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The factors determining uptake of energy crop cultivation and woodland creation in England: Insights from farmers and landowners

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ABSTRACT

Perennial energy crops (PECs) and trees have key roles to play in delivering the negative emissions needed for the UK to reduce greenhouse gas emissions to net zero by 2050. Significant changes to land use are needed and the decision to make changes will lie with individual landowners. Using in-depth, semi-structured interviews, this research explores the attitudes of farmers and landowners in England to replacing traditional arable and livestock farming with growing annual or perennial energy crops or planting trees. It was concluded that considerable government policy intervention will be needed to overcome the many economic and social barriers in place including lack of markets and attractive contracts for growers, high establishment costs, loss of annual income, high prices available for cereal crops and the cultural division between farming and forestry. Although energy crops and woodland creation are generally researched and regulated separately, this research suggests that annual energy crops, PECs and woodland creation form a spectrum of land use options for a landowner, with the propensity to adopt these crops being determined predominantly by crop attributes including the risk of planting and the term of commitment.

1. Introduction

As the urgency of climate change is recognised, targets for reducing greenhouse gas (GHG) emissions have become increasingly ambitious worldwide. The IPCC (Intergovernmental Panel on Climate Change) has modelled pathways that limit warming to 1.5 °C that require combinations of land-based mitigation and land-use change, including reforestation, afforestation, and bioenergy with or without carbon capture and storage (CCS) [1,2]. The UK target to reduce GHG emissions to net zero by 2050 [3], exceeds global reductions needed to limit the expected rise in global average temperature to well below 2 °C, and if adopted worldwide, would deliver a greater than 50 % chance of limiting the temperature increase to 1.5 °C [3]. The UK Climate Change Committee (CCC) [4] (an independent statutory body that advises the UK and devolved governments on emissions targets and reports on the progress made in reducing GHG emissions) proposes that to achieve *net zero*, emissions from sectors which are hard to decarbonise (e.g. agriculture and aviation) will have to be balanced by negative emissions, which can be delivered by direct air capture and storage of CO_2, capturing and storing CO_2 from combustion [5,6], or by sequestration of carbon in soils or plant biomass [7]. The CCC recommends large-scale bioenergy with carbon capture and storage (BECCS) using perennial energy crops (PECs) and woodfuel as feedstocks, significant woodland creation and peatland restoration [8]. These measures require significant change of land use. The *Further Ambition* net zero scenario constructed by the CCC would require an increase in the woodland cover in the UK from 13 % to 17 % by 2050, and increases in the area of PECs from 10 kha (thousand hectares) to 700 kha by 2050 [8]. Other net zero scenarios require even greater planting of trees or PECs, e.g. the Energy System Catapult's *Clockwork* and *Patchwork* scenarios [9] and the CCC *Speculative* scenario [8]. Although the target of Net Zero by 2050 has been set for the UK, the individual UK nations have their own targets, (2045 for Scotland and 2050 for England, Wales and Northern Ireland) [3], reflecting different emissions sources and different opportunities for reduction and sequestration. Energy policy is mostly a UK government responsibility, but agriculture, forestry, and land use policy are devolved to the constituent nations [10], complicating the delivery of GHG reduction [11]. Where matters are devolved, this paper focusses on England.

Currently plant biomass is the largest source of biofuels in the UK and 59 % is imported [12]. Wood pellets, imported predominantly from the United States and Canada, are used by power stations [13,14] and smaller domestic and commercial boilers [15]. The future supply of

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imported biomass depends on global supply and demand, and the UK may not always be able to rely on imports at this scale [16–18]. Domestic biomass could provide security of supply and deliver negative emissions if combined with carbon capture and storage. In the UK 72 % of land is agricultural [19], and the vast majority is privately owned with landowners renting some of their land to tenant farmers. The role of the landowner (individuals or institutions) and tenant is often overlooked when plans for land-use change are discussed, particularly when ambitious tree planting targets are proposed by politicians and environmental charities, but they will always make the key decisions needed to change land use, and so deliver climate change mitigation.

1.1. Energy crop cultivation in the UK

The PECs most commonly grown in the UK are miscanthus and short rotation coppice (SRC) willow, which are combusted in power stations or industrial plants to generate electricity and/or heat. Miscanthus, a giant grass grown from rhizomes, produces tall stems which can be harvested annually in winter from two or three years after planting [20], for 10–15 years, and up to 20 years on good land [21]. Miscanthus is tolerant of cold weather, requires a low input of fertiliser, and can be grown on poorer-quality agricultural land that is not suitable for food crops [20,22]. Miscanthus has a neutral or positive impact on soil carbon storage once plants establish, nitrous oxide emissions are lower than from fertilised crops, biodiversity may be enhanced, and its substitution for fossil fuel may result in GHG emissions reduction [23], even without CCS. SRC willow takes up to four years to establish and can be coppiced (cut back to ground level) every three years from then onwards [24] for between 22 and 30 years [22]. Willow can fix carbon in soils, improve biodiversity [25–27], control flooding, and increase soil stability [28,29].

Annual energy crops are grown for anaerobic digestion (AD) or for biofuel production (bioethanol or biodiesel) [30]. Wheat, barley, maize, sunflowers [31] and hemp [32] are all suitable AD feedstocks. Annual energy crops generally require higher inputs of chemicals and energy than PECs, but provide greater flexibility for farmers [33]. Although grass and grass silage (grass preserved under anaerobic conditions) are recognised AD feedstocks [34–38] no literature has been found on the advantages to farmers of growing grass for AD or that consider the attitudes of farmers to both annual and perennial energy crops.

Fig. 1 shows the areas of bioenergy crops grown in the UK from 2008 to 2020 [39,40]. Annual figures for the areas of PEC cultivation are only available for England, where miscanthus and SRC cultivation has not changed significantly since 2008. The majority of UK PEC cultivation is in England [41], but land in Scotland, Wales and Northern Ireland is also suitable [42,43]. Since 2014, when data for energy maize became available, its cultivation has increased, and maize is now the most widely grown UK energy crop.

Delivering the seventy-fold increase from 10 kha of PECs [40] to the 700 kha modelled in the CCC *Further Ambition* scenario by 2050 will be challenging, with no government incentives currently available, and public opinion less supportive of bioenergy than of other renewable technologies [44] or of planting trees [45]. Previous studies of UK PEC cultivation identified technical, financial, and behavioural barriers to energy crop uptake. PECs are traditionally targeted at poor quality land but when they *were* grown on such land, low yields resulted [46]. The grants and contracts offered by the ARBRE project [47] (to deliver a gasification power station in Yorkshire) in the 1990s were attractive [24,48], but the project failed [47,49,50], and reduced the confidence of energy crop growers [51,52]. High planting costs, the delay before income starts [24,53–56] and high cereal prices have also discouraged planting [48,55]. Farmers have been reluctant to make long term commitments, change traditional practices [57,58], lose flexibility [59] or risk damage to drains [48]. Other barriers to PEC adoption include the absence of a consistent UK energy crop policy [51,52,60], a lack of knowledge among farmers [57,61,62], technical issues with harvesting and processing [54,63,64]. McCormick and Kåberger [61] argue that the key barriers are not technical and are specific to local context. Although farmers support reducing carbon emissions, they also require their projects to be economically viable [57,60,65]. The a "*chicken and egg*" problem, that farmers will not plant PECs without a market in place, but there will be no investment in generation without a reliable biomass supply is widely discussed [23,66,67].

