UK Centre for Ecology & Hydrology

Ammonia Reduction by Trees (ART)

Farmer's views on practicalities and farm business benefits of tree planting to capture ammonia

Jan Dick and Bill Bealey

Title	Ammonia Reduction by Trees : Farmer's views on practicalities and farm business benefits of tree planting to capture ammonia
Client	Natural England
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UKCEH contact details	Bill Bealey UKCEH, Bush Estate, Penicuik, Midlothian, EH26 0QB e: bib@ceh.ac.uk
Author	Jan Dick & Bill Bealey
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1 Executive Summary

The aim of this task is to capture farmer's views on the practicalities and farm business benefits of tree planting to capture ammonia from hen or dairy units. This task is part of a larger project to test how effective tree shelterbelts and woodlands are at capturing ammonia emissions on five poultry and dairy farms in Cumbria and to improve information provided for farmers on how to design a tree shelterbelt.

Two interviews were conducted, one before and one after the data on the effectiveness of tree shelter belts and woodlands at capturing ammonia emissions was provided to the participating farmers and an ammonia capture calculator tool and shelter belt design guidance was distributed. Representatives from five farmers participated in the first interview and four in the second interview (due to COVID).

The initial interview protocol consisted of 22 questions adapted from the ADOPT model (Adoption and Diffusion Outcome Prediction Tool). This tool was selected as it explicitly addresses the motivation of farmers, relative advantages of a new innovation (such as planting trees to capture ammonia) and the learning associated with the new innovation. Both qualitative (narrative) and quantitative (Likert scale) data was documented for each of the 22 questions. In the second interview, 16 of the original questions were asked again plus five additional questions focused on the interviewees opinion of the ammonia calculator and guidance documentation.

The farmers considered planting trees to capture ammonia more positively after they received data for their farm, discussion of the ammonia capture calculator tool and shelter belt guidance documentation. The ADOPT model was parameterised with the scores from the first and second interviews which resulted in an estimated increase of peak adoption level from 45% uptake by farmers to 85% and a reduction in time to near-peak adoption levels from 18 years to 10 years. It must be remembered that these estimates are based on a very small biased sample but does indicate that increased knowledge of the influence of trees to capture ammonia is likely to increase the practice amongst farmers. Increase incentives for example via e.g. Environmental Land Management Scheme (ELMS) options is likely to increase the adoption of this practice further.

A further larger online survey was carried out between 22nd March 2021 and 24th April 2021 based on the ADOPT questionnaire using the same 22 questions. From 149 respondents the results gave similar (often the same) ADOPT scores across the 22 questions as with the interviewees. However, some questions scored much lower represented by a higher perception of risk, lower knowledge, and lower profit advantage. As a consequence the adoption peak level was only 2% with a 15-19 year time to near peak adoption period.

Addition survey questions were asked on the benefits of planting trees on the farm and motivation behind that. Over half of all farmers said they would consider planting shelter belts for other benefits, and only ~10% of farmers stated clearly they would not consider planting tree shelter belts. Of the expected benefits from planting tree the majority (54%) suggested that environmental benefits were the main benefit. Animal welfare through ranging and sheltering were seen as the next expected benefit from treebelt planting (13%). When asked about their motivation behind future planting of trees it was clear that the main motivation would be through financial support of grants and incentives with 60% of farmers stating this.

2 Introduction

The overall aims of the Ammonia Reduction by Trees project (ART) are to:

• To test how effective tree shelterbelts and woodlands are at capturing ammonia emissions on poultry and dairy farms in Cumbria – field work on 5 farms

• To help develop options for farmers in the Environmental Land Management Scheme (ELMS) targeted to improve air quality

• To improve information for farmers on how to design a tree shelter belt

• To capturing farmers views on practicalities and farm business benefits of tree planting to capture ammonia from hen or dairy units.

This work is focused on the latter aim, which has two components:

(i) The farmers will be interviewed for their views on their motivation for tree planting and their perceptions of it in terms of farm business, animal health or environmental benefits and any issues, practicalities or problems needing to be overcome.

(ii) Farmer feedback will be gathered on the usability of the guidance and tool, suitability of the design for the farm including practicalities and any constraints that affected the selection of species and final planting plan/location.

In addition, it was hoped to determine if there was a change in farmer responses before and after (i) the results of the air quality measurements are made known to the farmers and (ii) the training provided on the UKCEH tool to aid the design of farm woodlands to capture ammonia. The desire is to provide off farm stakeholders with an understanding of the farmers views in order to aid understanding and predict how others might adopt the practice.

3 Method

Given the aims and limited resources available, an adaption of a published predictive quantitative model of adoption was utilised (Kuehne et al 2017). The ADOPT model (Adoption and Diffusion Outcome Prediction Tool) is hosted by CSIRO in Australia (https://adopt.csiro.au/). This tool was selected as it explicitly addresses the motivation of farmers, relative advantages of a new innovation, the learning associated with the new innovation and provides the opportunity to model the likely uptake of the practice of planting woodland to capture ammonia elsewhere in the UK.

The ADOPT model is based on two overarching factors influencing the adoption process: the relative advantage of the practice (in this case tree planting to capture ammonia), and the effectiveness of the process of learning about the practice (in this case understanding the efficacy of trees to capture ammonia and the planting design guidance and ammonia capture tool). Relative advantage is considered the main driver of how many in a population decide to adopt, while the learning process influences the time lag before decisions to adopt are made. A number of variables influence these overarching factors. For example, the relative advantage of a practice may depend on its riskiness and costs or its reverability, while learning may depend on the observability of the practice and farmers' access to guidance and design tools. The variables of the model can be separated into two categories: those that relate to characteristics of the target population and those that relate to characteristics of the

practice. In some cases, individual variables from the target population and the practice can be closely linked. For example, the relative advantage of a practice can depend on its environmental benefits (a characteristic of the practice) but the 'value' of that can depend on farmers' attitudes towards environmental benefits (a characteristic of the target population). Combining these two pairs of issues (relative advantage and learning; the practice and the population) provide four sets of issues which are the basis of the ADOPT model (Fig 1)

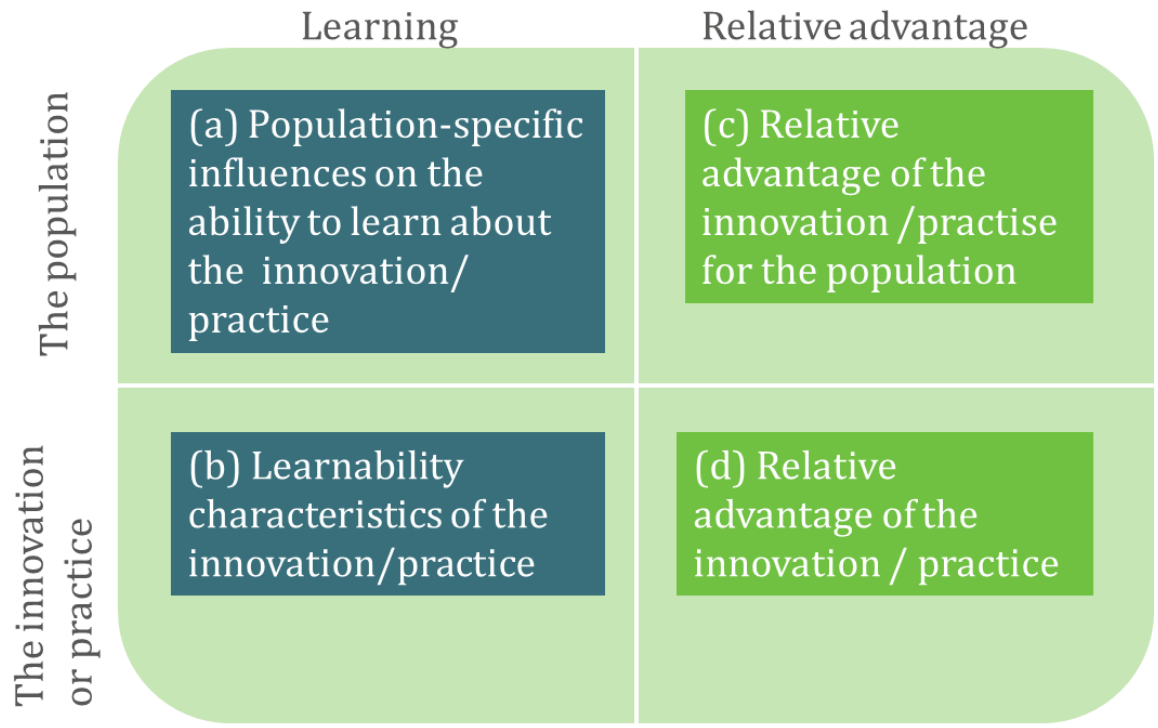

Figure 1. The basic conceptual framework of the ADOPT model highlighting the relationships between: learning, relative advantage, the population and the practice i.e. a) characteristics of the potential adopters that influence their ability to learn about the practice. b) characteristics influencing the ease and speed of learning about the practice, c) characteristics of the population influencing their perceptions of the relative advantage of the practice, and d) characteristics of the practice that influence its relative advantage.

