rural Development Programme (RDP) 2014-2021:

- The applicant must confirm to the FC that they meet various eligibility criteria (e.g. ownership details, registering the land on the rural land register etc.).
- The local (FC) Woodland Officer reviews the application to ensure it meets the minimum requirements of the UK Forestry Standard.
- The application is checked to ensure there is no double funding through the agri-environment scheme or other funding stream.
- The EIA process is undertaken as presented above.
- Consultation is conducted in line with consultation guidance for the grant scheme outlined above[36].

[35] http://www.forestry.gov.uk/forestry/infd-6dfl8y
[15] When serious objections to an application are raised through the consultation process, FC will discuss the concerns with all parties to see if we can reach agreement about how the proposals might proceed. In the majority of cases, objections are on the grounds of biodiversity, hydrological, archaeological/historic landscape character or visual impacts. Most conflicts of view are

- Subject to sufficient budget and any outstanding issues being addressed, a contract is issued.
- The applicant must then plant the site to the specification and timing within the contract and make a claim by the contract deadline.

1.1.1.1.26 Returning land to a previous non-forestry land use

In line with the UK Forestry Standard, once land is established as woodland, there "is a presumption against the conversion of forest land to other uses – unless there are compelling reasons in the public interest to do so". Therefore it is extremely unlikely that an owner can reverse their decision to plant woodland (unless there is some overwhelming environmental reason or they gain planning permission). In order to undertake permanent deforestation the process would be similar as above for the EIA process for afforestation i.e. they would have to apply to the FC/NRW/DARD for their opinion on whether consent is required under the EIA regulations. This applies equally to SRC plantations if they have been deemed to be long term or over and above what would be considered to be agricultural rotations.

Normally, in the case of woodland removal for development, Forestry Regulations do not apply and the proposal would be covered by the Town and Country Planning Act and associated EIA regime.

Table 37: EIA thresholds for a requirement to obtain a screening decision

	Project type	Threshold (where no part of the land is in a sensitive area)	Threshold (where project is wholly or partially within a sensitive area)	Consenting organisation (England)
EIA Agriculture	Planting Miscanthus or arable crops on uncultivated land*	2 ha	2 ha	Natural England
EIA Forestry	Afforestation: any tree planting including SRC and SRF on all land types	5 ha	2 ha (National Park, AONB**) No threshold for all other sensitive areas such as SSSIs	Forestry Commission
	Deforestation	1 ha	0.5 ha (National Park, AONB) No threshold for all other sensitive areas	

* Uncultivated land is land that has not been cultivated in the previous 15 years

** AONB – Area of outstanding natural beauty

4.2.2 Planning permission

Planning applications are predominantly managed by local planning authorities. National Infrastructure Planning (NIP) process planning applications for large infrastructure projects such as offshore wind farms, roads and water treatment works.

resolved satisfactorily by modifying the proposal. However, where there is an objection by a statutory authority FC are required to consult under the Ministerial Direction of 1984 and if FC are unable to address their concern (because the proposal meets UK Forestry Standard requirements and is unlikely to cause significant harm to the environment) the 'disputed case procedure' set out in the 1984 Ministerial Direction applies.

Planning rules are set out in primary and secondary legislation. These are listed on the Planning Portal website:

- Acts of Parliament[37]
- Statutory Instruments[38]

The National Planning Policy Framework states that local planning policies should promote the development and diversification of agricultural and other land-based rural businesses. Farms are governed by the same planning rules as other properties. Farmers do need planning permission if they wish to[39]:

- Change the use of land or buildings from farming to something else
- Build a house on their land

Farmers do not need planning permission for the following activities:

- For farming operations
- To use buildings already on the land for farming purposes
- To change the inside of a building, or make small alterations to the outside - e.g. installing an alarm box
- If there are permitted development rights[40]

Permitted development rights mean that if a farm is 5 hectares or more, farmers have the right to:

- Erect, extend or alter a building for agricultural purposes (within limits)
- Carry out excavations and engineering operations needed for agricultural purposes - though they still may require approval for certain details of the development.

Where permitted development rights are available, it is recommended that farmers check with the local planning authority before starting work.

For bioenergy production, farmers do not need planning permission to change the type of crops they grow on existing agricultural land. However, environmental legislation must be also be complied with and therefore other permissions may be required (Section 1.2.5). For instance, planning permission is required if they want to plant crops where there is a historic monument on the intended planting site. Farmers can perform an online search to see if there is a scheduled monument on their farms (Section 1.3.4). If the switch to bioenergy production requires the construction of extra farm buildings for storage or anaerobic digestion, planning permission may be required for these developments, depending on size.

4.2.3 Sustainability requirements for biomass energy projects

Participants in UK Government biomass energy schemes such as the Renewables Obligation (RO), Contracts for Difference (CfDs) and Renewable Heat Incentive (RHI) need to demonstrate that the fuels used are sustainably sourced. In order to comply, biomass fuel must currently (November 2015) meet a lifecycle greenhouse gas (GHG) emissions target of 60% savings against the EU fossil fuel average, and

[37] http://www.planningportal.gov.uk/planning/planningpolicyandlegislation/currentlegislation/acts
[38] http://www.planningportal.gov.uk/planning/planningpolicyandlegislation/currentlegislation/statutoryinstruments
[39] https://www.gov.uk/planning-permissions-for-farms/when-you-dont-need-it
[40] https://www.gov.uk/planning-permissions-for-farms/permitted-development

satisfy land criteria (i.e. adhere to rules on the type of land on which the biomass was produced). Sustainability requirements were introduced for the RO in 2009 (scheme closes to new applications in 2017) and the same criteria were introduced for the RHI from 5 October 2015. Criteria for projects awarded CfDs are determined on a case-by-case basis, as part of the CfD contract.

The following sections are relevant in projects where the end user also happens to be the producer of the fuel. This is the case when a farmer decides to self-supply their own energy crops for a biomass boiler or an on-farm combined heat and power (CHP) plant.

To be eligible for Renewable Obligation Certificates (ROCs) and RHI payments all biomass fuels used for renewable electricity and heat generation will have to report against either the land criteria (non-wood) or the timber standard (wood).

Land Criteria

The Land Criteria sets out that biomass cannot be obtained from land that[41]:

- At any time during or after January 2008 was primary forest
- At any time during or after January 2008 was land designated for nature protection purposes (unless production of that biomaterial did not interfere with purposes for which this land was designated)
- At any time in January 2008 was peatland (unless the cultivation and harvesting of biomaterial did not involve the drainage of previously undrained soil)
- At any time in January 2008 was a continuously forested area (unless that land is still a continuously forested area)
- At any time in January 2008 was a lightly forested area (unless that land is still a lightly forested area, or unless the biomass meets the GHG emission criterion when the GHG emissions from land use change are included using actual GHG values)
- At any time in January 2008 was wetland (unless that land is still a wetland).

Energy crops which have been assessed as meeting the requirements of the Energy Crops Scheme (ECS) or equivalent (i.e. SRC Challenge Fund in NI) are deemed to meet the land criteria. For energy crops planted outside the ECS, Ofgem will accept any proof that the land was farmland in 2008 (such as a map of the plantation and size of holding, deeds, aerial photographs, contractor's receipts showing agricultural work that was done on the land at this time etc.).

Timber standard

The 2014 Timber Standard (TS) for Heat and Electricity[42] sets out the sustainability and land use criteria which the UK Government is applying to the RHI scheme. These criteria closely reflect the internationally agreed, sustainable forest management principles outlined in the UK Government Timber Procurement Policy (UK-TPP)[43]. A key element of this policy is that any wood procured within the UK should be from a legal and sustainable source and should have a demonstrable chain of custody, from the forest source to the end user. The UK-TPP identifies two categories of timber – A and B. Timber from Category A is from recognised certification programmes such as Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) where the chain of custody is unbroken from source to end use. Category B is for all other demonstrably legal and sustainable timber.

[41] https://www.ofgem.gov.uk/sites/default/files/docs/2014/06/renewables_obligation_sustainability_criteria_guidance_0.pdf
[42] https://www.gov.uk/government/publications/timber-standard-for-heat-electricity
[43] https://www.gov.uk/guidance/timber-procurement-policy-tpp-prove-legality-and-sustainablity

The UK as a region is at very low risk of non-compliance with both the TS and UK-TPP. Statistics for 2013 show that 88%[44] of all softwood harvested in the UK is certified under FSC and/or PEFC.

All trees harvested in the UK must either be covered by a felling licence (unless they fall outside the scope of the felling licence regulations – see Appendix 4.1: Felling licences), or to a much lesser degree planning regulations. Planning permission for the removal of trees will be linked to permissions for development and woody biomass material harvested in this way meets the sustainability and legality requirements of the RO and RHI regulations.

Liaison with Gemserv who run the Biomass Supplier List (BSL) suggests that any SRC that was planted without support from the ECS falls under Category B of the Timber Standard[45]. This means that a Risk Based Regional Assessment (RBRA) needs to be filled in. However, as long as the amount of woodfuel produced/traded is less than 750 tonnes/yr then only elementary questions on site activities and a signed declaration need to be filled in.

Felling Licence

Depending on the type of silvicultural system applied e.g. species type and rotation, an SRF project would need to assess the requirement for a felling licence before the felling year is reached. For very short rotations such as 8 years, the stem diameter may not be within the scope of a felling licence whereas a plantation under a longer rotation such as 15-20 years is likely to have a stem diameter within the scope of the felling licence requirements. FC could take the view that as the rotation is so short it is more akin to an agricultural system or SRC and therefore falls outside the scope of the felling licence.

Before commencing felling, all SRF projects should seek advice from the FC as to whether or not, given the chosen species and rotation length, a felling licence would be required at the time of felling.

In any calendar quarter[46], you may fell up to five cubic meters on your property without a felling licence as long as no more than two cubic meters are sold[47]. You do not need a felling licence for trees, which when measured at a height of 1.3 meters from the ground:

- Have a diameter 8 centimeters or less; or
- If thinnings, have a diameter of 10 centimeters or less; or
- If coppice (i.e. managed by cutting to promote multi-stemmed growth arising at or near ground level) or underwood, have a diameter of 15 centimeters or less.

Other types of felling that do not need permission from the FC are listed in Appendix 4.1: Felling licences.

Achieving compliance under the Renewables Obligation

RO accredited biomass power plants are required to provide Ofgem with the following sustainability information[48]:

- Monthly reporting

[44] http://www.forestry.gov.uk/website/forstats2014.nsf/0/5646FE817AB3C3A680257322004AF3B4
[45] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/352488/Woodfuel_Advice_Note.pdf
[46] 1 January to 31 March, 1 April to 30 June, 1 July to 30 September and 1 October to 31 December
[47] Forestry Commission (2007) Tree Felling Getting Permission – accessed online October 2015 - http://www.forestry.gov.uk/england-fellinglicences
[48] https://www.ofgem.gov.uk/sites/default/files/docs/2014/06/renewables_obligation_sustainability_criteria_guidance_0.pdf

    - Report against the land criteria or timber standard criteria and GHG criteria each month as part of each ROC claim (this is only required for generating stations with a declared net capacity of more than $50kW_e$)
- Annual reporting
    - Provide a sustainability audit report, as compiled by an independent auditor, to verify the sustainability information reported to Ofgem (this is only required for solid biomass and biogas plants with a total installed capacity of $1MW_e$ or more).
    - Provide 'profiling data' for the biomass used within the obligation period. This includes information on the sustainability characteristics such as type of biomass, form of biomass, country of origin and whether it conforms to any environmental quality assurance standards (this is only required for generating stations with a declared net capacity of more than $50kW_e$).

The authors are unaware of any dedicated electricity/CHP self-supply projects using Miscanthus and SRC in the UK.

Achieving compliance under the Renewable Heat Incentive

For RHI participants there are two methods to meet the sustainability criteria[49]:

- Sourcing woodfuel from the Biomass Suppliers List (BSL)[50], and providing Ofgem with a quarterly declaration that the biomass fuel used was registered on the BSL and marked as sustainable. At the time of writing, only woody biomass sources (roundwood (hardwood and softwood), primary processing sawdust and chip, arboricultural arisings, SRC and waste wood) are on the BSL. Self-suppliers of wood sourced from farm woodlands or SRC produced on their own farm can register as self-suppliers on the BSL.
- Self-reporting to Ofgem on the sustainability of the fuel[51]. For farmers who are using self-supplied Miscanthus and/or agricultural residues in solid biomass boilers this involves agreeing a Fuel Measurement and Sampling (FMS) procedure with Ofgem, providing documentary evidence that the fuel used meets the land criteria and performing a lifecycle greenhouse gas (GHG) analysis using the UK Solid and Gaseous Biomass Carbon Calculator (B2C2) tool. Furthermore, growers need to make a quarterly declaration that the fuel continues to meet the GHG savings and land criteria. In addition, installations of $1MW_{th}$ or above must provide an annual independent sustainability audit.

4.2.4 Common Agricultural Policy (CAP)

The current CAP period runs from 2014 to 2020. The new Basic Payment Scheme (BPS) was introduced for UK farmers on 1st January 2015 and is scheduled to last until 2019. The Basic Payment (BP) will be a yearly payment given to farmers as long as certain land management rules (e.g. 'greening' and cross compliance) are followed. Growers of energy crops need to adhere to these rules.

[49] https://www.ofgem.gov.uk/sites/default/files/docs/2015/10/easyguide_to_sustainability_web_publish.pdf
[50] http://biomass-suppliers-list.service.gov.uk/
[51] https://www.ofgem.gov.uk/sites/default/files/docs/2015/10/sustainability_self-reporting_guidance_v1_publish.pdf

Cross compliance

'Cross compliance' is a set of rules which tells applicants what they must (and must not) do to receive rural payments including the BP, Countryside Stewardship (CS) and woodland grants[52].

The cross compliance rules include:

- A requirement to keep land in Good Agricultural and Environmental Condition (GAEC). This includes measures relating to soil erosion, soil organic matter and soil structure, habitat protection and protection and management of water
- Statutory Management Requirements (SMRs). These relate to the areas of public, animal and plant health, environment and animal welfare.

The GAEC and SMR requirements are summarised in Appendix 4.2: . This also indicates the relevance of each measure to energy crops and tree planting.

Greening

There are various top ups to the BP available. The most important is the 'greening' element which is termed 'agricultural practices beneficial for climate and the environment'. This increases the BP by 30% and claimants could lose all or part of this if they fail to comply with the rules. Penalties beyond this will be introduced from 2017 e.g. an additional 20% of the BP in 2017, 25% in 2018.

There are three greening measures that need to be complied with:

- Crop diversification
- Ecological Focus Areas (EFAs)
- Retention of permanent grassland

The third of these does not affect individual farmers directly as the rule is applied at national level, i.e. the area of UK grassland should not fall below 95% of the 2015 area.

There are three basic types of land considered under greening:

- Permanent grassland (Land that has been grass for 5 or more years)
- Permanent crops (covers Miscanthus and SRC)
- Arable land (includes crops, temporary grass and fallow land).

Crop Diversification

Any farmer with more than 10 ha of arable land will need to have a variety of crops planted on their land. The rules are applied as follows:

- Areas less than 10 hectares of arable are exempt from this requirement
- Areas of 10-30 hectares – need to have a minimum of 2 crops (main crop not more than 75% of the arable area)
- Over 30 hectares – need to have a minimum of 3 crops (main crop not more than 75%, two main crops not more than 95%)

The following exemptions apply:

[52] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/397044/Cross_compliance_handbook_v2_web.pdf

- More than 75% of the arable land is used for temporary grass or left fallow (if cropped area < 30 hectares)
- More than 75% of the eligible agricultural area is permanent or temporary grassland or used to cultivate crops grown in water (e.g. watercress) and the remaining arable land <30 hectares.

SRC, Miscanthus and SRF are classed as permanent crops (not arable). If a farm has more than 10 hectares of arable land in addition to the land planted with energy crops then they would still have to follow the crop diversification rules.

Ecological Focus Areas (EFAs)

Any farm with more than 15 hectares of arable land must have 5% of the land in EFAs. This could rise to 7% after 2017. EFA measures can be thought of as land set aside for environmental benefits. The long list of EFA measures proposed by the European Commission (EC) to member states included SRC. This has been adopted in Wales and Northern Ireland, but not in England or Scotland (Table 38). It is worth noting that to date, about 90% of energy crops planted in the UK has been in England[53].

Table 38: EFA measures adopted in different parts of the UK

Measure	England[54]	Scotland[55]	Wales[56]	Northern Ireland[57]
Fallow land	✓	✓	✓	✓
Hedges	✓		✓	✓
Buffer strips	✓	✓		
Catch crops or green cover	✓	✓		
Nitrogen fixing crops	✓	✓	✓	✓
Field margins		✓		
Ditches				✓
Traditional stone walls			✓	✓
Archaeological features				✓
Earth banks				✓
Agroforestry				✓
Short rotation coppice			✓	✓
Afforested areas			✓	✓

A conversion matrix is used to translate the lengths/areas of the EFA measures into equivalent land areas depending on how environmentally friendly they are deemed to be. Where SRC has been included as an EFA measure it (along with catch crops/green cover) has been assigned one of the lowest weightings (0.3). This means that one hectare of SRC only counts as 0.3 hectares when the calculating the percentage of EFA of the total farm area.

If an entire farm is planted with Miscanthus or SRC, or has less than 10 ha of arable land in addition to the area planted with permanent energy crops, then the greening measures do not apply. As long as the farmer meets other eligibility criteria then the farmer will receive the full BP. If a farm's arable area is at or just above one of the key trigger areas (10ha, 15ha or 30ha, then farmers could plant permanent energy crops to reduce their total arable area below the key trigger points.

[53] E4tech (2013) Energy crop competitiveness and uptake report. Available in the internal ETI database or from E4tech with ETI's permission
[54] https://www.gov.uk/government/collections/common-agricultural-policy-reform#greening-and-double-funding
[55] http://www.gov.scot/Resource/0047/00472454.pdf
[56] http://gov.wales/docs/drah/publications/150812-bps-greening-guidance-2016-en.pdf
[57] http://www.dardni.gov.uk/guide-to-the-greening-payment-2015.pdf

Table 39: Rules relating to the use of SRC as an EFA measure in Wales and Northern Ireland.

Feature	Wales	Northern Ireland
Species covered	Alder, Birch, Hazel, Ash, Lime, Sweet Chestnut, Sycamore, Willow and Poplar	
Max harvest cycle (years)	20	5
Weighting factor	0.3	
Area (m^2) of EFA	$0.3m^2$	
Conditions	No requirement to be on or adjacent to the arable land of the holding	
	No applications of mineral fertiliser allowed	
	No use of plant protection products, except for spot treatment of invasive non-native species, e.g. Rhododendron, Japanese knotweed and Himalayan balsam, as well as invasive injurious weeds e.g. common ragwort, dock, curled dock, within the first two years of planting	Plant protection products will not be permitted beyond the end of the second growing season post planting

4.2.5 General environmental legislation

Most farms will be claiming the basic payment (BP) and therefore will have to adhere to the cross compliance rules laid out in Section 1.2.4 and Appendix 4.2: GAEC and SMR measures. However, farms of less than 5 hectares who cannot claim the BP will also have to adhere to UK and EU environmental legislation. This is set out in Appendix 4.3: General environmental legislation. Much of this is very similar to that covered by Good Agricultural and Environmental Conditions (GAEC) requirements and Statutory Management Requirements (SMRs).

4.3 Current roles and responsibilities of different agencies

4.3.1 Natural England (and equivalent agencies in devolved administrations)

Natural England (NE) is the Government's adviser for the natural environment in England with a role in helping to protect England's nature and landscapes. They have a very wide remit (involving biodiversity, climate change adaptation, CAP reform, rural economy and water quality) and ran the Energy Crops Scheme (ECS) from 2008. Although the ECS closed to new applicants in September 2013, as a result of deferred applications there were still some new plantings taking place in 2015. This means that NE will still be making grant payments until the end of 2016 and holding agreements with growers until 2021.

Outside the ECS, NE has a very marginal interest and role in energy crops. However, many of the schemes and initiatives they run are relevant. For instance, a landowner who would like to plant Miscanthus on uncultivated land would need to consult NE and might be requested to embark on an EIA Agriculture (see section 1.2.1). NE also manage the Countryside Stewardship scheme (CS) and Catchment Sensitive Farming (CSF) scheme and in 2015 provided capital grants of up to £10,000 to help farmers reduce diffuse water pollution. This initiative could be relevant to a farmer wishing to plant energy crops as a means of improving water quality, but it is not clear if this grant scheme will continue in the future.

NE are in charge of various web portals used for checking landscape classifications, land based designations etc. These include:

- The Magic website[58] which provides an interactive map of geographic information covering the rural, urban, coastal and marine environments across Great Britain
- The SHINE (Selected Heritage Inventory for Natural England) website[59] which is a dataset of undesignated historic environment features from across England that could benefit from management within the CS. The latter is used by NE staff to request a Historic Environment Farm Environment Record (HEFER), a record of historic features suitable for management derived from the local authority historic environment record. CS applicants should use this information to ensure that historic environment features within the application area are not impacted by the options and capital items being proposed.

The equivalent remit In Scotland is covered by the Scottish Natural Heritage and Scottish Environmental Protection Agency; in Wales by Natural Resources Wales and in Northern Ireland by the Department of Environment Natural Environment Unit and NI Environment Agency.

4.3.2 Forestry Commission (and equivalent agencies in devolved administrations)

Forestry is also a devolved matter and the responsibility rests with Forestry Commission (FC) England, FC Scotland, Natural Resources Wales and the Department of Agriculture and Rural Development NI (DARDNI). The FC in England is involved in tree planting and woodland management, tree pests and diseases, grants, felling licences, forestry policy and woodfuel. In the past it has been very involved with SRC mainly through Forest Research (which ran a UK wide trials network and produced guidance notes) and through the Biomass Energy Centre. Recent energy crop related work has centred on SRF trials (involving native and exotic species) in England and Scotland.

The FC and its equivalent bodies in the devolved administrations support afforestation through the Rural Development Programme (RDP) funded Countryside Stewardship scheme in England, the Forestry Grant Scheme in Scotland, Glastir in Wales and the Forestry Grant Scheme in Northern Ireland (see section 2.2.4). These bodies are responsible for undertaking EIAs on afforestation schemes and providing an opinion on them.

4.3.3 Environment Agency (and equivalent agencies in devolved administrations)

The Environment Agency (EA) is the agency that is in charge of protecting the environment. Its responsibilities include flood warnings, flood risk maps, flood defence schemes, environmental permits and exemptions, waste and contaminated land. They work closely with Defra and Natural England (NE) on nutrient management, nitrate vulnerable zones (NVZs) and catchment sensitive farming (CSF). SRC, Miscanthus and SRF could be planted in NVZs and CSF areas in order to reduce diffuse pollution[60]. Farmers can find out if there farmland is in an NVZ by using the *What's in your backyard* portal managed by the EA[61].

In the past the EA has produced a regulatory position statement on the application of treated landfill leachate to SRC (2008)[62] and commissioned work that led to a report[63] and briefing note[64] on the

[58] http://www.magic.gov.uk/
[59] http://myshinedata.org.uk/
[60] http://www.forestry.gov.uk/pdf/fce-catchment-sensitive-farming.pdf/$FILE/fce-catchment-sensitive-farming.pdf
[61] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683&y=355134&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=nvz
[62] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/322320/leachate_1965094.pdf

possible flood risks and benefits of planting energy crops on flood plains (2010). The latter were not formally published on the EA website when the work was completed. It is thought that this oversight was as a result of a staff member being reallocated to a different project at this time[65]. However, the EA are intending to publish these outputs on their website in November 2015. The aims of the work were threefold:

- To make sure that energy crop applications under the Energy Crops Scheme (ECS) were not unnecessarily refused on a precautionary basis
- To explore a range of energy crop plantation configurations on the floodplain and how these might influence 1 in 100 year flood water levels
- To inform new guidance and practice regarding energy crops on floodplains and supplement EA guidelines entitled Flood Risk Management: Woodland, tree planting and flood risk.

Post ECS, new growers of energy crops are unlikely to come into contact with the EA unless they are intending to use the plantation as a bio-filtration system or to clean up a contaminated site.

A similar remit is dealt with by Natural Resources Wales, Scottish Environment Protection Agency (SEPA) and Northern Ireland Environment Agency (NIEA).

4.3.4 Historic England (and equivalent agencies in devolved administrations)

Historic England is the body that looks after England's historic environment and is responsible for identifying and protecting designated heritage assets (e.g. archaeological remains, scheduled monuments and battlefields).

A useful document was published in 2006 called *Biomass Energy and the Historic Environment*[66]. Although some of the planning references are out of date it still provides some helpful advice, guidance and case studies.

Under the ECS, the FC or NE would check whether there were any historic remains (be they designated or non-designated) as part of their site visit. This is still done under the Countryside Stewardship scheme and woodland grant schemes. However, any farmer who wants to plant energy crops and be certain that they are not going to cause any harm to archaeological remains will need to do a check themselves. They can do this by searching the Heritage List for England and do a location search[67] to find records within a particular county, district, parish, constituency or region. Farmers should be encouraged to do this as it will give peace of mind that they are staying within the CAP cross compliance rules. If there are no scheduled monuments on a farmer's land then they don't need planning permission to plant energy crops (see section 4.2.2 for details on planning permission requirements).

4.3.5 Local authorities

Local authorities are responsible for planning issues concerning non-designated heritage assets. These include buildings, monuments, sites, places, areas or landscapes identified as having a degree of significance meriting consideration in planning decisions, but which are not formally designated heritage assets. Of course not all archaeological remains on farmland have been identified so there is a danger

[63] http://www.crops4energy.co.uk/wp-content/uploads/2015/09/JBA-consulting-Energy-crop-report.pdf
[64] http://www.crops4energy.co.uk/wp-content/uploads/2015/09/Energy-Crops-Flood-Guidelines.pdf
[65] Doug Whitfield Research Expert, Environment Agency Evidence Directorate , Flooding and Communities Team, personal communication 06/1/2015.
[66] https://content.historicengland.org.uk/images-books/publications/biomass-energy-historic-environment/biomass-energy.pdf/
[67] http://list.historicengland.org.uk/advancedsearch.aspx

that planting energy crops could be have a harmful effect. Nevertheless, farmers are not compelled to contact their local planning team before they plant.

As part of the cross compliance rules it is necessary to maintain public rights of way (PROW). The owner or occupier of land with a PROW across it must keep the route visible and not obstruct or endanger users. Local authorities will normally have a 'definitive map' of the local area showing all the PROWs. A landowner should consult with their local authority as failure to comply could result in a reduction of the basic payment or other rural payments. Local Authorities don't (in themselves) have the power to veto any energy crop planting plans.

4.3.6 Defra (and equivalent agencies in devolved administrations)

Defra is the UK government department involved in safeguarding the environment, supporting the food and farming industry and rural development. Defra works closely with 34 agencies and public bodies including NE, FC and EA[68]. Agriculture and the environment are devolved issues with Defra covering England only. The remit is also dealt with by the Scottish Government, Welsh Assembly and the Department of Agriculture and Rural Development NI. Defra were ultimately responsible for supporting energy crops in the past with over a decade of support through the Energy Crops Scheme (ECS).

Despite the current lack of policies which provide direct financial support for energy crops, Defra still has a very important impact on the energy crops sector as they deal with agriculture policy, rural development policy and define the agricultural and environmental research agenda.

4.3.7 DECC

DECC covers the entire UK and is responsible for securing clean, affordable energy supplies and promoting international action to mitigate climate change. It works with nine agencies and public bodies including Ofgem and the Committee on Climate Change. DECC are not directly involved in energy crops and will normally forward any energy crop related queries to Defra. However, the activities of the department which include; energy policy, defining the energy research agenda, providing renewable energy incentives (e.g. RHI, FITs, CfD etc.) and rules governing sustainability lists, have a marked impact on energy crops.

4.3.8 Ofgem

Ofgem is the Office of Gas and Electricity Markets whose principal objective is to protect the interests of existing and future electricity and gas consumers. They are charged with managing the Renewables Obligation (RO) and both the domestic and non-domestic Renewable Heat Incentive (RHI see section 2.3.2) including the portal through which applicants apply for RHI accreditation, provide quarterly meter readings and self-report on sustainability criteria.

4.3.9 Biomass Suppliers List (BSL)

The BSL is the sustainability list for producers, producer/traders, traders and self-suppliers of woodfuel. Participants of the RHI using wood as their fuel need to source it from a provider on this list (unless self-reporting). Using the BSL is currently free, although it is likely that an annual fee will be introduced when

[68] https://www.gov.uk/government/organisations#department-for-environment-food-rural-affairs

Government funding ceases in March 2016[69]. It is administered by Gemserv, with expert input from Woodsure and Hetas.

4.3.10 Other organisations/people that should be consulted

Under the ECS it was necessary to consult with utility companies if there were power lines on a field that the farmer wished to plant. This is most important for SRF and SRC. SRC which grows to a height of 7-8m after 3 years and could have the following repercussions:

- Coppice stems could interfere with and possibly damage overhead wires
- May put harvesting operatives in danger from electric shock
- Make it more likely that accidents could occur between the harvester and pylons (due to the dense nature of the crop)
- Make it more difficult for utility company to access pylons and carry out any routine repair and maintenance.

As part of the ECS, a 6m strip was necessary under a power line. It would be practical for future growers of energy crops to discuss their plans with the relevant utility company before carrying out planting. Utility companies do not have the power to prevent a planting scheme from taking place but should seek a compromise such as moving a plantation away from the power line or leaving a sufficient wayleave.

Although it is not necessary for farmers to consult with their neighbours on what they intend to plant, it might be worthwhile to do this in order to preserve relationships. The height of SRC crop (and to a lesser extent Miscanthus) could restrict views and cause friction. There are cases in the past of farmers removing SRC because of complaints about the numbers of willow beetles entering neighbouring properties[70]. Growers should be aware of these issues before they plant.

[69] Wood Heat Association Business Plan 2016 – Presentation by Julian Morgan Jones, Chairman, WHA at Wood Heat 2015 Conference, 4-5 November 2015, Bristol.
[70] Gareth Gaunt, Chairman of Regro personal communication.

Table 40: Current roles and responsibilities of the agencies involved in energy crops and woodland management

Agency (England)	Involvement in energy crops/tree planting	Responsibilities
Natural England	Energy Crops Scheme; Countryside Stewardship scheme; Catchment Sensitive Farming	Managing claim forms and ongoing agreements under ECS2 until 2021 Statutory body dealing with EIA (Agriculture)
Forestry Commission	Woodland Grant Schemes	Statutory body dealing with EIA (Forestry); Felling licenses
Environment Agency	Energy crops and flooding; Discharge of wastewater; nitrate vulnerable zones	Statutory consultee for discharge of wastewater and treated effluent through bio-filtration systems
Historic England	Protecting designated heritage assets	Statutory consultee for growers wishing to plant on sites with scheduled monuments etc.
Local authorities	Protecting non-designated heritage assets; Maintaining public rights of way (PROWs)	Statutory consultee for growers wishing to plant on sites with non-designated heritage assets and PROWs
Defra	Energy Crops Scheme, CAP reform, Rural Development, Funds; Air quality	Agriculture policy; Rural development policy; define the agricultural and environmental research agenda; apply air quality standards and emissions levels from biomass boilers
DECC	Renewable energy incentives (ROCs, CfD, RHI)	Energy policy; define the energy research agenda; in charge of sustainability lists
Ofgem	RO, Domestic and non-domestic RHI	Delivery of Government renewable schemes; Develop guidance notes on sustainability compliance, host carbon calculators

5 Review of opportunities and barriers

This part of the report considers the relative ease or difficulty by which farmers and landowners can convert their land to energy crops or forestry. In the sections below we provide an expert view of the barriers to land use conversion, how they might be addressed and identify where opportunities can be promoted. We deal with five areas: information, finance, regulations/policy, markets and practical considerations.

5.1 Information

If the UK is to produce more bioenergy from its land then farmers will need to play a major role in the supply chain. However, lack of knowledge is frequently cited as one of the main reasons why farmers are deterred from land conversion to energy crops and trees[71],[72].

Before a grower plants an alternative crop like Miscanthus, Short Rotation Coppice (SRC) or Short Rotation Forestry (SRF) they would normally want to get as much information as possible so they can be sure that they are making the right decision that fits well with their land, their facilities and the local market. Initially, would-be growers are likely to seek out and read official guides on how to prepare land and manage an energy crop. Following this, they may wish to read articles on the internet and in the trade press to find out more about successful projects and local markets. They might be prepared to go on a farm walk or attend a seminar to hear from expert practitioners. All of this might help them come to their own decision, but some may wish to get third party independent advice from a consultant or a trade body to make sure they aren't missing something. Some will be sufficiently interested in the subject that they are prepared to go on an accredited course to find out as much as they can about the subject.

Below we summarise the information that is available and identify some of the gaps that exist which, if filled, may encourage more farmers to plant energy crops.

5.1.1 Official growers guidelines

Various official best practice guideline documents have been produced in the UK and Ireland over the last 15 years. However, most of the documents were produced in order to provide guidance to growers in England as part of the Energy Crops Scheme (ECS). The last updates for SRC, Miscanthus and broadleaved coppice were done as part of the remit of Biomass Energy Centre (BEC) in 2007, but the manuscripts were never turned into professionally formatted and designed booklets (i.e. they were published as PDFs of the original Word documents). Furthermore these documents do not relate to the current CAP programme or reflect recent developments in best practice. The most up to date information on Miscanthus in England has been produced by Terravesta in their Essential Growers Guide most recently updated in 2015. By contrast, in Ireland and Northern Ireland ongoing collaboration between Teagasc and the Agri-Food and Biosciences Institute (AFBI) has enabled the production of up to date (2015) and very comprehensive publications on SRC and Miscanthus. There are no specific SRF

[71] Prospects for arable farm uptake of Short Rotation Coppice willow and miscanthus in England. Neryssa J. Glithero, Paul Wilson, Stephen J. Ramsden. Applied Energy Volume 107, July 2013, Pages 209–218. http://www.sciencedirect.com/science/article/pii/S0306261913001402

[72] Eves, C., Johnson, M., Smith, S., Quick, T., Langley, E., Jenner, M., Richardson, W., Glynn, M., Anable, J., Crabtree, B., White, C., Black, J., MacDonald, C., and Slee, B. (2014). Analysis of the potential effects of various influences and interventions on woodland management and creation decisions, using a segmentation model to categorise sub-groups - Volume 4: Woodland creation segmentation Defra, London http://www.forestry.gov.uk/pdf/Volume-Four_Woodland-creation-segmentation.pdf/$FILE/Volume-Four_Woodland-creation-segmentation.pdf

best practice guidelines. The nearest thing to this is a review by Forest Research in 2011 called *Short Rotation Forestry: Review of growth and environmental impacts*[73].