Slow PECs adoption has been a problem across Europe. Willow cultivation in Sweden has had a similar adoption pattern to the UK, with a period of planting when grants were available followed by stagnation after incentives became less favourable [68] and competition from higher cereal prices restricted uptake [69]. Sweden, Germany, Spain and Ireland have all experienced a lack of lobbying groups and low awareness of SRC among farmers [70]. Miscanthus has also failed to be widely

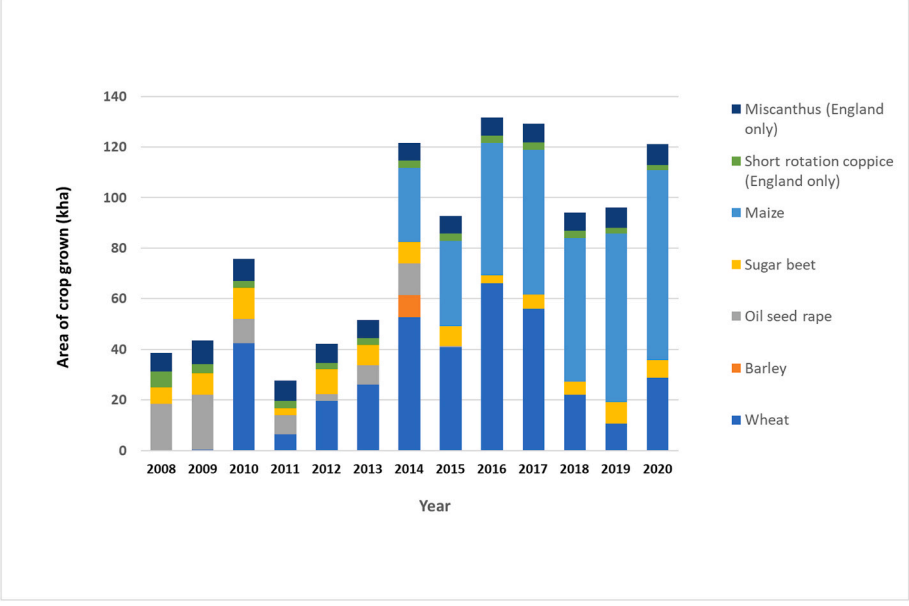

Fig. 1. Areas of crops grown for bioenergy in the UK from 2008 to 2020
Data from DEFRA [39,40].

adopted despite trials in Germany, Denmark, and Switzerland [23], and planting has been disappointing e.g. in France (6 kha by 2019) [71] and Germany (a total of 11 kha of SRC and miscanthus by 2018) [72].

1.2. Woodland creation

Woodland creation is proposed to sequester carbon in trees, soil, and timber products, but sustainable woodland management will also produce woodfuel [73] and meaningful GHG reductions can be delivered from its use [74]. Woodlands also deliver increased biodiversity, flood control, recreational space, and improved air quality [73]. Currently, the UK only has 13 % canopy cover, much lower than most European countries [145], and cover in England is even lower at 10 %. The UK Government's annual woodland creation target is 30 kha [75] and the target for England is 7 kha per year by 2024 [76], but the UK has repeatedly failed to hit annual woodland planting targets despite planting grants being available. In 2020–21, 13,290 ha of woodland was created in the whole of the UK, with only 2060 ha created in England; the majority (10,660 ha) being in Scotland [77]. Planting fell throughout the UK in the mid-1970s when tax advantages for conifers ended. Some recovery in England was achieved from the early 1990s when incentives provided income-foregone payments, but declined again under the 2007 English Woodland Grant Scheme and fell to 700 ha in 2015 when the Countryside Stewardship Grant Scheme was introduced in England [78].

Woodland creation has had a high profile in the media, and the benefits are widely promoted, although the potential negative impacts are seldom discussed [79], and there is a risk that emphasising the benefits of tree planting can distract attention from other GHG mitigation activities e.g. restoring peatland and reducing fossil fuel consumption [80]. The UK Government's woodland creation target demonstrates a desire for significant woodland creation, but this has not yet been converted into significant planting. Most planting will be on privately-owned land, with the decision to plant being made by individuals or families, so meeting targets is dependent on the attitudes and objectives of the landowner [81]. As there is no compulsion to plant [78], woodland creation must be economically advantageous for the landowner as well as being environmentally beneficial [82], and planting can be complicated further when land is held by tenants [83,84]. All felling requires a licence from the Forestry Commission (FC), and usually replanting is required, [85]. Thus, most woodland creation results in permanent land-use change.

Government grants are available for planning, planting, management and maintenance [75], and a comprehensive summary of grants is available from the FC [86], including the Woodland Carbon Guarantee which rewards farmers for carbon sequestered by their woodlands [87]. Assistance is also available from national [88,89] and local charities [90] and woodland owners receive preferential tax treatment [91,92]. Although some grants include initial and annual payments, there is still a long period before any income is generated from thinning or felling, and forestry on poor land may never be profitable even with grants [78,93–95].

A cultural division between forestry and farming has been identified. Some farmers view the permanent change from farming to forestry as bad for both the landscape and food production [83,93,96,97], and fear that planting trees will reduce land values [82]. The availability of suitable land for planting is also a constraint [82], and it has been suggested that much of the most suitable land has already been used, meaning that the land remaining is either productive land, or also suitable for other uses, such as arable farming [7]. Prioritising native broadleaved trees over non-native (generally productive conifers) and honorary native species in new schemes, can also deter planting [82].

1.3. Research aims

If the UK is to meet its net zero target, then landowners and farmers will have to grow more energy crops and plant more trees in the face of competition for their land from food production, habitat restoration, solar farms, and the expansion of settlements.

This research aims to answer three questions. Why has the adoption of perennial energy crop cultivation continued to stagnate, despite the role that biomass can play in meeting net zero targets? Why have annual woodland planting targets failed to be met? Are there common factors in the attitudes of farmers and landowners to these two types of land use change?

Past research has separately identified barriers to PEC adoption and to woodland creation but subsequent uptake has continued to be disappointing. This case study of the Yorkshire and Humberside region assesses current attitudes to both practices, now that there is more attention on net zero targets, and farmers face the prospect of having to deliver public goods if they are to receive farm subsidies. This study covers annual energy crops, PECs and woodland adoption to gain a wider understanding of attitudes to land-use change, identifying the common factors that drive and prevent adoption of these practices, including the important human elements of decision-making as well as technical and financial constraints.

2. Materials and methods

This research is based on evidence gathered from in-depth semi-structured interviews (n = 30) carried out with farmers, landowners and land managers, and also their farming and forestry advisors, to understand attitudes to changing from traditional arable or livestock farming, to growing perennial energy crops or creating woodland. Ethical approval for the research was granted by the University of Leeds Research Ethics Committee and protocols were put in place for consent and data management.

The Y&H region in the north-east of England was used as a case study to understand the attitudes in England. Y&H contains 12.5 % of English farmland [98], and a variety of agricultural condition with fertile farmland in the centre, south, and east, with lower quality land on the Pennine Hills in the west, the Yorkshire Dales in the north west, and the North Yorkshire Moors in the north. It also has a history of energy crop projects and areas of commercial forestry. In 2019, when regional data was last available, Y&H grew 23 % of the miscanthus and 19 % of the SRC grown in England with only the East Midlands growing more of each crop [99].

2.1. Analytical framework

Rogers' theory of the diffusion of innovation (DOI) [100] was used as an analytical framework. Rogers argues that adoption of an innovation depends on its relative advantage, compatibility, complexity, trialability, and observability. White et al. [101] in their assessment of biofuel adoption by farmers add a sixth factor: degree of risk. Within a social system, members will be influenced by norms of behaviour, opinion leaders, and change agents. Time is an important part of the Rogers model, covering five steps in decision-making: knowledge, persuasion, making the decision, implementation of the innovation, and confirmation. Discontinuance can follow where an innovation is abandoned by a dissatisfied adopter or is superseded by a newer innovation [100].

Innovation studies, including DOI, have been criticised for having a pro-innovation bias [100,102–104] which can lead to lack of attention to unintended consequences [103], being more often used for studying successful diffusions than for unsuccessful cases, and having limited scope for identifying factors responsible for failure of adoption [104]. DOI has also been criticised for having a single perspective (the adopter of the innovation) [105], but this focus on decisions of individuals [106], is appropriate for this research. Rogers is widely used to study adoption of novel crops and renewable energy by individuals and small organisations [97,101,107–111] and was felt to be a suitable framework

for studying farmers' attitudes and behaviour.

2.2. Research design

Semi-structured interviews [112–115] were used because of their suitability for interviewing experts [112,115] where the expertise of the interviewee is of interest as well as their experiences. Although face-to-face interviews are often considered to produce richer data than telephone interviews [112–115], for in-depth interviews with geographically dispersed interviewees, telephone interviews are also effective [116–120]. Six interviews were carried out face-to-face and twenty-four by telephone. These interviews formed a qualitative cross-sectional survey, but also captured data on retrospective and prospective activities [112].