The model aims to characterize adoption for a population of farmers, rather than an individual farmer. In this project, the questions were adapted to gain an understanding of the individuals' views and a second interview assessed if the individual farmers had changed their scores following training on the UKCEH ammonia capture tool to aid woodland design and quantification of the amount of ammonia captured if the trial woodlands on each farm.

3.1 Arranging Interviews

Initially a trusted farm advisor Paul Arkle, Cumbria Farm Environment Partnership, sent an individual email to each farmer and attached the interview protocol and Participant Information and Consent Sheet (Appendix 1). The interviews were arranged via email or telephone directly by the author with the farmer. Prior to arranging the second interview an email (Appendix2) was send by the author to all famers providing links to a video demonstrating the ammonia calculator (accessed here https://www.farmtreestoair.ceh.ac.uk/ammonia-calculator--video), and general guidance advise accessed here

(https://www.farmtreestoair.ceh.ac.uk/sites/default/guidance/index.html). In addition, a report of the data collected from each farm was included.

3.2 Interview protocol

Both interviews were focused around the 22 questions that provide the inputs to the ADOPT model (https://adopt.csiro.au/). The model input (Fig 2) is framed at the level of the population and were therefore rewritten to be relevant to an individual farmer (Table 1). The aim of the initial set of interviews was not to estimate time to near-peak adoption or peak adoption level of the UK farming population as the interviewees are a biased sample (four of the farms planted woodland as a condition of their egg contract which required woodland creation; the fifth, a dairy enterprise, obtained no such market monetary benefit from the woodland near his dairy enterprise, although the woodland planting was grant aided).

The second interview was designed to determine if the farmer's views had changed following a deeper understanding of the influence of woodland on ammonia capture on their farm. Data collected on their farmers, guidance on planting trees to enhance ammonia capture and an ammonia capture calculator was distributed prior to the interview. Sixteen of the original 22 questions were repeated and five questions included to determine their views on prioritisation of improvements for the ammonia calculator. The ADOPT was parameterised with the indicative values for the two interviews for the four farmers which participated in both interviews. The results should be consider only as an indication of the likely difference increased knowledge of an innovation may have on the likely adoption of tree planting to capture ammonia, rather than as an indication of the likely update by UK farmers.

Both qualitative and quantitative data was documented at both interviews. The farmers were asked to score each question (Table 1) and asked to provide their thoughts and reasoning for their score. In order to maintain the one hour interview guideline questions were sent ahead of the first interview, but without obligation to read.

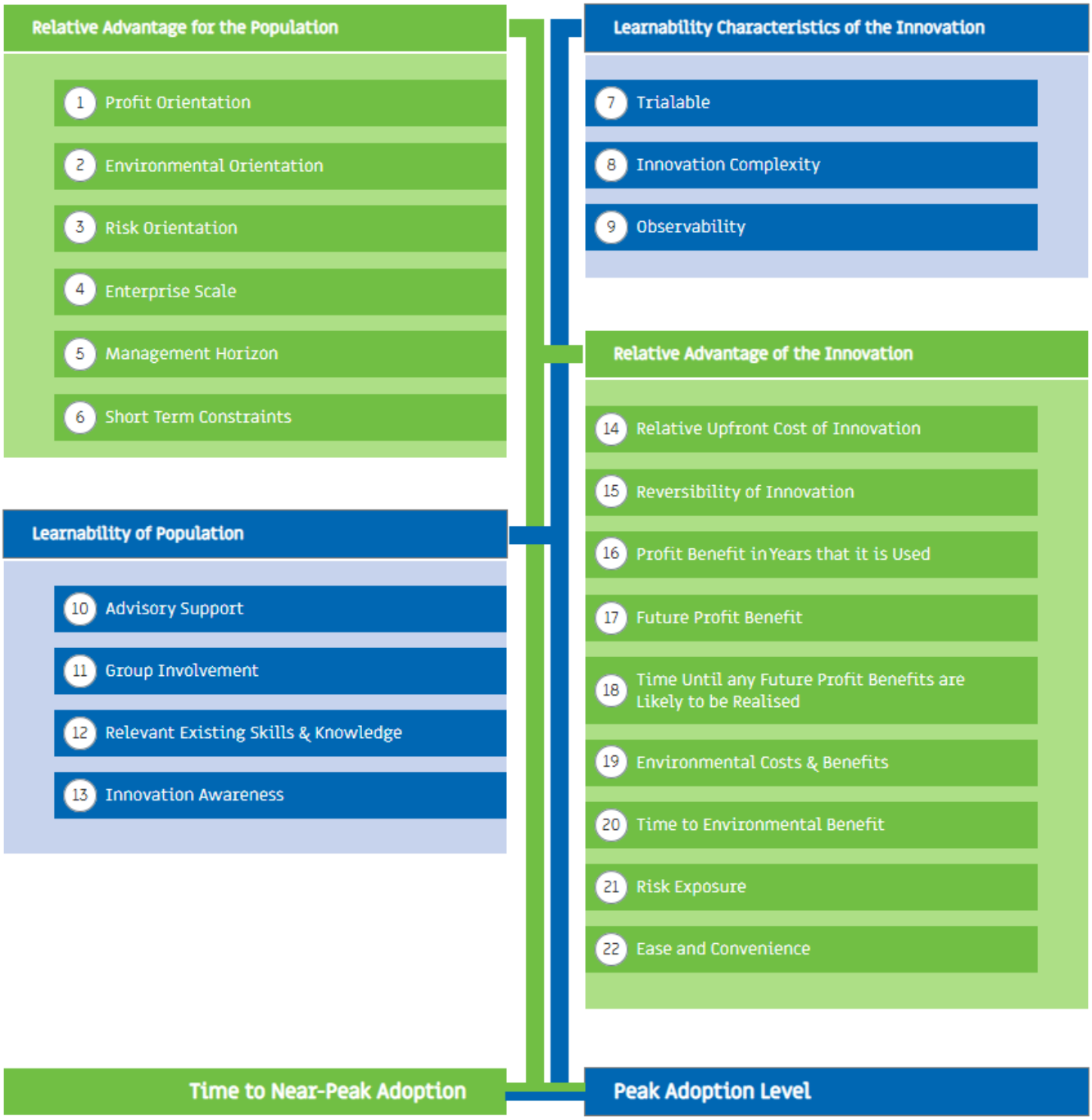

Figure 2. Schematic of the four quadrants of the Standard ADOPT model and how the questions fit into them.

The average of the numeric scores was computed and content analysis conducted on the narratives provided with each question and the free conversation at the end of the interview to identify common themes. Four themes were pre—defined: two based on the ADOPT model: (i) the relative advantage of the practice, and (ii) the effectiveness of the process of learning about the practice; and two defined by the aims of the project (iii) improving information for farmers on how to design a tree shelter belt and (iv) developing options for farmers in the Environmental Land Management Scheme (ELMS) targeted to improve air quality.

3.3 Date and duration of interviews

The first interviews took place between 2nd and 18th Nov 2020. The duration of the interview varied with answering the ADOPT questions taking between 20 and 40 min and further open discussion lasting between 5 and 30 min. The shortest interview was 25 min and the longest 55 min. In total six people were interviewed (four male, two female). Four of the farms were represented by one individual, while a mother and son answered the questions together for one farm. Representatives from four farm agreed to conduct the interview via Zoom and to be recorded and one via telephone which was not recorded rather field notes were typed directly into the excel spreadsheet along with the scores provided for each question.

The second interviews took place 3rd to 18th March 2021. One farmer, when contacted was just recovering from Covid-19 virus and although keen to take part was time limited. It was agreed that if he had time before 22nd March 2021 he would get in touch. He had not got in touch at the time of writing this report. Three of the interviews commenced with a demonstration of the ammonia calculator and brief run through of the guidance documentation (15-30 min). The fourth farmer had seen the calculator before and helped write the guidance documentation. Answering the pre-defined questions took between 25-60 min and further open discussion 10-25 min. The shortest interview was 45 min and the longest 120 min. Three interviews were conducted via zoom and recorded, the forth via telephone and field notes taken.

4 Semi-structured interview results

4.1 Farmers responses to questions

There was a wide range of scores for each question (Table 1) which reflected the different circumstances on each farm.

The scores are considered indicative of the UK farming population but biased in so far as four of the target farms already obtained additional income from their hen enterprises and had followed planting instructions of the contractor which required woodland. The scores are not considered representative of the UK population of farmers.