The following best practice guideline documents are available for SRC and broadleaved coppice:

- Short Rotation Coppice in the Landscape. *Forestry Commission Guideline Note*. 2001[74]
- Establishment and Management of Short Rotation Coppice. *Forestry Commission Practice Note*. 2002[75]
- Growing Short Rotation Coppice: Best practice guidelines for Applicants to Defra's Energy Crops Scheme. *Defra.* 2004[76]
- Growing Short Rotation Coppice: Best practice guidelines for Applicants to Defra's Energy Crops Scheme. *Defra*. 2007[77] Unformatted
- Establishment and Management of Broadleaved Coppice Plantations for energy. *Biomass Energy Centre 2007*[78]. Unformatted
- Information Sheet 3 Short Rotation Coppice (SRC) *Forestry Commission/ Biomass Energy Centre 2009*[79]
- Willow Varietal Identification Guide. *Teagasc/AFBI* 2012[80]
- Short Rotation Coppice Willow Best Practice Guidelines. *Teagasc/AFBI* 2011. Updated 2015[81]

The following best practice guideline documents are available for Miscanthus:

- Planting and growing Miscanthus. Best practice guidelines For applicants of Defra's Energy Crops Scheme 2001[82]
- Planting and growing Miscanthus. Best practice guidelines for applicants of Defra's Energy Crops Scheme 2007[83]. Unformatted
- Miscanthus Best Practice Guidelines. *Teagasc/AFBI 2011*[84]. Updated 2015[85]
- The Essential Growers Guide. *Terravesta.* Issue 1 2012[86], Issue 2 2013[87]. Issue 3 2015[88].

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[73] http://www.forestry.gov.uk/pdf/FRMG002_Short_rotation_forestry.pdf/$FILE/FRMG002_Short_rotation_forestry.pdf
[74] http://www.forestry.gov.uk/pdf/fcgn2.pdf/$FILE/fcgn2.pdf
[75] http://www.forestry.gov.uk/pdf/fcpn7.pdf/$FILE/fcpn7.pdf
[76] http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/SOURCES%20OF%20BIOMASS/ENERGY%20CROPS/SHORT%20ROTATION%20ENERGY%20CROPS/SHORT%20ROTATION%20COPPICE/WILLOW%20SHORT%20ROTATION%20COPPICE%20(SRC)/SHORT-ROTATION-COPPICE_TCM6-4262.PDF
[77] http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/SOURCES%20OF%20BIOMASS/ENERGY%20CROPS/SHORT%20ROTATION%20ENERGY%20CROPS/SHORT%20ROTATION%20COPPICE/POPLAR%20SHORT%20ROTATION%20COPPICE%20(SRC)/SRC%20VIEW%20EDIT%2018%2012%202007%20IT.PDF
[78] http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/SOURCES%20OF%20BIOMASS/ENERGY%20CROPS/SHORT%20ROTATION%20ENERGY%20CROPS/SHORT%20ROTATION%20COPPICE/BROADLEAVED%20COPPICE%20GUIDE%20REVISION%20020309.PDF
[79] http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/RESOURCES/REF_LIB_RES/PUBLICATIONS/3.%20SRC%20V5%209-2009.PDF
[80] http://www.teagasc.ie/publications/2012/1494/Willow_Identification_Guide_2012.pdf
[81] http://www.afbini.gov.uk/willowbestpractice.pdf
[82] http://adlib.everysite.co.uk/resources/000/023/838/miscanthus-guide.pdf
[83] http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/SOURCES%20OF%20BIOMASS/ENERGY%20CROPS/GRASSES%20AND%20NON-WOODY%20ENERGY%20CROPS/MISCANTHUS/MISCANTHUS-GUIDE.PDF
[84] http://www.afbini.gov.uk/miscanthus-best-practice-guidelines.pdf
[85] http://www.teagasc.ie/publications/2011/315/Miscanthus_Best_Practice_Guidelines.pdf
[86] http://www.terravesta.com/user_uploads/essentialgrowersguide.pdf
[87] http://www.terravesta.com/user_uploads/Essential_Growers_Guide_Issue2.pdf
[88] http://terravesta.com/user_uploads/Essential_Growers_Guide_Issue3.pdf

The energy crops sector would benefit from the provision of up to date guidance that is relevant to all parts of the UK and has support from all the organisations involved in the land conversion process. It would also be advantageous if this was all available from one central online location.

The key guideline document for afforestation, including but not specific to SRF, is the UK Forestry Standard (UKFS) published in 2011[89]. This document sets out the UK Government's approach to sustainable forestry. The UKFS sets out requirements for each element of sustainable forest management. These are:

- General Forestry Practice
- Forests and Biodiversity
- Forests and Climate Change
- Forests and Historic Environment
- Forests and Landscape
- Forests and People
- Forests and Soil
- Forests and Water

The UKFS sets out guidelines under each of these headings. The forest industry sector is very familiar with the requirements of the UKFS. All new woodland creation under forestry grant schemes that require Environmental Impact Assessments (EIAs) must be designed, planted and managed in accordance with the UKFS requirements and guidelines.

Another key tool to help guide decision making for woodland creation is the Ecological Site Classification Decision Support System (ESC-DSS). This is a PC-based software system which can help guide forest managers to select ecologically suited species to sites[90]. The ESC-DSS matches key site factors with ecological requirements of different tree species and woodland communities, as defined in the National Vegetation Classification (NVC) for Great Britain. The latest version of the software, ESC 3, features future climate change projections.

5.1.2 Internet

Energy crop growers and interested farmers are not particularly well served by up to date information on the web. Most Government sources of energy crop information on the internet are out of date. Simple Google searches using the terms "short rotation coppice", "Miscanthus" or "energy crops" continue to rank these official pages highly (Table 41). Many of these pages refer to the ECS or old guidance documents.

The Biomass Energy Centre (BEC) served as a one stop shop for biomass information with a comprehensive website and telephone query service. Government funding for this activity ceased in March 2014, so all the information on energy crops pre-dates the end of the ECS.

The Gov.uk website was launched in February 2012 in order to provide a single point of access to HM Government services. Content from the old Natural England website, which included information relating to energy crops and the ECS was transferred to this website at the end of September 2014. However, not all the pages have made the transition. Instead these are retained on the National

89 http://www.forestry.gov.uk/theukforestrystandard
90 http://www.forestry.gov.uk/esc

Archives website[91] but have lost their Google rank as a result. One of the important sources of information residing here are the series of *Opportunities and optimum sitings maps* which help farmers identify whether their land would be suited to energy crops[92].

Table 41: Top 10 web pages relating to energy crops in order of rank based on simple search terms (15 September 2015).

Rank	Energy crops	Short rotation coppice	Miscanthus	Short rotation forestry
1	Wikipedia	Wikipedia	Wikipedia	Biomass Energy Centre
2	Biomass Energy Centre	Biomass Energy Centre	Renewable Energy Crops*	Wikipedia
3	Crops for Energy	Biomass Energy Centre	RHS (Royal Horticultural Society)**	Forestry Commission
4	International Energy Crops	Forestry Commission	UK Agriculture	Forestry Commission
5	Gov.UK	Forest Research	Biomass Energy Centre	Scottish Forestry Commission
6	Gov.UK Energy Crops Scheme	Forest Research	Biomass Energy Centre	Crops for Energy
7	UK Agriculture	AFBI 2015 BP guidelines	Crocus**	Cheviot Trees
8	International Energy Crops	DARD Northern Ireland planting scheme	Terravesta	FAO (Food and Agriculture Organization)
9	Renewable Energy Crops*	Crops for Energy	Knoll Gardens**	EUBIA (European Biomass Industries Association)
10	Renewable Energy Crops*	Crops for Energy	Defra 2001 BP guidelines	IUFRO (International Union of Forestry Research Organizations)

* Company is no longer active. **Non-biomass website

On the Gov.UK website itself, the first two search results for “short rotation coppice” relate to tax law (section 2.2.3) and a regulatory statement from 2008 regarding the application of treated landfill leachate to SRC. There is no information at all on what growers of energy crops need to do to comply with current CAP measures.

The Forestry Commission (FC) website has lots of information on SRC (748 search results) and SRF (1070 search results). You can sort these by relevance or by date. The ones that are most relevant tend to be out of date, whilst the more up to date pages tend to mention SRC and SRF in passing. The page which states that growers of SRC should seek the FC’s opinion regarding the possible need for an Environmental Impact Assessment (EIA) does not feature highly in the search results[93]. The FC’s UseWoodFuelScotland website has a single page related to forestry energy[94].

There are only two websites within the top 10 ranking places that are regularly updated with new information relating to energy crops. The Crops for Energy[95] website has posted 81 news items since

[91] http://webarchive.nationalarchives.gov.uk/20140523111208/http://www.naturalengland.org.uk/ourwork/farming/funding/ecs/default.aspx
[92] http://webarchive.nationalarchives.gov.uk/20140605090108/http://www.naturalengland.org.uk/ourwork/farming/funding/ecs/sitings/default.aspx
[93] http://www.forestry.gov.uk/forestry/infd-6dfl55
[94] http://www.usewoodfuel.co.uk/supplying-woodfuel/sources-of-raw-woodfuel/energy-forestry.aspx
[95] www.crops4energy.co.uk

May 2013. The Terravesta[96] website has posted 35 news items and 46 blogs since July 2012 and the company has produced a monthly newsletter since 2013. This is the only website relating to energy crops that has a page devoted to planting Miscanthus under current CAP guidelines[97]. The Iggesund Biofuel[98] website does not feature highly on general searches, but is the only other English website with new information posted regularly. This website has had 30 news items and 7 case studies posted since June 2012.

There is a wealth of freely available technical information on woodland creation, species selection and silvicultural practices being created as a response to climate change and threats from pests and diseases. Most notable is the Silvifuture[99] network which was established to promote and share knowledge about novel forest species across Britain. The network focuses on providing information that will help the design of new forests and inform the future management of existing forests. It provides information and case studies on alternative species including typical SRF species such as *Eucalyptus spp*, aspen, birch, ash[100], alder, sycamore, sweet chestnut and *Nothofagus spp*. The following information is provided for each species listed:

- Native range
- Provenance choice
- Site requirements
- Pests and pathogens
- Timber characteristics

Additional information can be found on the Forest Research Tree Species and Provenances web pages[101].

The energy crops sector would clearly benefit from a single website that could provide links to guidance documents for Miscanthus, SRC and SRF. The removal of Government funding for the Biomass Energy Centre might suggest that the only way this could be achieved is if the industry itself provides this role. One possible option for supporting this would be through an energy crops levy (Section 2.1.6).

5.1.3 Open days, farm walks and shows

Open days, farm walks and shows are all potential opportunities for farmers to obtain information about and see demonstrations of energy crops. Farmers are more likely to replicate a venture if they see it for themselves and are able to talk to the farmer that is already making a success of it. Government department/agency led events are beneficial as they generally provide information on a range of crop options. By contrast events put on by the private sector are more likely to promote a specific option (e.g. Miscanthus) and not consider alternatives (such as SRC and SRF).

The Agri Food and Biosciences Institute (AFBI), a public body regularly run energy crops events and visits in Northern Ireland. However, in England the most recent DECC sponsored activity occurred in 2010, with subsequent events led by various private sector companies. The main providers in the last five years have been: Terravesta (Miscanthus), Iggesund (SRC in Cumbria), plus two European projects (Rokwood and LogistEC).

[96] www.terravesta.com
[97] http://www.terravesta.com/news/CAP-Reform-and-Greening---what-it-means-for-growers-
[98] http://biofuel.iggesund.co.uk/
[99] http://www.silvifuture.org.uk/
[100] Moratorium on planting ash at present due to the threat of Chalara ash die back disease
[101] http://www.forestry.gov.uk/fr/treespecies

Several trade associations and societies regularly organise open days, site visits and workshops on forest management, silviculture and woodland creation. Of note are the regular field visits organised by the Royal Forestry Society (RFS) across the country, regional meetings of the Confor and Institute of Chartered Foresters (ICF) groups with visits to SRF trials and productive commercial plantations not unusual.

5.1.4 Training courses

Training courses are valuable in a fledgling industry as they help to share knowledge and skills and pass on recent advancements in best practice and technologies. Bespoke training courses for farmers can provide them with the understanding and confidence to develop local opportunities and increase economic output.

Post higher education, there are no formal qualifications on woodland creation that can be taken. However, short courses for professionals are provided by Forestry Commission Learning and Development on Ecological Site Classification. Lantra Awards offer courses relevant to woodland establishment and other training providers offer specialist courses on topics such as farm woodland creation, deer management and continuous cover forestry. There do not seem to be any courses specific to SRF currently on offer.

The woodfuel sector is well served by the award winning three day Ignite course[102] which was created by Rural Development Initiatives (RDI) in 2003. Since its inception over 70 courses have been run in all parts of England, Wales and Scotland and trained over 500 people. A number of related courses have been created under the Ignite umbrella; including Managing Woods for Woodfuel and Woodfuel Quality Standards. The courses do provide some basic knowledge on SRC and SRF, but the content mainly covers woodfuel characteristics and use rather than crop production.

The energy crop sector is less well provided for with regards training. A number of courses have been developed (such as a 2 day energy crops course for Lantra Awards), but there was insufficient demand to enable the courses to become established[103]. Similarly, energy crops do not currently take up much time in agricultural college syllabuses. The lack of education and training on these crop options does not encourage new entrants into the supply chain.

This gap could be potentially filled by the setting up of Knowledge Transfer Groups for the energy crops sector. This opportunity is being considered in Ireland using support from the Rural Development Programme (RDP) and European Agricultural Fund for Rural Development (EAFRD). Under this scheme farmers would be paid for attending the training run by Department of Agriculture approved facilitators.

5.1.5 Trade press

Information on energy crops is available through publications such as Farmers Weekly. This helps to raise the profile of the crops and provides farmers with information about potential opportunities for diversification into energy crop production. The articles tend to focus on economics of production or grower case studies. Many articles are based on press releases from companies active in the sector. This is positive in that energy crops (especially Miscanthus) possibly get more coverage than the small size of the industry would normally justify. However, the articles tend to focus on one or two companies

[102] http://www.ruraldevelopment.org.uk/training-and-events-services/
[103] The course was developed by Kevin Lindegaard of Crops for Energy Ltd. In 2010, C4E was awarded funding to run five free courses in the South West and two subsidised courses in the East Midlands and Yorkshire and Humber. Only three courses went ahead and a total of 13 persons trained.

offering services which could have the undesirable consequence of making the industry look small. SRF is occasionally covered in Forestry and Timber News, the members' magazine of Confor.

5.1.6 Membership organisations

There are a number of membership organisations that provide professional advice to farmers and woodland owners. These organisations provide the opportunity for members to receive high quality impartial advice (on areas such as CAP reform, renewable energy, agri-environment schemes, Environmental Impact Assessments (EIAs), Water Framework Directive etc.) provided they are prepared to pay the membership fee. The cost of membership varies depending on the size of the farming/woodland operation, with annual fees typically starting at £100-200. The level of knowledge and understanding of energy crops and the information provided on their websites is variable however.

Many of these organisations are frequent responders to Government consultations on agricultural, rural development and energy issues. However, energy crops are often not their key focus. Hence, for a farmer who is growing Miscanthus, SRC or SRF there is no one body focused purely on the needs of energy crop farmers.

Examples of these membership organisations include:

- National Farmers' Union (NFU)
- Country Land and Business Association (CLA)
- National Non Food Crops Centre (NNFCC)
- Confor
- Wood Heat Association (WHA)

A possible way of improving this would be the creation of a levy body for energy crops. Arable and horticultural crops have a levy body, the Agriculture and Horticulture Development Board (AHDB), that takes a levy from the sale of all crops both at the farm gate and up the supply chain and uses that to support research and information to help businesses develop and become more competitive. A similar vehicle could help to improve the economic viability of energy crops by increasing the availability of impartial information and facilitating applied research intended to make the industry more competitive. A levy body could also potentially provide much needed lobbying influence.

5.1.7 Consultancy services

Although there are many independent consultancies that specialise in agriculture and farm energy there are few sources of expert and impartial advice on Miscanthus, SRC and SRF. Most of the knowledgeable authorities involved with these crops are mainly involved in selling plant material or contract services. This is certainly a barrier for a farmer who would like to be provided with in depth independent information prior to making an informed choice on the right crop for their land, facilities and market.

In the South West of England under the last round of the Rural Development Plan there was a scheme called Resource Efficiency for Farms (R4F) run by Rural Focus, a subsidiary of Business Link (BL)[104]. This ran from 2009-2013. Under this scheme a consultant was paid to visit a farm and draw up a free action plan dealing with energy and water consumption and waste production. Following this, farmers were given the option of paying for a further two days of discounted consultancy (£150 per day with the balance paid by BL) for completing feasibility studies and other technical investigations. This was well

[104] http://www.swarmhub.co.uk/resource_farmers.php?id=2375

received as it enabled farmers to obtain impartial advice at a low cost. Many biomass boilers were correctly specified under this scheme. A similar initiative rolled out nationally in which the all-round bioenergy potential for a farm was assessed, would help new entrants make correct decisions and reduce the likelihood of mis-selling.

Advice for planting new woodlands including SRF is offered by a number of private consultancy and forest management companies and land agency firms. The Forestry Commission (FC) can provide high level outline advice on the grant application and EIA processes, but are less likely to offer advice on planting design, species, silviculture and future management, mainly due to resource and time constraints. This said, grant applicants and those going through the EIA process may find that FC staff offer opinions on the suitability of planting design, species and silviculture as part of the consultation and feedback processes.

FC Scotland, under the last round of the Forestry Grant Scheme, did offer a planning grant for creating productive woodlands (which would include SRF). The grant could be used towards the costs of collecting and analysing site information (soil surveys, Ecological Site Classification, windiness assessment, habitat and bird surveys), appraisal and analysis of landscape, historic environment and cultural landscape assessment and determination of stakeholder interests. £100/ha was offered with a maximum payment of £20,000. The overall planting area had to be 30 hectares or more with proposals meeting the eligibility criteria set.

The Institute of Chartered Foresters (ICF) is the professional membership body for forestry in the UK. It maintains a directory of consultants by UK region and all members of the ICF are named under a members list. Membership of the ICF is by professional membership entry or by assessed professional competence. There is no regulatory requirement to be a member of the ICF to practice forestry in the UK or to offer consultancy or advisory services on forestry related matters. Confor has a professional forester membership category, but professional competence is not assessed in order to join other than a statement of experience must be provided.

5.2 Finance

Energy crops are long term investments with a different risk profile to farming annual crops or livestock. There is a perception amongst farmers that that energy crops and woodland offer significantly lower profitability and higher risks compared to other agricultural crops[105],[106]. These perceptions need to be tackled if farmers are to be encouraged to convert large areas of land to energy crops. In the sections below we set out the issues and provide some options for overcoming these.

5.2.1 Establishment costs

The high establishment cost of energy crops (£2000-3000/ha) has always been one of the largest barriers preventing more farmers from planting these crops. The largest components of establishment costs are plant material (rhizomes, cuttings and seedlings), planting costs and rabbit fencing. The cost of rabbit fencing can be considerable especially when used to protect small plantations or around narrow strips (such as SRC planted as an Ecological Focus Area option).

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[105] Prospects for arable farm uptake of Short Rotation Coppice willow and miscanthus in England. Neryssa J. Glithero, Paul Wilson, Stephen J. Ramsden. Applied Energy Volume 107, July 2013, Pages 209–218. http://www.sciencedirect.com/science/article/pii/S0306261913001402

[106] Eves, C., Johnson, M., Smith, S., Quick, T., Langley, E., Jenner, M., Richardson, W., Glynn, M., Anable, J., Crabtree, B., White, C., Black, J., MacDonald, C., and Slee, B. (2014). Analysis of the potential effects of various influences and interventions on woodland management and creation decisions, using a segmentation model to categorise sub-groups - Volume 4: Woodland creation segmentation Defra, London http://www.forestry.gov.uk/pdf/Volume-Four_Woodland-creation-segmentation.pdf/$FILE/Volume-Four_Woodland-creation-segmentation.pdf

The investment potential from energy crops can be viewed as being attractive when the full lifetime of the plantation (21-22 years) is considered but most farmers are used to an annual cycle of planting and harvesting and associated cashflow. In the past, growers have been able to get up to 50% of their establishment costs covered using Energy Crops Scheme (ECS) grants. However, this scheme is no longer available and as a result growers have to finance the whole of the establishment cost themselves. Companies such as Terravesta are selling establishment packages combining planter hire and planting material, with the farmer's own tractor and labour to help reduce the cost of establishment, however it remains a large initial outlay, which can deter risk-averse farmers.

Some companies are aiming to address this: Iggesund are offering finance packages which mean a reduced outlay for the farmer, but with a reduced price paid for the crop in later years. Terravesta are also seeking interest from investment funds/financiers so they can offer similar.

Establishment costs may also be reduced by the development of seed based cultivation (for Miscanthus)[107] or by introducing billet planting (for SRC)[108]. The need for rabbit fencing could be reduced if breeders could select less palatable varieties.

ECS 1 and 2 were designed to stimulate the planting of 69,000 hectares of energy crops, but by the end of 2013 just 12,143 hectares had been planted[109]. This lack of uptake is one of the main reasons for the lack of an ECS3. An alternative to a national scheme would be a localised, targeted scheme with backing from the local enterprise agencies such as Local Enterprise Partnerships (LEPs) in England that focus on specific needs of an area (section 2.2.4). The design of a regional scheme would need to learn from previous establishment grants and aim to reduce the financial risk to the farmer.

The establishment costs of SRF are generally slightly higher than other energy crops at around £2828/hectare[110], but should be less of a barrier if a project can be supported with a grant (Section 2.2.4) or carbon finance (Section 2.3.4.4).

5.2.2 Contracting arrangements

There are a range of contracting arrangements available for SRC these range from effectively a "hands off" crop. After the initial land preparation, the contractor would take care of virtually all the management and pay interim payments, a guaranteed price for the fuel with annual incremental increases. This was seen as being reasonable economically and largely risk free.

Some growers have taken the approach of developing grower's co-operatives that enable risk sharing and price certainty. Another approach taken to reducing risk, if the area grown is sufficient has been to for the grower to purchase their own harvester. Elsewhere, where projects have been set up or contracts offered, they have largely used external contractors.

There are examples of CHP plants that offer long-term contracts for SRC where they also provide planting advice, some financial support to ease cash flow in early years, harvesting and transport services and index-linked pricing. There are also arrangement which offer index linked contracts for Miscanthus. In this situation, contracting services are provided by external operators.

[107] https://www.aber.ac.uk/en/ibers/news/archive/2013/july/title-136670-en.html
[108] http://www.salixab.se/Billet-Planting-of-short-rotation-coppice/13
[109] A critical appraisal of the effectiveness of UK perennial energy crops policy since 1990.
Adams, P.W.R. & Lindegaard, K (2015) Renewable and Sustainable Energy Reviews (in press)
[110] http://www.forestry.gov.uk/fr/ccfcosts £2828/ha Includes £1,420/ha for cultivation and planting, £175 for beat-up, £300 for scarify, £200 for herbicides, £375 for cleaning. Plus £458 for overheads, mammal control and road maintenance

Energy crop planting levels could be increased if investment risk could be significantly reduced. One possible way of achieving this would be for the Government to underwrite industry contracts or provide some guarantee to farmers that new markets will be found in the event of one user failing.

Forestry, including SRF, has a number of well-established contracting businesses operating in the supply chain – harvesting, extraction and haulage – across the UK. The contracting base is diverse and there is a wide range of equipment available for harvesting and extracting timber from large scale fully mechanised commercial plantation processes to smaller scale specialist hardwood felling and extraction and conservation related work. Most contractors involved in single stem timber harvesting will either buy the timber standing and sell it directly on to markets or be employed by a timber merchant who will pay the contractor for their services and then market the timber themselves. Some large estates do have their own in house forestry teams, but as market conditions have changed this is becoming less common. There are also long standing establishment contractors and many of the larger landscaping companies have become involved in afforestation schemes.

5.2.3 Tax Law

The cultivation of SRC and Miscanthus is treated as husbandry and thus farming and not woodland for income tax, corporation tax and inheritance tax purposes[111]. As such bioenergy crops are eligible for payments under the Basic Payment Scheme (BPS) while woodland is not. Farmers may be swayed towards woodland (including SRF) as profits from are exempt from tax whereas profits from the sale of energy crops are subject to income tax and corporation tax[112]. All rotational arable crops and trees that are planted and harvested at least every 10 years (e.g. SRC and some SRF) are exempt from inheritance tax[113]. Longer rotation SRF and woodland crops are covered by Woodland Relief which means that whoever inherits the woodland only pays inheritance tax on the trees when they're sold or given away as timber[114].

During the productive life of an energy crop plantation, management activities such as harvesting, weed control, labour and machinery costs are considered to be revenue expenses and can be offset against taxable profits. However, at the end of a plantation's life the removal of stools and their roots is regarded as a capital expense which is not tax deductible. In the event that energy crops cause any disruption to drains, the cost of restoring drainage is allowed as a revenue cost, but this is expensive.

Surveys[115] suggest that these future costs are off-putting to new entrants. Ideally, energy users could incorporate the cost of crop removal into their supply contracts or HM Revenue and Customs (HMRC) could make a change in tax law to make this activity tax deductible.

5.2.4 Funding opportunities

There are a range of potential funding opportunities that farmers can access in order to make the planting of woodland more attractive. These include grants for the establishment of the plantation and annual payments for the benefits the trees provide to the local environment. Examples of funding opportunities include:

- **Agri-environment schemes** which aim to protect and enhance the natural environment, in particular biodiversity, water quality and flood management. For example Countryside

[111] https://www.gov.uk/hmrc-internal-manuals/business-income-manual/bim55120
[112] http://www.hmrc.gov.uk/manuals/bimmanual/BIM67701.htm
[113] https://www.gov.uk/guidance/agricultural-relief-on-inheritance-tax
[114] https://www.gov.uk/inheritance-tax/inheritance-tax-reliefs
[115] Prospects for arable farm uptake of Short Rotation Coppice willow and miscanthus in England. Neryssa J. Glithero, Paul Wilson, Stephen J. Ramsden. Applied Energy Volume 107, July 2013, Pages 209–218. http://www.sciencedirect.com/science/article/pii/S0306261913001402

Stewardship (CS) in England offers a range of capital grants for 1 to 2 year projects for hedgerows and boundaries, improving water quality, developing implementation plans, feasibility studies, woodland creation, woodland improvement and tree health.

Woodland creation grants are administered by the devolved administrations across the UK. In England, grants are available through the CS scheme. Priorities for supporting woodland creation projects are where an application supports wildlife, particularly where new woodland can link habitats, reduces the risk of flooding, improves water quality and prevents soil erosion, is resilient and can adapt to climate change and enhances the landscape. There is an annual application window of February to April each year and, depending on the priorities and options listed, up to £6,800/ha is available with a £200/ha annual payment for 10 years. A woodland creation plan is required which covers; planting objectives, species to be used, planting density, percentage of open space, methods of protection and the areas to be planted within the site.

These schemes do not cover SRC, but could in theory support SRF as long as the project meets the objectives and priorities of the scheme. If a project were to proceed with an FC planting grant, then it may be a requirement that no felling can take place until after year 15. A case study of a project in Cornwall shows that RDP funding can be used to support SRF projects[116].

- **Rural development grants** - In addition to the environmental schemes described above there are also funding pots for increasing farming and forestry productivity (£140 million scheme in England) and to develop world class production and supply chains. A further £138 million will be available through LEADER[117] which gives Local Action Groups (LAGs) the responsibility to identify local needs and the resources to fund projects to meet them[118].

  Local enterprise agencies such as Local Enterprise Partnerships (LEPs) in England could also play a part in stimulating bioenergy supply chains at the local level. Under the Rural Development Programme for England (RDPE), LEPs have been assigned £177 million to help grow the rural economy[119]. LEPs are responsible for setting local priorities and rural renewable energy projects are seen as one of the headline activities most likely to attract funds. The policy briefs put together as part of the Rokwood project suggest several opportunities where LEPs and LAGs could help stimulate local production of energy crops[120]. It is argued that LEP and LEADER funding could be deployed to help set up SRC supply chains in off-gas grid areas with low woodland cover and fund feasibility studies to identify suitable locations for pilot schemes. In the South West of England there has already been some interest in SRC and SRF shown by the Heart of the South West LEP and Dorset LEP, specifically around multifunctional benefits of energy crops (see section 5.3.4).

5.3 Regulation/Policy

Energy crops and SRF are widely accepted as a useful means of producing a low carbon energy source that can help diversify farmer incomes and contribute to delivery of other ecosystem services. There are numerous policy instruments that could be used to encourage the planting of energy crops. We look at some of these issues below and suggest some ways of overcoming the barriers.

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116 http://www.rfs.org.uk/media/65542/climate-change-case-studies-08-2014.pdf
117 LEADER is a French acronym which translates as 'Liaison among Actors in Rural Economic Development'
118 https://www.gov.uk/government/publications/leader-approach-in-the-rdpe-national-delivery-framework/leader-approach-in-the-rdpe-national-delivery-framework
119 https://www.gov.uk/government/publications/rural-development-programme-for-england-outline-of-new-programme/rural-development-programme-for-england-outline-of-new-programme
120 http://www.rokwood.eu/public-library/policy-briefs/send/20-policy-briefs/17-rokwood-uk-cluster-policy-briefs.html

5.3.1 Common Agricultural Policy (CAP)

The provisions of the current CAP for energy crop growers is set out in Section 5.2.4. While there are no measures that are likely to significantly expand the energy crop area there is provision to support small-scale renewable energy to help communities and businesses. The use of SRC as an Ecological Focus Area (EFA) measure (i.e. land set aside for environmental benefits on arable farms) was on the long list proposed by the EC to member states, but in the UK this has only been adopted in Wales and Northern Ireland. In these countries, this is unlikely to result in much new SRC planting as cropped areas comprise just 5.3% [121] and 5.7%[122] of agricultural land respectively. In addition, arable areas tend to be small in these two countries. For instance, in the whole of Northern Ireland there are only 138 farms with more than 50 ha of arable land. As there is already around 1000 hectares of SRC planted in Northern Ireland it is likely that the vast majority of farmers assigning SRC as an EFA measure will be existing growers.

Furthermore, the low weighting (0.3) discriminates against SRC as it requires as much as five times the amount of land to be taken up compared to other measures. Some farmers may only choose to plant energy crops as one of the options to reduce their total arable area below one of the greening trigger points.

There is the potential opportunity for energy crop areas to increase, if SRC planting was adopted as an EFA measure in all parts of the UK. If significant areas are to be planted one would expect that the weighting factor would also need to be increased. There is evidence that energy crops have multi-functional benefits (see section 5.3.4) which, if reviewed and taken in to account by government may provide sufficient evidence to increase the EFA weighting factor of SRC.

The CAP supports SRF and woodland through planting grants under agri-environment schemes in Pillar 2. Under the CAP approximately £3 billion will be made available to enhance England's countryside over the next 5 years with an allocation of £90 million for woodland creation, some 3% of the budget. Woodland creation could mean any type of woodland, SRF or otherwise, as long as it meets the priorities of:

- Biodiversity;
- Water (quality and flooding); and
- Climate change.

The policy is far more likely to produce small areas of non-productive broadleaf and mixed woodland rather than SRF or other productive plantation forests[123].

5.3.2 Renewable Heat Incentive (RHI)

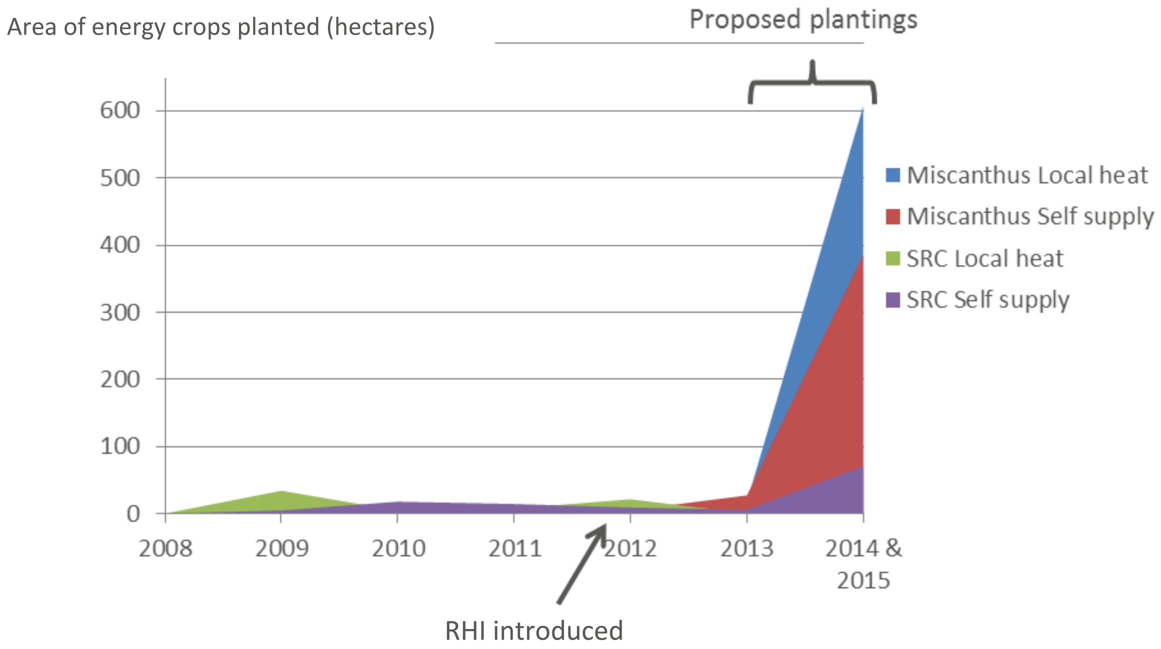
The Renewable Heat Incentive (RHI) has facilitated a massive increase in the small scale biomass heating industry. By 18 August 2015 there were 11,680 accredited biomass systems under the non-domestic scheme and 6,950 accredited under the domestic scheme[124]. The vast majority of these systems are using wood pellets, wood chips and logs. Based on a Freedom of Information (FOI) request made by Crops for Energy in September 2014, only around 3.5% of boilers under the non-domestic RHI (~400 installations) are using energy crops or agricultural residues.

However, the RHI has provided a real opportunity for some existing growers to maximise the income from their energy crops. The cost of producing Miscanthus or SRC can be as little as 1-1.5 pence/kilowatt

[121] http://gov.wales/docs/statistics/2015/150728-agricultural-small-area-statistics-2002-2014-en.pdf
[122] http://www.dardni.gov.uk/stats-review-2014-final.pdf
[123] Crispin Golding (2015) England's Conifers: Not Quite What we Wanted. A discussion paper on the role of conifers in England. Accessed online October 2015 - http://www.goldingforestry.co.uk/#!english-conifers/cg3w
[124] Information up to date on 18 September 2015. Provided by Frank Aaskov, Renewable Energy Association

hour (p/kWh) compared to bought-in woodfuel costs of 3-4 p/kWh[125]. This can result in large fuel savings, in addition to the rebate payments from the RHI. Initially, the majority of energy crop growers benefitting from the RHI were existing growers who planted their crops long before the RHI started in November 2011. However, a significant number of new growers have been encouraged to plant energy crops for their own use or to exploit the local demand for biomass. Figure 37 shows how the interest in planting energy crops for heat markets increased under the ECS following the introduction of the RHI. In 2014 and 2015, Natural England received Energy Crops Scheme (ECS) applications for the planting of 993 hectares of Miscanthus covering 38 separate agreements for heat projects[126]. If these plantings went ahead then around 10,000 oven dry tonnes of biomass would be made available annually. This would be enough feedstock to support 150 biomass boiler projects with a total installed capacity of 30 MW thermal output, supplying 0.045 TWh/yr of heat.