Landowners and farmers of the following types were recruited for interview: current growers of miscanthus, willow and maize, growers who had planted miscanthus or willow and removed it, farmers who had created woodland, estate owners with experience of managing and creating woodland, and charity, utility, and local authority landowners. Land managers with experience of energy crops, a miscanthus supplier, an AD advisor, woodland researchers and commercial and public sector foresters were also interviewed as they understood the attitudes of a wide range of landowners that they had advised or supplied, and had a national understanding of attitudes throughout the sectors. Although most of the landowners and farmers were from Y&H, most of the industry experts were from other regions of England. Interviewees were selected for their knowledge and experience (judgemental or purposeful sampling) [121] with some accidental or convenience sampling [112, p244] of contacts made at conferences and socially. Former energy crop growers were traced by comparing maps of land which had received PEC planting grants [122] with current land use [123]. Snowball sampling [121] was used for hard to reach groups e.g. current PEC growers, and commercial foresters. Details of interviewees are in Table 1.

The interview questions were based on Rogers' DOI framework and themes identified in literature, and can be found in Appendix A. All landowners, farmers and land managers were asked about their sources of information, membership of organisations, participation in information networks, experience of farm diversification (including renewable energy), previous practices, social system norms, attitudes to innovation, and factors influencing decision making. They were then asked specific questions about their experience of annual and perennial energy crops (including costs, contracts, harvesting, and impact on soils) and/or their experience of woodlands (including grants for creation, financing, pests and diseases, woodland management, skills, and education). Advisors, researchers, and foresters were asked about their experience, and about the attitudes to energy crops and/or woodland held by farmers and landowners they had worked with. Twelve interviews covered energy crops, and twenty-five covered woodland topics: including seven that covered both as most energy crop growers had also planted trees. The format was flexible, giving the opportunity to discuss some topics in depth. All interviewees were asked whether their experience was influenced by their location, how they viewed the prospects for land-use change and were given the opportunity to raise other relevant topics. Most interviews took between one and 2 h, depending on the breadth of experience of the interviewee, and were carried out by the same researcher who then transcribed the audio recordings verbatim ready for analysis.

Interviewees were recruited until two or more interviews had been completed with most types of landowner and farmer, no new themes were emerging, and it was clear that the research was approaching saturation. After completing the interviews, the researcher attended a farm walk hosted by a miscanthus grower, which provided a useful opportunity to ask several current and prospective growers about their attitudes and concerns. As no new themes emerged, it was confirmed that saturation had been reached on the miscanthus research.

Thematic analysis [124] of the transcript data was performed using

Table 1
Interviewees' roles, experience, and locations.
Some details are excluded to maintain anonymity.

Interviewee	Experience	Location	Interviews Carried Out	
			Energy crop	Woodland
PF	Poultry farmer who has planted woodland on farm.	Eastern England		✓
MF1	Mixed farmer. Former maize grower. Planted trees on farm.	Y&H	✓	✓
ADC	AD consultant for poultry litter and Maize.	Y&H	✓	
AF1	Arable farmer who grew willow and miscanthus in the past and has planted trees on farm in last 15 years.	Y&H	✓	✓
AF2	Arable farmer. Grew miscanthus and willow in the past. Grows maize. Has planted trees.	Y&H	✓	✓
AF3	Arable Farmer who grew miscanthus in the past and has planted trees in last 5 years.	Y&H	✓	✓
AF4	Arable farmer. Current grower of miscanthus.	Y&H	✓	
AF5	Arable farmer. Grew willow for more than 10 years and trial of SRF. Planter of woodland.	Y&H	✓	✓
AF6	Arable farmer who has planted and managed woodland for over 10 years.	England		✓
LM1	Land manager and farmer. Miscanthus grower, former miscanthus contract manager.	Y&H	✓	
AF&A	Arable farmer and advisor on growing of maize for AD.	England	✓	
MISCS	Employee of company offering miscanthus contracts and rhizomes.	England	✓	
EO1	Estate owner growing feedstocks for AD and large-scale forestry.	Y&H	✓	✓
EO2	Estate owner, farmer growing wheat for biofuels. Manages forest over 100 years old.	NE England	✓	✓
EO3	Estate owner. Woodlands over 100 years old and plantation woodland.	Y&H		✓
SLO	Small upland landowner planning a small planting of trees.	Y&H		✓
HF	Hill farmer, planted trees over 12 years ago and plans more trees.	Y&H		✓
HCLO	Historic charity landowner.	England		✓
ULO	Utility landowner, managing catchment land and has major planting target.	Y&H		✓
LAF1	Local authority forester and manager of parkland.	Y&H		✓
LAF2	Local authority forester involved in Northern Forest project.	Y&H		✓
WCA	Woodland charity advisor to farmers.	UK		✓
WCR	Woodland charity researcher.	UK		✓
FTREP	Technical director of a forestry trade body.	UK		✓

(continued on next page)

Table 1 (*continued*)

Interviewee	Experience	Location	Interviews Carried Out	
			Energy crop	Wood-land
FCF1	FC advisor on planting and funding. Former land agent. Woodland owner.	Y&H		✓
FCF2	FC advisor on planting and funding. Former urban forester.	Y&H		✓
MEG	Member of environmental group promoting planting of trees in Yorkshire.	Y&H		✓
WSUP	Woodchip processor and supplier. Forester.	Pennines		✓
FOR1	Manager with major UK forestry company.	Central and N. England		✓
FOR2	Manager with major UK forestry company.	Y&H		✓

Nvivo software to identify key themes and drivers and barriers for adoption. This used an initial coding list based on the DOI theory and identified a very large number of themes. To provide more insight, a further analysis was carried out during which each interview was analysed through the steps of the core DOI decision-making process and the factors influencing their decisions were recorded. These factors affecting decision-making for annual crops, perennial crops, and woodland creation were presented in a table to allow comparison.

3. Results

The key themes identified during the analysis are discussed and then key barriers for each type of land use are summarised in Table 2. The results of the analysis of decision-making using the DOI framework are presented in Table 3 and then all the findings from the interviews are discussed.

3.1. Themes

The four key energy crop themes and the six most important woodland themes identified from analysis are presented in turn, drawing directly from the interviewees' comments.

3.1.1. Experience of annual crops had been much better than for perennial crops

Experience of willow had been difficult for all four early growers, and three had abandoned the crop, reverting to traditional food crops. Willow was slow to establish and needed more inputs than expected: some fertiliser, weed control and insecticide. Harvesting was initially a problem for all the early growers interviewed e.g. *AF1* found that the heavy willow harvester sank further each year. Once established the willow cropped well, but harvest was at an inconvenient time for one farmer. Early growers for the ARBRE project received planting grants, payments per acre grown and payments at harvest, but after the project failed there was no market until the farmers collectively negotiated contracts with Drax Power Station. Later, farmers planted willow specifically for Drax, under long-term contracts, but Drax cancelled all willow contracts in 2016, preferring to use imported wood pellets, which once again left farmers without a customer.

Table 2
Barriers and drivers for crop adoption identified from interview data.

Annual energy crops		Perennial energy crops		Woodland creation	
Drivers	Barriers	Drivers	Barriers	Drivers	Barriers
•Grass and maize fit in well with farms' crop rotations and help eradicate black-grass •Attractive contracts from AD plants are available	• Attitude that farms should grow food not energy crops	•Long term contracts for perennial crops give income security to farmers •Require low input of both effort and fertiliser •Low input crops suit difficult to cultivate land •Farmers will plant if the price and contract are right •Low maintenance use of poor-quality land, or awkward field corners	• There are few markets for willow or miscanthus • Cereal crop prices currently make PECs unattractive • Government policy: PECs were excluded from greening payments and stewardship schemes, and no grants are available for planting. • Negative perceptions of energy crops persist	•Grants for planting, fencing and guards •Long-term investment which can be cashed in when needed •Diversification of farm activities – risk spreading •Shelter belts and farm warming •Supply of woodfuel •Creates habitats for biodiversity •Creates attractive landscapes •Controls flooding and improves water quality •Tax advantages •Recreation for landowner and the public •Low maintenance use of poor-quality land, or awkward corners •Climate change mitigation •Replacing trees lost to disease •Charity funding (rural and urban) • Attractive to companies looking for Corporate Social responsibility activities and carbon credits •Local authority tree cover targets • Certification of farm products	• Initial planting costs of trees, guards, and fencing • Loss of income from agriculture and long wait for income from wood • Loss of farm payment unless planted in a stewardship scheme • Competing with grant farming on upland farms • Woodland grants may be too restrictive on species and layout • Permanent land use change • Fear of reduction in value of land • Complex grants can scare off farmers who fear grant payments may be clawed back • Hope of building on land • Planting may not be permitted in protected landscapes e.g. sites of special scientific interest or national parks • Division between farming and forestry industries and identities • Reluctance to plant over the "sweet spot" for tree planting of about 7 % for a farm, and 25–29 % for an estate

Table 3
Comparison of DOI crop attributes.