Table 1. Questions asked and numerical score of farmers interviewed; note question number retained as in ADOPT model (Fig 2) for easy of reference but rearranged to group questions with similar scale; five additional questions asked in second interview added as questions 23-27.

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
Relative advantage for the farmer (Scale 1-5)			**# 1**	**# 2**	**# 1**	**# 2**	**# 1**	**# 2**	**# 1**	**# 2**	**# 1**	**# 2**		
1	Profit orientation	How important is maximising profit a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	4		3		3		4		3		3.4	
2	Environmental orientation	How important is protection of the environment a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	2	5	5	5	2	4	5	3	2		3.2	4.3
3	Risk orientation	How strong is risk minimisation a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	3	3	4	5	1	5	4	3.5	5		3.4	4.1
4	Enterprise scale	If tree planting found to be beneficial would it benefit a major enterprise on your farm (1= very small enterprise 5 = major enterprise)	4		5		1		2		5		3.4	
5	Management horizon	Do you have a long-term management horizon (1= no i.e. less than 1 year, 5= yes i.e. more than 50 years)	5		5		5		2		3		4	
6	Short-term constraints	Do you have a severe short-term financial constraint that may influence	5		5		5		2		5		4.4	

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
		you planting trees on your farm (1= yes, 5 = not an issue)												
Learnability characteristics of the practice (Scale 1-5)														
7	Trialing ease	Do you think it would be possible to have a trail before fully committing to incorporating tree planting to capture ammonia for your hen or dairy enterprise (1=not trialable 5=Very easily trialable)	2	4	4	4	3	4	2	2	1		2.4	3.5
8	Practice complexity	Do you think it will be easy to evaluate the effects of tree planting on ammonia capture from your hen/dairy enterprise due to complexity of understanding the practice (which tree species to plant, the planting design etc.) (1= very difficult, 5= not at all difficult, easy, not complex)	3	4	1	4	4	5	2	4.5	4		2.8	4.4
9	Observability	Do you think the benefits of the woodland planting will be easily observed (1= Not observable at all, 5= Very easily observable)	4	5	1	2	4	4	1	3.75	5		3	3.7
Specific influences on the ability to learn about the practice **(Scale 1-5)**														
10	Advisory support	How much do you rely on farm advisors (1= Almost never use a farm advisor 5 = often use an advisor)	1		2		1		5		4		2.6	

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
11	Group involvement	Are you involved in any groups that discuss farming (1=no only my mates , 5= yes several industry groups and/or associations that discuss aspects of farming that interest me)	1		5		2		1		4		2.6	
12	Relevant existing skills & knowledge	How would you rate your knowledge about how to design planting trees to capture ammonia (1- currently have no skill or knowledge 5= I do not need any new skills or knowledge to design effect tree planting to capture ammonia)	1	4	4	4	2	4	1	4	3		2.2	4.0
13	Practice awareness	How common is tree planting to capture ammonia in your district (1= tree planting to capture ammonia never used or trailed in my district 5= common I am fully aware of the practice/trail in my district)	1	5	2	3	2	3	2	4	2		1.8	3.8
Relative advantage of the practice (Scale 1-5)														
14	Relative upfront cost practice	How large an investment would you judge designing and planting trees to capture ammonia would be on your farm (1= large investment 5=no initial investment required)	4	3	2	4	3	3	1	1	4		2.8	2.8
15	Reversibility practice	How reversible would you judge planting trees on the farm to capture ammonia from your chick or dairy enterprise (1= not reversible at all 5= very easily reversed)	3	4	2	3	3	4	2	2	1		2.2	3.3

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
18	Time for future profit benefits to be realized	How soon do you think the profit benefits would be realized (1= 1 year, 2=2 years 3= 4 years, 4= 8 years 5= 16 years or more)	1	4	2	4	1	5	5	5	1		2	4.5
20	Time for environmental impacts to be realized	When do you expect the environmental impacts would be realized (1= 1 year, 2=2 years 3= 4 years, 4= 8 years 5= 16 years or more)	3	4	3	4	4	3	1	1	4		3	3.0
		Note scale -3- to +4												
16	Profit benefit in years that it is used	How large a profit disadvantage do you consider planting trees to capture ammonia would be on your farm (-3= large profit disadvantage in years that it is used +4 = Very large profit advantage in years that it is used	0	3	4	4	3	2	-2	-3	4		1.8	1.5
17	Profit benefit in future	How large a profit disadvantage do you consider planting trees to capture ammonia would be on your farm in the future (-3= large profit disadvantage in years that it is used , +4=Very large profit advantage in years that it is used (+ 4)	-1	1	4	4	3	4	-2	-3	4		1.6	1.5
19	Environmental impact	How large an environmental disadvantage do you view planting trees to capture ammonia (-3= Large environmental disadvantage, +4= Very large environmental advantage	3	4	4	4	4	4	4	3	4		3.8	3.8

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
21	Risk	How large an increase in risk do you consider planting trees to capture ammonia (-3= Large increase in risk , +4=Very large reduction in risk	3	4	4	4	4	4	4	3	0		3	3.8
22	Ease and convenience	How large a decrease in ease and convenience in your work is associated with tree planting to capture ammonia (-3= Large decrease in ease and convenience , +4= Very large increase in ease and convenience (+ 4)	-2	2	0	2	0	0	1	-2	-3		-0.8	0.5
Ammonia calculator and guidance document (Scale 1-5)														
23	Ammonia Calculator	In the current version of the Ammonia Calculator tool the user can only select one main tree species to plant. The development of multi-species treebelts would be worthwhile? 1= strongly disagree 5= strongly agree		5		5		5		4				4.8
24	Ammonia Calculator	The current Ammonia Calculator tool has a limit on the width of a main canopy treebelt of 50m. Adding more options for deeper treebelts would be worthwhile? 1= strongly disagree 5= strongly agree		5		5		2		4				4.0

Q #	**ADOPT Variable**	**Question**	Farmers Score Interview #1 & #2										Mean Interview 1 (n=5)	Mean Interview 2 (n=4)
25	Ammonia Calculator	There is no cost element in the current version of the Ammonia Calculator tool to estimate the cost of establishing and maintaining a treebelt (young trees, guards, fencing if required, labour). Adding an estimated cost of establishing and maintaining a tree belt would be worthwhile. 1= strongly disagree 5= strongly agree		5		3		5		5				4.5
26	Ammonia Calculator	Estimation of carbon capture at different stages of the treebelt growth would be worthwhile 1= strongly disagree 5= strongly agree		5		4		3		5				4.3
27	Guidance Document	The guidance document was helpful 1= strongly disagree 5= strongly agree		5		4		4		5				4.5

The average scores recorded for the five farmers taking part in the first interview are presented graphically in Fig 3-6.

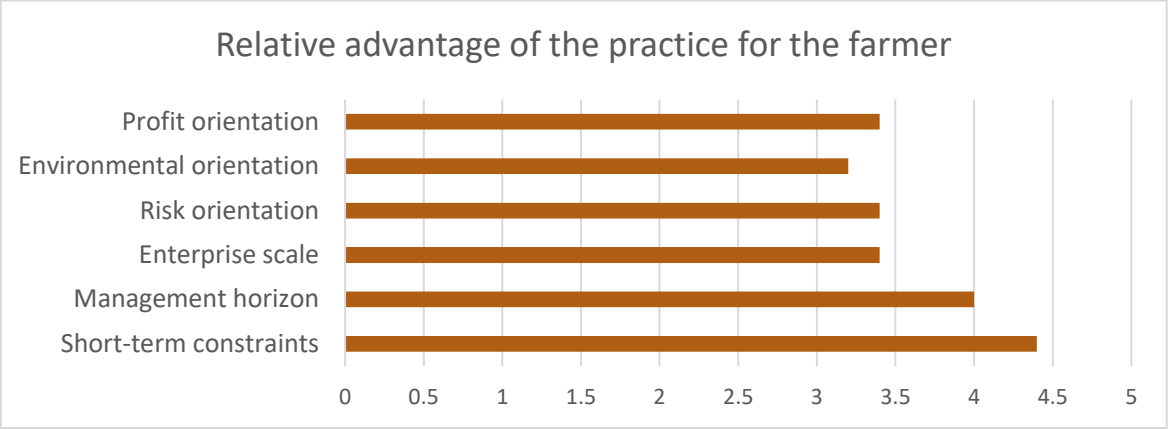

Figure 3. Mean score (n=5) for questions in ADOPT model answered in interview 1 focused on the relative advantage for the farmer (see Table 1 for full question and scale definition)