Figure 37: Area of energy crops planted for heat markets 2008-2012 and proposed planting for 2013-2015 showing the effect of the introduction of the Renewable Heat Incentive (RHI)[127]



Growing SRC and Miscanthus for heat projects (with RHI tariffs) is more lucrative for farmers than growing for larger power producers. Local Miscanthus growers can significantly undercut the price of woodchips and could be of interest to local end users with compliant boilers. In November 2015 Miscanthus bales fetched an average price of £98 per oven dry tonne including haulage costs. By contrast the cost of woodchip from woodland sources used for heating costs between £140- £179 per oven dry tonne including delivery costs depending on UK location and size of delivery. However, issues associated with the RHI (see below) and the nature of the fuel (Section 5.4.2) would need to be overcome for Miscanthus to gain greater market share.

Tariff digressions (small biomass tariff has fallen by 58% in the last year) and recent uncertainty about the future of the scheme has already curtailed the growth in the boiler market[128]. However, in the

[125] http://www.crops4energy.co.uk/wp-content/uploads/2013/05/Why-we-need-energy-crops-in-the-SW-final-report-updated.pdf
[126] Natural England. Intended end use for energy crops being planted in 2014 and 2015 under the Energy Crops Scheme, Freedom of Information (FOI) request, provided by Katie Vowles, Natural England; 18th August 2014.
[127] Natural England. Intended end use for energy crops being planted in 2014 and 2015 under the Energy Crops Scheme, Freedom of Information (FOI) request, provided by Katie Vowles, Natural England; 18th August 2014.
[128] Wood Heat Association Business Plan 2016 – Presentation by Julian Morgan Jones, Chairman, WHA at Wood Heat 2015 Conference, 4-5 November 2015, Bristol.

Treasury's Comprehensive Spending Review (25th November 2015) it was announced that the scheme will continue for the next 5 years until 2020/21.

Emissions thresholds

The introduction of an emissions threshold (less than 150 grams per gigajoule (g/GJ) of NOx and 30 g/GJ of particulates when using a particular fuel) for biomass boilers on 24 September 2013 has proven to be a barrier to Miscanthus consumption. In order to comply with RHI regulations and continue receiving rebates participants of the scheme must submit an emissions certificate showing the boiler and fuel they are using and confirming that the thresholds are met.

Although there are compliant Miscanthus boilers on the market, most of these have not been tested against the emissions criteria. There is no accepted standard for Miscanthus chip or bales so this means that any manufacturer who does test the fuel would have to make sure that the boiler always used the exact same specification of fuel as that tested. This means that there is little incentive for manufacturers to obtain an emissions certificate for this fuel, leaving the responsibility with the end user. Furthermore, the testing procedure can be expensive costing around £5000 for a single range.

As there are already standard fuel specifications for woody fuels[129] it easier for end users using SRC and SRF to remain compliant.

Sustainability criteria

In order for energy crops to be acceptable for use under the RHI it is important that their sustainability criteria are robust and they show a reduction in greenhouse gas (GHG) emissions compared to the use of fossil fuels. For wood fuels there is the Biomass Supplier List (BSL) on to which farmers can register as a producer, producer/trader or self-supplier. This way, potential end users are confident that the product they are buying is sustainable. However, the BSL only covers woody energy crops such as SRC and SRF. Growers of Miscanthus currently have no register that they can list their products on, making it more difficult for potential customers to purchase crops with any surety of sustainability criteria. DECC has recently given partial backing to a business plan for a Waste, Residues and Energy Crops Sustainability List (WRECSL)[130]. However, the Secretary of State will only give full support to a scheme that is up and running, and this is some months away.

In the absence of a functioning register farmers have to self-report (section 4.2.3). This is a complex task and not an easy process for non-professionals. The draft sustainability guidance[131] and the B2C2 user guide[132] are very detailed (each over 80 pages). As a result of all this, many affected parties have to pay consultants to do their reporting on their behalf. The cost of this can range from £750-850 for simple self-supply projects to £1600 for more complicated ones. This complexity is a potential barrier to the uptake of energy crops. In the simplest self-supply scenarios (e.g. producing Miscanthus on a single field, storing on site and burning it to supply heat to the farm) these regulations are too onerous. However, the development of a sustainability register with default values for a range of energy crops would present a potential opportunity for the simplification of the process for demonstrating sustainability compliance and making it easier for farmers to meet consumers' needs.

As long as the hurdles facing Miscanthus remain, then the RHI is unlikely to bring about much increase in production and use. The following interventions would aid Miscanthus to compete on a level playing field with SRC and other woody biomass:

[129] http://www.forestry.gov.uk/fr/beeh-9uspgh
[130] Letter from Karina Stibbards, Head of RHI delivery, DECC dated 16 September 2015
[131] https://www.ofgem.gov.uk/sites/default/files/docs/2015/07/sustainability_guidance_published_version.pdf
[132] https://www.ofgem.gov.uk/ofgem-publications/93896/b2c2rhiusermanualv71-pdf

- Official assistance to create a Miscanthus standard against which to test boilers for emissions.
- Government backing (not financial) for a list (such as the proposed WRECSL) on to which producers, traders and self-suppliers can register so it is simpler for them to demonstrate their sustainability compliance.

5.3.3 Environmental Impact Assessment (EIA)

The requirement for an EIA (section 4.2.1) prior to the planting of an energy crop is not widely known about, nor publicised. Therefore, there is the risk that growers will go ahead and plant crops without completing the EIA process due to a lack of awareness. This could lead to damage to the local environment or heritage sites. The impact on the farmer is that in the worst case they might be fined up to £5,000, asked for their crop to be removed and also see their Basic Payment (BP) affected.

There is a real opportunity to provide a new official guidance note explaining what interested farmers need to do before they plant. This guidance note should be simple (similar to the Forestry Commissions' EIA quick guide[133]) and provide the following:

- Summary of the EIA rules that are relevant to energy crops
- Link to an energy crops specific opinion request form for the relevant agency depending on the energy crop choice
- Dedicated email address and contact number
- Information on what will happen if they fail to comply with the EIA rules, such as
    - Will they get fined?
    - Will they be asked to remove the crop?
    - Who is responsible for dealing with this?
    - How will any indiscretion affect their BP?
    - How will it affect their ability to claim RHI (e.g. by not meeting the land criteria)?
- Is it possible to get retrospective EIA?

This could be circulated to project developers and planting material suppliers so they can pass this information on to new growers.

The EIA screening process is likely to be applied to a larger proportion of SRC and SRF projects compared to Miscanthus projects. This is because SRC and SRF are considered as afforestation under EIA (Forestry) regulations. The EIA (Forestry) threshold is 5 hectares on all land types and 2 hectares in sensitive areas whilst the EIA (Agriculture) threshold for Miscanthus is 2 hectares but this only covers uncultivated land, and semi natural land in Scotland. In most other ways (e.g. CAP measures, Tax rules) SRC is dealt with as an agricultural crop so this additional scrutiny means that SRC is disadvantaged compared to Miscanthus. As many SRC projects are likely to require EIA screening, the aforementioned EIA energy crops guidance note should be prioritised. An alternative option could be for the FC to increase the threshold on non-sensitive land.

However, it should be noted that in the vast majority of cases there will be no need for a full EIA when planting energy crops. For instance, over the past five years less than 1% of general forestry EIA cases (including afforestation) have required consent, and only one afforestation project has required consent (Table 42:). Where possible, the FC tries to work with applicants to modify proposals and address

133 http://www.forestry.gov.uk/forestry/infd-6dfl45

potentially significant issues at the start of the process. While this can be an involved process it can address issues that would otherwise mean the proposal has to go through the consenting process.

Table 42: EIA afforestation decisions taken by the FC since 1st April 2012[134].

No. of Woodland Creation schemes submitted	No. of schemes that FC deemed relevant/significant projects	No. of schemes where an Opinion has currently been made	No. of schemes requiring FC consent	Average size of schemes regarded as relevant projects (hectares)
1,234	113 (<10%)	98	1 (<1%)	14.3

Nevertheless, the UK Government wants to ensure that regulations don't unnecessarily deter investment in appropriate woodland creation (Defra Forestry Statement, 2013[135]). To meet this challenge the Government is looking at introducing a new approach that would reduce burdens on landowners who want to plant woodland by clarifying where a full Environmental Statement is unlikely to be required.

FC is currently running a project with partners in County Durham to identify how communication, best practice in woodland design, the provision of a strategic view on woodland creation and information sharing can help clarify understanding of both why, and in what situations, EIA consent may be required[136].

5.3.4 Multiple uses

The multifunctional potential of energy crops is currently being under exploited. Planting of energy crops should be encouraged where they can provide key local services. For instance in the South West of England there is an opportunity for energy crops to provide a range of services in areas where there is low woodland cover, large off gas areas, high levels of fuel poverty, areas affected by flooding and water quality issues. This would enable significant economic benefits to be afforded. The report "Why we need energy crops in the South West"[137] suggests that the planting of 66,000 hectares of energy crops (which equates to 3.5% of farmland) would have the following benefits:

- 2.64 Terawatt hours of energy per year equalling 37.5% of the regions renewable heat target
- 662,146 tonnes CO_2 equivalent saved each year, offsetting 21% of the emissions from agricultural food production
- £768 million of investment stimulated in biomass boiler projects
- £55.4 million/yr saved in fuel costs by consumers
- £27.8 million/year in additional farmer profit
- 3,745 renewable energy jobs equalling a 134% increase on the current number of jobs in the bioenergy sector

There have been many reports on where energy crops can be grown and the yield they could produce. A related area of work could identify where energy crops could be planted to provide the most added

[134] James Anderson-Bickley, Forestry Commission. Personal communication October 2015.
[135] Defra (2015) Government Forestry and Woodlands Policy Statement. Accessed online October 2015 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221023/pb13871-forestry-policy-statement.pdf
[136] Richard Pow (2015) Personal communication October 2015.
[137] http://www.crops4energy.co.uk/wp-content/uploads/2013/05/Why-we-need-energy-crops-in-the-SW-final-report-updated.pdf

value benefit. This would involve a mapping exercise and an evaluation of the economic benefits that energy crops could bring.

Flood mitigation

Energy crops and woodland could play a part in flood risk management by acting as 'green leaky dams' holding water back and reducing its flow across floodplains. SRC and Miscanthus are particularly well suited as a result of their fast growth and multiple stems. The latter provide vegetation roughness or hydraulic roughness, which retains sediments and when planted strategically it is thought that this can delay flooding events downstream by a critical 1-2 hours[138]. Table 43 shows why energy crops are potentially better suited to flood risk management than native trees. A barrier to this use of energy crops is that there are no grants available for planting energy crops for flood alleviation. The use of energy crops was supported by work commissioned by the EA in 2010[139],[140],[141] but this has so far not been published online and is therefore not available for wider decision making (see Section 1.3.3). However, the EA are intending to publish these outputs on their website in November 2015.

Table 43: How SRC and Miscanthus compare against native woodland as a flood mitigation option[142].

Vegetation option	Woodland	SRC	Miscanthus
Time to maturity	> 20 years	4-5 years	4-5 years
Stocking rate (plants per hectare)	Typically 2,250 (up to 10,000)	15,000	13,000
Management	Thinned after 15 years	Cut every 3 years	Cut every year
Hydraulic roughness (Manning's n coefficients)	0.1 when mature	0.1-0.34	0.2
Potential of reducing flood risk in < 10 years	Low	Medium - High	Medium -High
Subsidy payments (arable land in lowlands)	£1.28 per tree plus other supplements e.g. fencing but up to £6,800 per hectare establishment grant. £200/ha/yr for 10 years.	£0	£0

Forest Research has been very actively involved in mapping potential areas for new woodlands to provide flood mitigation and intercept diffuse water pollution[143]. As a result of this research, the FC has made new woodlands that can help meet flooding criteria a priority for funding to help encourage landowners to plant native trees in areas prone to flood incidents. SRC (or Miscanthus) do not appear to have been included in any of the mapping exercises. Extending this grant programme for planting to guard against flood impact to cover energy crops would provide a potential opportunity to increase areas of energy crops in these situations.

Water quality improvements

Energy crops have been demonstrated to be effective bio-filtration systems. They are particularly well suited and cost effective option for dealing with low volumes of wastewater produced by small rural communities[144],[145] and dealing with landfill leachates[146], industrial effluents and remediating heavy

[138] http://www.forestry.gov.uk/pdf/FRMG004_Woodland4Water.pdf/$FILE/FRMG004_Woodland4Water.pdf
[139] http://www.crops4energy.co.uk/wp-content/uploads/2015/09/Energy-Crops-Flood-Guidelines.pdf
[140] http://www.crops4energy.co.uk/wp-content/uploads/2015/09/JBA-consulting-Energy-crop-report.pdf
[141] http://www.crops4energy.co.uk/time-environment-agency-publish-work-energy-crops-flood-mitigation/
[142] http://www.logistecproject.eu/wp-content/uploads/2014/06/Kevin_Logistec-Impact-of-Energy-Crops-presentation-Dec-2014.pdf
[143] http://www.forestry.gov.uk/fr/infd-7t9jrd
[144] http://www.afbini.gov.uk/answer_current_knowledge-_web.pdf
[145] http://www.rokwood.eu/public-library/best-practice-booklet.html

metal contaminated sites[147]. Combustion of SRC chip from plantations that have been used for these purposes is likely to have higher emission levels. However, the majority of heavy metal contaminants are retained in the fly ash and it should be possible to minimise air pollution with efficient filters[148].

There are various schemes that deal with water quality improvement such as the Catchment Sensitive Farming (CSF)[149] project and the Countryside Stewardship scheme (CS)[150]. These schemes are headed up by Natural England, but also involve input from the Environment Agency and Defra. Land owners can apply for a £10,000 grant[151] to help pay for work to reduce diffuse water pollution from agriculture (DWPA). It is not clear whether planting energy crops is an allowable option. Gaining greater clarity of the role of energy crops in these schemes could open up greater opportunities to farmers wishing to plant these crops.

As with the flooding criteria above, the new CS scheme will also prioritise new woodlands that help meet water quality criteria.

Pollination services

Willows produce profuse amounts of nectar and pollen in the early months of the year. This could play a major role in helping rebuild the populations of bees and other pollinators. The majority of willows produce catkins in the lean late winter, early spring months when there are few other abundant sources of pollen or nectar available in the countryside[152]. Some 20% of UK cropland is covered by insect pollinated crops and the value of pollination to UK agriculture is estimated £430 million[153]. Currently this opportunity is not being exploited. In order to take advantage of this opportunity more knowledge transfer is required about the benefits of male SRC willows to bee populations, with the potential of increasing awareness to the point where they would be more likely to be considered as an Ecological Focus Area (EFA) option with a higher weighting factor.

Woodland carbon code

In 2011 the Forestry Commission launched the Woodland Carbon Code[154] (WCC), a voluntary standard for woodland creation projects in the UK. Carbon sequestration resulting from certified projects will contribute directly to the UK's national targets for reducing emissions of greenhouse gases. More generally, since 2013 all companies listed on the stock exchange are legally required to measure and report their Greenhouse Gas (GHG) emissions. All other companies are encouraged to do so voluntarily.

The WCC provides a framework and reassurance regarding the carbon savings claimed from woodland creation projects. The code encourages a consistent approach to woodland carbon projects, and offers clarity and transparency to customers about the carbon savings that their contributions may realistically achieve. To date, the WCC has registered 202 projects covering an area of 15,400ha of woodland and is projected to sequester 5.7m tonnes of carbon dioxide[155]. SRF plantations could theoretically come under the WCC, but due to their intensive harvesting systems would be less able to store carbon than say a longer rotation plantation and would therefore not be as attractive to prospective investors.

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146 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/322320/leachate_1965094.pdf
147 http://www.sciencedirect.com/science/article/pii/S0269749105004628
148 http://www.kiwiscience.com/JournalArticles/BiomassBioenergy2013.pdf
149 https://www.gov.uk/guidance/catchment-sensitive-farming-reduce-agricultural-water-pollution
150 https://www.gov.uk/government/collections/countryside-stewardship-get-paid-for-environmental-land-management
151 https://www.gov.uk/government/publications/guide-to-countryside-stewardship-water-capital-grants-2015/guide-to-countryside-stewardship-water-capital-grants-2015
152 http://www.crops4energy.co.uk/src-willows-abundant-source-pollen-bees/
153 https://www.reading.ac.uk/news-and-events/releases/PR367212.aspx
154 http://www.forestry.gov.uk/forestry/infd-84hl57
155 Forestry Commission (2014) Woodland Carbon Code Statistics Data to March 2014

New woodland planting, supported by carbon finance and/or public funding, could deliver significant additional carbon storage. A 2012 report[156] modelled three different woodland types - productive conifer, native broadleaf and mixed. Over a 100 year period the productive conifer woodland[157] was found to have the greatest net carbon gain.

5.3.5 Plant protection product legislation

All plant protection products that are used on any crop have to be approved for use on that crop, either as part of the official label or under an Extensions of Authorisation for Minor Use (EAMU). Most energy crops are considered to be 'minor' uses and therefore are rarely included as part of the main label registration of any plant protection product. Instead interested parties have to invest in getting EAMUs for products that can be safely used on energy crops (costing approximately £1000, per EAMU). There have been recent changes to the plant protection product approvals legislation with the introduction of the Sustainable Use Directive and European Union Plant Protection Products (PPP) Regulation - 1107/2009. This has resulted in a number of older plant protection products losing their registration, including a number that were previously approved for use on energy crops. There has also been a lack of funding for research and development into identifying suitable herbicides for use in energy crops. The combination of these factors means that it is becoming increasingly difficult to keep crops of Miscanthus and SRC weed free, especially during the vulnerable establishment phase.

The only pre-emergence option (mainly broad leaved weed activity) left for Miscanthus is pendimethalin, which is best suited to heavy land, but has limited effect on grass weeds. The only robust grass weed control option currently available in Miscanthus is to use glyphosate pre-planting or at the end of year one growth. Anecdotal evidence suggests that poor grass weed control can add 3 or 4 years before the Miscanthus reaches mature yield. The lack of herbicides and poor establishment is a barrier to new plantings of Miscanthus and SRC.

There has been very little research in recent years on herbicides for energy crops. There were a great many investigations funded under the DTI's New and Renewable Energy Programme in the 1990s[158],[159],[160],[161],[162] and guidance booklets produced by the Forestry Commission[163]. As with the best practice guidelines the most up to date guidance on herbicides for use on Miscanthus and SRC willow crops has been produced in Ireland[164],[165].

In order to improve the situation, funding for herbicide trials needs to be identified and the research carried out to identify which herbicides have the best activity against the main weed problems in the energy crops, and identify whether these options are crop safe. Once these trials have been completed more targeted EAMU applications could be made. In the horticulture sector, where a lot of 'minor uses' occur, this type of research is funded by the levy body, AHDB Horticulture. However, no similar funding body exists for the energy crop sector, so an alternative funding source would need to be sought.

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[156] Sandwood Enterprise (2012): A Carbon Account for the Woodlands in the Lake District National Park

[157] Productive Conifer would imply a thinning regime followed by an end of economic rotation clear fell and restock. With productive conifer stands you could get up to 2.5 rotations in 100 years.

[158] Weed Control and Soil Management Systems for Short Rotation Coppice: Present Knowledge and Future Requirements 1993

[159] Report on experiments on weed management in coppice 1994-1995 http://www.opengrey.eu/item/display/10068/600880

[160] Evaluation of residual and foliar-acting herbicides on poplar and willow cultivars 1994 http://www.opengrey.eu/item/display/10068/369686?lang=en

[161] Weed control in short rotation coppice crops ADAS 2000

[162] An evaluation of herbicides for post-emergence use in short rotation coppice 2001. http://www.techrepublic.com/resource-library/whitepapers/an-evaluation-of-herbicides-for-post-emergence-use-in-short-rotation-coppice/

[163] Herbicides for farm woodlands and short rotation coppice Forestry Commission 1996 http://www.forestry.gov.uk/pdf/fcfb014_main.pdf/$FILE/fcfb014_main.pdf

[164] http://www.teagasc.ie/publications/2010/866/866_MischantusWeedControl.pdf

[165] http://www.teagasc.ie/publications/2010/865/865_WillowWeedControl.pdf

Advice on the use of herbicides in preparing for and protecting new areas of woodland is provided by Forestry Research through the Herbicide Advisor[166]. All approved pesticides for use in forestry situations can be found on the HSE website Pesticides pages[167].

5.4 Markets

Miscanthus and SRC are being successfully deployed in both power and heat markets in the UK as are products from SRF and more traditional silvicultural systems.

5.4.1 Large scale markets

There are only a limited number of large scale outlets for Miscanthus, SRC and SRF in the UK, and due to cost of transport and the bulk nature of the raw materials these tend to have a regional focus, with suppliers tending to have to be from within a certain distance of the plant to make production cost effective. Supply to these large scale outlets is dependent upon a crop meeting certain specifications, e.g. for moisture content, storage method, contamination. Examples of large scale buyers in operation in 2015 included: Drax in Yorkshire (Miscanthus and SRC), EPR Ely in Cambridgeshire (Miscanthus) and Iggesund in Cumbria (SRC). In 2017 Drax will stop using SRC chip. This is because most of the fuel in their supply chains comes to them as pellets and SRC chip presents a very small, but significant inconvenience[168].

5.4.2 Small and medium scale heating boilers

Supplying fuel for small and medium scale heating boilers presents a real opportunity for energy crop growers. If the production costs of SRC and Miscanthus are spread over the lifetime of a plantation it is possible to produce fuel for less than 1 pence per kWh (p/kWh)[169]. If supplied to local end users (thereby minimising transports costs) then energy crop fuels would be highly competitive compared to other woodfuels, and fossil fuels such as heating oil. However, there are a number of barriers and challenges that need to be overcome to enable more rapid expansion of this sector.

Despite what looks like a significant competitive edge, so far the majority of energy crop use in heat boilers in England is for self-supply projects. The only part of the UK where there is a relatively mature SRC to heat supply chain is in Northern Ireland. Various practical barriers need to be overcome before this sector is likely to see a more rapid expansion.

Miscanthus can be adequately used in medium scale heating boilers, but does have some limitations[170]. For instance:

- The fuel is dusty and generally has much higher particulate emissions.
- In the chip form it is bulky. As a result it is not physically possible to get enough fuel into the combustion chamber of a boiler to achieve peak output. Most boilers are downgraded by around 30% when using Miscanthus chip compared to wood chip.
- The fuel has a high ash content (around 3%) and a low ash melting point which results in clinker. This means that boilers tend to need more cleaning and ash removal than woodchip and wood pellet boilers.
- The fuel has a high concentration of chlorine and therefore can lead to corrosion of boilers.

[166] https://www.eforestry.gov.uk/forestdss/
[167] http://www.pesticides.gov.uk/guidance/industries/pesticides/home
[168] Louise Martinson, ReGro personal communication 11 November 2015
[169] http://www.crops4energy.co.uk/wp-content/uploads/2013/05/Why-we-need-energy-crops-in-the-SW-final-report-updated.pdf
[170] http://www.teagasc.ie/publications/2011/315/Miscanthus_Best_Practice_Guidelines.pdf

The use of Miscanthus as a widely used heating fuel is further hindered by the rules of the RHI (see section 2.3.2). Nevertheless, more boilers are now being tested for emissions and innovations are being made in boiler design[171] and the production of densified fuels using mobile pelleting systems[172].

Compared to Miscanthus, SRC woodchip is easier to use in small-medium scale heating boilers and there are many case studies of growers in the UK and elsewhere who are successfully self-supplying[173]. In order for SRC chip to be suitable for this use it needs to be dried and in some cases reprocessed. There are a number of ways of doing this:

- Direct chipping and active drying
- Direct chipping and passive drying (with or without grading)
- Rod harvesting, passive drying, re-chipping and grading
- Billet harvesting, passive drying and granulation

The absence of SRC harvesting machines is a barrier to further expansion. This barrier could potentially be overcome by the support of local supply chains with Rural Development funding delivered through Local Enterprise Partnerships (LEPs) and Local Action Groups (LAGs). In spite of there being no harvesting machinery available locally, some growers have recently planted small areas (0-4 hectares) in the South West of England and Wales who are intending to harvest the crops manually with chainsaws.

5.5 Practical considerations

A farmer who is interested in planting energy crops needs to know how this activity will fit in with their day to day activities. For instance will the peak times for energy crop activities occur at a busy time or a quiet time for the farm? Will the harvest products require storage; will the space required and timescale needed cause scheduling difficulties; and, what machinery is available locally to plant and harvest the crops? In some circumstances a plantation of energy crops might be a useful option in reducing or eradicating a problem such as blackgrass in arable fields.

5.5.1 Time of planting and harvesting

The maritime nature of the UK climate means that it is not always possible to plant or harvest SRC and Miscanthus at the optimum times. If land is dry enough to be worked then March planting is ideal for SRC and April for Miscanthus. However, planting is often pushed back much later into the year. In certain climates (e.g. Cumbria for SRC) it is possible to plant much later into the season. It is not unknown for SRC and Miscanthus to be planted as late as June. Unfortunately, this is likely to lead to only limited growth in the first year and could make the crop vulnerable to dry periods which can prevent the energy crops growing strongly or prevent them from emerging at all. Also, if there is insufficient moisture in the soil it can prevent herbicides from being activated leading to a stunted crop being overrun by weeds. There is additional cost associated with later planting as a result of the need for cold storage of cuttings and rhizomes.

Another barrier facing energy crops is the lead in time required and the failure of would be growers to embark on land preparation activities in a timely manner. Farmers need to begin preparing the land according to best practice at least 6-9 months in advance of planting. Hence, if a farmer intends to plant in March then they should carry out the first glyphosate spray in September the previous year. In the past the late decisions on ECS planting grants have also prevented farmers adhering to best practice meaning that everything was done at the last minute, resulting in poor yielding crops. It is preferable to

[171] http://www.b-g-i.co.uk/pdf/BGIOctoberNewsletter2015.pdf
[172] https://www.youtube.com/watch?v=b6Kk-xPM_wk
[173] http://www.rokwood.eu/public-library/best-practice-booklet/send/27-best-practice-booklet/45-best-practice-booklet.html

delay by a year if adequate autumn weed control measures have not been put into place. These delays in establishing the crop can result in some farmers changing their minds and subsequently not planting the energy crop.

The ideal time to carry out SRC harvesting is during December-February when the crop is dormant. However, wet soils usually prevent this optimal harvest window being exploited. As a result, most SRC is harvested in late autumn and early spring and at these times will probably be in leaf leading to a slight reduction in woodfuel quality. Investment in R&D to produce light weight harvesters that can work on wet soils would help overcome this barrier.

At least five SRC contractors provide both planting and harvesting services. In busy harvesting years, the deployment of planting teams may be delayed so an opportunity to plant during a dry period in March or early April may be missed.

Miscanthus harvesting can be carried out as early as late January, but again this is dependent on soil conditions. Frequently crops are harvested as late as April. In early years it is often necessary to spray glyphosate on a crop after harvesting in order to check weed growth. However, the later that a harvest is carried out the more at risk the crop is as new shoots may be emerging at the base of the plant.

Although in theory energy crops could be managed at times of the year with little activity, in practice, this is not always possible. As a result, these activities can get in the way of other farm pursuits or compete with other activities that farm contractors will be doing.

New woodland creation including SRF is best done from late autumn to later winter, when planting stock is dormant, avoiding excessively wet and indeed frozen conditions. Timber harvesting for coniferous species can be done year round, whilst it is usually best to harvest broadleaf species during leaf fall/dormancy. Ground conditions will also dictate when timber can be harvested so as to minimise impact on the forest floor. In many situations harvesting SRF is likely to require a felling licence (Section 1.2.3 and Appendix 4.1: Felling licences).

5.5.2 Storage constraints

Energy crops tend to be very bulky fuels taking up a large space for many months. The amount of space and the conditions in which they are stored depend on the harvest method. This is dictated by the end use, but also what harvester is available locally and the facilities that exist on the farm. The storage characteristics of different energy crops are summarised in Table 44.

Miscanthus is sold to Terravesta in the form of large Hesston bales. Terravesta offer a premium (Barn Bonus) of up to £2/tonne extra if the bales are kept in a barn and the crop meets the specifications. In order to benefit growers need to keep their bales under cover until after 1st October for the £2/tonne uplift. There is no problem with storing Miscanthus under cover in spring as bales are likely to be brought into empty barns as a result of cattle being turned out to grass, pole barns of winter bedding are empty and stored grain being dispatched from farms. However, keeping bales inside until October is much more likely to cause a conflict for storage space with any grain and cereal straw harvested between July and September.

Table 44: Storage characteristics of different energy crops

	Miscanthus		SRC		
	Hesston Bales	Chips	Billets	Chips	Sticks
Bulk density (kg/m^3)*	130	90	90	150	100
Where stored	Barn or outside covered	Barn	Outside	Barn or outside in windrows	Outside, covered
No of months stored	2-10	12	4-5	3-5	3-6
Storage duration	April-January	April-March	March-August	March-August	March-September
Storage volume (m^3) required based on 10 ha harvest**	962	1389	3555	2133	3200

*Bulk densities based on figures in Teagasc/AFBI Best practice guidelines[174],[175].

**Based on standard yields of 8 odt/ha/yr for SRC and 10 odt/ha/yr for Miscanthus. Miscanthus harvested annually, SRC harvested every 3 years.

Growers self-supplying their own biomass boilers with Miscanthus tend to use chip. This comes straight off the field into barns during March-April and will take up this space year round. If this necessity usurps other equipment or harvested crops then it may require additional sheds to be built. The competition for farm space could potentially be eased by provision of capital grants for biomass storage sheds.

Most SRC for power markets has in the past been stored outside in windrows either as chips or billets. This does lead to some degradation of the crop. If stored on soil then a proportion of the harvest is lost as a sacrificial layer at the bottom of the pile. If outside storage is necessary then a concrete base is preferable, but this is not often available on smaller farms. Billets retain more of their dry matter when stored outside due to the greater air spaces in the stack, but take up more space as a result of their low bulk density. They also need to be reprocessed to be useful as a boiler fuel.

SRC that is intended for local heat markets needs to be stored inside or under cover in order to achieve the correct moisture content. As with Miscanthus chip, storage of woodchip in barns is a year round commitment of this space. In Northern Ireland, there is a Stemster rod harvester available. The harvested rods are laid on rafters (to allow air circulation) and covered with Walki Biomass Cover[176]. Stored this way the moisture content should drop to less than 20% by mid-September when the product can be chipped. At this point the chip would need to be stored under cover or transferred in bulk to the end user.

The recent trend for many woodchip suppliers is to force dry their product rather than rely on natural seasoning to lower moisture content. Force drying helps with stock rotation, improves cash flow and lessens the need for large areas of covered and outside storage space. A big motivating factor for force drying is that driers running off biomass boilers can receive RHI payments. This, combined with improvements in dryer technology and rising demand has led most producer-traders of woodchip to go down the forced drying route with natural drying being more typically adopted by self-suppliers and small scale producer traders.

5.5.3 Machinery requirements

Both Miscanthus and SRC require bespoke planting and harvesting machinery.

[174] http://www.teagasc.ie/publications/2011/314/Short_Rotation_Coppice_Best_Practice_Guidelines.pdf
[175] http://www.teagasc.ie/publications/2011/315/Miscanthus_Best_Practice_Guidelines.pdf
[176] http://www.heganbiomass.co.uk/walkipaper.html

Miscanthus

The machinery required for Miscanthus tends to be cheaper and more widely available than that used for SRC. There are around 10 planting machines in the UK located in the South West, Shropshire and Lincolnshire. These are relatively cheap to produce at approximately £15,000 (November 2015). Miscanthus is harvested generally with forage harvesters with some of the blades removed. There are thousands of machines that could potentially do this job across the UK, but at the time of writing there are less than 30 contractors who regularly engage in this activity[177].

Short rotation coppice - SRC

The machinery required for SRC cultivation is highly specialised and expensive. A new 4-row Step planter costs in the region of £55,000 whilst a new Henriksson Salix AB (HSAB) harvesting head costs around £90,000 (November 2015). Modifications are also required to the self-propelled forage harvester onto which the harvesting head is mounted. The total cost for a header, a forage harvester, making the necessary modifications and spare parts is around £250,000 (August 2015)[178].

As a result of the expensive nature of the kit there are only five fully functioning planters and ten harvesters in the UK. Most of these are located in areas where there are localised markets for SRC fuel (Nottinghamshire, Yorkshire, Cumbria and Northern Ireland). The lack of machinery outside these areas is a major barrier for existing growers or anyone interested in planting. This is because the machinery is expensive to transport and contractors prefer to travel with their own trained operatives increasing the cost considerably. Contractors are usually only willing to travel if there is an ample amount of work to do, spread over several growers. Hence, a grower in for instance the South West of England wishing to set up their own self-supply project growing five hectares of SRC would have to seriously consider how they will harvest the crop. One potential opportunity for these growers is to link with local chainsaw operators to manually cut their crops. On a small scale this can be cost effective, but has so far not been widely adopted.

Another piece of equipment that is essential for SRC management is a finger bar mower. This is used to cut the SRC down after the establishment year. These are not particularly expensive, but they are not widely available. This is unlikely to change unless the market has a significant upturn as they are only are useful for a single operation for each plantation planted. It is not possible to use a flail on a tractor (used to cut hedges) as this produces very poor results.

Despite the shortage of infrastructure there have been no capital grants available for SRC machinery since the 2007 Bioenergy Infrastructure Scheme Round 2[179]. A more recent funding scheme called the Farm and Forestry Improvement Scheme (FFIS) did not cover energy crop machinery.

Machinery availability is only really a problem for SRC. There has been almost no R&D carried out on planting or harvesting machinery in the UK over the last 10 years. There are good machines available and these could become more affordable if the market for locally produced biomass develops. However, many farmers that are interested in planting SRC tend to prefer planting small, odd shaped, marginal fields. As there is obviously some desire for small scale planting for self-supply woodfuel there is an opportunity for research into appropriate machinery design to produce reasonably priced SRC machinery that can be applied to marginal areas such as small fields, wet soils and sloping fields.

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[177] http://www.terravesta.com/Guidelines#b2link
[178] Jamie Rickerby, Rickerby Estates personal communication. 25 August 2015.
[179] There was a third round in 2009 but this was cancelled as part of Government austerity measures. There were two applications for SRC harvesters in this round that therefore did not receive funding.