Characteristic	Maize for AD	Grass Leys for AD	Miscanthus	Willow	Woodland planting
Relative advantage	Contracts available directly with AD plants. No grants available.	Contracts available directly with AD plants. No grants available.	Long term fixed price contracts available in some areas. Low input crop. Can revert to arable at the end of a contract. No grants available.	Contracts available in some areas. Long term fixed price contracts. Low input crop. Can revert to arable but may be hard to remove. No grants available.	Grants available for planning, planting, and maintenance. Long term investment. Long wait for income. Enhances farm environment. Income can be taken when needed. Risk of reducing land value.
Compatibility	Compatible with arable rotation and good for black-grass eradication.	Compatible with farm practices and good for black-grass eradication.	Fits well with arable farming for some farmers. Not a food crop so incompatible with normal behaviour.	Fits well with arable farming for some farmers. Not a food crop so incompatible with normal behaviour.	Work can be done in winter when farms are not busy. Very different to arable or livestock farming. Not a food crop so incompatible with normal behaviour.
Complexity	New crop but not complex.	Traditional land use – not complex.	A new crop but low input.	A new crop but low input.	A new set of knowledge and skills required.
Trialability	Can try a small contract.	Easy to try a small contract.	Can plant a few ha at a time.	Can plant a few ha at a time.	Can plant a few ha at a time.
Observability	Easily observable.	Easily observable.	Easily observable.	Easily observable.	Easily observable.
General perception	**Just a new crop.**	**Traditional land use easy to adopt.**	**Not a traditional crop or traditional land use, but "basically a tall grass".**	**A "new mindset" needed, more like a tree than an arable crop. Fear of damage to field drains.**	**A completely separate practice from agriculture. Grants are complex and onerous. May reduce value of land.**
Term	**1 year**	**Up to 5 years**	**10–25 years**	**22–30 years**	**Permanent in most cases.**
Risk	**Lowest risk**	**Lowest risk**	**Higher risk**	**Higher risk**	**Highest risk**

The Iggesund paper mill in Workington, Cumbria, is now the only large customer for willow in the north and west of Y&H. The mill, powered by a 50 MWe combined heat and power plant [125], consumes 500,000 t of biomass per year, including willow grown on Iggesund's own land, and on local farms. Their "*Grow Your Own Income*" scheme encourages farmers to plant willow under index-linked 22-year contracts, particularly on wetter unproductive ground where it provides some flood protection and does not compete with food production [126].

Farmers further south have no large customers, so one former willow grower (*AF1)* was left with:

> "… a mountain of willow on the farm, sitting there, rotting away, so it was all a bit of a disaster really."

None of the growers had been able to use willow as a fuel as the biomass boilers commonly used in the UK cannot cope with the high moisture content. Although willow has a reputation for being difficult to remove, and for damaging drains, no long-term damage to the land or drains was experienced by interviewees.

The early miscanthus growers also had some bad experiences. Many farmers were recruited through adverts in the local press to supply Drax [127]. Some were contacted by salesmen and others heard about the new crop from fellow farmers. With planting grants and five-year index-linked contracts, many farmers, such as former miscanthus grower *(AF1)* signed up:

> "It's my dad's side, but it must have been quite attractive for him to go into it, he's usually quite reticent about stuff like that."

The early adopters found miscanthus was difficult to establish, and the quality of the early rhizomes was mixed: resulting in the need for some replanting. The first harvests were later than expected, with lower yields than predicted, and higher moisture contents than the power stations wanted. When Drax ceased using local biomass in 2016 the farmers' contracts were taken over by Terravesta (a Lincolnshire company which supplies miscanthus rhizomes and arranges biomass contracts), but confidence in the sector took a blow. Miscanthus is still supplied to Brigg (Lincolnshire), and Snetterton (Norfolk) power stations.

Three farmers had abandoned miscanthus. The main reasons given for discontinuance were failing to find a buyer and deciding not to renew at the end of a contract, but recovery in the price of wheat was another key factor for miscanthus grower AF1:

> "When we started with miscanthus, wheat was at £65–70 per tonne, and when we finished with miscanthus wheat was at £110 per tonne, £120 per tonne … so it was just a financial decision."

Even for early planters the crop did eventually establish well, and the interviewees thought that current strains and planting techniques would result in better establishment. Farmer *AF3* thought that with hindsight they had suffered from being early adopters and "*were a little bit too soon"* in growing the crop.

Miscanthus is still attractive to farmers with specific requirements of a crop, and contracts for planting were available at the time of the interviews. Although originally targeted at marginal lands it can be successful on land which is expensive or difficult to cultivate, e.g. in fields far from the main farm, with difficult or mixed soil, or of an awkward shape. Miscanthus needs little management other than harvesting, so allows farmers to concentrate on more productive land. Land manager *LM1* recommended farmers

> "Plant miscanthus on the 10 % of your worst land then you should focus on the other 90 % and the miscanthus will look after itself."

This is now one of the main attractions for farmers growing miscanthus as a part of a diversified farm plan.

In contrast, interviewees' experiences of annual crops had all been good. Maize was popular with farmers near AD plants, who had light soils, and were far enough south to grow it (Yorkshire is currently at the northern limit). They signed up to annual contracts directly with local AD plants. Maize was viewed as a good addition, which sometimes allows an extra crop in a rotation and also helps eradicate black-grass (Alopecurus myosuroides, a herbicide-resistant weed which reduces cereal yields). Some farmers viewed maize as a tricky crop before they planted it, but with attention to detail, grew it successfully. Maize is attractive to both AD plants and farmers as it:

> "… is relatively easy to manage, most of the growing can be done under contract. So I can understand why it is attractive to them … It can also efficiently use the digestate from AD plants, so it is genuinely a circular relationship" AD consultant (ADC).

Growing grass did not feature strongly in literature on energy crops and was not included in the original interview questions. However, farmers who supplied maize to AD plants also talked about crops such as

grass, wheat, and hybrid rye to supply a varied diet for an AD plant. Planting grass leys (fields planted with grass for between one and five years in an arable rotation [128]) was a popular option for farmers on heavy land prone to black grass. As one farmer reflected on his decision to plant grass leys: "*Yes, it was a good decision. Yes, it was an easy decision.*" (*AF2*).

3.1.2. Contracts and finances drive the planting of all types of energy crops

Energy crop planting was driven by the availability of contracts. Farmers planted PECs when contracts were strongly marketed, and financially attractive, but the loss of contracts, and strong competition from other crops, had led to areas of the crop being removed.

Farmers will not make speculative plantings of PECs: they will only plant when a financially attractive long-term contract is in place. All the farmers were concerned about the environment, and most took part in environmental schemes e.g. planting or preserving hedges, or protecting marshland. They balance financial and environmental considerations in decision-making, but their farming activities always need to be financially viable.

The three interviewees who had abandoned the cultivation of PECs were asked if they would replant in the future. On reflection they all said that they would consider growing the crops again if the price was right and they were happy with the contract terms. This reaction to replanting was typical of early growers:

> "If the price was right I would look at it, but I would have to see some kind of guarantees behind the contracts. I firmly believe that the contract should come directly from the end user rather than a third party." AF2.

Ultimately, the decision on what to plant is financial: if the contract on offer is attractive enough compared with other land uses, some farmers will consider PECs*: "there is bound to be a price where it gets people looking at it again … Yes it's always down to price." former PEC grower AF1*.