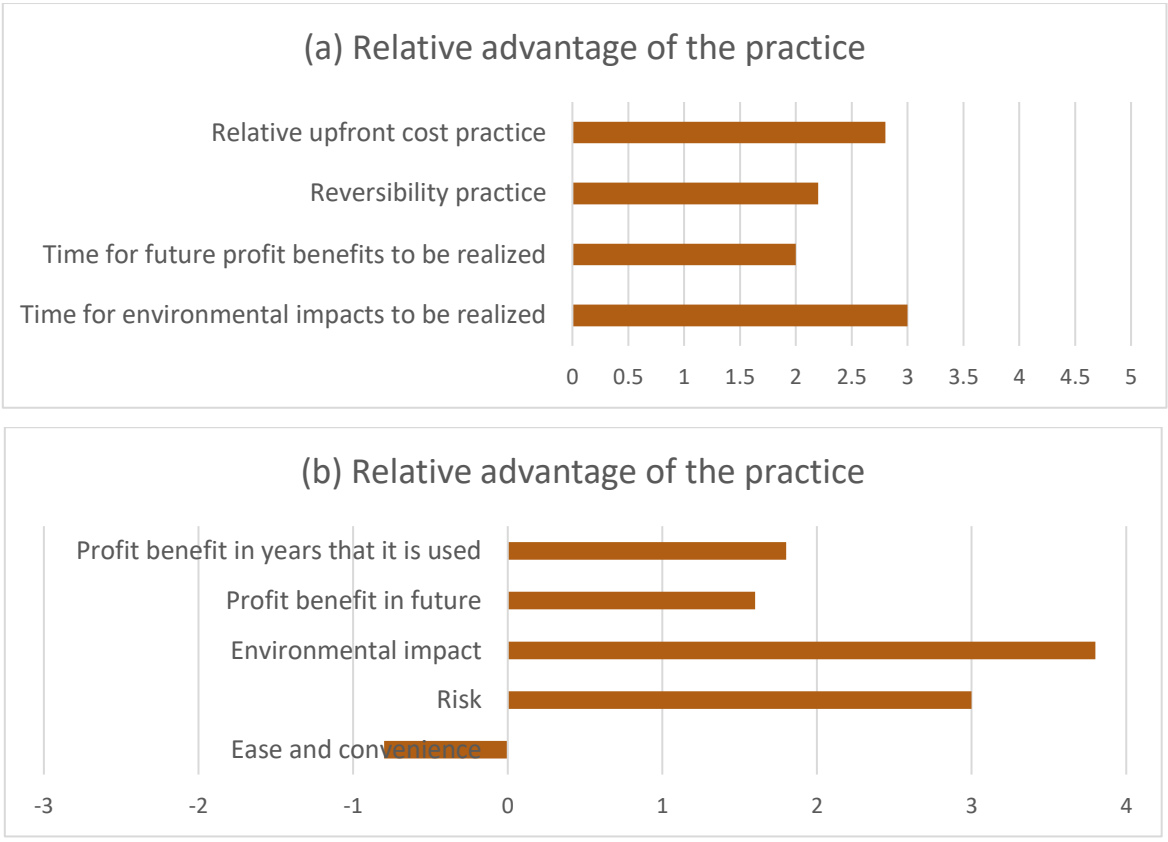

Figure 4. Mean score (n=5) for questions in ADOPT model answered in interview 1 focused on the relative advantage of the practice (a) with scale of 1-5 and (b) scale -3 to +4; see Table 1 for full question and scale definition.

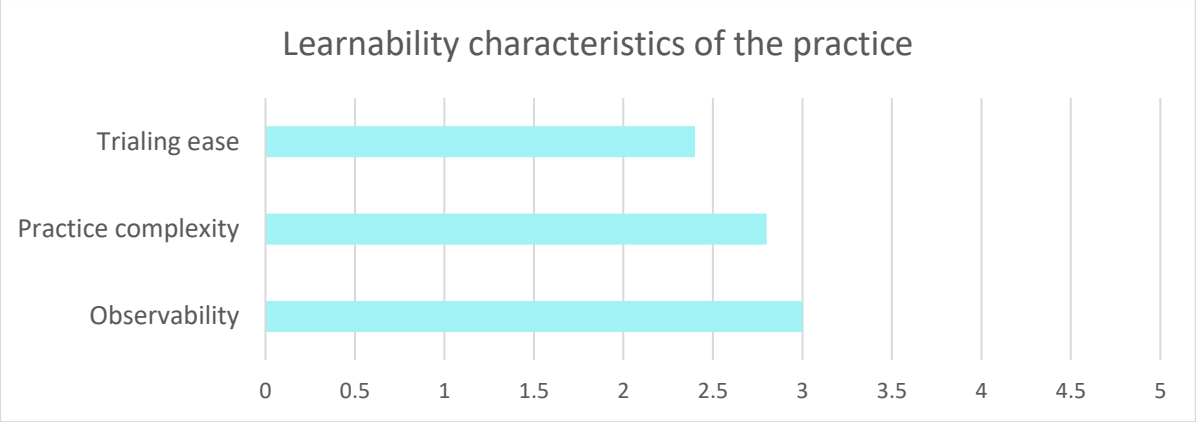

Figure 5. Mean score (n=5) for questions in ADOPT model answered in interview 1 focused on the learnability characteristics of the practice (see Table 1 for full question and scale definition).

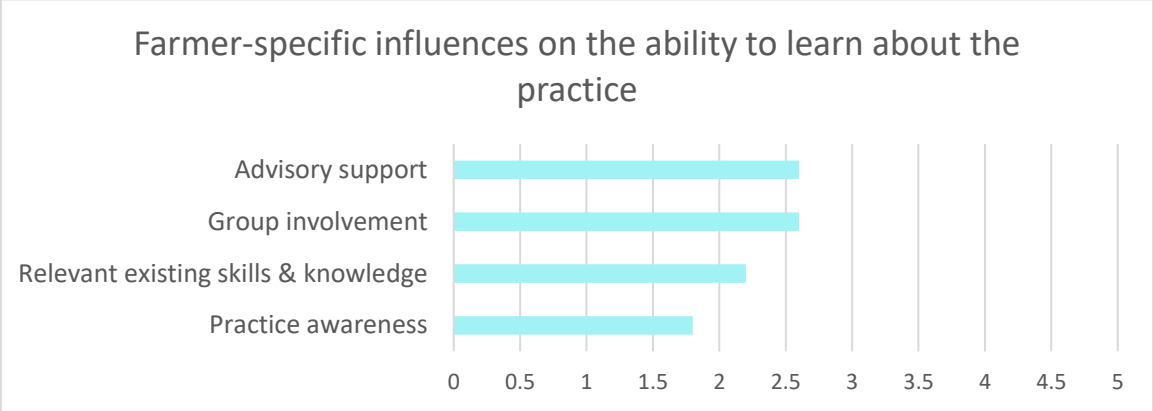

Figure 6. Mean score (n=5) for questions in ADOPT model answered in interview 1 focused on farmer-specific influences on the ability to learn about the practice (see Table 1 for full question and scale definition).

A summary of the narrative responses for each of the 22 questions answered in interview 1 are reported in Table 2. The response from each farmer is presented as associated either with a high score to the question (scale 3-5 and 1-4) or a low score. The order of the responses is random in order to maintain anonymity of the farmers.

Table 2. Summary of narrative responses to each of the 22 questions (see Table 1) of the ADOPT model (Kuehne et al 2017).

Q#	**ADOPT Variable**	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
1	Profit orientation	• Increases production • I would say that having a tree cover encourages birds to leave the shed and roam much more outside and that reduces the pressure on the building… they've got plenty of rewards and activities …they probably will stay healthy and that is the key driver of profitability.	• Not a profit from the wood, but I do get paid for having the trees for cover for the hens • Not a massive driver • Didn't have a choice in this occasion because of the contract
2	Environmental orientation	• Wasn't initially but is now with Clean Air Act etc. • Environmental consideration a strong motivation for us	• Wildlife increased massively but can be negative attracting e.g. stoat but contact requires trees so wasn't a strong motivation • Already quite a wooded area • I would score 2 when I planted but now 4 because of carbon capture
3	Risk orientation	• Economic risk of not planting due to egg contact • It make us stronger • There wouldn't have been a contract • hope ...guess trees do capture ammonia … but need the research – planted because we need diversity on farm	• never even crossed my mind
4	Enterprise scale	• 80% of income • a major enterprise • it is our major enterprise	• it's not a massive proportion of our business • could not give up too much land to trees

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
5	Management horizon	• Maybe not the next 50 years but … probably be the next 20 years • As soon as you start being keen on planting trees looking minimum 50 more like 150 years • I like to look to the future. • looking at about a 20 year	• limited as will retire
6	Short-term constraints	• Not an issue that we can afford to plant trees • Not an issue • Not an issue • Not an issue	• yes a bit
Learnability characteristics of the practice		• **High Score (5-3)**	• **Low Score(2-1)**
7	Trialing ease	• It depends on number of chicken sheds…you're going to have to jump in with both feet • Could be possible	• So it depends on the scale. 10 trees or 1000. • Well yeah trees or a long term thing… In my view, you can't really try trees, can you? • not very easy to trail
8	Practice complexity	• I know where I would want the trees… You've got to think were you going to plant them for the welfare of the animals • The process of planting per se isn't particularly difficult but then I think there would need to be more understanding on or information available in terms of which trees benefit or help to capture ammonia over others	• That's why we're doing this research …more you understand about it the more you realize how little we know • if only considering ammonia there is a trade-off … need all acres for grass ..