Short rotation forestry (SRF)

SRF, being a single stem silvicultural system, can be harvested with conventional forestry harvesting and forwarding machinery. There is a well-established contracting base throughout the UK with a range of machinery capable of harvesting and extracting timber from plantations on a range of sites with different constraints. Large scale mechanised harvester and forwarder combinations are capable of harvesting in excess of 150 tonnes of timber a day in large plantations, whereas for smaller or more constrained sites small scale mechanised harvesters, feller bundlers and forwarders can be used.

Despite this, the lack of necessary equipment and access to contracting services are frequently cited by farmers as common obstacles to planting woodland[180]. Regional bodies and initiatives do exist which can supply information and contact details on the local availability of contractors and the type of machinery available[181]. Forestry businesses can apply for funding via a number of different RDPE grant schemes such as the Growth Programme, Leader and Countryside Productivity scheme[182]. Funding is available for primary processing equipment such as chippers.

5.5.4 Black-grass control

Planting Miscanthus (or SRC) could be an option for arable growers who have a pervasive issue with black-grass (*Alopecurus myosuroides*) in their arable fields. Black-grass is resistant to many herbicides and even herbicides that do work are very weather dependent for their success. Resistance is found on at least 80% of the 20,000 farms that spray regularly against the weed[183]. Black-grass populations of 12-25 plants/sq m can result in cereal yield losses of 0.4-0.8t/ha, whilst higher weed densities of more than 100 plants/sq m can result in losses of over 2t/ha. A loss of this magnitude may be the difference between producing a profitable crop or making a loss on the venture.

A Miscanthus crop established with exemplary husbandry should initially outcompete the black-grass and over a 10 year period would significantly reduce or potentially even eradicate the problem. Once black-grass has been removed it should enable improved cereal yields in a clean seed bed. With the increasing challenges of managing black-grass in arable rotations farmers are starting to look to alternative solutions for severely infested fields. In the last year Terravesta has seen an increase in the number of enquiries about Miscanthus for black-grass control, especially on the east side of the country[184].

5.6 Discussion

5.6.1 Land conversion process

In the past the vast majority of energy crops planted in the UK have been supported by grant schemes such as the Energy Crops Scheme (ECS) or Energy Crops Challenge Fund. In order to qualify for these grants the applicant needed to demonstrate that they adhered to any regulatory requirements. Any issues with the proposed planting would be identified by an environmental appraisal and site visit by a

[180] Eves, C., Johnson, M., Smith, S., Quick, T., Langley, E., Jenner, M., Richardson, W., Glynn, M., Anable, J., Crabtree, B., White, C., Black, J., MacDonald, C., and Slee, B. (2014). Analysis of the potential effects of various influences and interventions on woodland management and creation decisions, using a segmentation model to categorise sub-groups - Volume 4: Woodland creation segmentation Defra, London http://www.forestry.gov.uk/pdf/Volume-Four_Woodland-creation-segmentation.pdf/$FILE/Volume-Four_Woodland-creation-segmentation.pdf

[181] Such regional initiatives include Heartwoods in the Midlands, Cumbria Woodlands in the North West and Northwoods in the North East. A more complete list can be found at http://www.forestryace.eu/

[182] http://www.forestry.gov.uk/forestry/BEEH-A2MDMG

[183] http://academy.fwi.co.uk/Courses/Arable/grassweed-management-in-cereals/Blackgraas

[184] Alex Robinson, Terravesta. Personal communication.

local Natural England/Forestry Commission advisor. The aim of this procedure was to make sure that the planting of energy crops would not have a significant impact on the environment including:

- Surrounding dwellings
- Adjacent habitats
- Archaeological sites and historic features
- Public rights of way
- Surrounding landscape
- Water resources and water quality

As part of the process the advisor would assess whether an Environmental Impact Assessment (EIA) was necessary and statutory consultees such as Local Authorities, Historic England and the Environment Agency would be contacted. In addition, the advisor would suggest other people/organisations to consult such as neighbouring households and utility companies. A very similar procedure was conducted under the Woodland Grant Scheme.

The ECS in England was closed in September 2013. Anyone wishing to plant energy crops after this date still needs to comply with many of these procedures in order to receive payments under the Common Agricultural Policy (CAP) and meet sustainability requirements required by biomass fuel end users. However, without the framework provided by the ECS environmental appraisal it is not certain if new growers are aware of the steps they need to take and the organisations that they need to consult before they plant energy crops.

There is no one UK organisation that oversees all aspects of energy crops. Instead, there are a number of organisations and agencies which have responsibilities for certain parts of the land conversion process. The picture is further complicated by the fact that agriculture and forestry are devolved matters so different organisations deal with these activities in different countries within the UK. Much of the official information that is available (e.g. Government sponsored websites and guidance notes) are out of date and refer to schemes such as the ECS that have ceased. To aid further uptake of energy crops in the future growers would benefit from up to date guidance that is relevant to all parts of the UK and has support from all the organisations involved in the process.

Prior to planting, all growers need to know the EIA thresholds for energy crops and who they need to contact to conduct an EIA screening if their project exceeds this area. In many cases there will be no environmental issues identified, and as long as there are also no designated heritage assets, public rights of way (PROWs) or utility lines on their land, they will be able to proceed to planting. In some situations the EIA screening will flag environmental issues and this will require an Environmental Statement to be produced and the proposal to be shared with statutory consultees. After a set period the organisation leading the EIA will make a decision on the proposal. A rejected application can go through an appeals process. The existence of any heritage assets would mean that the farmer would need to consult Historic England (or the equivalent devolved agencies) and in this situation planning permission would be required. If PROWs or utility lines are present on the land then the farmer should liaise with the Local Authority or Utility Company to make sure that the crop is planted appropriately and provides sufficient access.

Some aspects of the process, such as the EIA are dealt with by different organisations depending on the energy crop in question. In England, EIAs for Miscanthus are dealt with by Natural England (under EIA Agriculture regulations) and EIAs for SRC and SRF are dealt with by the Forestry Commission (under EIA Forestry regulations). SRC is classed as a permanent agricultural crop under CAP and treated differently from woodland in terms of grant provision and tax law. However, because it is covered by EIA (Forestry) which has an afforestation threshold of 5 hectares on all land types and 2 hectares in sensitive areas, many more SRC projects require scrutiny. By contrast the threshold for Miscanthus is 2 hectares, but this only covers uncultivated land, and semi natural land in Scotland.

Miscanthus, SRC and SRF are all classified as permanent crops and as such are eligible for Basic Payments (BP) under the CAP. Growers of energy crops needs to adhere to cross compliance rules (Good Agricultural Environment Conditions (GAEC) and Statutory Management Requirements (SMRs)) in order to ensure they are paid the BP. GAEC rules include maintaining buffer strips around watercourses and field boundaries as well as maintaining PROWs and preserving scheduled monuments. Farms under 5 hectares fall outside the CAP, but growers of energy crops still need to adhere to UK and EU environmental legislation, which covers the same ground.

The Greening measures under CAP are unlikely to increase energy crop planting. Miscanthus, SRC or SRF are not on the list of eligible diversification crops for arable land, but could be planted to reduce the total arable area below key trigger points. SRC has been included as an Ecological Focus Area (EFA) measure in Wales and Northern Ireland. However, the weighting factor of 0.3 is much lower than other options (e.g. hedges, fallow land etc.). Furthermore, the arable areas are less than 6% of the total farmland in each country, and average farm sizes tend to be lower than the UK average.

UK Government backed renewable energy schemes such as the Renewable Heat Incentive (RHI) and Renewables Obligation (RO) require biomass fuels to be obtained from sustainable sources. End users need to be able to demonstrate that their biomass fuel source meets lifecycle greenhouse gas (GHG) emissions target of 60% savings against the EU fossil fuel average, and satisfy land criteria (i.e. adhere to rules on the type of land on which the biomass was produced) or report against the Timber Standard. This is relevant in cases when the end user of the fuel is also the supplier (known as self-supply).

Energy crops which have been assessed as meeting the requirements of the ECS or equivalent will automatically meet the land criteria. Growers of energy crops planted outside the ECS need to provide Ofgem with proof that the land was farmland in 2008. Evidence can include maps of the plantation, size of holding, land deeds, aerial photographs, contractor's receipts showing agricultural work performed etc. Evidence of consultation with statutory consultees and any official responses (e.g. EIA screening decisions) will provide additional evidence that the crop was planted sustainably.

Under the RHI, self-suppliers of SRC and SRF can register on the Biomass Suppliers List which is an official body that confirms the sustainability of the source. Miscanthus self-suppliers currently (November 2015) have to self-report, but there are plans for an industry led Waste, Residues and Energy Crops Sustainability List (WRECSL) to meet this need.

Under the RO self-suppliers of SRC or Miscanthus would need to self-report on a monthly and annual basis (projects >$50kW_e$) and provide an independent sustainability audit (projects ≥$1MW_e$). At the time of writing (November 2015) there are no dedicated electricity/CHP self-supply projects using Miscanthus and SRC in the UK.

5.6.2 Opportunities and barriers

In this section we consider in detail at some of the key barriers to converting land to Miscanthus, SRC and SRF. As Miscanthus and SRC are usually considered to be agricultural crops and SRF to be forestry we have summarised them separately in the sections below.

Barriers to energy crop cultivation

Despite over 25 years of policy support and numerous incentives, the uptake of energy crops has been very slow and achieved less than 10% of the anticipated planting area[185]. The industry has been affected by stop-start policy support, the high profile failure of projects (e.g. Project Arbre in 2003) and liquidation of companies associated with these crops (e.g. Bical in 2008). In addition, many of the policy instruments deployed have not had the desired results[186].

The SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) performed as part of the EU funded Rokwood project[187] suggests that the main strengths of energy crops are the ability to provide low carbon fuel, to assist in fuel security and deliver multifunctional benefits (e.g. energy supply, water quality improvements and flood mitigation). The major weaknesses are the lack of long term markets, insufficient large markets to provide economies of scale, the lack of infrastructure and funding to enable the set-up of supply chains and the lack of official guidance, publications and training days to transfer knowledge of up to date information coming out of research organisations.

A recent paper suggests that farmers are very indifferent to planting energy crops[188]. This found that out of 244 English arable farmers 81.6% and 87.7% respectively would not consider growing Miscanthus or SRC. The reasons cited for this were impact on land quality (damage to drains, cost of land change back to agricultural use), lack of appropriate machinery, commitment of land for a long period of time, time to financial return and profitability. The paper suggests that if the low level of interest in planting energy crops was matched across the whole of England then this would lead to planted areas of just 89,900 ha of Miscanthus and 50,700 ha of SRC. This is far lower than the estimates in the other parts of this report and Government policy documents (such as the UK Bioenergy Strategy 2012)[189].

Table 45 below summarises the barriers and makes recommendations on how the process of converting land to energy crops could be improved. Some of the barriers are market related i.e. more farmers could be encouraged to convert land to energy crops if a market pull is created or if hurdles to end use are removed.

Table 45: Summary of key issues faced by the energy crops industry and recommendations for overcoming barriers and achieving potential

Barriers	Opportunity
The provision of official guidance and advice is un-coordinated. Many of the pages on Government and agency websites and guidance	The availability of up to date information in paper form and on a dedicated website provided by an independent source would be beneficial to help farmer understanding and acceptance. Guidance documents need to provide current information on land conversion procedures for energy crops with specific information on EIA

185 The expectation was for 125,000 hectares of energy crops to be planted by 2010 as a result of policy stimulus. MAFF. England Rural Development Plan - Energy Crops Scheme Consultation Document. London: Ministry of Agriculture, Fisheries & Food (MAFF); 2000. The 2007 UK Biomass Strategy suggested a figure of 350,000 hectares by 2020: http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/RESOURCES/REF_LIB_RES/PUBLICATIONS/UKBIOMASSSTRATEGY.PDF

186 A critical appraisal of the effectiveness of UK perennial energy crops policy since 1990. Adams, P.W.R. & Lindegaard, K (2015) Renewable and Sustainable Energy Reviews (in press)

187 www.rokwood.eu Rokwood: European regions fostering innovation or sustainable production and efficient use of woody biomass was supported by the European Commission under call FP7-Regions-2012-2103-1 "Regions of Knowledge" of the 7th Framework Programme for Research and Technological Development. The general coordinator of the project was ttz Bremerhaven. The project ran from December 2012 – November 2015.

188 Prospects for arable farm uptake of Short Rotation Coppice willow and miscanthus in England. Neryssa J. Glithero, Paul Wilson, Stephen J. Ramsden. Applied Energy Volume 107, July 2013, Pages 209–218. http://www.sciencedirect.com/science/article/pii/S0306261913001402

189 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48337/5142-bioenergy-strategy-.pdf Suggests that the theoretical maximum available land for SRC and Miscanthus in the in England and Wales not impinging on food production is between 0.93 and 3.63 Mha.

Barriers	Opportunity
documents are out of date. There is a lack of consolidated leadership in the energy crops sector with no one body focused purely on the needs of energy crop growers. There is a lack of trained independent experts and understanding amongst farm management consultants.	procedures, statutory consultations prior to planting, CAP protocols and sustainability requirements of renewable energy schemes. An industry led energy crops levy board could make the sector more competitive by increasing the availability of impartial information and facilitating applied research. Advice could be made available through agricultural extension workers similar to the Resource Efficiency for Farms (R4F) scheme. Knowledge Transfer Groups could be set up for energy crop growers and prospective growers using Rural Development funding.
The cost of establishing energy crops is high and there is currently no planting grant. Growers have to accept poor cash flow in the early years of crop growth. Several markets have failed in the past. Energy crops are frequently considered to be high risk, long term investments. Energy crop removal is as a capital expense which is not tax deductible.	The high establishment costs of Miscanthus and SRC could be reduced by novel planting techniques using seed (Miscanthus) or billet (SRC) planting techniques. Cashflow issues up until the first harvest could be assisted by end users offering a finance package with reduced price for the crop in later years in order to pay farmers a reasonable return during the first 3-4 years. Risk could be reduced if the Government was prepared to underwrite industry contracts or provide some guarantee to farmers that new markets will be found in the event of one user failing. Concerns over the cost associated with crop removal could be addressed by the introduction of a grant for land reversion. Alternative measures might include greater risk sharing with end users bearing these costs or a change in tax law to make this activity tax deductible.
There is a lack of large markets to kick start industry and provide economies of scale. There is a lack of infrastructure and funding to create supply chains.	LEPs and other regional enterprise agencies could be encouraged to conduct feasibility studies to identify suitable locations for pilot projects. Energy crops could be planted in areas where there are specific needs e.g. high off gas areas with low woodland cover. Rural Development funds (LEP Growth fund, LEADER funds via LAGS) could be channelled into forming local initiatives such as producer groups with supply hubs to support these opportunities alongside establishment grants. Capital grants offered through Rural Development Programmes (RDP) could include energy crop machinery in addition to forestry kit.
The multifunctional benefits of energy crops are not being fully recognised in UK policy frameworks. There is little encouragement to plant energy crops under the current CAP.	A full evidence based review and cost benefit analysis of multi-functional environmental and socio-economic benefits offered by energy crops (supported by all the Government Departments and agencies involved) would make it more likely for energy crops to be looked on favourably under CAP schemes. Defra and the Scottish Government could reconsider including SRC as an EFA measure. The pollination services provided by SRC willows require more research activity. This could bring about a re-evaluation of the low weighting awarded to SRC plantations. Energy crops should be considered for grant provision in flood risk areas or where they can help reduce diffuse water pollution from agriculture bringing them in line with woodland plantings.

Barriers	Opportunity
There is a lack of research and development funding for machinery and plant protection products	Research is needed to design, test and bring to market reasonably priced SRC machinery that can be applied to marginal areas such as small fields, wet soils and sloping fields. The development of mobile pelleting machinery is still in its infancy. An affordable unit capable of producing quality pellets on farms is required. More research on herbicides that can be used on energy crops would be beneficial to the cost effective establishment of crops. Consideration could be given to how to make it easier for Extensions of Authorisation for Minor Use (EAMUs) to be transferred when herbicide and pesticide product names are changed.
It is more difficult for farmers using Miscanthus to get projects accredited under the RHI.	The creation of a Miscanthus standard against which to test boilers for emissions would enable more manufacturers to easily test their products and lead to more choice for end users. The creation of an industry led sustainability list for Miscanthus and straw users will make it simpler for farmers to demonstrate compliance.

Barriers to woodland creation

SRF grown for bioenergy production has longer rotations than Miscanthus and SRC. As a result the majority of barriers to land conversion to SRF are more closely associated to general barriers to woodland creation. A report in 2014[190] based on a national segmentation survey identified a number of key barriers to woodland creation amongst farmers. The survey responses were analysed to identify five farmer segments:

i. Pragmatic planters (17%) – farmers who undertake multiple activities and are sympathetic to conservation. They tend to have a strong profit motive and are a suitable target for interventions and incentives designed to increase income from woodland, such as developing woodfuel supply chains and increasing access to carbon finance.
ii. Willing woodland owners (24%) – farmers who are most willing to sacrifice profit for environmental benefits are the second most likely to plant new woodland and have the largest proportion of existing planted woodland.
iii. Casual farmers (23%) – farming is not their dominant activity and income is not their main driver.
iv. Business-oriented farmers (20%) – farmers who believe farming is all about profit, and that the quality of their land is too high for woodland creation.
v. Farmers first (17%) – farmers with a strong belief that farming, including its environmental benefits, is superior to woodland.

[190] Eves, C., Johnson, M., Smith, S., Quick, T., Langley, E., Jenner, M., Richardson, W., Glynn, M., Anable, J., Crabtree, B., White, C., Black, J., MacDonald, C., and Slee, B. (2014). *Analysis of the potential effects of various influences and interventions on woodland management and creation decisions, using a segmentation model to categorise sub-groups - Volume 1: Summary for Policy-Makers and Volume 4: Woodland creation segmentation* Defra, London. London
http://www.forestry.gov.uk/pdf/Volume-One_Summary-for-Policy-makers.pdf/$FILE/Volume-One_Summary-for-Policy-makers.pdf
http://www.forestry.gov.uk/pdf/Volume-Four_Woodland-creation-segmentation.pdf/$FILE/Volume-Four_Woodland-creation-segmentation.pdf

Across all groups the largest barrier identified was the profitability of agriculture in comparison to woodland. The second most important barrier identified was the potential restriction on when farmers will be able to harvest the woodland planted. The availability of spare land to plant woodland was the third highest rated barrier although the Pragmatic Planters and Willing Woodland Owners were least likely to see this as a problem.

Table 46 summarises the barriers identified in this report and makes recommendations on how the process of converting land to woodland and SRF could be improved.

Table 46: Summary of key issues faced by afforestation (including SRF) and recommendations for overcoming barriers and achieving potential

Barrier	Opportunity
There is a lack of knowledge on tree planting amongst the farming sector.	Improved knowledge and skills could be achieved by better dissemination of best practice and silvicultural techniques and greater provision of training and awareness raising amongst farmers.
Planting and management grants are available, but there are many different levels depending on the type of trees planted and the type of farmland being replaced. The application process is complicated and the bureaucracy involved can be off-putting.	There is a need for better/more simplified guidance on the application process for afforestation schemes and the EIA process. This could be achieved by offering planning grants and or a handholding service for woodland creation schemes as per the FC Scotland Planning Grant example provided in Section 2.1.7[191]. Farmers should be made more aware of the afforestation options under Countryside Stewardship (CS) and how schemes can meet the stated priorities and still retain an element of productivity. Farmers should also be provided with information on other sources of finance for woodland creation such as carbon finance.
Many farmers don't think they have enough land to plant woodland. This view is reinforced by the widespread perception that the profitability of forestry is much lower than agriculture. There are long timescales to obtain benefits.	A full evidence based review and cost benefit analysis could show how afforestation can compete on commercial terms with certain types of agriculture. The wider availability of upfront financing deals as per the examples given above could help ease cash flow issues.
Farmers are deterred from planting by not having the necessary equipment to plant, maintain and harvest trees or lack of access to contractors.	There is a need for improved dissemination on the availability of local contracting services and the range of forest machinery available. Farmers should be encouraged to take up RDP funds such as Countryside Productivity and Leader to support farmers in making investments in machinery.

[191] The UK Government has made a recent announcement (10th November 2015) that an additional £1 million Forestry Innovation fund is being made available. This could be used for supporting afforestation schemes. Forestry Commission England are currently developing plans to roll this fund out. Confor (2015) accessed online at http://www.confor.org.uk/NewsAndEvents/News.aspx?pid=23&id=2889

Barrier	Opportunity
The regulations involved in tree planting such as EIA and felling licences can be off-putting to farmers. The need for a felling licence may restrict when farmers will be able to harvest their woodland.	More farmers might be encouraged to plant trees if the FC increased the EIA threshold area for planting in non-sensitive areas. There is a need for simple guidance for farmers as to when and how they can fell trees depending on the system selected, ensuring that any harvesting is done according to felling licence requirements.
Farmers are concerned that there is no certainty of a market for wood products.	The quick growth in the local biomass heat market has gone a long way to addressing the issue of lack of local wood markets with most regions now showing considerable demand for woody biomass fuels. The current uncertainty surrounding the future of the RHI is unhelpful although the outcome of the Comprehensive Spending Review on 25 November 2015 will address this.

In addition to the above analysis, the segmentation research highlights three further important approaches to targeting support for woodland creation which applies to all the segments:

- Target larger freehold farms. Farm holdings over 250ha are more likely to plant woodland with tenanted farms being least likely.
- Target farms with existing woodland. Farmers with woodland on their land are more than twice as likely to plant woodland.
- Target stakeholders through organisations (such as the NFU, CLA, RFS). Motivational factors for woodland creation cut across ways of classifying land owners. This could make it difficult to target these groups of owners with incentives and initiatives, but one suggestion is to target them through the organisations to which they belong.

6 Final summary and conclusions

6.1 Review of existing studies

Chapter 2 reviewed 46 peer-reviewed academic and grey literature studies published between 2003 and 2015 that used one or more method for estimating land availability for bioenergy. In the literature, numerous methods have been used for the estimation of land availability, including land-balance modelling, GIS constraint modelling, economic optimisation, agent-based modelling and farmer surveys.

It is important to recognise, however, that none of these methods can be considered a predictive or forecasting tool. The differing context, methodologies, data and assumptions of the studies analysed lead to the area ranges shown in chapter 2 being very large. Overall, it can be concluded that currently the data does not exist to provide precise land area estimates (nor is it likely that the study methodologies and global drivers would ever allow this accuracy). Nevertheless, the studies collected do allow identification of the key drivers and sensitivities, and from this there is certainly a credible range of estimates within which the future for the energy crop and SRF sectors may lie – provided the policy, markets and crop technology are all developed and supported.

Estimates of UK land area available for energy crops from these studies ranged between **7 kha and 1,723 kha** in the near-term (up to ~2020). The bottom of this range represents a historical figure for the area of energy crops planted, which contrasts with the **10.3 kha** known to be planted today from Defra (2014) statistics. The top end of this range corresponds to a demand led scenario in which the entirety of UK's 2020 bioenergy target under the EU Renewable Energy Directive is met from domestic production. UK studies also give a range of **89 – 10,569 kha** available for energy crops as a long-term potential, and areas of **0 – 4,131 kha** available for SRF planting in the long-term.

Further sub-categorisation of studies does not lead to a large amount of new insight (Table 47 to Table 49). Very large ranges still exist within the categories, with no distinct clustering. Farmer surveys and agent based simulations are typically the most cautious, followed by inventories. Demand led, GIS and land balance approaches are typically the most optimistic. Potential demand scenarios can exceed the maximum feasible land availability derived by GIS and land balance (imports may be required).

Table 47: UK Estimated area available for energy crops (kha)

kha	Near term		Future Potential	
Study Type	**Min**	**Max**	**Min**	**Max**
Demand led	7	1,723	314	10,569
GIS	638	800	337	9,086
Land balance	177	890	478	7,349
Inventory / meta analysis	7	740	99	3,630
Agent based model	39	303	89	1,800
Farmer survey	29	99	546	968
All studies	**7**	**1,723**	**89**	**10,569**

Table 48: UK estimated area available for SFR (kha)

kha	Near term		Future Potential	
Study Type	**Min**	**Max**	**Min**	**Max**
Land balance	50	2,498	305	4,131
Inventory / meta analysis	0	66	0	1,241
All studies	**0**	**2,498**	**0**	**4,131**

Table 49: EU estimated area avaialble for energy crops (kha)

kha	Near term		Future Potential	
Study Type	**Min**	**Max**	**Min**	**Max**
Demand led	940	25,217	1,640	18,793
Land balance / meta analysis	4,000	20,500	7,780	108,200
Inventory	1,350	1,350	No data	No data
All studies	**940**	**25,217**	**1,640**	**108,200**

GIS based assessments provide a snapshot of how much land is hypothetically available for energy crops after excluded land areas are removed. This approach can provide a greater level of spatial resolution than estimates at country (NUTS2) level calculated using land balance methods. However, existing uses of the available land areas (e.g. competition with food and feed production) are typically not considered, hence available areas in these GIS studies are typically high. Over the last eight years, GIS modelling has emerged as an important strand of analysis in the UK and the constraint masks describing excluded land have become increasingly sophisticated. One of the most influential GIS studies identified in the review was Lovett et al. (2009). Outputs from this study have been used in other studies, either through use of a similar or updated approach (Lovett et al., 2014; Aylott et al., 2010), or combining them with yield mapping or biomass supply and demand locations (Hastings et al., 2014; Thomas et al., 2013). In addition to the economic competitiveness points above, one of the key limitations of these GIS studies was found to be the lack of validation through the use of ground-truthing. This limitation was addressed in the current project.

6.2 Refining BVCM Estimates of Land for Biomass

The methodology used by Lovett et al. (2009, 2014) created a suite of mask layers. These masks (including the UKERC 9w mask used as the baseline for this study) are used in the Energy Technologies Institute's Bioenergy Value Chain Model (BVCM). The objective of this project was to analyse the impact of adding additional datasets to BVCM assumptions on land availability for energy crops (Miscanthus, SRC and SRF). This was addressed by carrying out a GIS analysis, including a review of the strengths and weaknesses of additional datasets, which was subsequently validated and improved through data collected as part of a field survey (Chapter 3).

The use of outputs from the field survey provided an opportunity to test the impact of the inclusion of additional datasets to the UKERC 9w mask on predictions of land availability. Logistic regression analyses were performed to quantify the relative effect that each one of the datasets had on the prediction of the field survey classification of the sub-cell. The field survey also provided the opportunity to examine the reasons for discrepancies between the results. The final mask was chosen based on the results of the regression analyses and the analysis of reasons for discrepancies between field survey and desk study results. Examining the reasons for discrepancies also allowed for the identification of 'gaps' in the mask, meaning that potential alternative or additional datasets could be sourced.

Across the five cells included in the study, the estimated available land was 9,136 km^2 (74%) with the UKERC 9w mask, which was reduced to 7,701 km^2 (62%) with the final desk study mask. Details of the differences in the individual cells are summarised in Table 50.

Table 50: Summary of available land with and without masks in each of the assessed cells (values in brackets are the percentage of land available).

Cell	Total land area (km^2)	Available UKERC 9w (km^2)	Available final mask (km^2)	Assessed in field survey (km^2)	Available in field survey cells – final mask (km^2)	Available in field survey – surveyor's view (km^2)
19	2,500	1,565 (63%)	1,013 (40%)	206	143 (69%)	121 (59%)
40	2,453	2,199 (90%)	2,000 (82%)	Na	Na	Na
46	2,500	2,053 (82%)	1,938 (78%)	202	194 (96%)	179 (87%)
72	2,412	1,999 (83%)	1,748 (72%)	Na	Na	Na
100	2,439	1,320 (54%)	1,002 (41%)	202	156 (77%)	173 (86%)
Total	**12,304**	**9,136**	**7,701**	**610**	**493**	**473**
Percentage 'available'		**74%**	**62%**		**81%**	**78%**

Additional datasets used to create the final mask included:

- Elevation – provided by an accurate dataset with a threshold supported by scientific studies
- Agricultural Land Productivity – a strong driver for limiting the planting of bioenergy crops, however it does not represent a hard constraint, and requires an update
- Buildings and Water bodies – provided by an accurate and up-to-date dataset, however was not able to provide all of the desired information (e.g. coverage of gardens or carparks)
- BAP Priority habitats – designed for the purpose of representing prioritised land at a sufficient scale
- Semi-natural woodland – extent determined by Ancient Woodland Inventory plus a Semi-Natural Woodland Inventory in Scotland. The Ancient Woodland dataset does not identify all semi-natural woodland for England.
- Parks and gardens – provided by an accurate dataset representing land unlikely to be used for planting

These datasets were used in the creation of a final mask that had been validated against field data. The final mask had a 77% match with the field survey, where only sub-cells that were classed as available using the UKERC 9w mask were surveyed. As discussed, the field survey was able to help highlight constrained areas not identified in the desk study. These included private gardens, golf courses, quarries and carparks. Conversely, there were masked areas identified by the desk study which could not be identified by the field survey. These included high grade land, high altitude land and certain land designations. Given that the field survey could not provide a perfect estimation of land availability due to some constraints not being visible on the ground, and because UKERC 9w was not disaggregated, it was not possible to provide an accurate value for the level of uncertainty in the final estimates.

Due to resource and time limitations, the field survey was only carried out in 10% of sub-cells within three 50 km x 50 km cells. Furthermore, one of these cells was in Scotland and the other two in England. Due to the small sample size and the variability in landscape and dataset availability across the UK, the predictive capability of the final mask cannot be assessed for the whole range of landscapes and constraints that occur in the UK. We therefore conclude that a UK-wide correction factor cannot be applied. Creation of a mask using the recommended datasets at UK scale would enable a national estimate to be produced, although the associated level of uncertainty would not be known. The inclusion of a field survey in this study has been fundamental in providing both a means for testing the strength of the inclusion of each dataset, and also in the identification of 'gaps' in methodologies. It is therefore recommended that any further study include a field survey or ground-truthing method to test the legitimacy of using the recommended mask in other cells.

A weakness of the reviewed GIS–based studies was that they only provided a snapshot of how much land was hypothetically available at the time of assessment. This is also true of this study since the datasets used are not predictive of future constraints. The study does, however, highlight the need for a regular review of any masks and land availability estimates. Furthermore, this study has been successful in identifying a refined estimate of land availability for bioenergy planting within the study cells, and provided a list of tested datasets that could be used to refine estimates of land availability for the UK.

6.3 Implications for land availability modelling.

Ultimately, the area available for energy crops depends on how competing demands for land are prioritised now and in the future. Social, technological, economic, environmental and political factors affect this prioritisation. Set against the complexity of attempting to determine a normative "best use" of land, the questions that bioenergy crop assessments can effectively tackle are comparatively simplistic. Demand led assessments only describe what might be needed, not how or where it can be achieved. Land balance models are sensitive to simple parameters describing complex phenomenon such as future yield growth and dietary trends, and consequently they are best used for scenario analysis. Agent based simulation and farmer survey methods are currently insufficiently mature to provide anything other than a crude indication of what might be achievable or plausible, given current expectations of decision makers' behaviour.

GIS models can provide detailed scenarios for land use, but the fact that there are some discrepancies between the results of the desk based study and the field survey should not be too surprising given the spatial heterogeneity of the UK agricultural landscape. Lovett et al (2014) used planting grant data from Natural England to show that only 83% of planted UK energy crops lie within areas modelled by the GIS masks as potentially suitable, underlining the importance of market factors and real world decision making, compared to just relying on GIS approaches.

A previous attempt to ground truth estimates of the area available for future cultivation – albeit in developing countries rather than the UK – identified two major sources of overestimation: firstly, the inability of models to take into account constraints that only become apparent at high levels of spatial resolution; and secondly, failure to take into account non-agricultural land uses (Young, 1999[192]). The analysis presented in this project indicates that these sources of overestimation are also likely to apply to the UK. It is also apparent that there is a trade-off between the cost of accessing and processing more detailed spatial data to produce updated masks, and the need for a more precise estimate of potential.

6.4 Barriers and opportunities

Refining the estimates of land availability for energy crops is only useful if the sector is actively growing. It is evident that are a range of barriers that have so far limited the planting of energy crops for biomass production. The barriers and opportunities for energy crops fall into five categories: markets, information provision, finance, policy (including regulation) and supply chain development.

[192] Young, A., *Is there really any spare land? A critique of estimates of available land in developing countries*. Environment, Development and Sustainability 1: 3–18, 1999.

There are only a limited number of large scale **markets** for Miscanthus, SRC and SRF in the UK, and due to cost of transport and the bulky nature of the raw materials these tend to have a regional focus, with suppliers tending to have to be from within a certain distance of the plant to make production cost effective. The price offered provides reasonable returns for farmers, but has not been a 'game changer' in persuading significant numbers of new growers to plant these crops. Supply to large scale outlets is dependent upon an energy crop meeting certain specifications, which can mean that storage facilities are tied up for long periods.

For energy crops, much of the official **information** that is available (e.g. Government sponsored websites and guidance notes) is out of date and refers to schemes such as the Energy Crops Scheme (ECS) that have ceased to exist. There are regular events and open days, but these tend to be industry led and crop specific. There is currently no accredited energy crop training available for farmers or consultants. As a result, the lack of impartial advice makes it difficult for land owners to make an informed choice on the right crop for their land, facilities and local markets.

Finance is a challenge for energy crops. Over the full lifetime of an energy crop there is attractive long term revenue profile, but these crops are typically viewed as risky investments with high establishment costs and poor cash flow in the early years. Some companies are trying to address this by offering planting services at cost and interim payments in the first 4-5 years to smooth out returns. The planting of Miscanthus is becoming more popular amongst arable farmers who have a pervasive issue with black-grass (*Alopecurus myosuroides*).

In terms of **policy** support, since the closure of the English Energy Crops Scheme (ECS) in 2013 there have been few incentives available for existing or would be growers in any of the UK countries. SRC has been adopted as an Ecological Focus Area (EFA) measure in Wales and N. Ireland. However, the limited arable area in these countries and low weighting (0.3) for SRC mean that this is unlikely to lead to much new planting. SRC cultivation (in particular) requires expensive, bespoke machinery, but this has not been eligible for funding under recent Rural Development grants. The Renewable Heat Incentive (RHI) has created opportunities for energy crop growers and farm woodland owners to self-supply woodfuel for their own heat provision. In most cases self-supply is a much cheaper option than buying in woodfuel. There are a number of barriers to the development of local heat **supply chains** (e.g. lack of infrastructure for harvesting and processing) and challenges (e.g. fuel quality) that need to be overcome if this is to expand.

There are a number of recommendations in the report that if taken forward could potentially increase the planted area of energy crops. In terms of funding and support, a coordinated approach is needed e.g. through local enterprise agencies, using a rationale of economic growth and community-based benefits of energy crops and woodland. Other opportunities include: greater incentives for SRC in CAP greening; setting up a levy body for biomass produced in the UK; a Miscanthus standard; more research on herbicides; land reversion grants; updating official guidance; and targeting woodland creation more effectively. The future development of the biomass sector would be improved by a single organisation taking a lead role overseeing all aspects of energy crops. Currently, there are a number of organisations and agencies which have responsibilities for certain parts of the land conversion process. The picture is further complicated by the fact that agriculture and forestry are devolved matters so different organisations deal with these activities in different countries within the UK.