3.1.3. Agricultural policies discouraged PEC planting

Not only were no grants for PECs available at the time of interviews, but most farmers were discouraged from planting them by agricultural policies. Without grants, the upfront cost of planting, and the lack of income for three or four years were big barriers to planting miscanthus and willow for the farmers interviewed. Farming was heavily subsidised throughout the EU, including the UK at the time of the research, and in 2018 Common Agricultural Policy (CAP) subsidies made up 50–80 % of UK farmer's income [129]. To qualify for full Basic Payment Scheme (BPS) payments farms had to have a minimum number of approved crops in their rotation [130], but permanent crops including willow and miscanthus did not qualify [131]. Miscanthus was approved in 2018 [132] and this restriction was removed in 2021 [133]. While growing PECs resulted in reduced farm payments, growing annual energy crops and grass leys did not, and this penalty discouraged planting.

Energy crops were excluded from agri-environmental schemes, although some farmers felt that the PECs were better for biodiversity than some of the included crops. Willow, undisturbed for three years, was considered by willow and miscanthus grower *AF5* to be a suitable habitat for birds, mammals, and insects, which improves water quality, reduces soil erosion and run off, and improves biodiversity, while miscanthus is a good habitat for songbirds and ground-nesting birds. Lobbying the Government to support PECS was unsuccessful and farmers thought that environmental charities had too much influence. For example, PEC grower *AF5* highlighted the damaging impact of press coverage of bioenergy, particularly the impact of the RSPB report on wood burning [134] which was critical of the carbon debt, lifecycle emissions and damage to wildlife resulting from combustion of the imported woodfuel that would be needed to meet demand.

3.1.4. Negative attitudes to energy crops persist

Among some farmers the perception persists that energy crops are "*a waste of good farmland*", (Poultry farmer and tree planter *PF)*. Even those who were open to innovation had some negative perceptions of energy crops. Farmers such as current miscanthus grower *AF4* had faced scepticism:

> "A lot of people questioned it but my decision was based on the quality of the land that we had and the output I knew that we could get from it.".

Farmers are aware of the problems that had been experienced by energy crop growers and this has fuelled their scepticism e.g. *AF2* took over land planted with miscanthus but admitted that:

> "I didn't really do any figures on the miscanthus, to be fair. We are arable farmers so it was always going to come out and be put back into arable crop rotation."

Planting willow was viewed as a bigger change to normal farm practices than planting miscanthus, and a longer-term commitment:

> *"While miscanthus is a very tall energy crop, it is, in essence a grass, and can be removed relatively easily within a cropping year. … Whereas willow is a lot more difficult and it is a different mindset: growing a field of trees compared to a grass."* (Land manager *LM1)*.

The fear that willow roots would damage farm drains was widespread and prevented miscanthus grower *AF*3 from planting willow.

3.1.5. Brexit was delaying decision-making on woodland creation

Although Brexit (the exit of the UK from the EU) was not included in the initial interview script, it was clear from the first interview that this it was a concern, and it was covered in subsequent interviews. The interviews were held from October 2018 to January 2019 after the UK had voted to leave but before the terms had been agreed. Some of the interviewees feared that the UK would leave without a trade deal, leading to falling incomes if tariffs were introduced on exports, and increased machinery costs as the Pound weakened. Most farmers interviewed were generally in favour of Brexit because it would allow reform of agricultural subsidies, putting greater emphasis on delivering environmental benefits. Farmers were delaying making major decisions, including entering environmental schemes and, planting trees until they knew whether incentives would be better:

> "Our future money from the Government will be environmentally based, so it seemed crazy to be planting when potentially there could be benefits from holding back a year or two." (early PEC grower and tree planter AF1).

Thus, uncertainty over Brexit was reducing the activities that the Government hoped to promote in the future. Since leaving the EU, the UK Government has maintained the payments previously made under the CAP but is phasing them out, and implementing the new Environmental Land Management (ELM) scheme in England, which rewards the delivery of "pubic goods" such as clean water and mitigation of, and adaptation to, climate changes [135]. Scotland, Wales and Northern Ireland will all implement their own environmental policies.

3.1.6. Attitudes to planting trees vary significantly between types of landowner

The landowners had a wide range of priorities. Farmers and small landowners planted on a small scale, up to about 5 ha at a time. There was little interest in larger-scale plantings, but some farmers had made a series of small plantings or were interested in adding to existing woodland areas. They aimed to improve the appearance of their farm, to diversify farm activities, and to provide cover for shooting, woodfuel, shelter belts, wildlife habitats, family recreational space, and future income. Some farmers were motivated by the threat of tree diseases such as ash dieback (Hymenoscyphus fraxineus). One arable farmer *(AF5)* wanted to plant a wider range of species to reduce susceptibility to disease and to improve biodiversity.

The forestry industry representative *(FTREP)* thought that many farmers were discouraged from planting by the permanence of the land use change as "*Once you have planted it with trees it's stuck in trees."* because a felling licence with no requirement to replant is "*pretty difficult to get hold of*".

Although grants are available to cover planting costs and some maintenance, farmers lose their farm subsidies and any annual income from arable or livestock farming when they plant trees and must wait for at least 15–20 years before any income can be generated. Most farmers and landowners were aware of the risk that planting trees could immediately reduce the value of land, but for small plantings they were generally interested in long term benefits to the farm, minimised losses by planting on less productive or flood-prone land, and did not think they had reduced the value of their farms. Even planting on good arable land has not affected the land value for a farmer who had made several plantings (*AF6)*. *Woodland advisor WCR* described an optimum level of tree cover that would enhance the value and appearance of a farm, but above this "*sweet spot*" at about 7 % by area, the value of a farm would begin to fall. Investing in woodland was always a long-term project, and any loss in value was viewed as a short-term problem and "*you have a high value timber crop in twenty to thirty years." (estate owner EO3)*. The forestry industry representative (*FTREP*) observed that recent rise in timber and woodfuel prices means that trees are a valuable long-term investment that can be cashed-in when required, and this future income will be reflected in the land value.

Although woodland planting is often promoted for low-grade upland farmland, the woodland charity advisor (*WCA)* thought that arable farmers may benefit more from tree planting than upland farmers. They would experience increased arable yields from sheltering and farm warming, and the trees would produce more woodfuel than those planted in exposed areas. This was borne out by the experience of a hill farmer (*HF*) who planted on an elevated, exposed site, and was less satisfied with his planting than the lowland farmers. After twelve years he had poor tree establishment and had "*lost money in what I would have got in farm payments."*

However, most farmers *have* been pleased with their tree planting, both aesthetically and financially. The comment by an arable farmer (AF6) that, by planting trees "*we have made the farm a nicer place to live and work",* was typical. When farmers plant small areas of trees the projects do not always need to be economically beneficial. They were often happy to forgo income in return for improving the look and biodiversity of their farms and did not view it as a commercial activity.

Farmers with biomass boilers, who use their own wood to heat their buildings, and claim the Renewable Heat Incentive (RHI) [136], made significant savings, e.g. one saved £6–7000 per year on fuel *and* received £12,000 RHI.

The estate owners interviewed had considerable commercial forestry activities: having 500 ha, 300 ha and 400 ha of managed woodland making up 25 %, 29 % and 11 % respectively of their land. Those with higher proportions of planting felt that they had enough land allocated to trees, whereas Estate owner *EO2*, with 11 % woodland, was interested in planting more and planned to:

"… dot the wildlife areas around the farm in the less productive bits while doing the high output farming alongside that."

Estate owners strike a balance between commercial forestry, which ties up capital for the long term, and enterprises generating annual income such as agriculture, events and visitor attractions. For the estate owners, forestry is a core business.

Charities, utility companies and local authorities own significant areas of land, and have diverse priorities, and hence different attitudes to woodland planting. The historic charity employee *(CLO)* was interested primarily in historic landscapes, restoration of ancient woodland and public access, with no interest at that time in new planting. They were unlikely to plant trees on land that had not been forested in recent centuries and were not influenced by grants although they would take any available. Since the interviews took place the charity's attitude has changed significantly and it now plans to create new woodland. The environmental charity whose advisor and researcher were interviewed (*WCA and WCR*) prioritised the preservation of existing habitats and mixed native broadleaved tree planting over timber production or carbon sequestration. The utility landowner (*ULO*) prioritised water quality and public access, factors regulated by OFWAT (the economic regulator of the water sector in England and Wales), but managed woodland and generated income from extracted wood. The local authority foresters prioritised recreation, public access and urban trees. Although urban trees are expensive to plant and maintain, and finding suitable land is difficult, their value to communities is enormous: providing cooling, improving air quality, and enhancing quality of life.