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
		• If you wanted to just go down that route of planting trees to capture ammonia. You'd have to do some research.	
9	Observability	• See a lot of environmental and health and welfare benefits for the birds • Yeah, it'd be easy for people to observe trees • Benefit to the hens. … and I like looking at them as well	• [considering] only efficient ammonia capture its not observable at all • science yet to prove they capture ammonia
Specific influences on the ability to learn about the practice		• **High Score (5-3)**	• **Low Score(2-1)**
10	Advisory support	• I use them a bit • yes - every 4 weeks	• we've got enough people trained outside of agriculture to offer valid input • we know what we are talking about with trees • no never use them … just read the farming comics
11	Group involvement	• work very close with a lot of various different agencies within the UK • Yeah, a few	• I would very much like there to be more group discussions but worthwhile group discussions, not just talk shops • I am not in a group as but I sell my milk to a company, they often have meetings, which we talk about various things • only NFU … Lack of time

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
12	Relevant existing skills & knowledge	• Well I would have my ideas but I would discuss with a farm advisor	• in terms of specifically for capturing ammonia • Almost none because this is completely new to us • Little skill.. I'll just be guessing about what type of trees, Do you plant them up wind or down wind of the farm - I wouldn't really know • we know how to plant a tree; I would guess for ammonia capture we should plant down wind at this farm but would not know how deep/wide the tree belt should be or how many trees etc
13	Practice awareness		• nothing in this area that I know of regarding tree capturing ammonia • not in our local area • as far as I know its not done in my area • there has been a lot of trees planted but not to capture ammonia • tree planting not done for not dairy enterprises that I know off
Relative advantage of the practice		**High Score (5-3)**	**Low Score(2-1)**
14	Relative upfront cost practice	• again it depends on scale… if you buy trees from a nursery. It's actually quite expensive.. it's probably 4 …take account of the business figures as a whole • Yeah it is going to take money to plant them • The tree were peanuts compared with building the sheds	• its a significant investment … but they actually pay for themselves in the first year, one of the best returns on a farm • large investment because plant trees means giving up land

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
15	Reversibility practice	• you could it would be disheartening • it wouldn't be very easy	• you would have to grubb out all the roots but its doable • I wouldn't like to dig out trees . .. trying to put it back to grass • not really reversible because trees longlived and have roots
18	Time for future profit benefits to be realized	• no profit advantages for capture ammonia so would say 5 but really none .. If planting for timber it would be over 16yrs	• as soon as we plant a tree we get paid 2 yrs science shows that • with me because of the hens it was year one • In the first year...we got that the bonus immediately
20	Time for environmental impacts to be realized	• it was five years before the trees actually grew to any height or any kind of canopy for the wildlife • you start to see it after probably four years • Between 5 and 8 say 8 years • I was going to choose five years but if there isnt a five option We can go to eight years.	• soon as trees planted … they grown every year … but not specifically for ammonia capture
		• **High Score (1-4)**	• **Low score (-3 to 0)**
16	Profit benefit in years that it is used	• no profit advantages for capture ammonia so would say 5 but really none .. If planting for timber it would be over 16yrs	• Well, this entirely depends on what happens with the agricultural policy after December • no evidence of advantages to capture ammonia only environmental advantage generally

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
17	Profit benefit in future	• It's a big benefit to production…it's a scientific fact • well because of the hens they are fairly profitable • if took away egg contact it would be quite a disadvantage unless we are penalised for producing ammonia on farm but for my business it would be a plus 4	• Whoever we supply eggs to would have to pay us a lot more money going forward to, take the land out to production of plant more trees • depends on grants may become profitable if environment prioritised …depends on penalties for ammonia … would currently be a cost … loose land … so negative
19	Environmental impact	• There's been a massive advantage, environmental advantage for planting those trees, it would only be a 4 if we had the data from ammonia capture to say, the trees capture all of the ammonia coming out of the shed. another aspect of the visual impacts that we've seen • [you are] speaking to the converted • useful for the environment • There's no environmental disadvantage • large environmental benefit generally	•
21	Risk	• because we would not have got the contact • Risk Reduction as Clean Air Act coming in very shortly • If I don't plant trees I risk not selling my milk and the hens • Yes I think trees make the farm more resilient ...more robust	• Yeah, it didn't reduce any risk because there wasn't the risk in the first place.

Q#	ADOPT Variable	Narrative responses	
Relative advantage for the population		**High Score (5-3)**	**Low Score(2-1)**
22	Ease and convenience	• trees don't really reduce work … may add work ... but whole ecosystem approach important … farmers interested to protect environment as this protects the farm	• Let's go for zero • yes extra work …but it is work that is benefiting me -its worth the effort • There's quite a lot of work involved in maintaining the trees • there has been a lot of work in tending to the trees and managing the trees…Also fencing for roe deer

The difference in the mean score for repeat questions asked in the second set of interviews are presented graphically in Figure 7 (n=4 for interview 1 and 2).

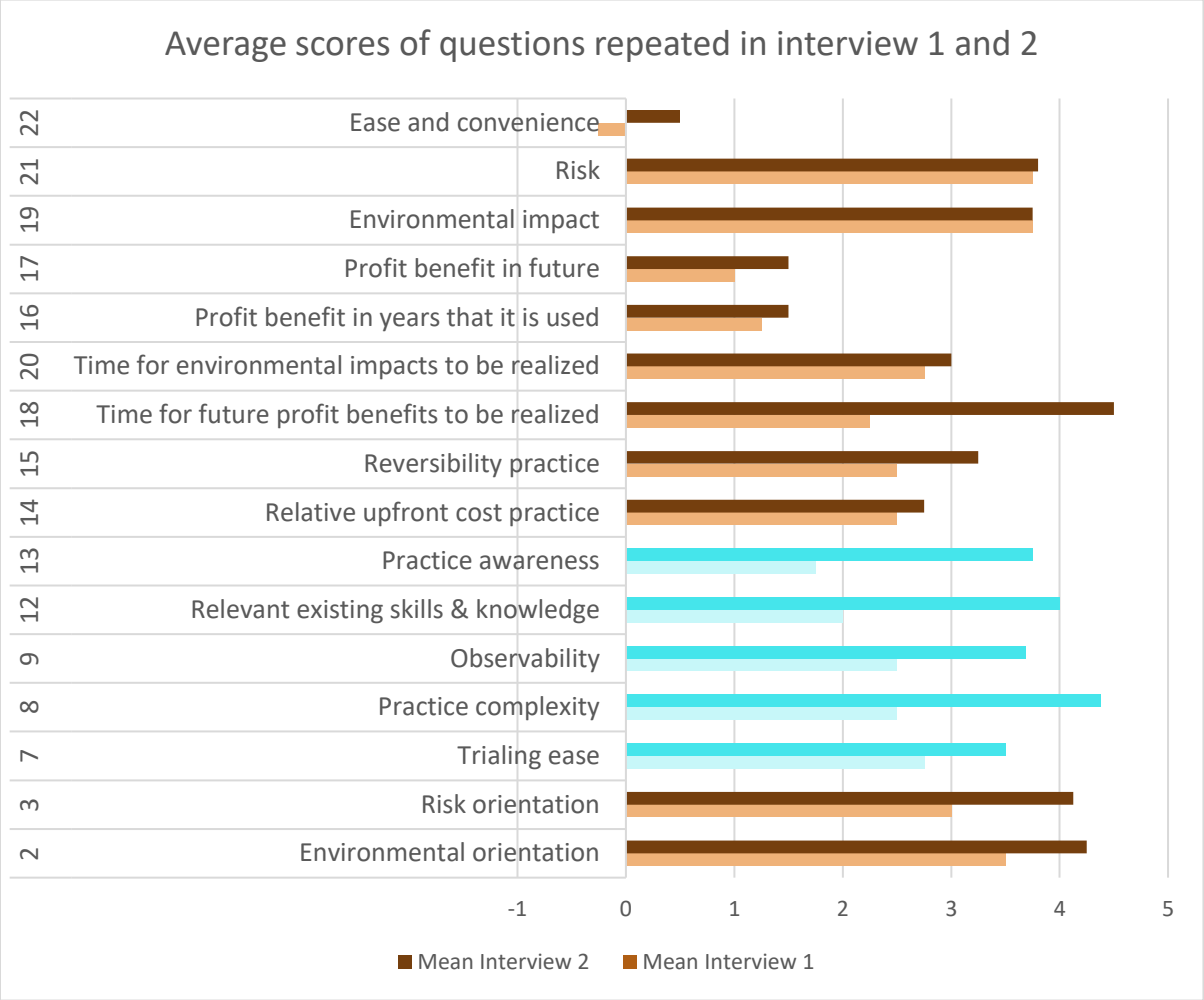

Figure 7 Mean score (n=4) for repeat question in interview 1 and 2 (see Table 1 for full question and scale definition). Darker colour indicates results from second interview; green indicated the question related to the relative advantage of the practice and blue the learning characteristics.