7 Mini Case Studies

7.1 Cell 019

Cell 019 is located in the South-East of England and falls within the counties of West Sussex, Brighton and Hove & East Sussex, Kent, Surrey and Outer London (South). Large towns within the cell include Sevenoaks, Reigate, Crawley, Horsham, East Grinstead, Royal Tunbridge Wells and Uckfield. Motorways passing through the cell are the M23 and parts of the M25 and M26. There are also a number of rail routes running through the cell.

The Corine land-cover dataset was used to calculate the breakdown of land cover types in the cell (Table 51). The distribution of these land cover types is shown in Figure 1. The cell is dominated by agricultural grassland (49%), with substantial areas of arable land (22%) and forests (13%). Urban fabric covers 10% of the cell and is scattered throughout, with concentrations in the NW and central areas. The land within the cell is mostly low-lying, with elevation ranging from sea level to a maximum of 269 m (Figure 39). There are no historic or live Energy Crop Scheme plantings in this cell.

Table 51. Areas of Corine land cover types in cell 019 in decreasing order of area

Land cover	Area (km²)
Pastures	1218
Arable land	550
Forests	317
Urban fabric	251
Artificial, non-agricultural vegetated areas (e.g. Green urban areas, Sport facilities)	84
Heterogeneous agricultural areas (e.g. Agro-forestry areas)	27
Industrial, commercial and transport units (e.g. Industrial areas, Road networks)	23
Scrub and/or herbaceous vegetation associations	22
Mine, dump and construction sites	6
Inland waters	3

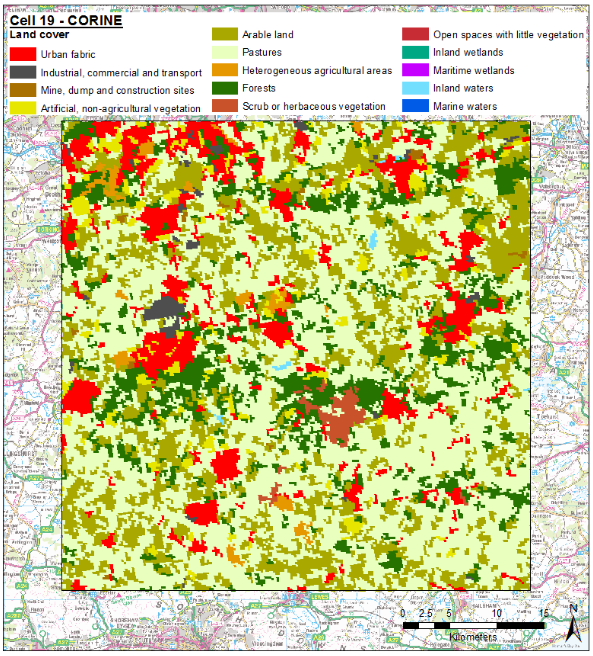

Figure 38. Distribution of Corine land cover types within cell 019

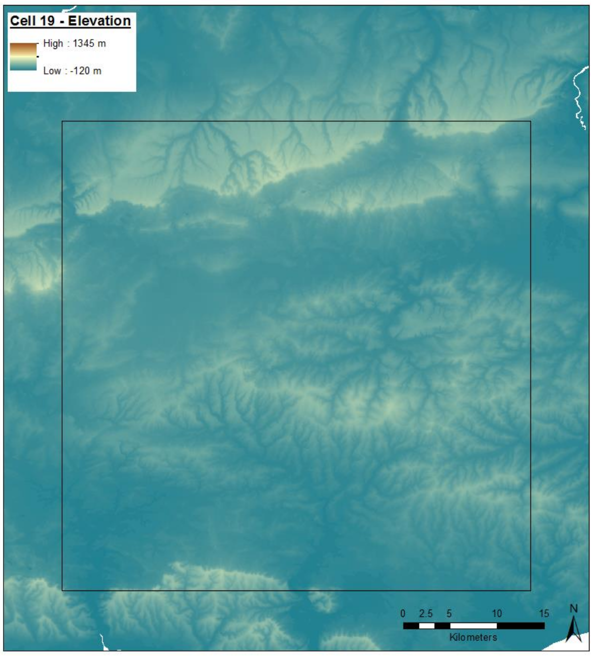

Figure 39. Elevation within cell 019

7.1.1 Planting targeting (using likelihood layers)

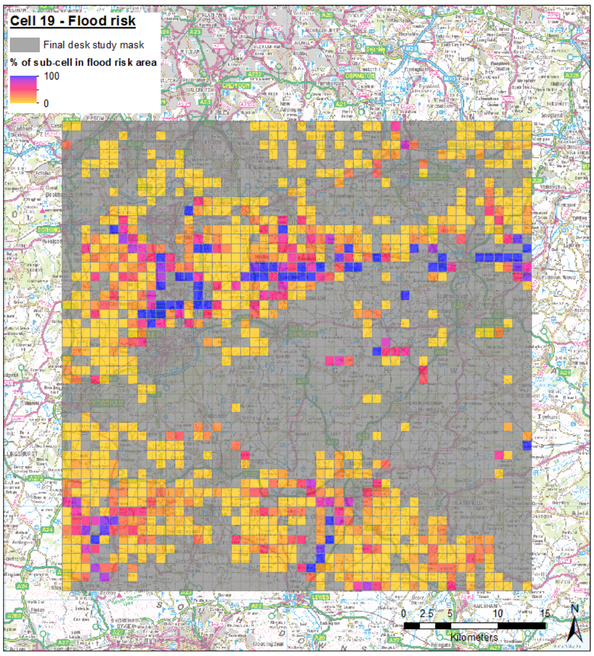

Figure 40. Percentage of sub-cells within a flood risk zone in cell 046

Some of the datasets identified for this study were not suitable for providing absolute constraints. They are however able to provide information that might help to target the planting of bio-energy crops. An assessment of the percentage of a sub-cell in a flood risk area was carried out. This was done using the Environment Agency; Risk of Flooding from Rivers and Sea dataset which identifies areas where each year, there is a chance of flooding of greater than 1 in 1000 (0.1%). The results of this for Cell 19 are shown in Figure 3. Of the 1,013 'available' sub-cells, there were 27 with over 50% of the sub-cell within a flood risk area. A similar assessment was carried out for the area of the sub-cell in within a Nitrate Vulnerable Zone (NVZ) 444 of the 'available' sub-cells in cell 19 are completely within a NVZ, 451 are not in a NVZ, and 118 are partially within a NVZ. Farm ownership within each cell was also examined. For cell 19, the average percentage of farm ownership was 65% (Figure 42).

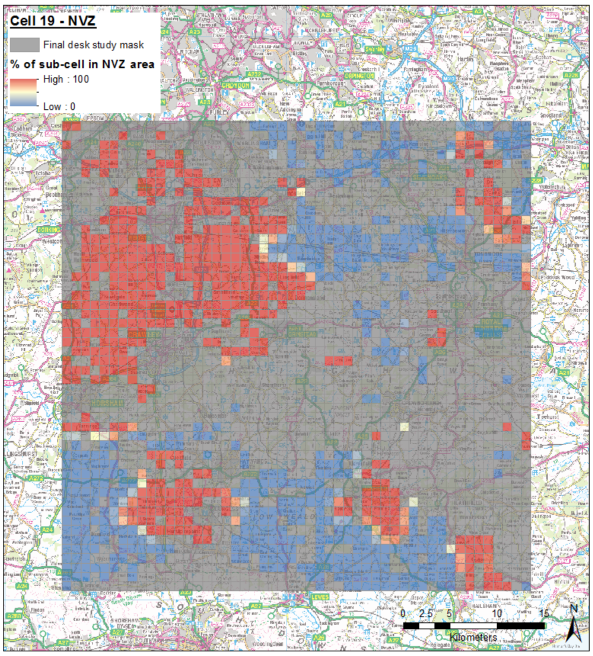

Figure 41 Percentage of sub-cells within a Nitrate Vulnerable Zone in cell 019

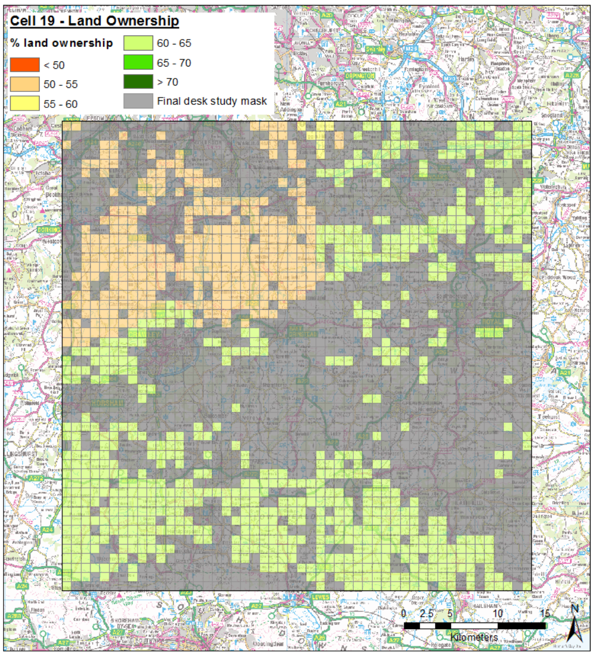

Figure 42 Percentage of agricultural land ownership (from regional Agricultural Census statistics for England) in cell 019 - data is provided at a country level and therefore colour changes reflect county boundaries giving a broad indication of ownership at a larger scale than the 1km sub-cells

7.1.2 Availability comparisons

Water Stress

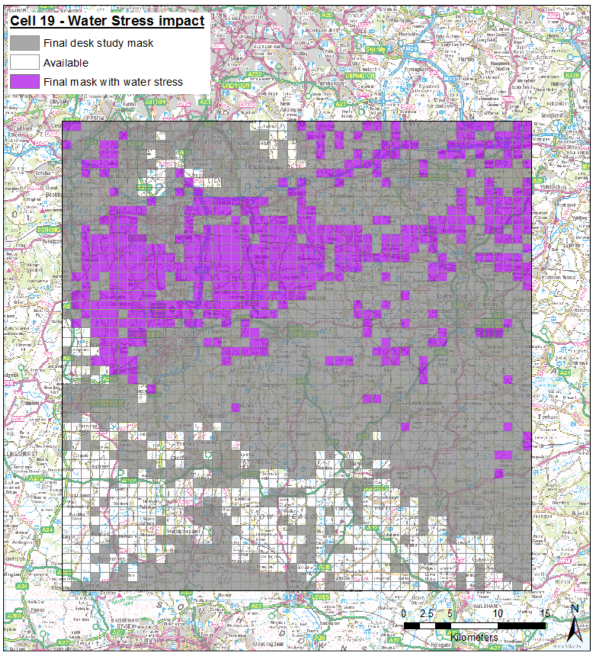

Figure 43 Impact on sub-cell availability when the water stress constraint is included for Cell 19

In the main desk study, the water stress was not included as a constraint in the assessment. For these case studies, an assessment has been carried out to see what impact the use of the water stress data would have on the availability of the sub-cells. Data from the Environment Agency Water Resource Availability and Reliability dataset. Areas selected as a constraint were areas where recent actual flows are below the Environmental Flow Indicator for the worst downstream water body at the flow percentile Q30 and water reliability is <30%. Figure 43 shows the additional sub-cells masked as a result of including the water stress dataset as a constraint. An additional 535 (2022 total) sub-cells are masked compared to 1487 in the final desk study mask, leaving 478 sub-cells available.

Desk study vs Surveyor opinion

There is a 70% match when the desk study is compared against the results of the field survey. Most of the discrepancies (42) are where the desk study has identified the sub-cell as available, while the sub-cell is unavailable according to the field survey (Table 52). Table 53 summarises some of the reasons for discrepancies that were identified in an assessment of aerial photography. Additional reasons can be found in the justification data from the field survey forms. These include land being used for horse paddocks or large gardens.

Table 52 Contingency table comparing the results from the field survey and final desk study mask for Cell 19

Cell 19 (number of sub-cells)		**Desk study** Unavailable	Available	**Total**
Field survey	Unavailable	43	42	**85**
	Available	20	101	**121**
	Total	**63**	**143**	**206**

Table 53 Summary of main reasons for discrepancies between desk study and field survey results at a sub-cell level in Cell 19

Primary desk study limitations where desk classed as available and field unavailable	Field survey limitations where desk classed as available and field unavailable	Primary desk study limitations where desk classed as unavailable and field available	Field survey limitations where desk classed as unavailable and field available
Houses and gardens not picked up by desk study Golf courses, quarries, carparks, power grid, sewage works not picked up by desk study Woodland not in ancient woodland or priority habitat (PH) inventories	Over-estimation of unavailable area by surveyors	UKERC-9w mask excluding land for unknown reason	PH/ ancient woodland not identified

Figure 44 provides an example of where limitations of data available for the desk study has resulted in a misclassification in a sub-cell. 8% of the cell is masked by the mask, however much of the land use in the sub-cell is either a golf course of a quarry.

Figure 44 Example of a sub-cell (RELB ID: 019_18_41) where limitations of the data have resulted in discrepancies between the desk study and field survey

Surveyor opinion vs Survey land area

In the 206 surveyed sub-cells, the surveyors were frequently only able to see a proportion of the sub-cell, with a proportion of the sub-cell unknown. The surveyor data, based on the visible portion of the sub-cell that had available land uses indicated that 104 sub-cells were available. However, when the unknown area was applied pro rata to the available and unavailable proportion of the sub-cell this increased to 106 sub-cells. The surveyor opinion indicated that there were 121 of the 206 sub-cells available.

Table 54 Contingency table comparing the results from the field survey (between the results of the land use coverage and the surveyor view) for Cell 19

Cell 19 (number of sub-cells)		**Land use (applied pro rata)** Available	Unavailable	**Total**
Surveyor view	Available	103	18	**121**
	Unavailable	3	82	**85**
	Total	**106**	**100**	**206**

There were 18 sub-cells where the surveyor thought that the cell was available, but the estimated area of available land indicated that they were not in fact available. There were nine of these sub-cells where the available land area was between 45% and 50% of the sub-cell area when the pro rata application of unknown land was applied, most were just 2% or less below the cut off threshold. In these cases the surveyor appears to have taken a pragmatic approach to deciding that the land was available. There were an additional four cells where there surveyor indicated that although they could not clearly see the unknown land they thought based on the maps and glimpses of the land that the majority of it was available (predominantly improved grassland), and therefore the proportion of land available would be higher than a pro rata calculation implies.

There were three sub-cells where the land area estimates indicated that the land was available, but the surveyor indicated that the land was not. The reasons these were marked as unavailable by the surveyors included;

- the inclusion of gardens to a hotel and land in front of a large manor house,
- the horticultural use being a vineyard – which was considered unlikely to be removed for bioenergy production,
- grassland used for equestrian use and therefore considered unlikely to change use to bioenergy.

7.1.3 Cell mask overview

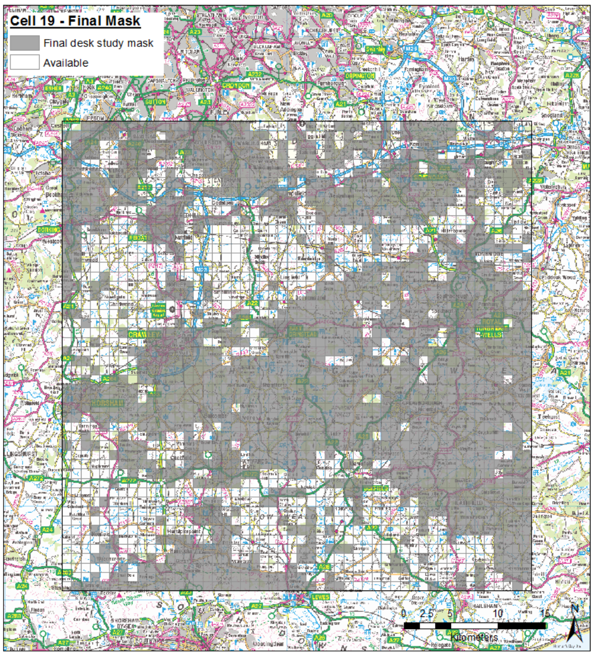

Figure 45. Impact of the final mask created from the desk study on cell 19

The available land in cell 019 is formed in two strips of land across the region. The first concentration of available land runs towards the north of the cell in an east west line level with Reigate and Tonbridge. The main concentration of available land sits around Reigate and Horley. This location has good transport links with a junction to the M23 accessible at Horley and the area also crisscrossed with A roads including the A22, A23, A24, A264 and A217. However, this area of land is highlighted in the water stress map as being under water stress, although given that it is also a valley there are parts of the land that are also prone to flooding.

The second area of available land in cell 19 is towards the south of the cell, following broadly along the route of the A272, from the A24 on the western boundary of the cell across to Uckfield and then moves to follow the A22 towards Hailsham on the south eastern border of the cell. Again the location has good transport links, both to the available land further north and to other areas of the country. This band of available land is typically 6-8km wide, with just occasional unavailable cells present, mostly around villages or small towns. The area below the A272 (known as the Low Weald) is a wooded and watery Medieval Landscape. This landscape character may lead to an issue with planting areas of Miscanthus or other Bioenergy crops.

Between these two bands of available land sits an area of forest, including St Leonard's Forest and Ashdown Forest, making much of the central part of the cell unavailable. The northern most extent of the cell sits within the M25, with large areas unavailable due predominantly to urbanisation.

There are a large number of villages and towns within this cell, this should mean that there are plenty of opportunities or markets for the sale of small scale bioenergy production. The mapping and surveying indicate that there is a good density of land that is potentially available for the use in bioenergy production, assuming suitable incentives and drivers are present for the establishment of bioenergy production in this location. However, the density of human population in this cell, could also mean that there will be challenges with neighbours objecting to the changing appearance of the land as bioenergy crops are planted and also lead to challenges in getting planning permission for biomass boilers or power plants due to local opposition.

The availability of the good road network means that this location would have the potential to move bioenergy crops to other locations with relative ease. Although, it should be noted that this location is well known for traffic congestion, especially around the more northern extents (M25 area) which will interfere with the ease of transportation.

7.2 Cell 046

Cell 046 is located in the Midlands of England and falls within the counties/ unitary authorities of Warwickshire, Leicestershire, Birmingham & Solihull, Coventry, Northamptonshire and Staffordshire. The cities of Leicester, Coventry and the eastern suburbs of Birmingham fall within the cell. Large towns within the cell include Tamworth, Hinckley, Nuneaton, Royal Leamington Spa and Warwick. Motorways passing through the cell are the M6, M42, M40, M1, M69 and M45. There are also a number of major rail routes running through the cell.

The Corine land-cover dataset was used to calculate the breakdown of land cover types in the cell (Table 55). The distribution of these land cover types is shown in figure 9.

Table 55. Areas of Corine land cover types in cell 046 in decreasing order of area

Land cover	Area (km^2)
Arable land	1285
Pastures	677
Urban fabric	331
Industrial, commercial and transport units	83
Artificial, non-agricultural vegetated areas	69
Forests	25
Mine, dump and construction sites	20
Inland waters	7
Scrub and/or herbaceous vegetation associations	3
Heterogeneous agricultural areas	2

The cell is dominated by arable land (51%), with substantial areas of agricultural grassland (27%) and urban fabric (13%). The urban areas are concentrated in the NE and centre of the cell. The land within the cell is mostly low-lying at close to sea level, with a maximum elevation of 220 m (Figure 47). There are 51 historic and 1 live Energy Crop Scheme plantings in this cell.

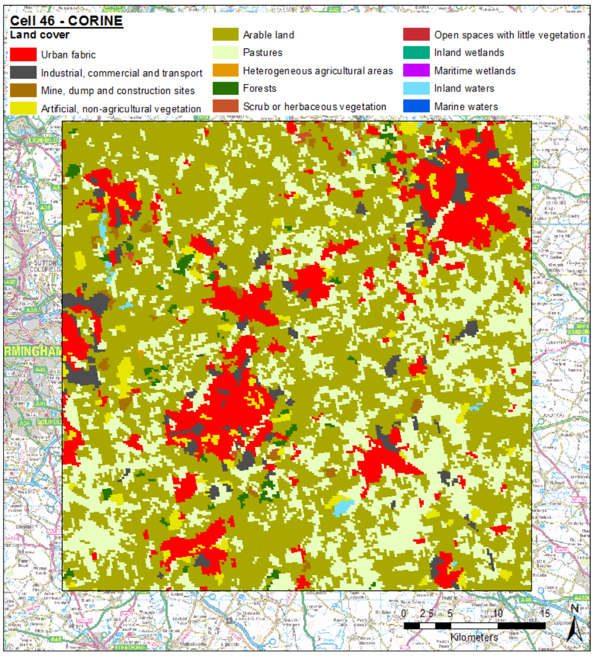

Figure 46. Distribution of Corine land cover types within cell 046

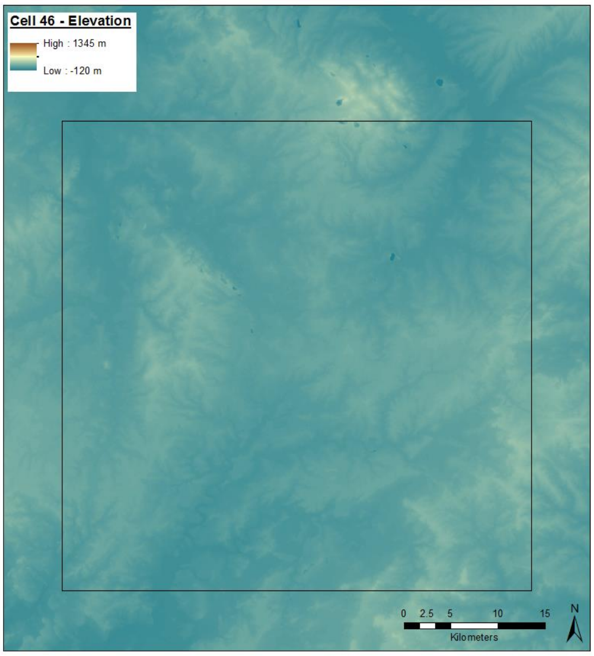

Figure 47. Elevation within cell 046

7.2.1 Planting targeting (using likelihood layers)

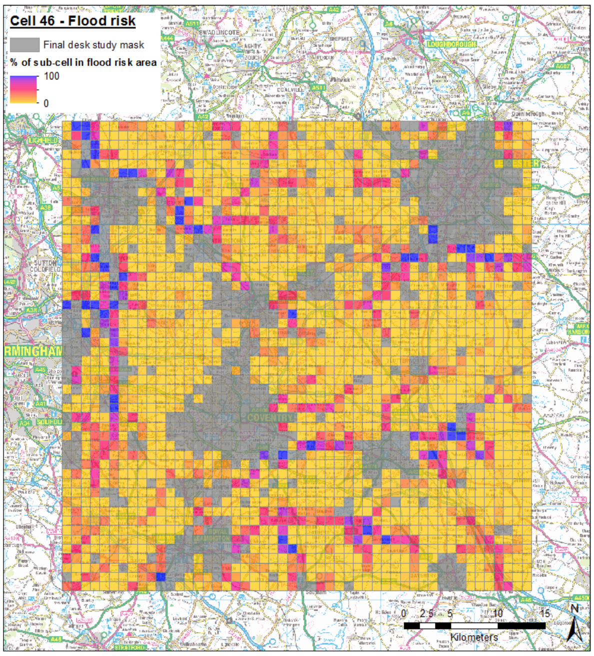

Figure 48 Percentage of sub-cells within a flood risk zone in cell 046

Maps for flood risk, nitrate vulnerable zones and farm ownership for Cell 46 are shown in Figure 11, Figure 49 and Figure 13 respectively. Of the 1,938 available sub-cells in cell 46, 33 were over 50% within a flood risk area. Almost all of the available sub-cells (1,937 of the 1,938) in cell 46 are completely within a NVZ; the one remaining sub-cell has a 90% coverage. The average farm ownership percentage in the cell is 65%.

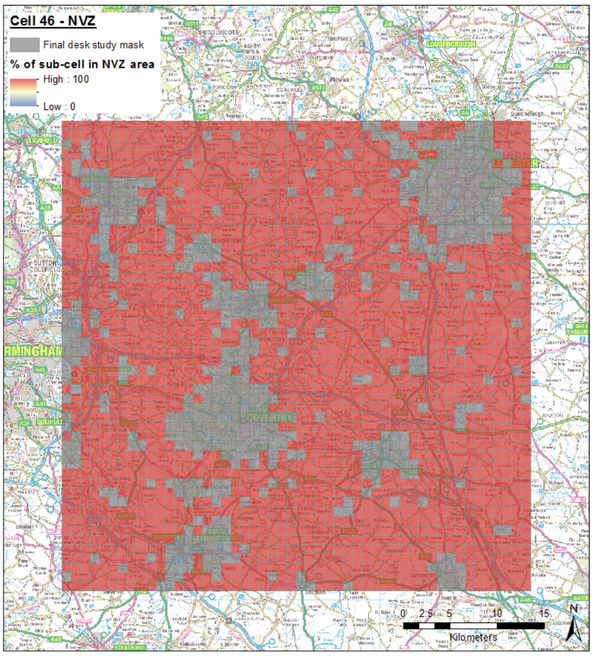

Figure 49 Percentage of sub-cells within a Nitrate Vulnerable Zone in cell 046

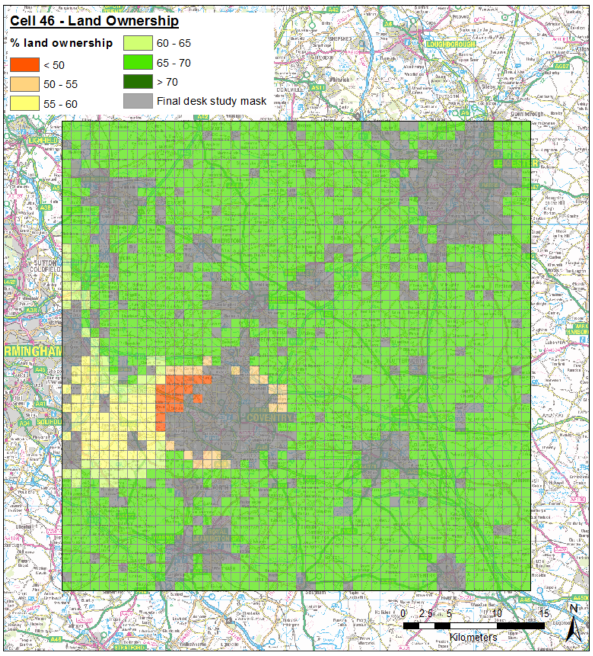

Figure 50 Percentage of agricultural land ownership (from regional Agricultural Census statistics for England) in cell 046 - *data is provided at a country level and therefore colour changes reflect county boundaries giving a broad indication of ownership at a larger scale than the 1km sub-cells*

7.2.2 Availability comparisons

Water Stress

Figure 51 shows the additional sub-cells masked as a result of including the water stress dataset as a constraint. An additional 109 (671 total) sub-cells are masked compared to 562 in the final desk study mask, leaving 1,829 available sub-cells.

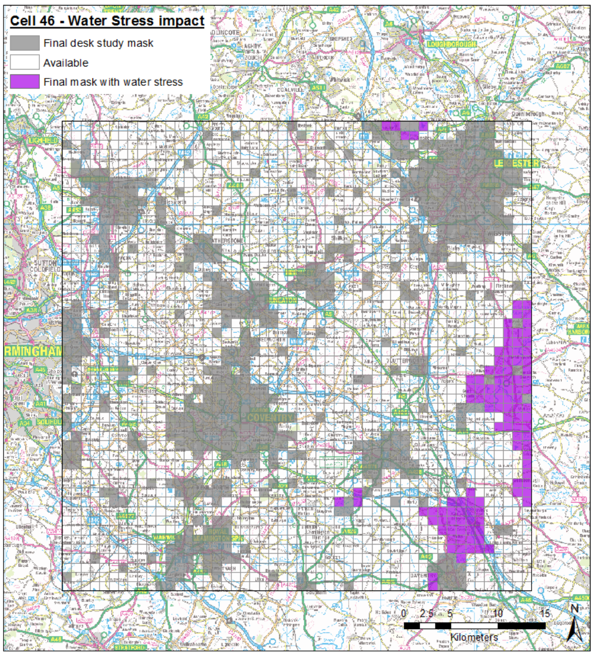

Figure 51 Impact on sub-cell availability when the water stress constraint is included for Cell 46

Desk study vs Surveyor opinion

There is a 91% match when the desk study is compared against the results of the field survey. Most of the discrepancies (16 out of 17 total) are where the desk study has identified the cell as available, while the sub-cell is unavailable according to the field survey (Table 56).

Table 57 summarises some of the reasons for discrepancies that were identified in an assessment of aerial photography. Additional reasons can be found in the justification data from the field survey forms.

Table 56 Contingency table comparing the results from the field survey and final desk study mask for Cell 46

Cell 46 (number of sub-cells)		**Desk study**		
		Unavailable	Available	**Total**
Field survey	Unavailable	7	16	**23**
	Available	1	178	**179**
	Total	**8**	**194**	**202**

Table 57 Summary of main reasons for discrepancies between desk study and field survey results at a sub-cell level in Cell 46

Primary desk study limitations where desk classed as available and field unavailable	**Field survey limitations where desk classed as available and field unavailable**	**Primary desk study limitations where desk classed as unavailable and field available**	**Field survey limitations where desk classed as unavailable and field available**
Houses and gardens not picked up by desk study Golf courses, motorways/main roads, carparks not picked up by desk study	Over-estimation of unavailable area by surveyors		ALC Grade 1 and Parks & Gardens areas not identified

One of the limitation of the field survey is that some of the land designations included in the final desk study mask cannot be identified on the ground. These include identification of Grade 1 Agricultural land and Parks & Gardens. An example of where a Park & Garden designation has not been identified in the field survey is shown in Figure 52. It shows the boundary of the designated land which covers a large proportion of the sub-cell. Although some of this land may be in agricultural land, it is unlikely that it would be used for growing bio-energy crops to maintain the aesthetic and historical value of the land.

Figure 52 Example of a sub-cell (RELB ID: 046_33_23) where limitations of the field survey have resulted in discrepancies between the desk study and field survey

Surveyor opinion vs Survey land area

There were 202 sub-cells assessed in cell 46, of which 37 were completely visible to the surveyor using one or more vantage point, the remainder of the cells had at least part of the sub-cell that was not visible to the surveyor – marked as unknown. When the unknown area was applied pro rata to the available and unavailable proportion of the sub-cells the number of available sub-cells was identified as 171 sub-cells. The surveyor opinion indicated that there were 179 of the 202 surveyed sub-cells that were available.

Table 58 Contingency table comparing the results from the field survey (between the results of the land use coverage and the surveyor view) for Cell 46

Cell 19 (number of sub-cells)		**Land use (applied pro rata)** Available	Unavailable	**Total**
Surveyor view	Available	171	8	**179**
	Unavailable	0	23	**23**
	Total	**171**	**31**	**202**

There were 8 sub-cells where the surveyor thought that the cell was available, but the estimated area of available land indicated that they were not in fact available. In all eight of these sub-cells the surveyor indicated that although they could not clearly see the unknown land they thought based on the maps, aerial photography and glimpses of the land that the majority of it was available (predominantly improved grassland), and therefore the proportion of land available would be higher than a pro rata calculation implies. There were no instances where the survey indicated that the land was not available when the land area estimates indicated that it was.

7.2.3 Cell mask overview

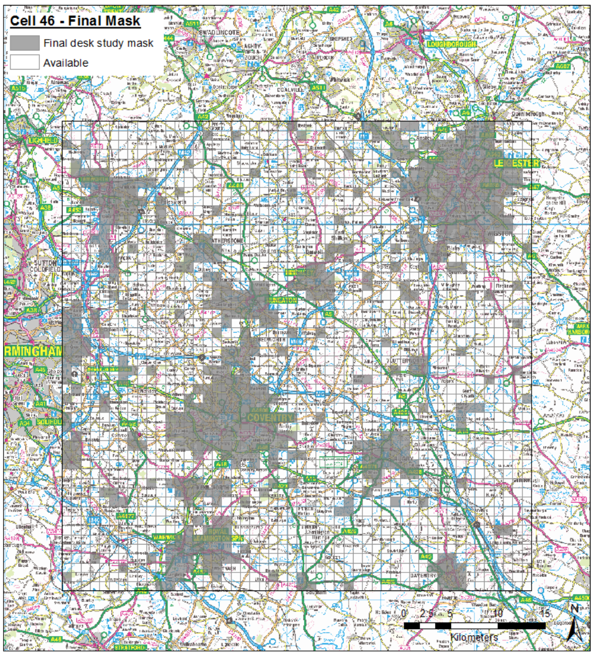

Figure 53 Impact of the final mask created from the desk study on cell 46

Cell 046 contains large areas of available land. The main areas of the cell that are 'unavailable' are the built up areas around the cities of Coventry and Leicester, plus the towns of Tamworth, Nuneaton, Rugby, Warwick/Royal Leamington Spa and Daventry, with occasional patches of 'unavailable' land dotted across the remainder of the square. The majority of the land between these large towns/cities is identified by the mapping and survey as 'available'. This location is well served with transport links being bisected by the A14 / M6 running east/west and the M1 and M6/M5 running north/south. There are also good networks of A roads to allow access to other parts of the cell. This well connected, highly available location, with a number of large towns and cities, should make it a suitable location to establish bioenergy production with both the land available for production and the potential market in the nearby towns and cities. Flood risk and water stress were low across the majority of the sub-cells. All sub-cells were in an NVZ and therefore bioenergy crops could be promoted as a means of reducing nitrogen use on farm.

7.3 Cell 100

Cell 100 is located in Scotland and is largely within the county of Dumfries & Galloway, but also covers small parts of South Lanarkshire and East Ayrshire and North Ayrshire mainland. The only major town in the cell is Dumfries in the south. The northern half of the cell is largely upland and includes the Lowther Hills and the Forest of Ae. The A74(M) runs down the eastern side of the cell and other major roads include the A76, A75 and the A701. There are two rail routes running through the cell. The south-eastern corner of the cell extends into the Solway Firth.

The Corine land-cover dataset was used to calculate the breakdown of land cover types in the cell (Table 59). The distribution of these land cover types is shown in Figure 17. The cell is dominated by agricultural grassland (35%) and scrub and/or herbaceous vegetation associations (29%) with substantial areas of forests (18%) and arable land (10%).

The land within the cell is varied in its elevation (Figure 55), with areas of upland in the north and lowland in the south. The maximum elevation is 723 m, with the lowest lying areas at sea level.