3.1.7. Tenants are less likely than farm owners to plant trees

The interviewees with tenants (historic charity, utility and estate owners), were open to discussing tree planting with their tenants who are eligible for grants and stewardship schemes, but tenants have different priorities from farm owners, and aim to make best use of all the land that they rent. They may be less likely to create planting schemes that tie up capital for 30 plus years, to take land out of agricultural production, or to invest in the aesthetics of a farm:

"Let land is worked harder … because you are paying for every acre. Whereas if you own it and you have got a bit of rubbishy land, well bigger picture you can put some trees on it and look at the long-term picture. Whereas if you are tenanted, it is year on year trying to make every penny you can off every acre you have" (estate owner EO2).

Tenants may also be less likely to change their farming activities, e.g. the utility landowner (*ULO)* thought his tenants would be uncomfortable with incentives to grow trees and would continue livestock farming *"because that's what they know."* Mixed farmer *MF1* was unable to plant trees when he was a tenant, but after buying the farm, his family planted 10 ha of woodland for shooting cover and to encourage wildlife.

3.1.8. Tree pests are a significant problem for woodland owners

Pests, the costs of protecting trees, and the risk to the value of timber are big problems for most woodland owners. The devastating effect that grey squirrels, deer, rabbits and voles can have on woodlands, especially broadleaves, was raised by most woodland interviewees, and for some the risk of pest damage was the main barrier to planting. Managing grey squirrel populations through shooting and trapping, and protecting newly planted trees with guards and fencing is costly. Allowing the grey squirrel population to rise can result in damage to broadleaved trees of any age, reduce their yield and change their form, making them unsuitable for timber. For example, forester (*FCF2*) explained that squirrels:

"… can ruin an oak plantation inside a season. Just eat the tops out, so you have lost it. In some ways it is quite a risky investment unless you have the money to invest on looking after them."

3.1.9. Government policy is not effective in driving tree planting in England

The Government is supporting tree planting through advice delivered by FC woodland officers and grants including agri-environmental schemes, but these were not delivering the scale of planting hoped for. Stewardship schemes were viewed as complex and onerous by many farmers. Although estates and some larger farms were still participating, smaller farms were dropping out of the schemes:

"We have assistance putting it together and I guess we have more knowledge internally than most landowners. Speaking to some of our tenant farmers, they don't have stewardship schemes because they

haven't got support to do an application. It is too complicated." (estate owner EO3).

The consensus was that more and more was expected for less money in return, and there was a fear that if a scheme failed, e.g. if trees died, then payments would be clawed back.

A few interviewees were interested in agroforestry but found that there were no grants to support it. Agroforestry, the integration of trees or shrubs with either arable crops (silvoarable) or livestock rearing (silvopasture) without reducing the area of land available for food production, can deliver ecological and economic benefits. Agroforestry planting density was too low to qualify for woodland creation grants but permanent planting resulted in the loss of BPS income [137]. Some interviewees favoured discouraging 'grant-farming' of uplands (where subsidised sheep grazing is causing flooding and soil erosion), instead proposing support in these areas for tree planting that would improve the environment, reduce flooding and increase carbon sequestration.

3.1.10. The division between forestry and farming is starting to breakdown

Many of the interviewees felt that there had traditionally been a division between the forestry and farming sectors but that this was beginning to breakdown as forestry knowledge was picked up by farmers. This was described by the forest industry representative (*FTREP)*, as a cultural split: "… *farmers perceive themselves as farmers, they don't see themselves as foresters.*". The woodland advisor (*WCA*) felt that this was perpetuated by education where a typical English agriculture course:

"didn't have any forestry components in it. If you are doing forestry there aren't any agriculture components. So we are very polarised: two separate sectors.".

The interviewees saw that this divide was narrowing, helped by recent improvements in the coverage of forestry in the farming-press, e.g. articles in Farmers Weekly on the rising value of woodfuel, and forestry companies advertising to farmers through social media and agricultural shows. The FC, Woodland Trust and forestry industry bodies are trying to make farmers more aware of the benefits of woodland, and the Government plan for delivering forestry grants through stewardship schemes was intended to breakdown the division. Forester *FOR2* had observed that farmers are becoming aware of the increase in wood prices, and this is encouraging them to consider forestry as a business, now it can be economic to thin even small woods that until recently could not cover the operational costs.

3.2. Drivers, barriers, influences and decision-making factors

The crop adoption drivers and barriers identified during thematic analysis, including those not discussed as individual themes, are summarised in Table 2. The barriers identified are consistent with existing literature on PECs discussed in section 1.1, and woodland creation in section 1.2, but from such a large number of drivers and barriers it is hard to determine those with most impact. Analysis using the five decision-making factors and the influence of the communication channels of the DOI theory was used to compare attitudes to adopting annual and perennial of energy crops, and woodland creation, to understand the importance of the different factors and provide better insight into the reasons for the barriers.

Analysis of the influence of communication channels, and the early steps in decision-making showed little variety between interviewees. Most belonged to informal networks of farmers and landowners including friends and family, with more formal networks including advisors and sales representatives. They all read farming publications such as Farmers Weekly, attended local farming shows and increasingly used social media to gather information. Some of the more innovative farmers read a wider range of farming magazines and were members of environmental groups. Most farmers became aware of PEC or woodland creation through these social networks, trusting information from peers while forming opinions. Decisions to continue or discontinue adoption of PECs were mainly based on the economic advantage of other uses for the land. Discontinuance was not an option for woodland owners.

Table 3 presents assessments of the relative advantage, compatibility, complexity, trialability, and observability for each land use, together with the *general perception*, based on the interview data.

Trialability measures how easy a practice is to adopt on a small scale or without committing a large financial investment e.g. by borrowing or leasing technology [100]. However, the important factor to the interviewees was not just the *scale* of the commitment, but the *term* of the commitment, so *term* was added to Table 3. Risk (identified by RFS [82] and Galik [138] as a key determinant of propensity to plant) was raised by many interviewees as a key factor in adoption, so was added as a factor in this analysis, as suggested by White et al. [101]. Risk will be taken here to be "the effect of uncertainty on objectives" [[139], p. 48]. The risks in growing novel crops (including trees) could include weather, pests and diseases, crop yield, fluctuations in price and demand, contract availability, land value, interest rates, subsidy levels and regulations. Risk was included in Table 3 and a very simple risk rating given to each crop based on the interview data. There is a steady increase from low-risk annual energy crops, through miscanthus then willow to woodland creation with the highest risk. It could be argued that risk, rather than being a sixth factor, is actually determined by some of the other factors such as complexity, trialability and length of commitment, which are clearly key factors in the risk to the farmer.

Other trends can also be observed in Table 3. Annual contracts for maize and grass were widely available, the crops were compatible with traditional farming activities and attitudes, were not complex, were easy to trial and observe, and were perceived overall as easy to adopt. They required the shortest term of commitment and carried the lowest risk for the farmers, so it is not surprising that these crops have been popular. Miscanthus was viewed as being similar to traditional crops in many ways, but required a fifteen-to-twenty year commitment, and carried a higher risk. Willow, with a longer commitment, higher risk and viewed as being more like trees than arable crops, was a bigger step from the norm for farmers. Even without considering availability of contracts, it is easy to see why adoption of PECs has been so much lower than AD crops.

Finally, woodland creation was at the extreme end of the spectrum. It has the longest commitment, is incompatible with current behaviour and attitudes, has the highest risk and requires the greatest change. Planting woodland is the hardest change for farmers to make, because of the shift of role from farmer to forester as well as a permanent change of land use.