The average scores for all repeat questions was higher or very similar in the second interview (Fig 7) after the farmers had access to data detailing the capture of ammonia on their farm, the ammonia calculator and the guidance document.

In addition, to the sixteen questions which were a repeat from the first interview, farmers were asked four questions related to their opinion of suggested improvements to the calculator and one related to the guidance document (Table 1 and Fig 8). All farmers interviewed agreed or strongly agreed that the guidance document was helpful (average score 4.5). One farmer expressed disappointment that all the pictures were of hen enterprises rather than a mix of hen and dairy and another commented that they appreciated being-led through the document, which raised the possibility of a video presentation of the main points being easier than reading alone. Another farmer commented that a clearer list of principles would be helpful *Its a long document ...An absolute checklist of things to do would be easier than having to run through all of the text.*

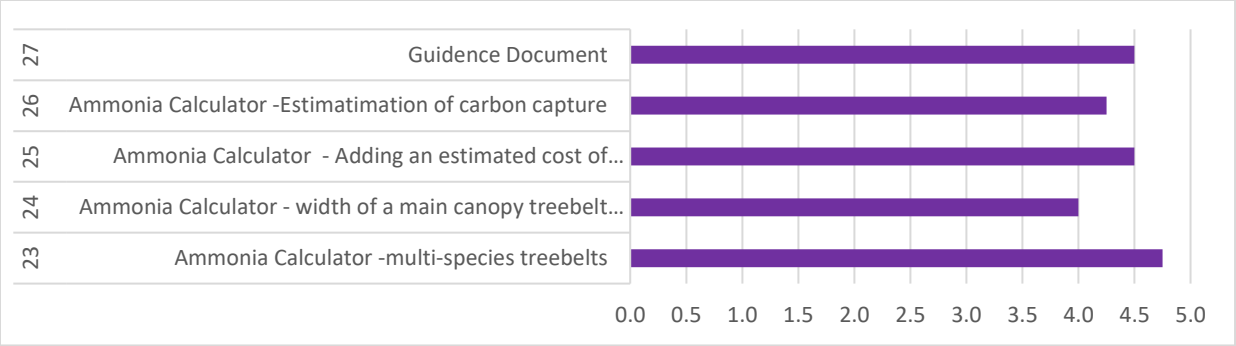

Figure 8 Interviewees (n=4) opinion of the guidance documentation and aspects of the ammonia calculator (see Table 1 for full question and scale definition 1-5).

The ammonia calculator was demonstrated to three of the farmers at the start of the interview and the forth had seen it several times during development. He comment that *the new version has a lot more help ... the question mark icon is really useful.*

Four improvements to the ammonia calculator were posed (Q23-Q26 Table 1). All improvements suggested were generally accepted as worthwhile (Table 1 and Fig 8). In terms of ranking, using the arithmetic mean, farmers considered including multiply species rather than a single main canopy species would be the most worthwhile (mean 4.8). One farmer commented *nobody plants one tree species* and another commented should *not be all one species because of the risk of disease … diversity important.*

Farmers varied in their opinion of including a cost associated with planting (Q25 Table 1) with scores between 3 and 5. The farmer which scored this improvement as 3 commented *Every single sites different isn't it - different thickness different number of gates...* but also commented *wouldn't do any harm ...to give people an indication.*

In terms of the current restriction of 50 m on the width of the shelterbelt in the calculator, most farmers agreed it would be worthwhile to estimate ammonia capture across a longer distance. One considered that it was important to consider succession of the trees. He considered it would be better to plant *three different phases over maybe six years or something and then in the future you can take bits out … replant them in phases, so you don't have it as an all or nothing.*

Including an estimation of the carbon gain associated with the trees species was considered a worthwhile addition with some farmers strongly agreeing while others indicated less enthusiasm for this improvement to the tool. One farmer commented that his egg purchaser was intending that *they're free range eggs are going to be carbon neutral by the end of the year,* while another comment that they knew *trees capture carbon but if want people to plant you need all info available …better if trees can do two jobs.*

4.2 Relative advantage of the practice - planting trees to capture ammonia

4.2.1 Response from first interview

There was a realisation amongst all farmers interviewed that planting trees to capture ammonia was a relatively new concept and woodland was yet to be proven to capture significant quantities of ammonia from hen and dairy enterprises. All farmers commented on other benefits associated with woodland, but stated that at present the advantages of planting trees to capture ammonia was unproven and had not been a major motivation to plant trees. One farmer commented *We have*

no aims to capture ammonia or carbon. To some extend the variation in motivation scores reflects the farmers view on the likelihood of trees capturing ammonia and the importance they attached to the other advantages associated with tree planting.

The environmental benefits of woodland was mentioned by all farmers. Both in terms of carbon capture and increasing biodiversity for example one farmer commented: *I suppose one thing we've really noticed for the last 10 years in having the trees is an increase quantity and variation of wildlife that we've seen in the immediate area where the tree are and also around the rest of the farm*.

The animal welfare advantage was also recognised by several of the farmers with one specifically commenting when discussing profit orientation that : *having a tree cover encourages birds to leave the shed and roam much more outside and that reduces the pressure on the building… some people would argue that by letting them outside you're introducing diseases. But actually the performance of the bird is led very much by its health status and if you can keep them healthy and happy, if they've got plenty of rewards and activities and so on, they probably will stay healthy and that is the key driver of profitability.*

The ability of the trees to camouflage the hen sheds was also recognised as an advantage by one respondent: *another aspect is the visual impacts that we've seen ...tree cover has totally blinded the appearance of the shed … where the birds, live from the road so nobody can actually see the building ...it blends into the landscape which I see as a positive.* No respondent commented on ability of the trees to reduce the odour from the hen or dairy shed.

All farmers scored profit orientation relatively high as a motivation for planting trees with one commenting: *it's not a profit from the wood, but I do get paid for having the trees for cover for the hens.* Another farmer remarked that the woodland on their farm was grant aided adding *our motivation was to improve the environment generally - not specifically for ammonia capture but better environment makes the farm more resilient.* The responses to the questions related to the profit benefit in the years that the practice is used generally varied amongst the interviewees depending on the scale of the hen enterprises which paid extra for the eggs dependant on the woodland available for the hens to roam for example: *Yeah well because of the hens they are fairly profitable.* The uncertainty in policy and trading conditions post-BREXIT influenced the response to the question focused on the profitability of planting woodland in the future. One farmer commented: *Well, this entirely depends on what happens with the agricultural policy after December* [2020].

Opinions amongst the farmers varied on the relative upfront cost of planting woodland partly depending on their views related to the scale of their hen enterprise. One farmer commented: *it depends on scale….. Depends as a proportion of the farm.* He scored question 14. How large an investment would you judge designing and planting trees to capture ammonia would be on your farm (1= large investment 5=no initial investment required): *it's probably 4 taking account of the business figures as a whole.* While another farmer who scored this questions as a 1 i.e. large investment commented *large investment because planting trees means giving up land.*

The long term nature of woodland creation was noted by all farmers with some commenting that although it was reversible i.e. *Well of course you can grubb up ancient woodland if you want to and plant wheat - I mean it's, reversible.* But all interviewees considered that once trees were planted they were relatively permanent e.g. *there's such a long term item that you plant a tree, you're not really going to want to change your strategy for at least another 30 years in terms of the tree planting.*

Opinions on work associated with tree planting varied but none consider that it reduced their work load. One farmer considered that planting and maintaining woodland was quite a lot of extra work

scoring -3 the maximum disadvantage for question 22 How large a decrease in ease and convenience in your work is associated with tree planting to capture ammonia (-3= Large decrease in ease and convenience , +4= Very large increase in ease and convenience). He commented: *There's quite a lot of work involved in maintaining the trees… every year there is maintenance.* While three interviewees selected zero for the same question as they recognised the extra work but thought it was justified one commented: *They are work so yes extra work got to prune branches - but I will go for middle of the road zero yes it is work but it is work that is benefiting me -its worth the effort.* One farmer scored the question as +1 commenting: *trees don't really reduce work on dairy farms … may add work … maintenance... but farm working only one aspect of things … working on the farm involves more.*