Table 59. Areas of Corine land cover types in cell 100 in decreasing order of area

Land cover	Area (km^2)
Pastures	879
Scrub and/or herbaceous vegetation associations	726
Forests	455
Arable land	253
Maritime wetlands	81
Inland wetlands	41
Urban fabric	19
Inland waters	12
Artificial, non-agricultural vegetated areas	12
Marine waters	10
Open spaces with little or no vegetation	9
Industrial, commercial and transport units	5
Mine, dump and construction sites	1
Heterogeneous agricultural areas	1

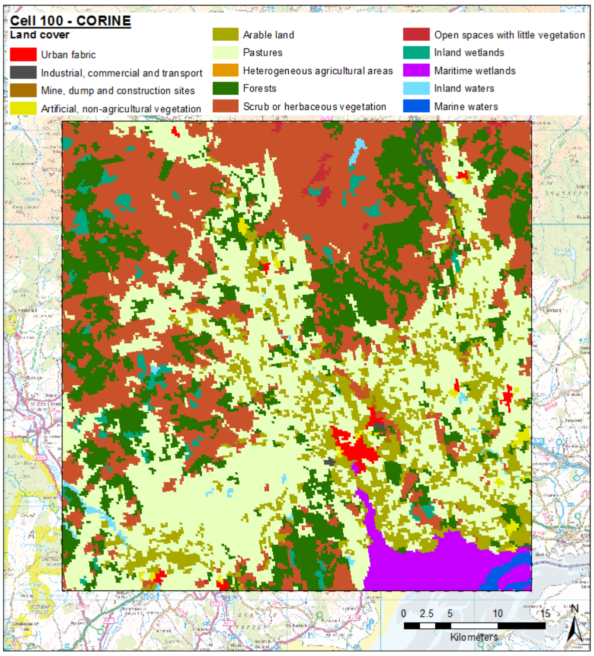

Figure 54. Distribution of Corine land cover types within cell 100

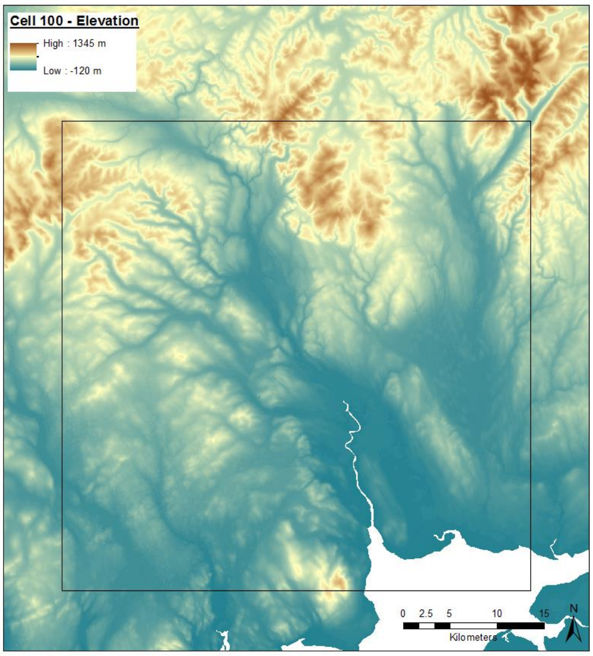

Figure 55. Elevation within cell 100

7.3.1 Planting targeting (using likelihood layers)

Maps for nitrate vulnerable zones and farm ownership for Cell 100 are shown in Figure 19 and Figure 57 respectively. The Scotland flood risk dataset could not be made available for this project. This dataset is only made available by SEPA (Scottish Environment Protection Agency) for responsible authorities for the purposes of flood risk management planning. Therefore no targeting map could be produced for Cell 100 based on flood risk. Of the 1002 sub-cells available in cell 100, 288 are completely within a NVZ, 641 are outside of a NVZ, and 73 partially a NVZ. The average farm ownership percentage in the cell is 77%.

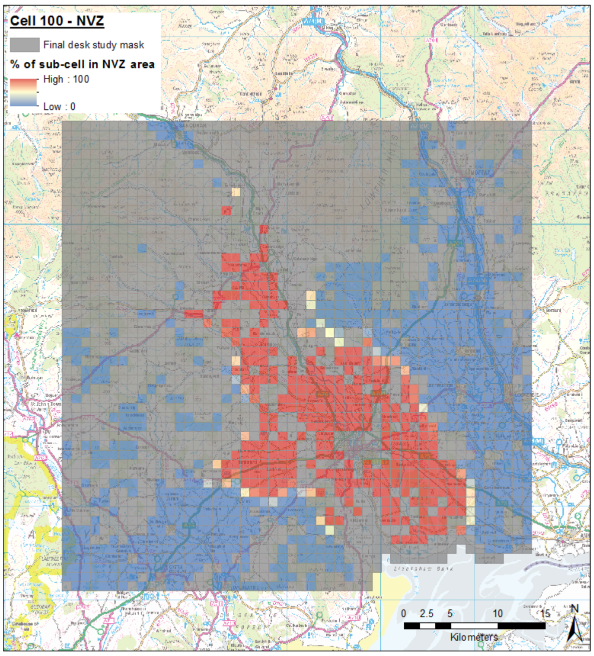

Figure 56 Percentage of sub-cells within a Nitrate Vulnerable Zone in cell 100

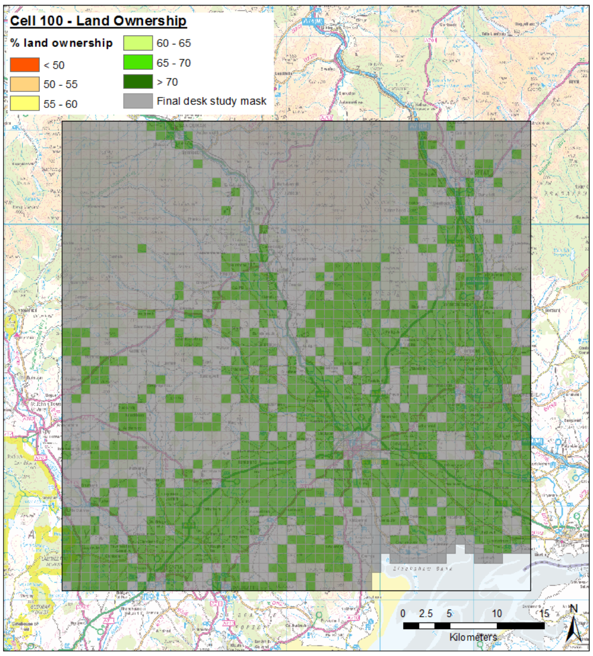

Figure 57 Percentage of agricultural land ownership (from national Agricultural Census statistics for Scotland) in cell 100 - data is provided at a country level and therefore colour changes reflect county boundaries giving a broad indication of ownership at a larger scale than the 1km sub-cells

7.3.2 Availability comparisons

Water Stress

The Environment Agency's water resource and availability dataset only covers England and Wales, therefore no comparison could be made for Cell 100.

Desk study vs Surveyor opinion

There is a 70% match when the desk study is compared against the results of the field survey. Most of the discrepancies (39) are where the field survey has identified the sub-cell as available and the desk study has classed it as unavailable.

Table 60 Contingency table comparing the results from the field survey and final desk study mask for Cell 100

Cell 100 (number of sub-cells)		Desk study		
		Unavailable	Available	**Total**
Field survey	Unavailable	7	22	**29**
	Available	39	134	**173**
	Total	**46**	**156**	**202**

One of the main reasons for this disparity is where areas of land are over 300 m. Table 61 lists some of the additional discrepancies that were identified in an assessment of aerial photography. Additional reasons can be found in the justification data from the field survey forms.

Table 61 Summary of main reasons for discrepancies between desk study and field survey results at a sub-cell level in Cell 100

Study Cell	Primary desk study limitations where desk classed as available and field unavailable	Field survey limitations where desk classed as available and field unavailable	Primary desk study limitations where desk classed as unavailable and field available	Field survey limitations where desk classed as unavailable and field available
100	Woodland not in ancient woodland inventory Golf courses, gardens carparks not picked up by desk study	Over-estimation of unavailable area by surveyors Slope assessed as too steep	UKERC-9w mask excluding land for unknown reason	Land not identified as over 300m elevation Ancient woodland not identified

Figure 58 highlights one of the reasons for sub-cell misclassification in Cell 100 and in the other surveyed cells. The buildings have been identified by the OS VectorMap dataset (and are shown in yellow) and most of these areas are covered by the mask. There are however areas of buildings that are not covered by the mask, and the areas around the buildings are hardstanding/car parks. This is due to the buildings not covering enough of the 100m 'mask cell' to be masked, and the dataset not including areas of hardstanding.

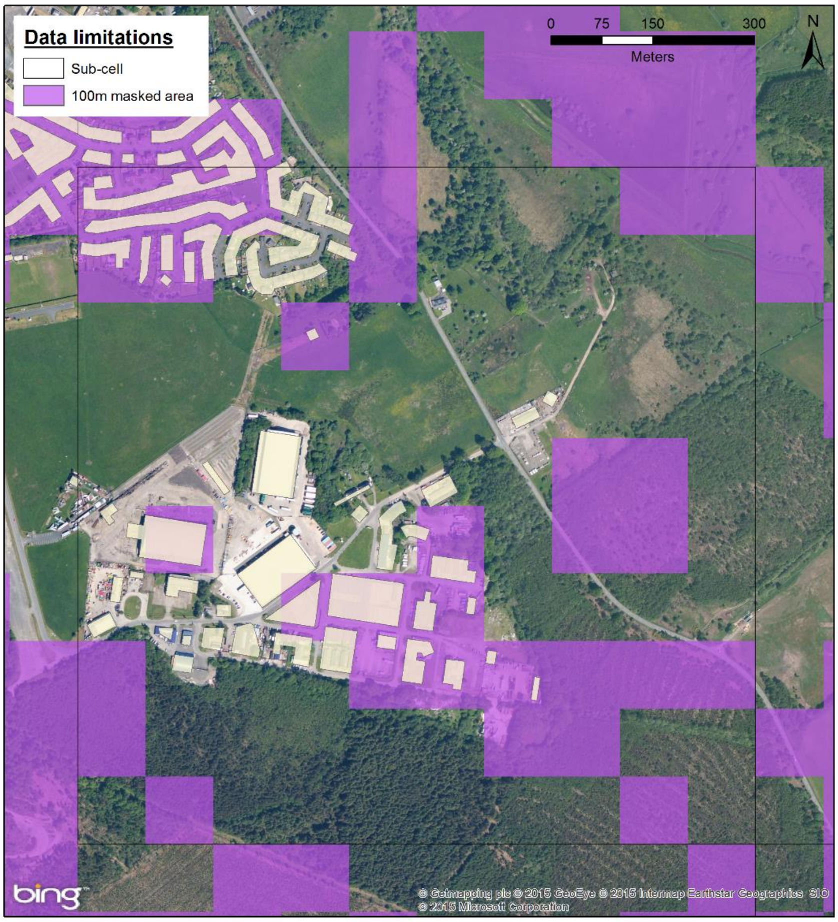

Figure 58 Example of a sub-cell (RELB ID: 100_35_18) where limitations of the data have resulted in discrepancies between the desk study and field survey

Surveyor opinion vs Survey land area

There were 202 sub-cells assessed in cell 100, of which 59 were completely visible to the surveyor using one or more vantage point, the remainder of the cells had at least part of the sub-cell that was not visible to the surveyor – marked as unknown. The surveyor data, based on the visible portion of the sub-cell that had available land uses indicated that 161 sub-cells were available. However, when the unknown area was applied pro rata to the available and unavailable proportion of the sub-cell this increased to 181 sub-cells. The surveyor opinion indicated that there were 173 of the 202 sub-cells were available.

Table 62 Contingency table comparing the results from the field survey (between the results of the land use coverage and the surveyor view) for Cell 100

Cell 100		Land use (applied pro rata)		
(number of sub-cells)		Available	Unavailable	**Total**
Surveyor view	Available	170	3	**173**
	Unavailable	11	18	**29**
	Total	**181**	**21**	**202**

There were three sub-cells where the surveyor thought that the cell was available, but the pro rata estimated area of available land indicated that they were not in fact available. Two of these cells were right on the borderline with over 48% available with pro rata inclusion of unknown land and the third had a large area (33%) of unknown land that in the surveyors view was available.

There were 11 sub-cells where the pro rata calculation of available land indicates that the cells should be available, but the surveyor view indicated that it was unavailable. Of those the initial land estimates (prior to the pro rata application of unknown land), indicated that seven of those sub-cells were unavailable – with the surveyor comments indicating that they thought the greater proportion of the unknown land in those sub-cells was expected to be unavailable based on mapping and aerial photography. All four of the sub-cells that had high levels of available land uses, but were considered by the surveyor to be unavailable were considered to be too steep for effective SRF, although some of the land was already in plantation forestry.

7.3.3 Cell mask overview

Cell 100 sits in the south of Scotland, in Dumfries and Galloway. The northern and western parts of the cell are dominated by an upland area with much of that land considered to be unsuitable for bioenergy crop production. The southern part of the cell around Dumfries has an area of available land stretching from Castle Douglas in the south west of the cell along an 8-10km wide corridor following the route of the A75 up to Dumfries. There is a large area of available land that stretches east from Dumfries along the A75, and also towards the north following the route of the A74(M). Just north of Dumfries there is an area of 'available' land that encompasses parts of the Forest of Ae.

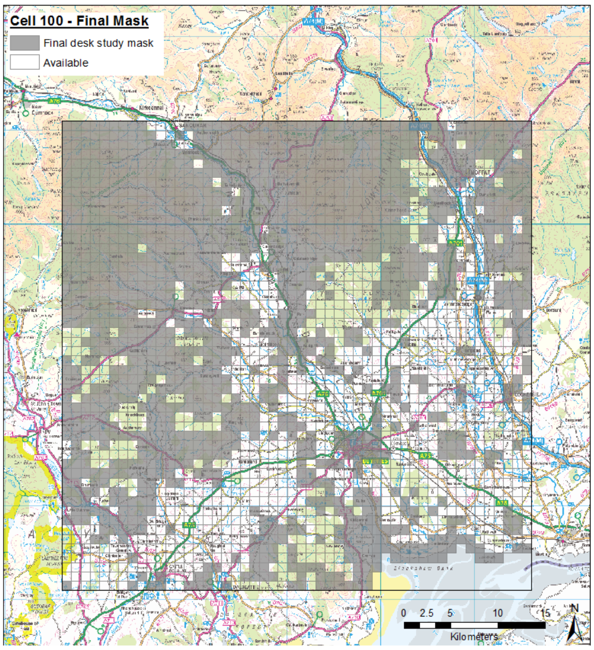

Figure 59 Impact of the final mask created from the desk study on cell 100

The 'available' land in this cell is concentrated in the south of the cell where the road links are best and where there is more habitation. This concentration of land around Dumfries may offer some opportunities for the development of localised bioenergy supply chains. This area of land also falls in an NVZ zone, so there would potentially be environmental benefits of planting bioenergy crops in this location. The establishment of medium or large markets would potentially be challenging in this location due to the relatively low population density (only one large town and dispersed villages). Although there are some decent road links the distances involved in accessing wider markets would need careful consideration to ensure that any larger project was economically viable.

7.4 Overview of all cells

These case studies highlight the variability across the country and the need for a specific study for each cell. This is highlighted first by the difference in extent in the final mask across each of the cells; with availability of 41%, 78% and 41% in cell 19, cell 46 and cell 100 respectively. Differences are further highlighted by the likelihood layers that have been examined. While the differences in the number of available sub-cells within a flood risk area are low between cells 19 and 46 (27 and 33 respectively), the differences in the number of available sub-cells within a NVZ are high; ranging from 288 in cell 100 to 1,937 in cell 46. There is also a large difference in the number of available sub-cells in water stressed areas; 109 in cell 46 and 535 in cell 19. These differences highlight the need for masks which are spatially derived, and how it isn't possible to provide a uniform mask correction that can be applied for the country.

8 List of abbreviations

Abbreviation	In full
ADAS	ADAS UK Ltd
AFBI	Agri Food and Biosciences Institute, Northern Ireland
ALC	Agricultural Land Classification
AONB	Area of Outstanding Natural Beauty
AHDB	Agriculture and Horticulture Development Board
B2C2	UK Solid and Gaseous Biomass Carbon Calculator
BL	Business Link
BP	Basic Payment
BPS	Basic Payment Scheme
BSL	Biomass Suppliers List
BVCM	Bioenergy Value Chain Model
C4E	Crop For Energy
CAP	Common Agricultural Policy
CCW	Countryside Commission Wales
CfD	Contracts for Difference
CHP	Combined heat and power
CLA	Country Land and Business Association
CORINE	COoRdinate Information on the Environment, a European Commission programme
CPRE	Campaign for the Protection of Rural England
CS	Countryside Stewardship Scheme
CSF	Catchment Sensitive Farming
DARD	Department of Agriculture and Rural Development Northern Ireland
DECC	Department of Energy and Climate Change
Defra	Department for Environment Food and Rural Affairs
DTI	Department of Trade and Industry
DWPA	Diffuse water pollution from agriculture
EA	Environment Agency
EAMU	Extensions of Authorisation for Minor Use
EC	European Commission
ECS	Energy Crops Scheme
EEA	European Environment Agency
EFA	Ecological Focus Area
EIA	Environmental Impact Assessment
ES	Environmental Statement
ETI	Energy Technologies Institute
EU	European Union
FC	Forestry Commission
FCS	Forestry Commission Scotland
FFIS	Farm and Forestry Improvement Scheme
FMS	Fuel measurement and sampling

Abbreviation	In full
FOI	Freedom of Information
FSC	Forest Stewardship Council
FWAC	Forestry and Woodland Advisory Committee
GAEC	Good Agricultural and Environmental Conditions
GHG	Greenhouse gas
GIS	Geographic Information System
ha	Hectare
HEFER	Historic Environment Farm Environment Record
HSAB	Henriksson Salix AB
ICF	Institute of Chartered Foresters
ICON	IC Consultants Limited
IEEP	Institute for European Environmental Policy
JNCC	Joint Nature Conservancy Council
kWh	Kilowatt hour
LA	Local authorities
LAGs	Local Action Groups
LEADER	French acronym which translates as 'Liaison among Actors in Rural Economic Development'
LEP	Local Enterprise Partnership
LRF	Long Rotation Forestry
LUCAS	Land Use/Cover Area frame Statistical Survey
MAGIC	Multi-Agency Geographic Information for the Countryside
NE	Natural England
NI	Northern Ireland
NIEA	Northern Ireland Environment Agency
NIP	National Infrastructure Planning
NFU	National Farmers' Union
NNFCC	National Non Food Crops Centre
NRW	Natural Resources Wales
NUTS2	Nomenclature of Territorial Units for Statistics
NVZ	Nitrate Vulnerable Zones
ODT	Oven dry tonne
Ofgem	Office of Gas and Electricity Markets
OS	Ordnance Survey
PEFC	Programme for the Endorsement of Forest Certification
PPP	European Union Plant Protection Products Regulation
PROW	Public rights of way
R4F	Resource Efficiency for Farms Scheme
RBRA	Risk Based Regional Assessment
RDP	Rural Development Programme
RDIA	RDI Associates
RHI	Renewable Heat Incentive
RFS	Royal Forestry Society
OSR	Oilseed Rape

Abbreviation	In full
RO	Renewables Obligations
ROCs	Renewables Obligation Certificates
SEPA	Scottish Environment Protection Agency
SHINE	Selected Heritage Inventory for Natural England
SMR	Statutory Management Requirements
SRC	Short rotation coppice
SRF	Short rotation forestry
SSSI	Site of Special Scientific Interest
SWOT	Strengths, Weaknesses, Opportunities and Threats
TS	Timber Standard
UKFS	UK Forestry Standard
UK-TPP	UK Government Timber Procurement Policy
UKERC	United Kingdom Energy Research Centre
WCC	Woodland Carbon Code
WHA	Wood Heat Association
WRECSL	Waste, Residues and Energy Crops Sustainability List

Glossary of terms

The definitions below have been taken from official Government sources.

Agricultural residues - The by-products from crops, such as wheat straw and seed husks, as well as other agricultural wastes including slurry and manure.

Biodiversity - The variety of all life on Earth, including all species of animals and plants, and the natural systems that support them.

Bioenergy – Biomass is derived from energy crops (such as short rotation coppice and Miscanthus), forestry and agricultural plant and animal wastes. It can be used to generate electricity and or heat and to produce transport fuel.

Biomass - Biological material that can be used as fuel or for industrial production. Includes solid biomass such as wood, plant & animal products, gases and liquids derived from biomass, and the biodegradable element of commercial and industrial wastes and municipal wastes.

Combined Heat and Power (CHP) – CHP is the simultaneous generation of useable heat and power in a single process, thereby discarding less waste than conventional generation.

Contracts for Difference - private law contract between a low carbon electricity generator and the Low Carbon Contracts Company (LCCC), a government-owned company. A generator party to a CfD is paid the difference between the 'strike price' – a price for electricity reflecting the cost of investing in a particular low carbon technology – and the 'reference price'– a measure of the average market price for electricity in the GB market.

Ecological Focus Areas (EFA) - land set aside for environmental benefits on arable farms.

Energy crops - Crops which are grown with the intention of being used only for the generation of energy. Examples include fast growing trees (such as short rotation coppice willow) and grasses with a high lignocellulosic content (such as Miscanthus).

Forestry and forest residues - Forest sector by-products including residues from thinning and logging (e.g. treetops, limbs, slash and small round wood) and secondary residues including sawdust and bark from wood processing. Forestry and forest residues can also include dead wood from natural disturbances, such as fires and inset outbreaks, biomass grown in forests that are not required for timber production, and biomass from dedicated plantations (e.g. short and long-rotation forestry).

Greenhouse Gas (GHG) - Any atmospheric gas (either natural or anthropogenic in origin) which absorbs thermal radiation emitted by the Earth's surface. This traps heat in the atmosphere and keeps the surface at a warmer temperature than would otherwise be possible.

Kilowatt hour (kWh) - A unit of energy, equal to the total energy consumed at a rate of 1,000 watts for one hour. Related units are: Megawatt hour (MWh) = 1,000 kWh, Gigawatt hour (GWh) = 1,000 MWh and Terawatt hour (TWh) = 1,000 GWh. The kilowatt hour is equal to 3.6 million joules.

Local Enterprise Partnership (LEP) - joint local authority-business bodies that promote local economic development. Replaced Regional Development Agencies.

Megawatt electrical (MW_e) - The megawatt is equal to one million (10^6) watts. Megawatt electrical is a term that refers to electric power, while megawatt thermal or thermal megawatt refers to thermal power produced.

Miscanthus - Species of energy grass called *Miscanthus x giganteus*.

Nitrate Vulnerable Zones (NVZs) - Nitrate Vulnerable Zones (NVZs) are areas designated as being at risk from agricultural nitrate pollution.

NUTS2 – Areas set out by the EU in the UK there are nine regions in England, plus Scotland, Wales and Northern Ireland.

Particulates/particulate matter (PM) - Airborne PM includes a wide range of particle sizes and different chemical constituents. Air Quality Objectives are in place for the protection of human health for PM10 and PM2.5 – particles of less than 10 and 2.5 micrometres in diameter, respectively.

Pellets - Pellets can be manufactured from woody, energy crop and agricultural residue feedstocks and used as fuel for electric power plants and biomass boilers. Pellets are very dense and have a low moisture content.

Renewable Heat Incentive (RHI) - Provides financial assistance to producers of renewable heat.

Renewables Obligation (RO) – The obligation placed on electricity suppliers to deliver a stated proportion of their electricity from eligible renewable energy sources.

Renewables Obligation Certificates (ROCs) – Eligible renewable generators receive ROCs for each MWh of electricity generated. These certificates can be sold to suppliers. In order to fulfil their RO suppliers can present enough certificates to cover the required percentage of their output, or pay a 'buyout price' per MWh for any shortfall. All proceeds from buyout payments are recycled to suppliers in proportion to the number of ROCs they present.

Short rotation coppice (SRC) - Some fast growing tree species, such as willow, can be cut down to a low stump (or stool) when they are dormant in winter and go on to produce many new stems in the following growing season.

Short rotation forestry (SRF) - Tree plantations with short harvest rotations (typically every 8 to 20 years). For tropical/subtropical regions, Eucalyptus is used as a representative type of short rotation forestry crop.

Viewshed – The geographical area that is visible from a location. It includes all surrounding points that are in line-of-sight with that location and excludes points that are beyond the horizon or obstructed by terrain and other features

Appendix 2.1 – Sub-cells surveyed

The sub-cells selected for possible survey and whether these are available or newly unavailable are shown in Figure 60 to Figure 62.

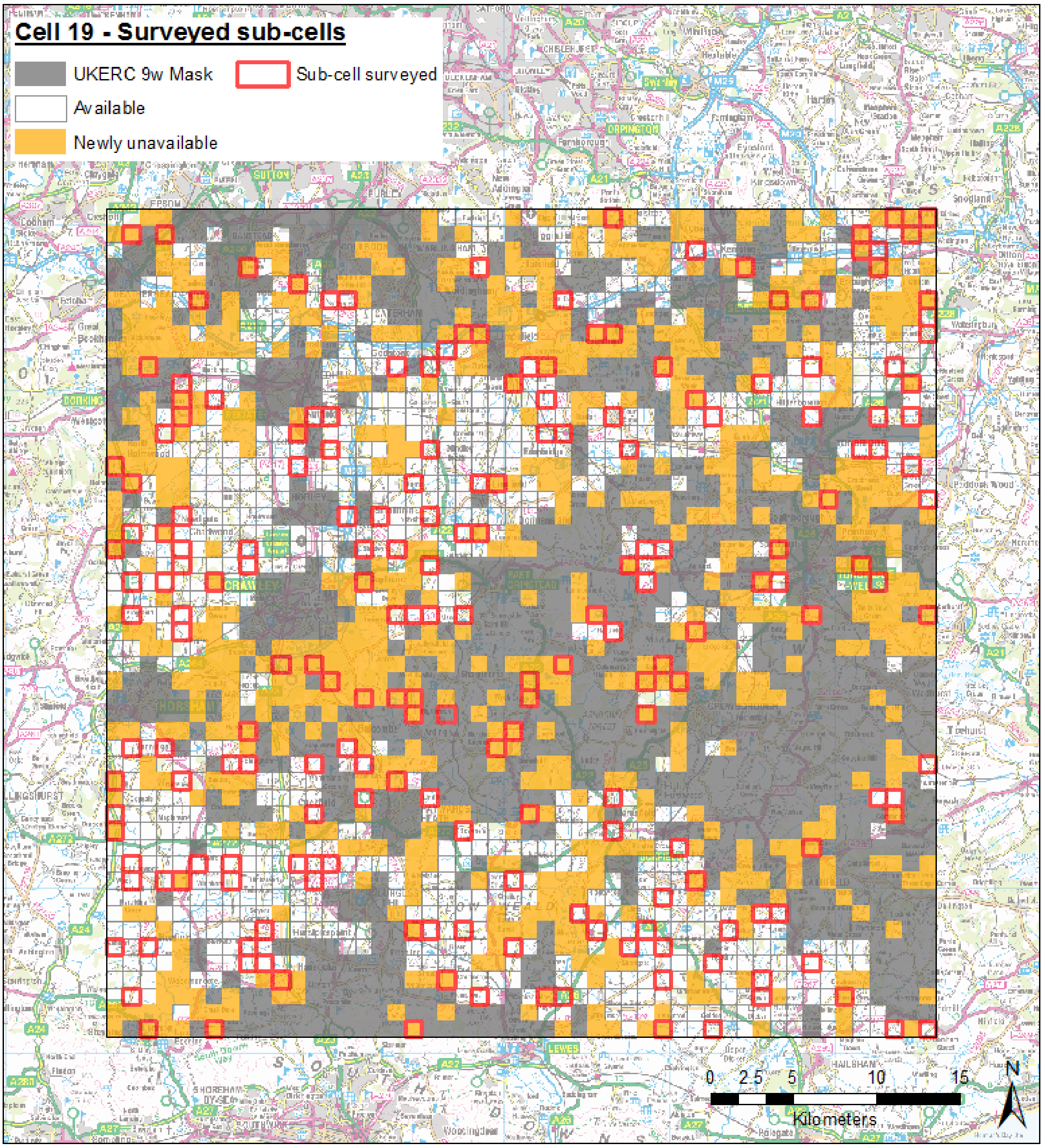

Figure 60. Location of 206 surveyed sub-cells in cell 19, of which 126 were 'available' and 80 'newly unavailable'

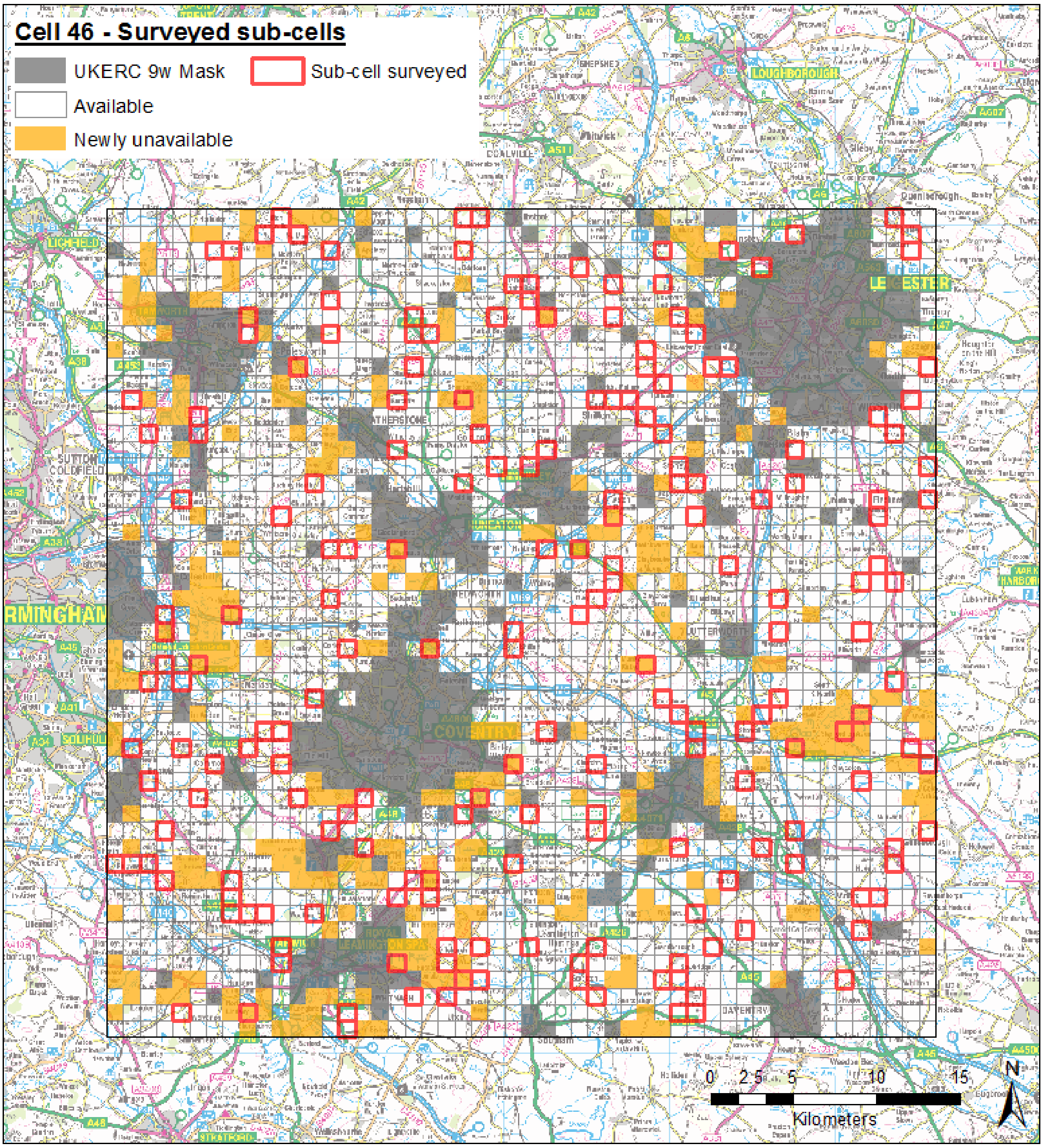

Figure 61. Location of 202 surveyed sub-cells in cell 46, of which 181 were 'available' and 21 'newly unavailable'

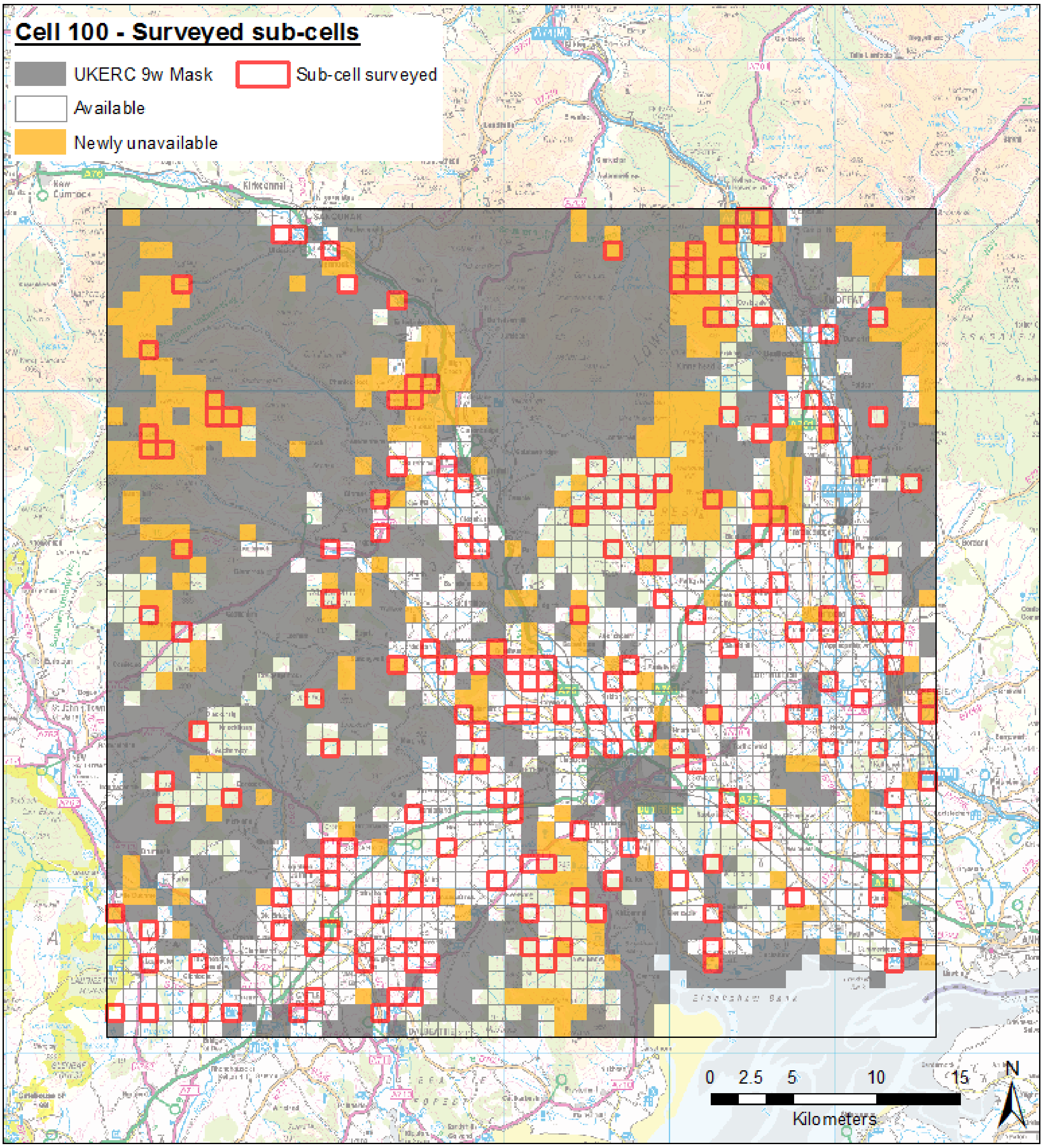

Figure 62. Location of 202 surveyed sub-cells in cell 100, of which 156 were 'available' and 46 'newly unavailable'

Appendix 2.2 – Links to data sets used in desk study and attribution of data IP

Data layer	Source of data	Download location	Licence	Attribution statement
Altitude	Terrain 50 (Ordnance Survey)	https://www.ordnancesurvey.co.uk/opendatadownload/products.html	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	*Contains OS data © Crown copyright [and database right] (2015)*
Agricultural land productivity	Agricultural Land Classification - ALC (Natural England)	http://www.magic.gov.uk/	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/391764/OGL-NE-OS.pdf	© Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [2002]
Agricultural land productivity	Life Cycle Analysis - LCA (James Hutton Institute)	http://www.macaulayscientific.com/gis2_dataset_5a.php	The James Hutton Institute Open Data Li	Land Capability for Agriculture copyright and database right The James Hutton Institute 2015. Used with the permission of the James Hutton Institute. All rights reserved. Any public sector information contained in these data is licensed under the Open Government Licence v.2.0.
Soil Parameters	European Topsoil Physical Properties	http://esdac.jrc.ec.europa.eu/content/topsoil-physical-properties-european-scale-using-lucas-topsoil	N/A	Ballabio C., Panagos P., Montanarella L. Mapping topsoil physical properties at European scale using the LUCAS database (2016) Geoderma, 261 , pp. 110-123.
Buildings and water bodies	VectorMap District (Ordnance Survey)	https://www.ordnancesurvey.co.uk/opendatadownload/products.html	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	*Contains OS data © Crown copyright [and database right] (2015)*
BAP Priority Habitats	Priority Habitat Inventory (Natural England)	http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/391764/OGL-NE-OS.pdf	© Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [2015]

Data layer	Source of data	Download location	Licence	Attribution statement
Semi-natural woodland	Ancient woodland/ semi-natural woodland inventories (Natural England/ Scottish Natural Heritage)	http://www.magic.gov.uk/dataset_download_summary.htm	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	© Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [2015] Contains public sector information licensed under the Open Government Licence v3.0. Copyright Scottish Natural Heritage Contains Ordnance Survey data © Crown copyright and database right (2015)
Parks & gardens	Historic Parks & Gardens (English Heritage)	https://historicengland.org.uk/listing/the-list/data-downloads/	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	© English Heritage [2015]. Contains Ordnance Survey data © Crown copyright and database right [2015] The English Heritage GIS Data contained in this material was obtained on [2015]. The most publicly available up to date English Heritage GIS Data can be obtained from http://www.english-heritage.org.uk.
Parks & gardens	Gardens & Designated Landscapes (Historic Environment Scotland)	http://portal.historic-scotland.gov.uk/spatialdownloads/gardens	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	Contains Historic Environment Scotland and Ordnance Survey data © Historic Environment Scotland - Scottish Charity No. SC045925 © Crown copyright and database right [2015].
Stewardship options	Environmental Stewardship and classic Countryside Stewardship options/areas	http://www.geostore.com/environment-agency/WebStore?xml=environment-agency/xml/ogcDataDownload.xm	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/391764/OGL-NE-OS.pdf	© Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [2015]

Data layer	Source of data	Download location	Licence	Attribution statement
		l		
Water stressed areas	Water Resource Availability and Abstraction Reliability (Environment Agency)	http://www.geostore.com/environment-agency/WebStore?xml=environment-agency/xml/ogcDataDownload.xml	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	Contains public sector information licensed under the Open Government Licence v3.0.
Flood Risk	Flood Risk Areas (Environment Agency)	http://www.geostore.com/environment-agency/WebStore?xml=environment-agency/xml/ogcDataDownload.xml	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	Contains public sector information licensed under the Open Government Licence v3.0.
Nitrate vulnerability	Nitrate Vulnerable Zones (Defra/ Scottish Government)	http://www.magic.gov.uk/Dataset_Download_Summary.htm https://data.gov.uk/dataset/nitrate-vulnerable-zones1	http://www.magic.gov.uk/Copyright_Information_Data_Download.htm http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	Copyright Defra, contains Ordnance Survey data Copyright Scottish Government, contains Ordnance Survey data
Land tenancy	June Survey of Agriculture county level results (Defra/ Scottish Government)	https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june	http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/	Contains public sector information licensed under the Open Government Licence v3.0.