These factors of relative advantage (determined largely by the contract), length of commitment, and deviation from normal practice can explain the relative popularity of the different crops and should be factors that are considered in the design of grants or incentives to encourage land use change. Other changes of land use could be analysed in this way. Short rotation forestry (SRF) is likely to be similar to traditional forestry but, with a shorter wait for income, could have a slightly lower risk. Peatland restoration or rewilding, activities alien to some farmers, could take up a similar position to woodland creation on the spectrum, especially if the changes were permanent.

3.3. Limitations of the research

It was felt that the 30 semi-structured interviews had provided sufficient range and depth of data to reach reliable conclusions. Although only twelve interviews were held to discuss energy crops, attendance at a farm walk, where discussions with current and prospective growers identified no new issues, confirmed that miscanthus research had reached saturation. Few current willow growers were interviewed: a result of the currently poor markets in Y&H. It may be worth expanding the research area, e.g. to Cumbria to include more current growers.

The interviewees were selected using purposive sampling: because of

their personal experience and their wider knowledge of their industry. They were not expected to be representative of all farmers in the region, but they were aware of the practices and attitudes within their sectors, drawing on their social networks for this information. A high a proportion of farmers were from larger family-owned farms, and it could have been desirable to interview more upland livestock farmers. Inevitably, there is a risk that enthusiastic and innovative farmers and landowners were over-represented in the research because of their experience of novel crops and practices, and their willingness to share their knowledge.

All the interviewees were asked whether their experience was influenced by their location and all felt that their experiences were similar to those of farmers throughout England. There were no regional grants or incentives, and the factors in deciding whether to plant energy crops or trees would likely be the same throughout England. The only geographical constraint was that Yorkshire is on the northern limit for growing maize, and on the southern edge of the area of the UK where commercial forestry is widely practised. Some of the interviewees had experience of biomass production for ARBRE, and Drax, that farmers in other regions will not have had, and others were more recent adopters. It was concluded by the authors that Y&H can provide insight into attitudes throughout England.

Using Rogers' Theory of DOI helped to identify the drivers of and barriers to land use change by focussing the interview questions and analysis on the key decision-making factors, the influence of communication channels, and the way in which attitudes towards the innovations developed over time. Although DOI has been used less often to study failures to adopt an innovation than for successful adoptions [104], in this study of *partial* adoption and some discontinuance it provided insight into the reasons for low uptake of both PECs and woodland creation in England.

4. Discussion

The interviews showed that there are still significant barriers discouraging English farmers and landowners from growing PECs on their land, including a lack of demand, competition from more profitable cereal crops and a lack of confidence resulting from the poor experiences of early adopters. These barriers have not been overcome since they were identified in previous studies (discussed in section 1.1). There has been no recent increase in the use of PEC biomass to supply heat and although contracts are available for planting [140] there has been no significant increase in planting. In contrast, annual crops of maize and short-term planting of grass leys to produce grass for AD are both easy, low risk practices for farmers and have been widely adopted. The success of AD crops, and their rapid acceptance as normal practice, could help to overcome the cultural reservations that farmers have about growing non-food crops, and be a step towards the acceptance of PECs.

This research found that the farmers who have abandoned PECs in the past recognise that the planting materials and machinery have improved and would consider replanting if the price and the contract terms were right. The attitudes of these innovative farmers could be important in rebuilding confidence in the crops. There are situations where PECs are already an attractive option for farmers (such as difficult to manage and remote fields), as confirmed by the current growers who were interviewed. PECs are still being planted, despite the current barriers, but to encourage planting at a larger scale, more attractive, long-term, guaranteed contracts will be needed.

There are also many barriers to woodland creation in England despite positive government and media attention, and a wide range of grants for planning, planting and maintaining woodlands, available from the Government and charities. Most of the interviewees were enthusiastic about planting trees at a small scale and valued their benefits, but the positive sentiment has not been converted into large scale planting. The financial barriers identified in previous studies (the initial cost, loss of income for at least 15 years, loss of farm payments, permanent loss of farmland, and the risk of reduced land values [93–95]), were all still deterring planting. The cost of protecting trees from pests and the risk of damage was of particular concern to the interviewees. The current grants available were failing to fully compensate for the financial risks of planting and loss of annual income, were viewed as complex, and were clawed back if establishment fails. To get more significant planting, above the 7 % "*sweet spot*" for a farm, then a different attitude is needed from farmers. Cultural, as well as financial, barriers will have to be overcome if farmers are to consider forestry as a core business rather than an environmental enhancement or a luxury. The cultural division between farming and forestry, and in particular the entrenched attitude of farmers who feel that they should produce food not trees [83,93,96], were familiar to some interviewees.

The interviews revealed a reluctance to plant trees on peri-urban land, because of the hope of securing planning permission for building, which is preventing planting in areas where it would have most public benefit. Interviewees were aware that there could be opposition from the public and environmental organisations to planting on land in national parks, Areas of Outstanding Natural Beauty (AONB) or Sites of Special Scientific Interest (SSSI), protected heath and moorland, and areas with protected bird populations. Many landowners were delaying planting until the ELM scheme is in place, in the expectation that future grants and payment for delivering public goods would be higher than current incentives. However, ELM will not be fully implemented until 2027 and this could delay planting, despite reassurances from the Government that planting before ELM will not put farmers at a disadvantage [141]. Upland farms where poor quality pasture is grazed by sheep and subsidies are needed to make farming viable, are often viewed as most suitable for tree planting. However, upland planting may not deliver the same benefits (to the farmer or to the environment) that lowland planting provides, especially if planting is limited to native broadleaved species that can fail to thrive in exposed positions: the volume of wood produced, and the CO_2 sequestered could be disappointing [93].

Few technical barriers were found to growing, managing, or harvesting PECs or trees, and much work can be contracted out to companies with both the experience and the necessary equipment. Economic barriers can be overcome with grants and contracts but, once they have been removed, social and behavioural barriers could still stand in the way of adoption: when good local contracts are available farmers may still reject them [97].

This research has identified many common factors between the barriers to adopting PECs and woodland. The land use changes that are most difficult for farmers to make are those which require most change from the norm, carry the highest financial risk and require a long term or permanent commitment. A long-term commitment to using their land for non-food crops can threaten their identity as food producers who prioritise continuity between the generations on a family farm [142]. Reducing productivity to deliver environmental public goods can be at odds with the identity of a "good farmer" and their standing in their local community [143]. However, these negative attitudes to non-food crops may not prevent planting, as farmers may adopt energy crops for financial reasons while still holding the traditional view that they should produce food not energy crops [144].

Many of the barriers to PEC and woodland adoption found by previous research are still in place, but farmers and landowners now face new challenges. They need to replace their farm subsidies with income earned from delivering public goods or other diversifications and will have to reconsider their farming strategy. Growing PECs and planting trees are two options which could replace this income and contribute to national energy security and meeting net zero targets. With the appropriate rewards this could now be the right time for wider adoption. However, there is competing demand for land for food production, habitat restoration, solar power generation and for house building. Although most farmers support environmental activities and are in favour of reducing greenhouse gas emissions, they will only change their

land use if it is financially viable and carries an acceptable level of risk.

5. Conclusions

These interviews identified many financial, regulatory, social and behavioural barriers to PEC and woodland planting, some of which have been in place since previous studies were carried out. By considering these two types of land use in the same research, and also including annual energy crops in the same study, useful insights have been gained into the decisions that farmers and landowners will have to make in the coming decades. Specifically, the importance of the degree of change from traditional farming practice, financial risk, and the term of commitment to a new type of land use were found to be the key factors in decision-making.

PECs have already suffered setbacks, from inconsistent policies and lack of government support and despite the inclusion of biomass in the CCC net zero scenarios, the future of energy crops looks uncertain. If the government wants to see large areas of PEC planting, then it must ensure that financially attractive, guaranteed, long-term contracts are on offer.

Recent levels of tree planting in England have been disappointing and the cost and permanence of woodland creation remain as barriers. The permanence of tree planting, high risk to farm incomes from permanent land use change, and the risk of pest damage may mean that landowners will not be persuaded to create woodland and may instead consider a land use with lower risk and a shorter term of commitment (as shown in Table 3), such as a PEC.