4.2.2 Responses from second interview

In total eleven questions related to the relative advantage of the innovation of planting trees to capture ammonia were repeated at the second interview (Q2-Q3 and Q14-22). Farmers generally held the same range of opinions but tended to score higher i.e. more positively (Table 1 Fig 8) after seeing the data from their farm and the numbers generated by the ammonia calculator. As one farmers commented when asked if the new knowledge would influence their environmental motivation to plant trees *It proves, if you like, what I already suspected to be the case, anyway, I suppose it's useful …but the ammonia wasn't, the main reason why we planted the trees in the first place.* While another commented *the more information you get and the further into the modern era we get the stronger that incentive gets to be thinking about environmental benefits of what we're doing.*

The calculator was seen to help in terms of mitigating risk but only if the government started to penalise farmers for ammonia production as one farmer commented *We know the benefits of what we're doing and really for us at the moment, until it becomes a government directive ammonia captures is nice… it does reduce risk but that's not particularly the driver.*

The date provided by the calculator was viewed positively in terms of understanding the practicalities but one farmer commented *well it helps if them figures are right sort of thing …* Following this remark the actual data of ammonia capture from this farmer was shared and he could see that the trees were indeed capturing ammonia he commented *So really them trees are working well aren't they… It shows the trees are reducing it* [ammonia]. It was clear he was more convinced when he could see actual data. When asked about the investment in planting trees he considered that the calculator would be helpful *to work out the cost of planting the trees yeah how many trees I would have to plant… yeah it would help to plan.*

The delivery of data from their own and similar farms, the ammonia calculator and the guidance documentation had a positive influence on farmers understanding of the practicalities of planting trees to capture ammonia.

4.3 Effectiveness of the process of learning about the practice

4.3.1 Response from first interview

Generally the farmers interviewed consider the "Learnability characteristics of the practice" i.e. trailing ease, practice complexity and observability as relatively low at the first interview. The farmers found it strange to consider tree planting for a single aim. One farmer summed up the possibility of trailing tree planting to capture ammonia before fully committing to the practice as *not*

very easy to trail - we have a lot of trees - we did not plant for ammonia capture. While another echoed the earlier comments about the long term nature of trees *Well yeah trees are a long term thing. You just got to get on it. In my view, you can't really try trees.* Farmers also commented on the scale issue related to learnability e.g. *It depends on number of chicken sheds. If you have one chicken shed It's not easy … need to jump in with both feet or you don't.*

Although the scores that farmers recorded for the observability of the benefits of the woodland planting were slightly higher than for trailing ease, farmers again found it hard to answer only in relation to trees in terms of ammonia capture. One interviewee commented *Benefit for ammonia capture or benefits for the environment or benefit for the birds?* While another commented *What benefits? If this is really only ammonia capture its not observable at all. You won't be able to tell the difference at all ... really unless you're going into ancient woodland just downwind and see the lichens have come back. So very difficult, but the other benefits like biodiversity like birds like bats like barn owls, like squirrels very easily observed.* One farmer again questioned that trees do in fact capture ammonia stating clearly in relation to the observability of trees to capture ammonia *science yet to prove they capture ammonia.*

In terms of evaluating the effects of tree planting on ammonia capture due to complexity of understanding the practice (which tree species to plant, the planting design etc.) farmers' scores ranged from very difficult to relatively easy. Farmers considered this question in two part as explained by one farmer *The process of planting per se isn't particularly difficult but then I think there would need to be more understanding on or information available in terms of which trees benefit or help to capture ammonia over others.* The need for research and understanding the role of trees in ammonia capture was echoed by all the farmers as one commented *That's why we're doing this research. … the more you understand about it the more you realize how little we know, and how much research needs to be done and hence us being involved in this sort of work.*

Within the group of farmers interviewed there was a wide range of opinions on their opportunity to learn about ammonia capture from trees through either involvement in interest groups or via farm advisors. Purchasing companies (eggs and milk), and the National Farmers Union were mentioned as means of learning along with the agricultural press as one farmer commented: [I] *just read the farming comics.*

All the farmers said they did not have the practical knowledge to design and plant woodland specifically to capture ammonia from their enterprises for example; *we know how to plant a tree; I would guess for ammonia capture we should plant downwind at this farm but would not know how deep/wide the tree belt should be or how many trees etc.*

4.3.2 Responses from the second interview

In total five questions related to learning linked to adopting a new innovation like planting trees to capture ammonia were repeated (Q7-9, and Q12 and Q13). The farmers all scored these questions more positively than in the first interviews.

The calculator was considered useful by some farmers to make the planting of trees to capture ammonia more trialable because of the numbers generated as one farmer commented *I can plant some trees and there will be in ammonia capture benefit of it, but if you're can you see in 25 years it'll be 30% and if you put in slightly different tree species in you make it 35% it's really useful to be able to do that.* While another farmer commented that *if I was going to plant some trees, again I probably would look at that information and work out some kind of plan*.

The images in the guidance document were considered very helpful and resulted in one farmer considering that the observability of the practice would be increased because people could see

real examples. Another farmer commented when asked about observability that the guidance document helped , *because I didn't understand it until you show them pictures and the way air coursed through the canopy and stuff so yeah that was good.*

While another farmer consider the calculator would help understand the implications of reversing the tree planting, as they would know what they were losing. In general the new knowledge was viewed positively by the farmers.

4.4 Improving information for farmers on how to design a tree shelter belt

4.4.1 Responses after first interview

All the farmers interviewed in the first interview commented that they required knowledge to design tree plantings to maximise ammonia capture. However, a common theme amongst the farmers was the multiple benefits of trees and the need for information to allow flexibility in tree planting schemes rather than a single focus. They understood that this study is focused on only ammonia capture but stressed that woodland should not be considered in terms of a single benefit but rather the multiple benefits of trees to a farm business and the environment should be borne in mind when designing tree planting schemes and grant incentives such as the ELM schemes. Issues raised by farmers relevant to this theme generally related to combating climate change, biodiversity and general farm business and environmental resilience.

The issue of trade-offs between the various benefits of planting trees was highlighted many times. For example one farmer commented that even when planting to capture ammonia the trees could not be situated too close to the dairy unit because they would restrict ventilation and increase the risk of pneumonia he commented: *but other thing you've got to think of is you can't plant too close to buildings for ventilation and so for a dairy farm you've got to think were you going to plant them for the welfare of the animals.* Another farmer also discussed trade-offs in terms of quantifying the desire of the research community to have a solid block of conifers as a back stop with branches to the ground to capture the ammonia. He commented *they needed a backstop of these dense bushy trees as a backstop for ammonia collection to stop it escaping….*[practically it] *wouldn't work at all because as soon as you start to get those bushy tree with branches, right down to the ground, hens lay their eggs.. commercial that'd be a nightmare. So it wasn't going to work. But that design may only reduce the ammonia absorption by two or 3% …3% out of 40% frankly it tiny.* Thus the farmer suggested that a trade-off between ammonia capture and commercial practice was genuinely possible.

The current food industry trend for carbon foot printing was also discussed in terms of designing woodlands. One farmer commented *So this carbon footprint thing that's the next thing.* He commented that currently his milk company wanted to get the carbon foot print to zero within three years. Trees had not been consider in term of carbon in their audit but he thought that they maybe in future and therefore the planting design to capture ammonia should also consider maximising carbon capture.

In terms of biodiversity several farmers mentioned both the advantages and disadvantages of the trees to enhance biodiversity for their business. One farmer for example commented *We've seen all kinds of mammals, …* [and] *a good cross section species of birds in particular things that we perhaps wouldn't have seen beforehand but year on year* they *increase* later the same farmer mentioned an increase in predators associated with the trees *We've found polecat and different ground mammals such as stoat and weasels come into the area now that we would have never*

seen before. The potential of trees to support biodiversity was considered important by many of the farmers interviewed.

The role of trees to enhance biosecurity on a farm was mentioned by one farmer who commented that avian flu was primarily transported by wild birds and trees were a deterrent i.e. *specifically waterfowl which bring avian influenza in to the country every year... They cannot land in trees...So if you have lots of tree cover for your chickens. It reduces your risk, which is a massive, massive risk to the business.* Thus planting density which discourages wild fowl is another consideration when design tree shelter belts.

An understanding of the multiple benefits claimed by farmers for planting trees was to some extend context specific. One farmer commented on desirability of incorporating willow within the planting scheme for example which he thought the hens would like. He had experience with this species as they currently had a 21 year contract to grow willow for biomass., but he also highlighted the biodiversity benefits of willow *its also very biodiverse...probably the second thing after oak ... willow is one of the first to flush in the spring ... one of the first for the pollinators.*

In summary farmers called for tree planting designs that capture ammonia to be multi-functional and recognised the trade-offs that would invariably result but considered flexibility to the individual farm circumstances important.