Appendix 2.3 – Field survey questionnaire template

ETI RELB- WP3 FIELD SURVEY- TO BE COMPLETED FOR EACH 1KM X 1KM Sub-cell

KEY
Available land
Unavailable land

	SECTION 0- CELL SPECIFIC QUESTIONS	1	2	3	4
SECTION 0	Surveyor				
	Date of Survey				
	Cell ID e.g. 019-25-10				
	Was the cell surveyed?	Select	Select	Select	Select
	If answered no the above question, please state why	Select	Select	Select	Select
	If other please explain				
	GPS location of where cell was surveyed (lat, long). NB: If more than one point in each cell surveyed please record the GPS locations in chronological order- see below				
	GPS Location 2				
	GPS Location 3				
	SECTION 1- % LAND USE	**1**	**2**	**3**	**4**
	How much of the cell is visible from your assessment point(s)?	0%	0%	0%	0%
	Proportion of the cell not assessed	100%	100%	100%	100%
SECTION 1	Arable	0%	0%	0%	0%
	Other cropping e.g horticulture	0%	0%	0%	0%
	Type of production	Select	Select	Select	Select
	Improved grassland (includes rough grazing areas)	0%	0%	0%	0%
	Semi natural grassland	0%	0%	0%	0%
	Scrub (unmanaged woody shrubs, tall ruderal vegetation, grasses, brambles)	0%	0%	0%	0%
	Moorland (bracken, dwarf shrub heath, fen/marsh/swamp, bog and montane habitats)	0%	0%	0%	0%
	Parkland	0%	0%	0%	0%
	Semi-natural broadleaved woodland	0%	0%	0%	0%
	Semi natural coniferous woodland	0%	0%	0%	0%
	Semi natural mixed woodland	0%	0%	0%	0%
	Plantation broadleaved	0%	0%	0%	0%
	Plantation coniferous	0%	0%	0%	0%
	Biomass crops/SRC/SRF	0%	0%	0%	0%
	Golf course/Polo pitch/other amenity land	0%	0%	0%	0%
	Development Residential/Industrial	0%	0%	0%	0%
	Buildings present	0%	0%	0%	0%
	Building type (select dominant type if more than one)	Select	Select	Select	Select
	Water body	0%	0%	0%	0%
	Water body type (select dominant type if more than one)	Select	Select	Select	Select
	Boundary area	0%	0%	0%	0%
	Boundary type (select dominant type if more than one)	Select	Select	Select	Select
	Solar farm	0%	0%	0%	0%
	Highways and associated verges	0%	0%	0%	0%
	Wind farm	0%	0%	0%	0%
	Other land type - please comment				
	Total land area	100%	100%	100%	100%
	SECTION 2- CELL FEATURES	**1**	**2**	**3**	**4**
SECTION 2	Topography	Select	Select	Select	Select
	Dominant field size	Select	Select	Select	Select
	Percentage gradient	Select	Select	Select	Select
	Estimated number of fields per sub-cell				
	Are there any field margins?	Select	Select	Select	Select
	Are there any scattered trees?	Select	Select	Select	Select
	Is there a public right of way in the sub-cell?	Select	Select	Select	Select
	Are utility poles / pylons present (including mobile phone masts) ie. anything that gets in the way of field operations?	Select	Select	Select	Select
	Are livestock present?	Select	Select	Select	Select
	If livestock are present, what type are present?	Select	Select	Select	Select
	Does any of the available land appear to suffer waterlogging?	Select	Select	Select	Select
	Will any of the above make more than 50% of this sub-cell unavailable?	Select	Select	Select	Select
	SECTION 3- CELL ACCESSABILITY	**1**	**2**	**3**	**4**
SECTION 3	Roads or tracks within 1km of cell boundary	Select	Select	Select	Select
	Motorway junction	Select	Select	Select	Select
	Adjacent to A road	Select	Select	Select	Select
	Adjacent B road	Select	Select	Select	Select
	Bridges/weight limits	Select	Select	Select	Select
	Other features of the cell- please comment				
	SECTION 4- PREDICTED AVAILABLE AREA	**1**	**2**	**3**	**4**
SECTION 4	Percentage area available - based on land area	0%	0%	0%	0%
	Percentage unavailable	0%	0%	0%	0%
	Unknown	100%	100%	100%	100%
	TOTAL	100%	100%	100%	100%
	In surveyors view is more than 50% of the land in this cell available (i.e. there are no other restrictions identified above that would make the land unavailable)	Select	Select	Select	Select
	Justification of why cell deemed unavailable- please comment				
	Other comments				

Appendix 3.1 – Stewardship codes included

Table 63: Area-based options selected from the classic Countryside Stewardship as being constraints to energy crop planting

Code	Description
R1	Re-creating grassland on cultivated land
RR1	Re-creating grassland on cultivated land
OS1	Overwintered stubbles followed by a spring crop
OS2	Overwintered stubbles followed by a low input spring cereal
OS3	Overwintered stubbles followed by a spring/summer fallow
P4	Managing chalk and limestone grassland
RP	Restoring historic parks
H3	Hay meadows
P1	Grazed pastures
P5	Restoring traditional water meadows
LH1	Maintaining existing lowland heath
LH4	Enhanced management of existing lowland heath
LH3	Re-creating lowland heath
RH3	Re-creating lowland heath
HI3	Restoring old orchards
UH1	Upland hay meadows
UP2	Upland rough grazing pastures
UP3	Upland rough grazing pastures
UP1	Upland grazed pastures
UP4	Upland limestone grassland
UM1	Regenerating heather on agriculturally improved land
UM3	Enhancing heather moorland
UM4	Management of heather moorland habitat
UW1	Management of small upland woodlands
F	Fen
R	Reedbeds

Table 64: Area-based options selected from the Higher Level Stewardship Entry Level Stewardship schemes as being constraints to energy crop planting

Code	Description
UX1	Moorland commons and shared grazing requirements
UX3	Moorland requirements
ED2	Take out of cultivation archaeological features currently on cultivated land
ED3	Reduced-depth, non-inversion cultivation on archaeological features (minimum till)
ED4	Management of scrub on archaeological features
ED5	Management of archaeological features on grassland
EF6	Overwintered stubble
EF8	Skylark plots
EF15	Reduced-herbicide cereal crops followed by overwintered stubble
EF22	Extended overwintered stubble
EG1	Undersown spring cereals

Code	Description
EG4	Cereals for whole-crop silage followed by overwintered stubble
EJ2	Management of maize crops to reduce soil erosion
EJ10	Enhanced management of maize crops to reduce soil erosion and run-off
EJ13	Winter cover crops
EK1	Take field corners out of management
EK2	Permanent grassland with low inputs
EK3	Permanent grassland with very low inputs
EK4	Management of rush pastures
EK20	Ryegrass seed-set as winter/spring food for birds
EK21	Legume- and herb-rich swards
EK5	Mixed stocking
EL1	Take field corners out of management in SDAs
EL2	Permanent grassland with low inputs in SDAs
EL3	Permanent grassland with very low inputs in SDAs
EL4	Management of rush pastures in SDAs
EL5	Enclosed rough grazing
EL6	Unenclosed moorland rough grazing
UC22	Woodland livestock exclusion
UL18	Cattle grazing on upland grassland and moorland
UL20	Haymaking
UL21	No cutting strip within meadows
UL22	Management of enclosed rough grazing for birds
UL23	Management of upland grassland for birds
HC12	Maintenance of wood pasture and parkland
HC13	Restoration of wood pasture and parkland
HC14	Creation of wood pasture
HC7	Maintenance of woodland
HC8	Restoration of woodland
HC9	Creation of woodland in Severely Disadvantaged Areas
HC10	Creation of woodland outside Severely Disadvantaged Areas
HC15	Maintenance of successional areas and scrub
HC16	Restoration of successional areas and scrub
HC17	Creation of successional areas and scrub
HC18	Maintenance of high-value traditional orchards
HC19	Maintenance of traditional orchards in production
HC20	Restoration of traditional orchards
HC21	Creation of traditional orchards
HD6	Crop establishment by direct drilling (non-rotational)
HD7	Arable reversion by natural regeneration
HD8	Maintaining high water levels to protect archaeology
HD10	Maintenance of traditional water meadows
HD11	Restoration of traditional water meadows
HG5	Brassica fodder crops followed by overwintered stubble
HG6	Fodder crop management to retain or recreate an arable mosaic (rotational)
HG7	Low-input spring cereal to retain or recreate an arable mosaic (rotational)

Code	Description
HJ3	Arable reversion to unfertilised grassland to prevent erosion or run-off
HJ4	Arable reversion to grassland with low fertiliser input to prevent erosion or run-off
HJ6	Preventing erosion or run-off from intensively managed, improved grassland
HJ7	Seasonal livestock removal on grassland with no input restriction
HK6	Maintenance of species-rich, semi-natural grassland
HK7	Restoration of species-rich, semi-natural grassland
HK8	Creation of species-rich, semi-natural grassland
HK9	Maintenance of wet grassland for breeding waders
HK10	Maintenance of wet grassland for wintering waders and wildfowl
HK11	Restoration of wet grassland for breeding
HK12	Restoration of wet grassland for wintering waders and wildfowl
HK13	Creation of wet grassland for breeding waders
HK14	Creation of wet grassland for wintering waders and wildfowl
HK15	Maintenance of grassland for target features
HK16	Restoration of grassland for target features
HK17	Creation of grassland for target features
HE11	Enhanced strips for target species on intensive grassland
HL7	Maintenance of rough grazing for birds
HL8	Restoration of rough grazing for birds
HL9	Maintenance of moorland
HL10	Restoration of moorland
HL11	Creation of upland heathland
HO1	Maintenance of lowland heathland
HO2	Restoration of lowland heathland
HO3	Restoration of forestry areas to lowland heathland
HO4	Creation of lowland heathland from arable or improved grassland
HO5	Creation of lowland heathland on worked mineral sites
HP1	Maintenance of sand dunes
HP2	Restoration of sand dunes
HP3	Creation of coastal vegetated shingle and sand dunes on arable land
HP4	Creation of coastal vegetated shingle and sand dunes on grassland
HP5	Maintenance of coastal salt marsh
HP6	Restoration of coastal salt marsh
HP7	Creation of inter-tidal and saline habitat on arable land
HP8	Creation of inter-tidal and saline habitat on grassland up to
HP9	Creation of inter-tidal and saline habitat by non-intervention
HQ3	Maintenance of reedbeds
HQ4	Restoration of reedbeds
HQ5	Creation of reedbeds
HQ6	Maintenance of fen
HQ7	Restoration of fen
HQ8	Creation of fen
HQ9	Maintenance of lowland raised bog
HQ10	Restoration of lowland raised bog

Appendix 3.2 – Sub-cells masked for each constraint layer

Agricultural Land Classification (ALC)

Cell 19 not shown because ALC had no impact in this cell

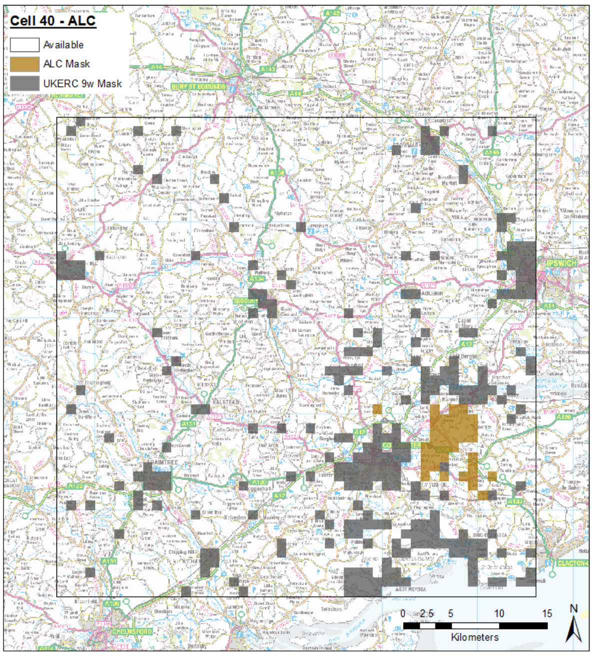

Figure 63: Map showing additional sub-cells masked as a result of adding ALC as a constraint in Cell 40

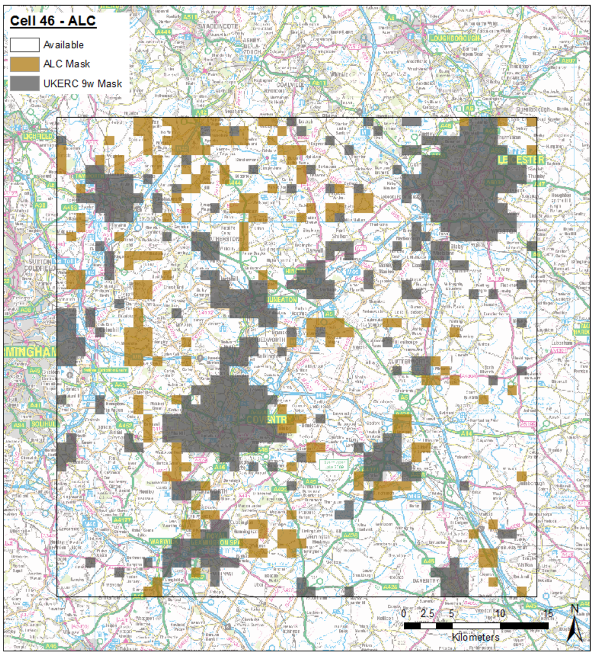

Figure 64: Map showing additional sub-cells masked as a result of adding ALC as a constraint in Cell 46

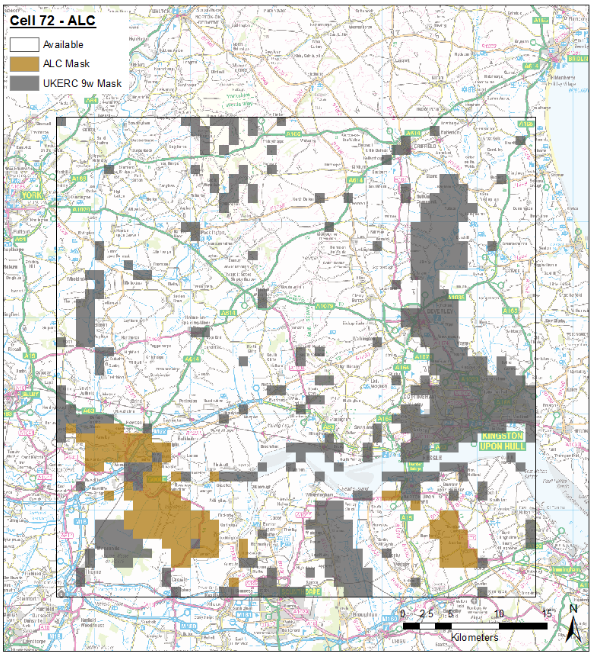

Figure 65: Map showing additional sub-cells masked as a result of adding ALC as a constraint in Cell 72

Cell 100 not shown because ALC had no impact in this cell

Ancient Woodland

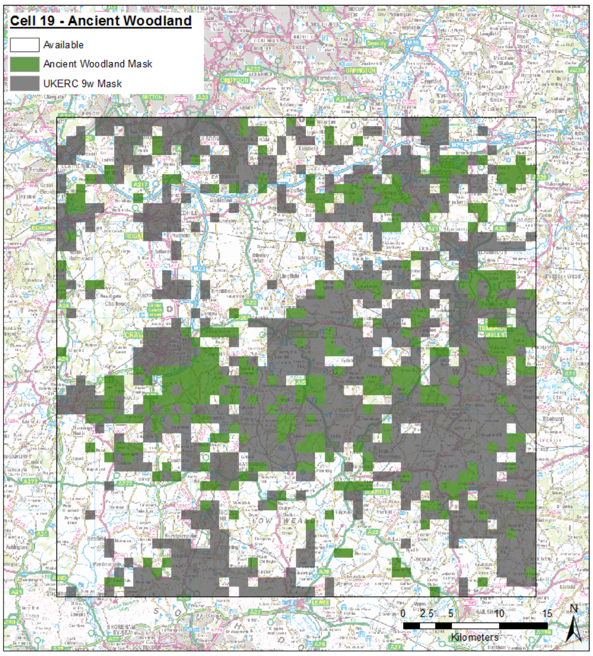

Figure 66: Map showing additional sub-cells masked as a result of adding Ancient Woodland as a constraint in Cell 19

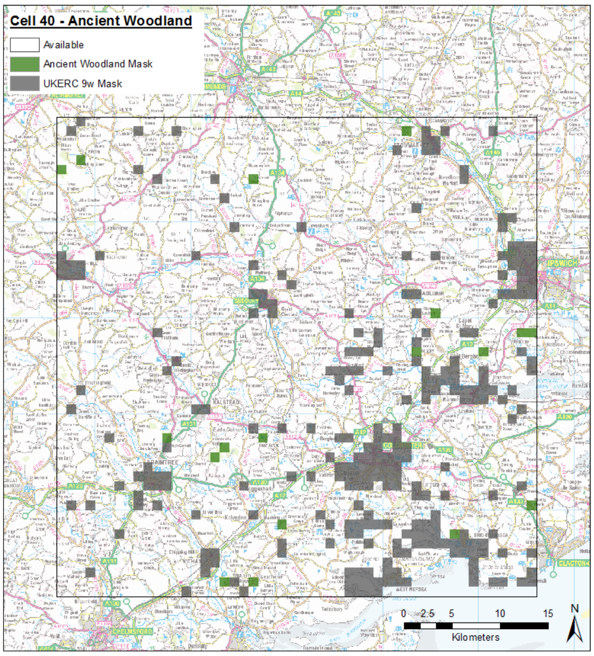

Figure 67: Map showing additional sub-cells masked as a result of adding Ancient Woodland as a constraint in Cell 40

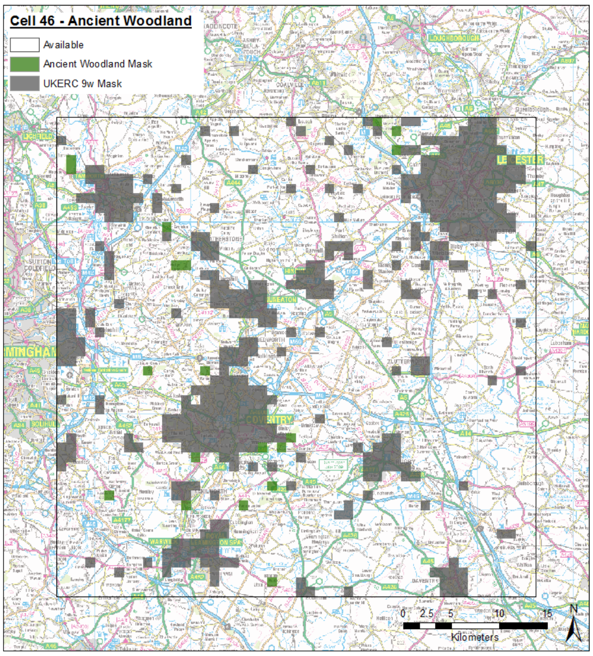

Figure 68: Map showing additional sub-cells masked as a result of adding Ancient Woodland as a constraint in Cell 46

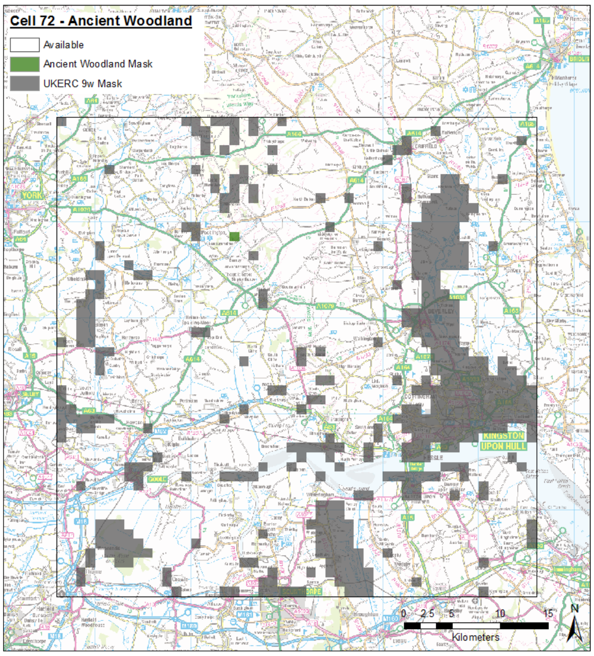

Figure 69: Map showing additional sub-cells masked as a result of adding Ancient Woodland as a constraint in Cell 72

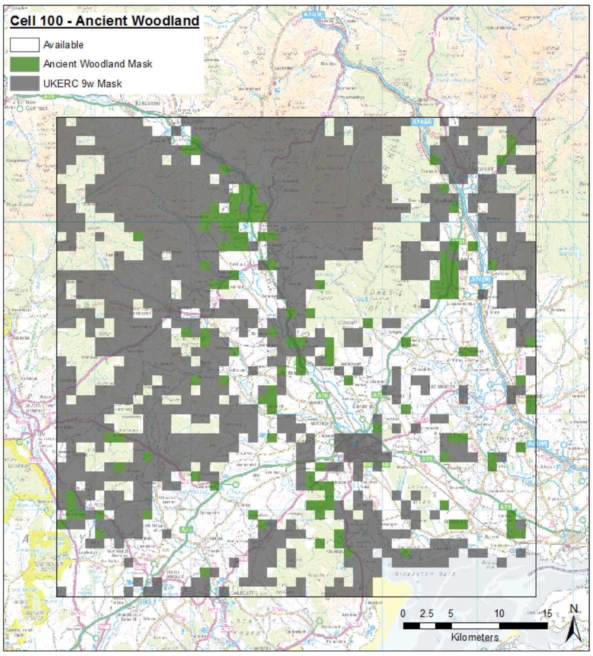

Figure 70: Map showing additional sub-cells masked as a result of adding Ancient Woodland as a constraint in Cell 100

Ancient woodland inventory – Scottish Natural Heritage[193]

[193] Ancient Woodland Inventory - Copyright Scottish Natural Heritage Contains Ordnance Survey data © Crown copyright and database right 2015

BAP Priority Habitats

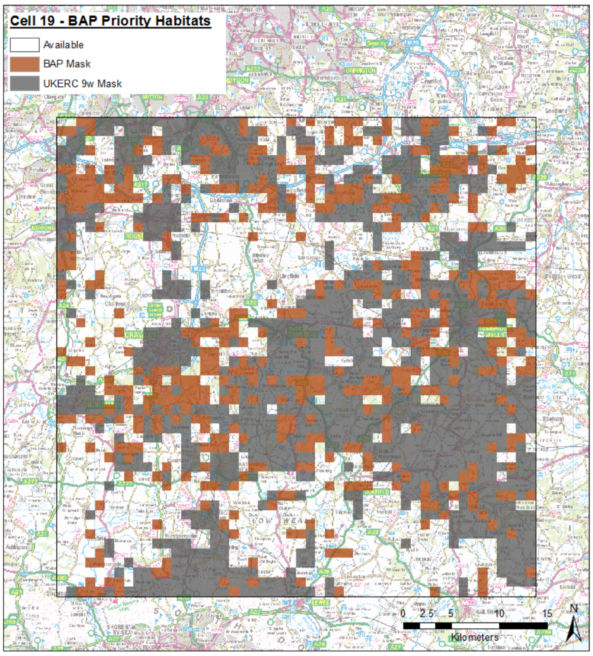

Figure 71: Map showing additional sub-cells masked as a result of adding Priority Habitats as a constraint in Cell 19

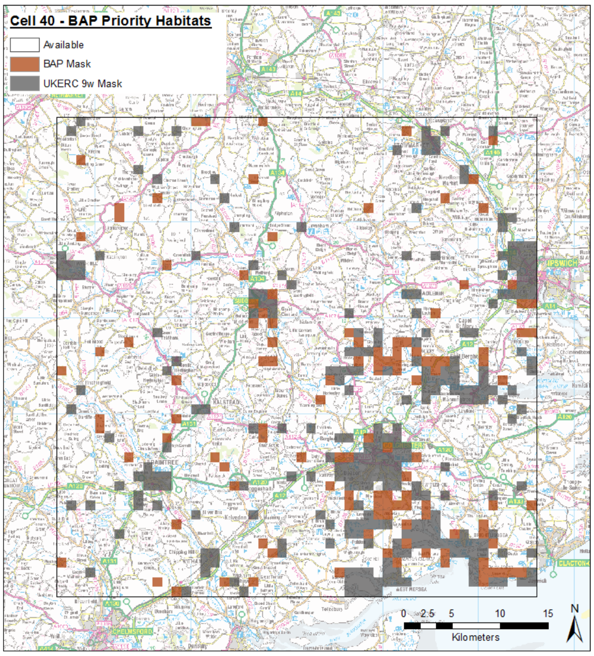

Figure 72: Map showing additional sub-cells masked as a result of adding Priority Habitats as a constraint in Cell 40

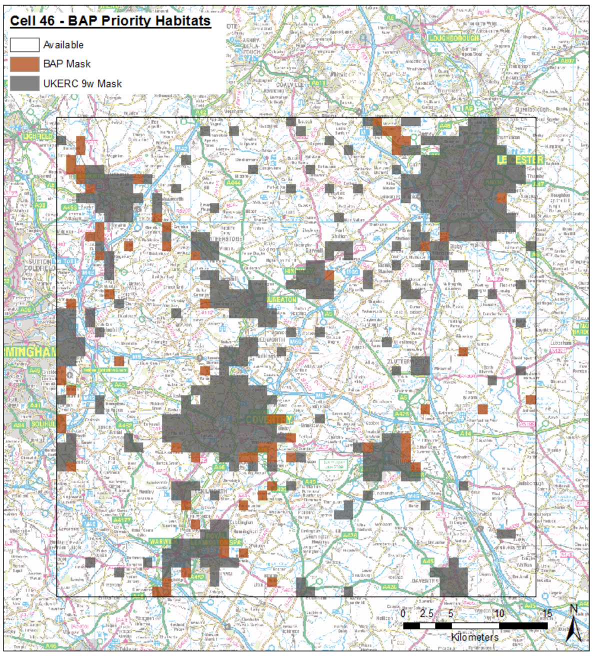

Figure 73: Map showing additional sub-cells masked as a result of adding Priority Habitats as a constraint in Cell 46

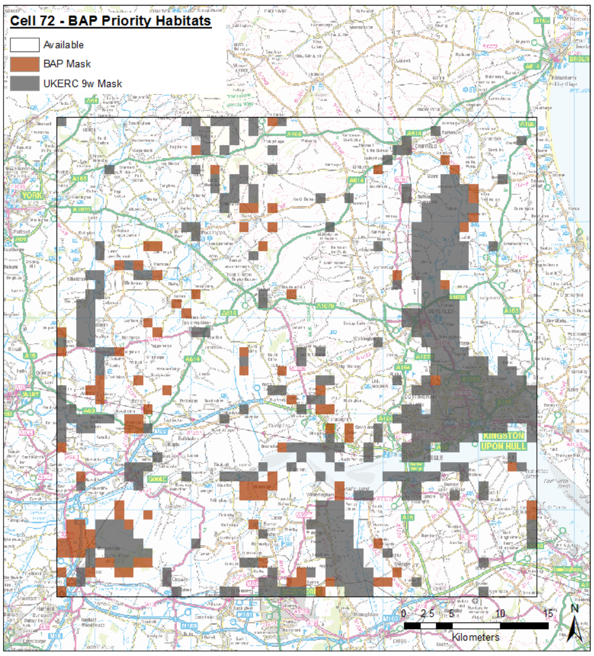

Figure 74: Map showing additional sub-cells masked as a result of adding Priority Habitats as a constraint in Cell 72

Cell 100 not shown because dataset not available in Scotland

Elevation >300m

Cells 19, 40, 46 and 72 not shown because elevation had no impact in these cells

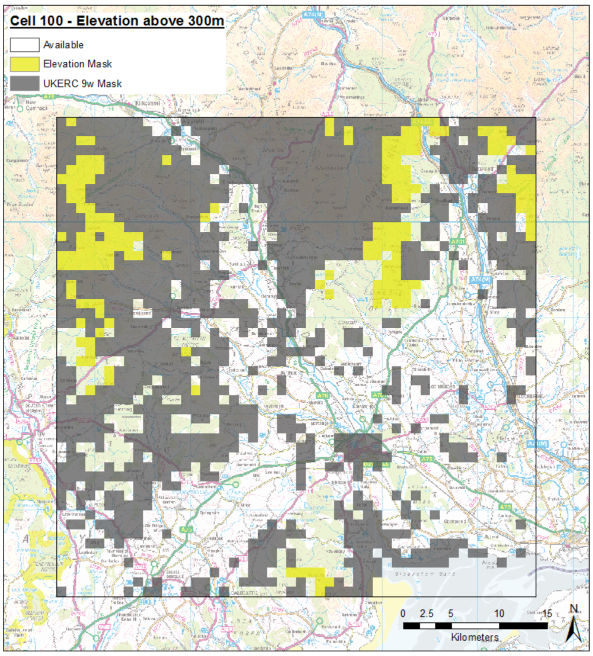

Figure 75: Map showing additional sub-cells masked as a result of adding Elevation as a constraint in Cell 100

Buildings and Water bodies

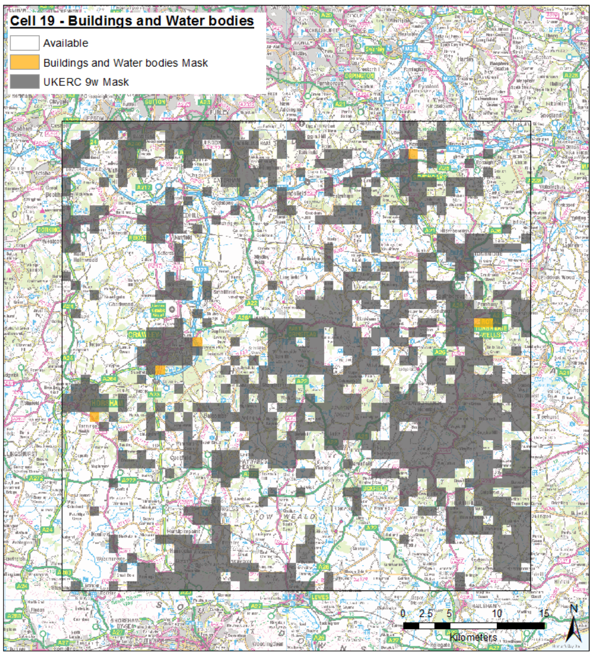

Figure 76: Map showing additional sub-cells masked as a result of adding Buildings and Water bodies as a constraint in cell 19