No matter how ambitious government plans are for tree planting or PEC cultivation, the decision to plant will most often be made by an individual landowner or a family, and these decision makers will ultimately determine whether the planting targets will be met. As well as the easily identified technical and financial barriers, social and behavioural barriers must not be overlooked. The change from being a farmer who produces food, to an energy-crop grower or forester may be incompatible with their identity as a farmer, particularly for a tenant. However, the easy acceptance of growing feedstocks for AD may be a significant step to overcoming reluctance to planting non-food crops.

Significant policy intervention will be needed to overcome the present barriers to land use change. Many interviewees suggested how this could be achieved, including an integrated land use policy, planting grants for PECs, government backing for PEC supply contracts, improved and simpler forestry grants, removal of the requirement to replant after felling trees, improving the public perception of biomass use, government supplied advice to farmers, and education to breakdown the divide between farming and forestry. An assessment of the potential effectiveness of these policies, and those proposed by lobby groups, could provide useful input to government policymakers.

This study focussed on Y&H, a region with a high proportion of English PEC planting [99], and as few regional influences on adoption were found, these findings should be relevant to most of England, subject to geographical constraints. Scotland, Wales and Northern Ireland have some different land policies, regulations, and practices in forestry and agriculture, but similar financial, social and behavioural factors are likely to influence decisions on land use (including adoption of PECs, woodland and restoring or rewilding land) throughout the UK. Other countries have their own social, cultural, geographical, environmental, and regulatory conditions creating specific barriers and drivers in each.

This research has identified the factors which influence English farmers and landowners making decisions on the future of their farms, and the barriers that policy makers will have to address to deliver the significant changes to land use needed to reach net zero by 2050.

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Data statement

All interview data are confidential.

Data availability

The data that has been used is confidential.

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Appendix A. Stakeholder interview questions

Introduction

Introductions, gather consent and describe topics to be covered.

Background information

Ask the interviewee to describe their role as landowner, farmer, farm manager, estate manager, consultant, sales rep, government employee or combination of roles.

Personal details

Age or age range if they prefer: under 35, 35–44, 45–54, 55–64, 65 and over.
Highest level of Education.
Subject of degree/diploma *
(* specifically whether the interviewee studied for a degree in an environmentally focussed subject or Agricultural/forestry)

Did this course include renewable energy (or forestry for agriculture degrees)?
Are you or your company members of any organisations which promote environmental activities/awareness or countryside stewardship?
Are you involved with any trade organisations or network?
Do you subscribe to any papers or journals?
Do you use consultants, advisors etc.?

Is the environment important to you and your organisation and is this an important factor in your business decisions?
For family businesses - is succession planning important to you?

For farmers, and landowners and land managers

Please provide details of.

- Farm type: Cereals, general cropping, horticulture, speciality pigs, poultry, grazing livestock (least favoured area?), grazing livestock (lowland), Dairy, mixed other (using the robust classification of farms). For arable, capture details of crops grown and rotation.
- If mixed or other, please provide brief details
- Farm or estate size in Ha.
- Farm size in SLR (DEFRA standard labour requirement)

What sort of land is it – agricultural land rating (1–5), existing woodland etc.?
If this is not a farm, please provide details of the operation e.g. estate, council park, …
Are you the farm owner, manager, or tenant?
Have you been involved in any farm diversification projects – are any environmental?
Have you adopted any innovative practices on your farm?
Is the farm organic, or accredited with by a livestock welfare standard?
Do you generate any renewable energy e.g. do you have:

- A wind turbine,
- A ground or air heat pump,
- solar panels (PV or thermal),
- hydro power,
- a biomass boiler – if so which type of fuel and who supplies it,
- anything else?

Incentives and grants

Do you receive any incentives – FIT, RHI etc., or have you done so in the past, or are you planning to do so in the future.

Energy crop questions. What experience do you have of Miscanthus, SRC (Willow or other) - harvesting, planting, machinery?
What experience do you have of annual energy crops (wheat, maize, beet …)?
When did you become aware of energy crops – annual and perennial as an option?
Did you have a particular reason for considering them – on farm demand for biomass, marginal land, reduction in labour requirement, environmental interest, incentive for planting energy crops …
What did you grow before that?
Before you got involved with energy crops -
What did you think of this use? Did you have any reservations?
What was the attitude of other farmers you know to energy crops?
Where did you get information about the innovation?

- Part of previous of education
- Farming press
- From other farmers
- From suppliers/salesmen
- From Consultants
- From organisations such as NFU
- Other.

Did you use a consultant or developer or contractor when planting?
Did you see energy crops being used successfully on neighbouring farms or farms elsewhere?
Were you able to trial it's use? On a small scale?
Were grants available to fund the planting at that time? Was this a significant factor in planting?
Was finance needed? Was it easy to arrange? Could this be an issue for other farmers?
Were up front costs a barrier to adopting energy crops?
Did you have to buy new equipment for planting and harvesting or was this contracted out?
Were incentives easy to apply for?
Has this innovation proved to be profitable/successful/manageable/delivered all the expected benefits?
Did you view this innovation as a **risky** activity?
How compatible was it with your other farm practices?
Was it easy to implement/install/operate?
Was any specific training needed/are staff able to operate it easily etc.?
Have you got contracts in place for the biomass? When and how were these agreed?
Have you got any opportunity for an integrated supply chain?
Do you harvest in winter? Have you considered earlier harvest for AD use?
Will you replant? If not, what will you plant instead?

Has there been any impact on drainage or land quality from growing the energy crops?
How has their experience been – as expected, better worse?
Do you think that any of the problems you face are specific to your local area, or do you think they are the same throughout the UK?
What changes to your industry do you anticipate in the future, and will these changes affect your attitudes or practices?
Any other issues that you think are relevant?
Woodland questions.
When did you first consider planting trees for fuel or changing your management of existing woodland?
Did you have a particular reason for considering planting trees or managing existing woodland:

- Wind break,
- Long term investment,
- Reduce need for labour,
- Environmental reasons,
- Demand for woodfuel?

Was there an existing heat demand?
Were there environmental reasons?
What did you use the land for before woodland?
Before you got involved with this innovation -
What did you think of this use?
Is it compatible with being a farmer? Did you have any reservations about planting/managing woodland e.g. concerns about the long-term impact on – landscape, perception of farm by others?
What was the attitude of other landowners you know to this planting?
Where did you get information about the innovation?

- Part of previous of education
- Farming press
- From other landowners
- From suppliers/salesmen
- From Consultants
- From organisations such as CLA or woodland trust
- Other?

Did you use a consultant or developer when planting?
Did you see planting/management used successfully on neighbouring land or elsewhere?
Were you able to trial it's use? On a small scale? What were the limits on size of planting?
Were/are grants available to fund the planting at that time?
Was this a significant factor in planting? Were grants easy to apply for?
Was finance needed? Was it easy to arrange? Could this be an issue for other landowners?
Were up-front costs a barrier to planting/managing woodland?
Did you have to buy new equipment for planting and harvesting or was this contracted out?
Has this innovation proved to be profitable/successful/manageable delivered all the expected benefits?
Did you view this change as a **risky** activity?
How compatible was it with your other farm practices?
Was it easy to implement/install/operate?
Was any specific training needed/are staff able to operate easily etc.
How has your experience been – as expected, better worse?
Where does the biomass go – used within organisation or sold externally? Is a contract in place?
Are there any opportunities for an integrated supply chain?
Were you concerned about the impact on land values?
Do you think that any of the problems you face are specific to your local area, or do you think they are the same throughout the UK?
What changes to your industry do you anticipate in the future, and will these changes affect your attitudes or practices?
Any other issues that you think are relevant?

Questions for forestry or energy crop consultants. What services do you provide?
What Incentives and advice are currently available to farmers/landowners?
How easy is the process of claiming grants?
What pros, cons, barriers, and drivers do you think there are for adopting perennial energy crops/woodland planting or management for woodfuel.
Are there any specific issues with the perception of woodland/energy crops?
How do you disseminate information about new technologies? Are these the most effective ways?
What could be done to improve uptake?
Has the innovation(s) fulfilled expectations?
What sort of landowners/farmers are best suited to this type of activity?
Do you think that any of the problems you face are specific to your local area, or do you think they are the same throughout the UK?
What changes to your industry do you anticipate in the future, and will these changes affect your attitudes or practices?

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