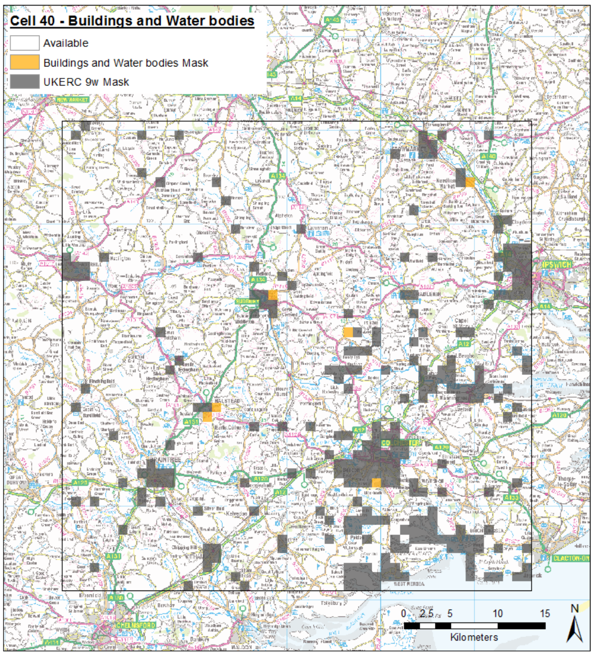

Figure 77: Map showing additional sub-cells masked as a result of adding Buildings and Water bodies as a constraint in cell 40

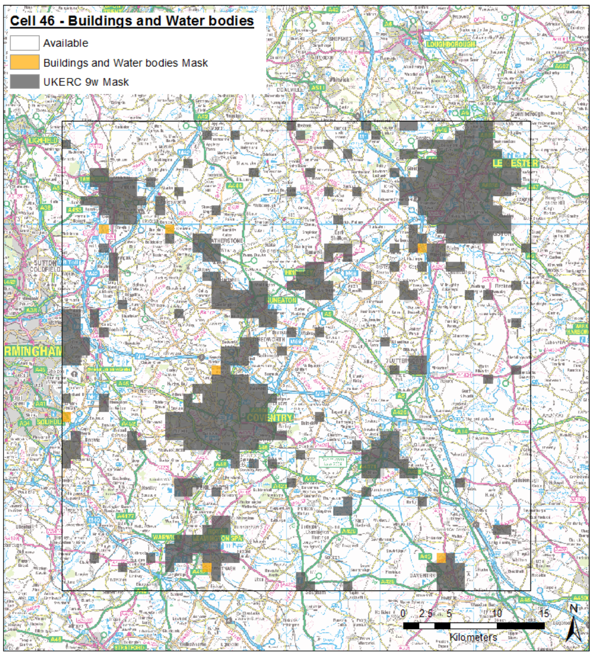

Figure 78: Map showing additional sub-cells masked as a result of adding Buildings and Water bodies as a constraint in cell 46

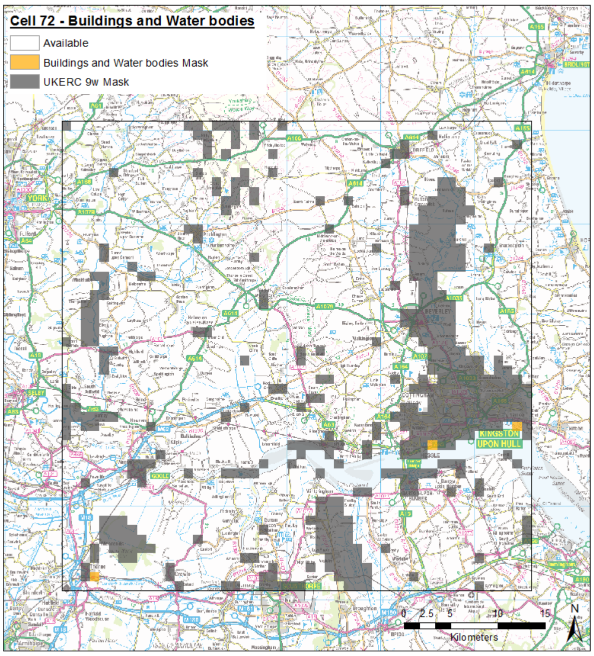

Figure 79: Map showing additional sub-cells masked as a result of adding Buildings and Water bodies as a constraint in cell 72

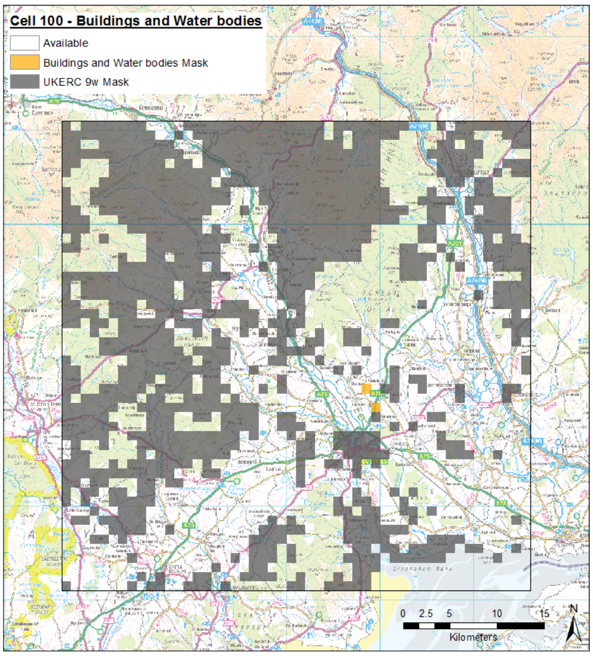

Figure 80: Map showing additional sub-cells masked as a result of adding Buildings and Water bodies as a constraint in cell 100

Parks and Gardens

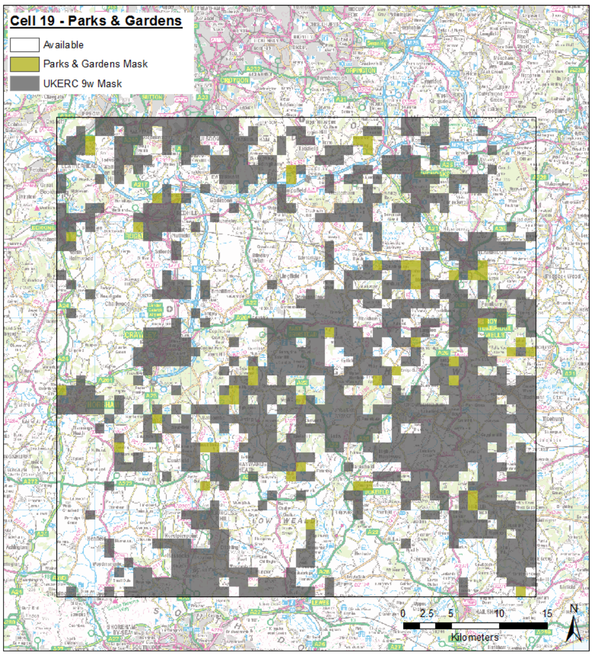

Figure 81: Map showing additional sub-cells masked as a result of adding Parks & Gardens as a constraint in Cell 19

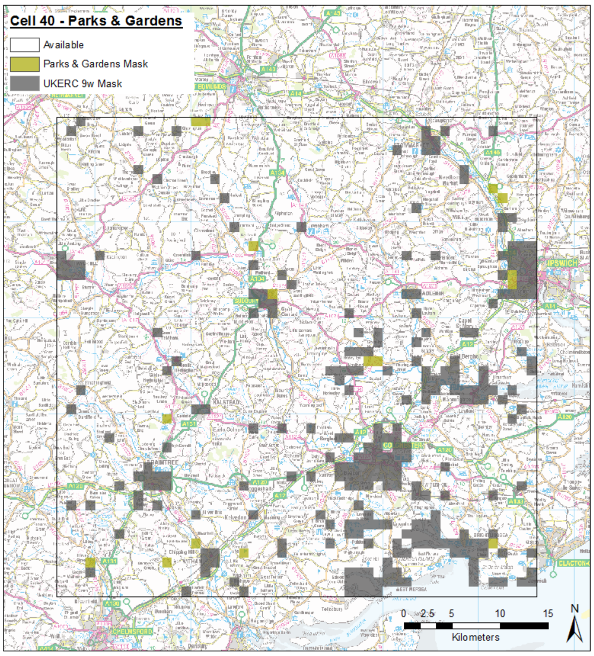

Figure 82: Map showing additional sub-cells masked as a result of adding Parks & Gardens as a constraint in Cell 40

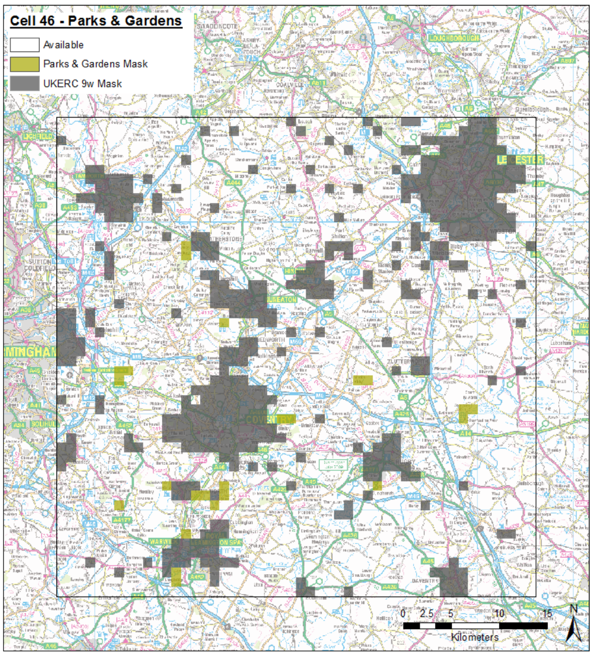

Figure 83: Map showing additional sub-cells masked as a result of adding Parks & Gardens as a constraint in Cell 46

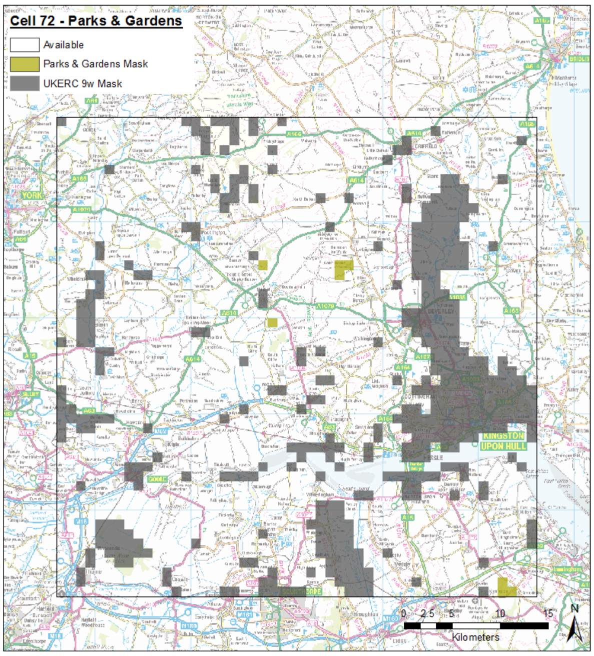

Figure 84: Map showing additional sub-cells masked as a result of adding Parks & Gardens as a constraint in Cell 72

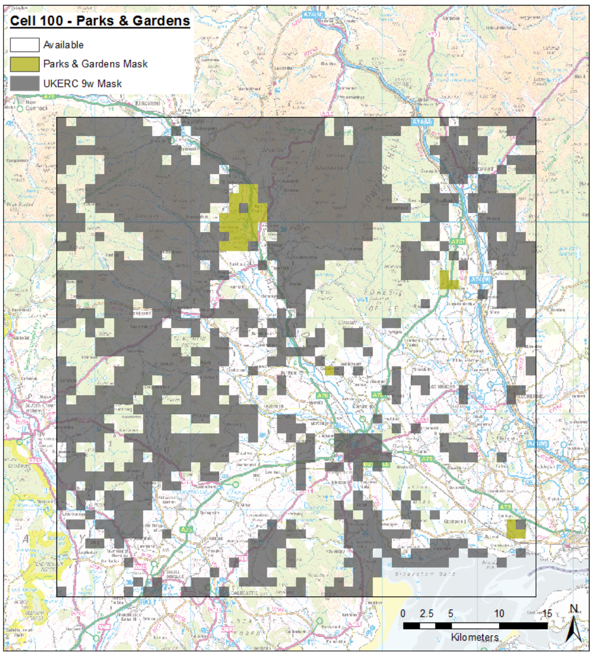

Figure 85: Map showing additional sub-cells masked as a result of adding Parks & Gardens as a constraint in Cell 100

Environmental Stewardship options

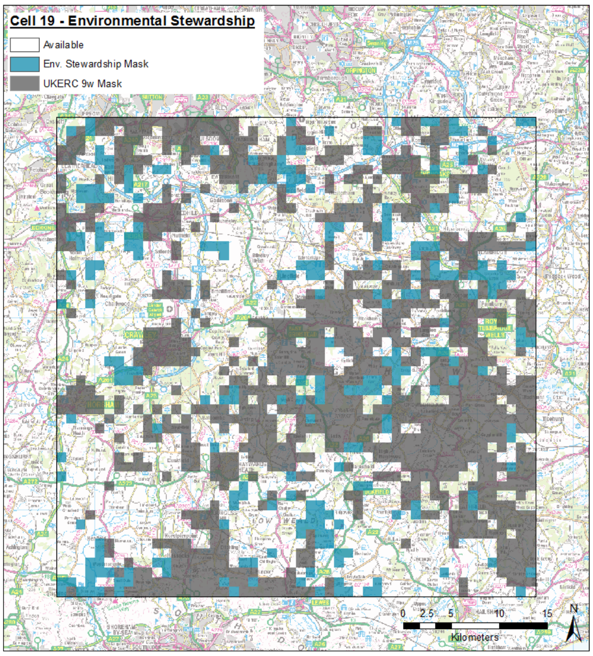

Figure 86: Map showing additional sub-cells masked as a result of adding Stewardship Agreements as a constraint in Cell 19

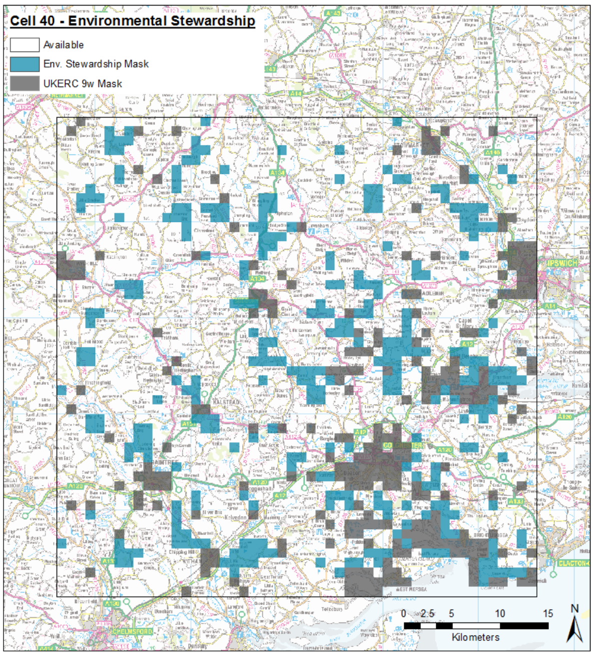

Figure 87: Map showing additional sub-cells masked as a result of adding Stewardship Agreements as a constraint in Cell 40

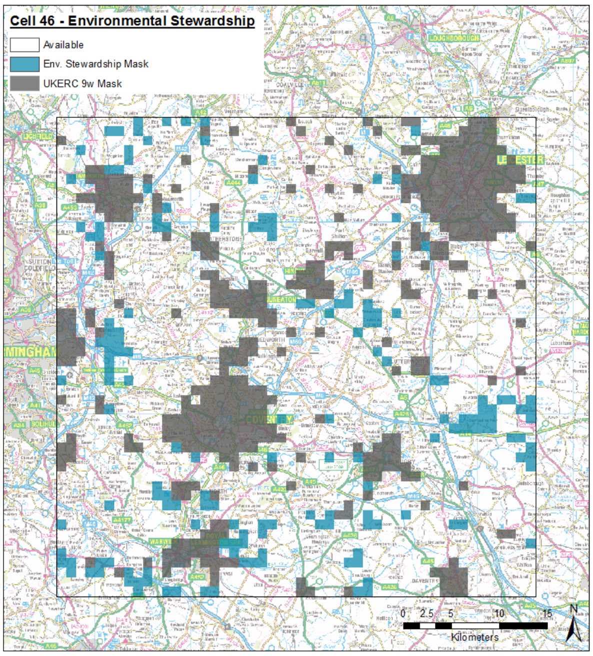

Figure 88: Map showing additional sub-cells masked as a result of adding Stewardship Agreements as a constraint in Cell 46

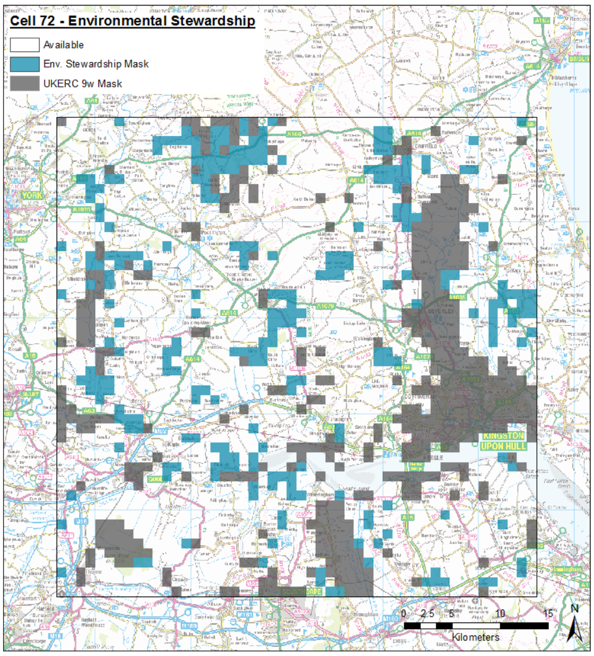

Figure 89: Map showing additional sub-cells masked as a result of adding Stewardship Agreements as a constraint in Cell 72

Cell 100 not shown because dataset not available in Scotland

Water Stress

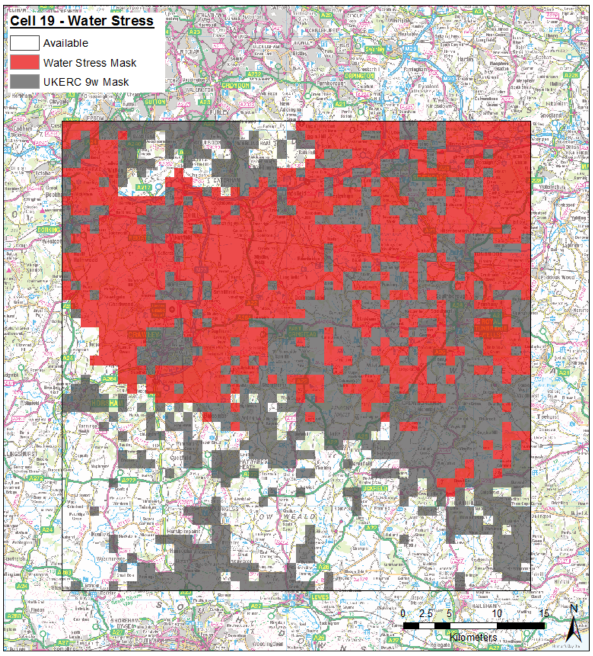

Figure 90: Map showing additional sub-cells masked as a result of adding Water Stress as a constraint in Cell 19

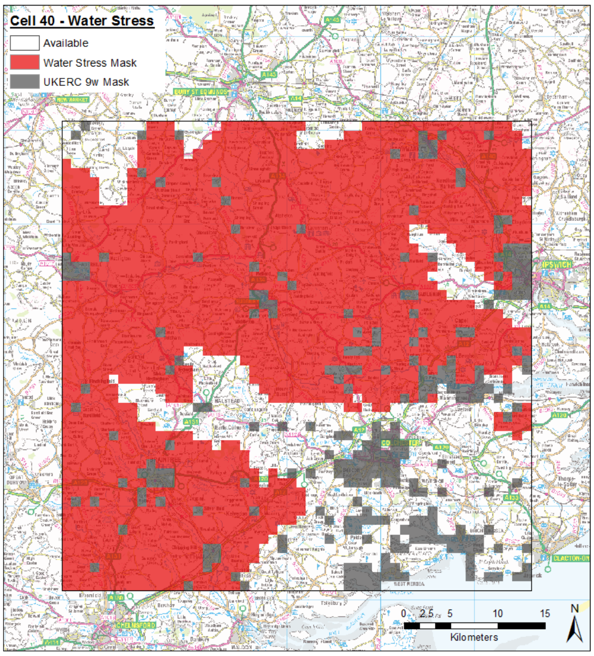

Figure 91: Map showing additional sub-cells masked as a result of adding Water Stress as a constraint in Cell 40

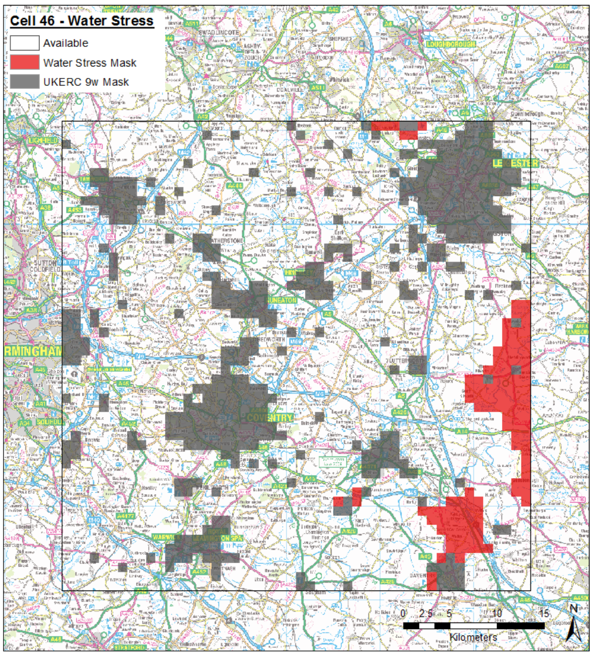

Figure 92: Map showing additional sub-cells masked as a result of adding Water Stress as a constraint in Cell 46

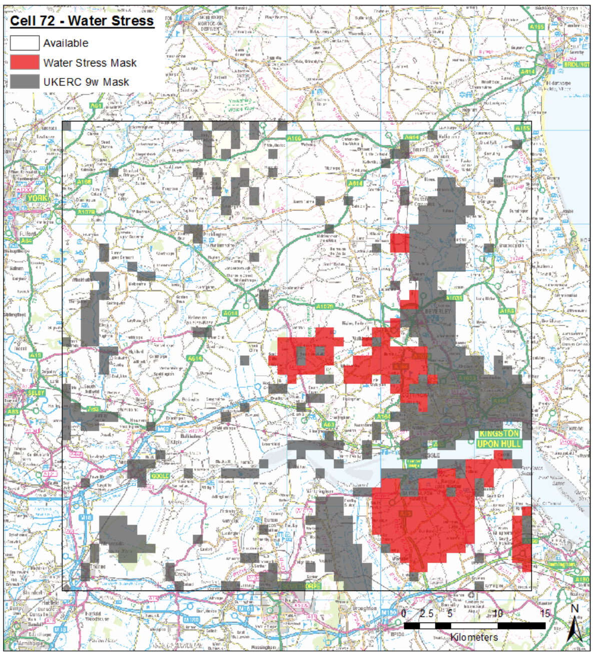

Figure 93: Map showing additional sub-cells masked as a result of adding Water Stress as a constraint in Cell 72

Cell 100 not shown because dataset not available in Scotland

Appendix 4.1: Felling licences

In any calendar quarter (1 Jan to 31 March, 1 April to 30 June, 1 July to 30 September and 1 October to 31 December) you may fell up to 5 cubic metres of timber on your property without a licence as long as no more than two cubic metres are sold.

Woodland owners should contact their local Forestry Commission (FC) office if they are not certain whether these exemptions apply.

Certain types of felling do not need permission from the FC. The Forestry Act 1967, as amended, and related regulations gives these exceptions in full. The main categories are listed below:

1. Lopping and topping (which usually includes tree surgery, pruning and pollarding).
2. Felling included in an approved Dedication plan.
3. Felling fruit trees, or trees growing in a garden, orchard, churchyard or designated public open space (e.g. under the Commons Act 1899).
4. Felling trees which, when measured at a height of 1.3 metres from the ground:
    - have a diameter 8 centimetres or less; or
    - if thinnings, have a diameter of 10 centimetres or less; or
    - if coppice (i.e. managed by cutting to promote multi-stemmed growth arising at or near ground level) or underwood, have a diameter of 15 centimetres or less.
5. Felling trees immediately required for the purpose of carrying out development authorised by planning permission (granted under the Town and Country Planning Act 1990) or for work carried out by certain providers of gas, electricity and water services and which is essential for the provision of these services.
6. Felling necessary for the prevention of danger or the prevention or abatement of a nuisance (e.g. which may involve threat of danger to a third party). This exemption will only apply if there is a real rather than a perceived danger. The FC may be able to give applicants advice that would minimise the danger without felling the trees. The FC strongly recommends that they are contacted if tree felling is being considered in these circumstances. Prosecutions for illegal felling are possible if it is shown that the tree did not present a real or immediate danger.
7. Felling necessary to prevent the spread of a quarantine pest or disease and done in accordance with a notice served by a FC Plant Health Officer (under the Plant Health (Forestry) (Great Britain) Order 1993, as amended).
8. The felling is done in compliance with any objection imposed by or under an Act of Parliament.

Appendix 4.2: GAEC and SMR measures

Reference	Requirement	Previously covered by	Measures that must be followed	Relevant to energy crops / tree planting?
GAEC 1	Establishment of buffer strips along watercourses	GAECs 14 and 19	Protect watercourses against pollution and run-off from agricultural sources by maintaining buffer strips; Take all reasonable steps to maintain a green cover on land within 2 metres of the centre of a watercourse or field ditch and 1 metre on the landward side of the top of the bank; Cultivate or apply fertilisers or pesticides to land within 2 metres of the centre of a watercourse or field ditch, or 1 metre on the landward side of the top of the bank of a watercourse or field ditch.	Yes
GAEC 2	Water abstraction	GAEC 18	You must have a licence from the Environment Agency (EA) to take (abstract) more than 20 cubic metres (4,400 gallons) of water, from an inland or underground source for irrigation, in a single day.	Unlikely
GAEC 3	Groundwater	GAEC 20	You must have a permit from the EA before you release (discharge) any substance that may harm or pollute groundwater, unless that discharge is an activity that is exempt.	Possibly, if using energy crops as a bio-filter
GAEC 4	Minimum soil cover		You must take all reasonable steps to protect soil by having a minimum soil cover unless there is an agronomic justification for not doing so, or where establishing a cover would conflict with requirements under GAEC 5.	Yes
GAEC 5	Minimum land management reflecting site specific conditions to limit erosion		You must put measures in place to limit soil and bankside erosion caused, for example, by: cropping practices and cropping structures; livestock management, including outdoor pigs and poultry, causing overgrazing and poaching etc.	Yes
GAEC 6	Maintenance of soil organic matter level through appropriate practices, including a ban on burning arable stubble, except for plant health reasons		You must maintain your soil organic matter through appropriate practices. Burning of arable stubble is not allowed except for plant health reasons.	Yes
GAEC 7a	Boundaries	GAECs 13, 14 and 15	You must: take all reasonable steps to keep a green cover on land within 2 metres of the centre of a hedgerow. You must not: cultivate or apply fertilisers or pesticides to land within 2 metres of the centre of a hedgerow; remove existing stone walls, earth banks and stone banks; remove earth or stone from an existing stone wall, stone bank or earth bank.	Yes
GAEC 7b	Public Rights of Way	GAEC 8	Public rights of way (public footpaths, bridleways, restricted byways and byways open to all traffic) must be kept open and accessible.	Yes
GAEC 7c	Trees	GAEC 16	"You must: follow the Forestry Commission's rules by applying for a licence to fell a tree, where a licence is required; contact your local planning	Yes (SRF only)

Reference	Requirement	Previously covered by	Measures that must be followed	Relevant to energy crops / tree planting?
			authority if the tree has a preservation order or is in a conservation area; follow the rules about when you can trim or cut trees.	
GAEC 7d	Sites of Special Scientific Interest (SSSIs)	GAEC 6	You must: comply with any requirements set out by Natural England in relation to Sites of Special Scientific Interest.	Yes
GAEC 7e	Ancient Monuments	GAEC 7	You must preserve scheduled monuments.	Yes
SMR 1	Reduce water pollution in Nitrate Vulnerable Zones (NVZs)	SMR 4	Claimants with land in NVZs must help to reduce water pollution by using and storing fertiliser and manure carefully.	Yes
SMR 2	Wild birds	SMR 1	You must protect all wild birds, their eggs and nests.	Yes
SMR 3	Habitats and species	SMR 5	You must protect species of flora and fauna.	Yes
SMR 4	Food and feed law	SMR 11	You must make sure that the production of food for human consumption and the production of food or feed that's fed to food-producing animals is safe.	No
SMR 5	Restrictions on the use of substances having hormonal or thyrostatic action and beta-agonists in farm animals	SMR 10	It is illegal to use substances that have a hormonal or thyrostatic action and beta-agonists for growth promotion in stock farming.	No
SMR 6	Pig identification and registration		You must: identify your animals and keep accurate records to enable the movements of pigs to be traced.	No
SMR 7	Cattle identification and registration		You must: identify your cattle, including bison and buffalo and keep accurate records including births, movements and deaths.	No
SMR 8	Sheep and goat identification		You must: identify your animals and keep accurate records to allow movements of sheep and goats to be traced.	No
SMR 9	Prevention and control of transmissible spongiform encephalopathies (TSEs)	SMR 12	You must minimise the risk posed to human and animal health by certain TSEs.	No
SMR 10	Plant Protection Products (PPPs)	SMR 9	You must: follow good plant protection practice including the Health and Safety Executive's Code of Practice for using PPPs; use only PPPs with a valid UK authorisation or parallel trade permit; meet the conditions and rules on the product label, in the authorisation, permit or in any extension of use.	Yes
SMR 11	Welfare of calves	SMR 16	You must protect the welfare of calves (bovine animals up to six months old) by meeting minimum standards for their care and husbandry.	No
SMR 12	Welfare of pigs	SMR 17	You must protect the welfare of pigs by meeting minimum standards for their care and husbandry.	No
SMR	Animal welfare	SMR 18	You must protect the welfare of farmed animals by	No

Reference	Requirement	Previously covered by	Measures that must be followed	Relevant to energy crops / tree planting?
13			setting minimum standards for their care and husbandry.	

Appendix 4.3: General environmental legislation

- Forestry Act 1967 – sets out the duties of the Forestry Commission and covers felling licences.
- Ancient Monuments and Archaeological Areas Act 1979 – allows the Secretary of State to designate areas of historical importance, acquire land (compulsory purchase) and makes harming a historically important sites an offence.
- Wildlife and Countryside Act 1981 – protection of plants and animals (list reviewed every five years). Implemented by the statutory conservation agencies: Natural England, Natural Resources Wales and Scottish National Heritage. They are co-ordinated by the Joint Nature Conservation Committee (JNCC)
- Control of Pesticides Regulations 1986 - COPR has largely been overtaken by EU legislation regulating plant protection products (pesticides to protect plants/crops), and only survives to regulate a few commodity substances and products used to generate ethylene (for fruit ripening) in the UK, which fall outside the scope of the EU regime[194].
- Heather and Grass etc. (Burning) Regulations 2007 – Sets out time of year that burning is allowed (Nov-Mar or Oct-Mid-April in certain areas) and requires certain safety measures to be followed.
- Water Resources Act 1991 and Water Act 2003 – covers abstraction and impounding licences, water pollution, drought orders, flood defences and fisheries management.
- Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 (as amended 1997) – storage requirements for silage, slurry and fuel oil.
- Clean Air Act 1993 – Creation of smoke control areas and prohibition of 'dark smoke' from chimneys.
- Crops Residues (Burning) Regulations 1993 – prohibited burning of cereal residues unless for educational purposes, disease prevention or to dispose of straw stack remains. When allowed, crop burning must comply with schedule 2 of the regs (H&S, timing etc.).
- Conservation of Habitats and Species Regulations 2010 – Designation of conservation areas and protection of species.
- Ancient Monuments (Class Consents) Order 1994 – allows the continuation of certain agricultural activities following the designation of ancient monuments.
- Plant Protection Products Regulations 1995 – requires weed killer, slug pellets etc. to be tested and licensed before sale.
- Hedgerow Regulations 1997 – certain hedgerows require permission from the local planning authority before they can be removed.
- Groundwater Regulations (England and Wales) 2009 – Prohibits the discharge of hazardous substances to groundwater and covers permitting regime for discharges to groundwater.
- Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 – establish action plans for nitrate vulnerable zones which must be implemented by farmers.
- Countryside and Rights of Way Act 2000 – establishes rights of way (and exceptions – e.g. firing range) and Areas of Outstanding Natural Beauty.

[194] http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/legislation/fepa-and-copr

Appendix 4.4: Price specification

Buyers of energy crops are likely to specify the following elements of the crop; moisture content (Range), time of production, bale weight (Miscanthus), bale size and how they are tied (Miscanthus), contamination rules, loading speed and date of dispatch.

Achieving the base price for Miscanthus is also dependent on:

- The harvest declaration being received before mid-May (there is a 10% deduction for submissions after this point)
- Having a cane chop length of between 300mm and 450mm
- Hesston Bales
  - Length: 2250-2650 mm
  - Height: 1220-1320 mm
  - Width: 1150-1250 mm
  - Tied with string - no wire
- Be free of contamination and extraneous material (this could lead to the bales being rejected)
  - There being no ground litter or leaf in the bales
  - Does not contain any mould or other substances present in concentrations harmful to health
  - Is not contaminated with process chemicals, non-energy crop based feedstock, demolition wood, or wood containing halogenated compounds or wood preservatives
- The grower loading the bales onto the transport vehicle and achieving a loading time of less than 1 hour. (Failure to achieve this will mean an excess standing charge of £20/tonne)