4.4.2 Responses from the second interview

All farmers consider the ammonia capture tool positively as an aid to designing tree shelterbelts to capture ammonia e.g. *it's a helpful tool* and *Well, definitely yes yeah if you were putting up a new building yeah the calculator would help.*

There was criticism in so far as choosing a soil type was difficult and help to understand the terms would be useful. All the suggested improvements were consider worthwhile but again the multi-use of the shelterbelts in terms of welfare and profitability of the hens, biodiversity, and carbon sequestration in addition to ammonia capture was stressed.

4.5 Developing options for farmers in the Environmental Land Management Scheme (ELMS)

The 22 questions of the ADOPT model utilised in this study does not seek to identify specific adoption constraints arising from the off-farm institutional environment, such as incentives or indeed lack of coordination between the public and private sectors. However, the interviewees did made remarks in answers to the ADOPT questions and during the informal discussion at the end of the interviews which are relevant to an ELMS theme generally (not simply when focused on ammonia capture).

In recent decades the institutional structures in the eyes of several interviewees has created an 'us and them' culture which was lamented by several farmers, one commented specifically that this was not the situation in the past: *We had ADAS before ...the guys used to come in and say there's a grant for this, this, and this and helped us fill the forms. It just worked really well.* In these past times, however, the aim of government grants was primarily uni-directional i.e. increased food production, which meant that the government, government agency staff and the research community had a common goal with the farmers i.e. all were paid for success when food production was increased. Food production was recognised as a simpler goal than protecting the environment, which is multidimensional and frequently had no market value for the farmer. The latter fact is well understood and recognised explicitly in the design of ELMS. However, farmers were not sure that

the multi-dimensional problem of protecting the environment was equally recognised with what they consider single focused research or single target ELMS options. One farmer remarked *What does ELMS want – biodiversity, increase species of birds and butterflies, months, or do they want a reduction in ammonia. Can we do both? I don't know... that's the bigger picture, which is why I get a little bit worried when somebody says …* [they] *will come up with a perfect tree planting plan for getting rid of the ammonia because it's bigger than that.*

The multi-purpose use of trees and woodland on farms was a common theme with a recognition by several of the farmers that schemes should have flexible aims and not become tick box exercises or too prescriptive. They commented that nature was not like a technology solution that tended to have a single function. When questioned about tree planting generally one farmer commented *Well, I wouldn't mind planting trees not necessarily around the steading but there are other parts of the farm …. but rather than blanket acres and acres or even one acre blocks of a single species better to have shelter belts and things like that from the past. Yeah, but you don't want to take land out of food production … let us plant trees where we want them, you would get a lot more trees planted definitely.* This sentiment was echoed by another famer who remarked *Farmer should decide where on the farm the trees should go for example the nuisance areas or the worst bits of the farm. The trees will work pretty well on most land or you can find the right trees for the land and I mean we have some terrible land which we planted years ago with alder and now they are huge.* The need to engender trust resonated with another farmer who commented *need to think more carefully and work more with the farmers … for example 1 ha is a huge amount of land in a single block is that really needed … need to work with farmers... government agencies should listen to farmers.*

Several of the farmers also recognised the conflict created by multiply agencies desiring different environmental goals. One farmer commented: *We are in a catchment area that floods and, you know, we had various bodies wanting to do various jobs on our farm but they don't work together ...This was instigating about two years ago. And so far nothing has happened because they cannot agree among themselves.* The farmer was clearly frustrated and commented further: *I am tired now ... when they arrive, I'll probably just say I have change my mind.*

The lack of practical understanding by those designing government incentive schemes was also lamented which one farmer consider resulted from a lack of understanding. The farmer remarked concerning DEFRA: [those] *working on the ground level are often making decisions about things that they aren't really qualified to know about. And so … I think there needs to be much more training all the way around. And that might sound expensive, but actually in the medium to long run, it would work out as better value for money for the taxpayer … because very often we're asked to do things and told to do things and it becomes a Box ticking exercise because the things we're being asked to do we already know are not worthwhile … But in order to attract funding we have to do it. And I just feel sometimes that the people that are at the grassroots level of asking the questions and those doling out the rules aren't really qualified to do that.*

A common theme, which all the farmers remarked on, was the need to consider the environment and the farming business as a whole. One farmer remarked in relation to tree planting *trees don't really reduce work on dairy farms … may add work … maintenance... but farm working only one aspect of things … working on the farm involves more ...a whole chain ... whole ecosystem approach … farmers interested to protect environment as this protects the farm.*

In the second interview, a farmer mentioned the conflict between public incentives. She commented *Well, on my specific farm it [tree planting] has a negative impact on the profit per acre because if we're planting trees, we wouldn't currently get the basic from payment Single Farm*

Payment on those parcels of land that had been planted with trees… so the advantages of dissipating the ammonia are to be balanced with the amount of profit, money that we would lose. Other farms echoed the need to multi-dimensional holistic thinking related to incentive schemes.

5 Online Farmer Survey

5.1 Delivery and number of responses

A remote survey was conducted between 22nd March 2021 and 24th April 2021 based on the ADOPT questionnaire (Appendix 4 shows the full survey questions from Q1-Q27). The first 23 questions were repeated from the one to one interviews, but some additional questions (Q24-Q27) were asked at the end of the survey covering planting trees for reasons other than for ammonia mitigation.

The survey was distributed via mailing lists of the British Egg Industry Council, Sainsbury's dairy and egg supply group and the National Farmers Union.

In total 149 farmers completed the survey. One farmer omitted to answer question 1 "What are your farming livestock operations" (Figure 1). This response was omitted from the numerical analysis but included in the analysis of the four final open questions.

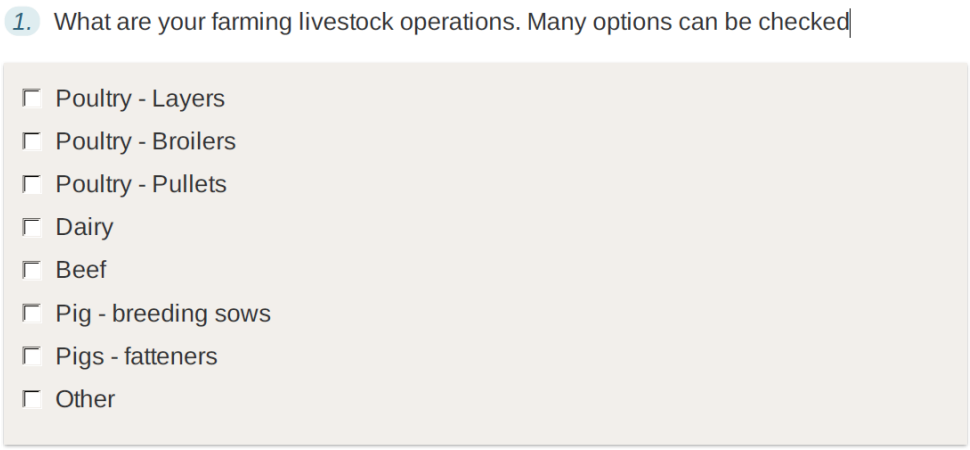

Figure 1: First question in the survey and options. Users were able to select multiple options

Approximately half (52%) reported a single farm enterprise while 31%, 14% and 3% reported 2,3 or 4 enterprises respectively (Table 1).

Table 1: Options selected by respondents to the questions "What are your farming livestock operations"

Options selected by respondents	Number
Beef	23
Beef,Other	6
Beef,Pig - breeding sows,Pigs - fatteners	2
Beef,Pig - breeding sows,Pigs - fatteners,Other	1
Beef,Pigs - fatteners	3

Beef,Pigs - fatteners,Other	1
Dairy	6
Dairy,Beef	2
Dairy,Beef,Other	2
Dairy,Beef,Pig - breeding sows,Pigs - fatteners	1
Dairy,Beef,Pigs - fatteners	1
Other	10
Pig - breeding sows,Pigs - fatteners	11
Pig - breeding sows,Pigs - fatteners,Other	2
Pigs - fatteners	4
Poultry - Broilers	5
Poultry - Broilers,Beef	1
Poultry - Broilers,Other	1
Poultry - Broilers,Pigs - fatteners	1
Poultry - Layers	28
Poultry - Layers,Beef	10
Poultry - Layers,Beef,Other	9
Poultry - Layers,Beef,Pig - breeding sows	1
Poultry - Layers,Dairy	2
Poultry - Layers,Dairy,Beef	1
Poultry - Layers,Dairy,Beef,Other	1
Poultry - Layers,Other	3
Poultry - Layers,Poultry - Pullets	6
Poultry - Layers,Poultry - Pullets,Beef,Other	1
Poultry - Layers,Poultry - Pullets,Other	1
Poultry - Pullets	2
Grand Total	148

For analysis the farms were grouped hierarchically into four categories depending if they reported either dairy, pig, poultry, or beef/sheep enterprises, i.e. mixed farms which mentioned dairy plus other enterprises were assigned to dairy.

Table 2: Number of respondents grouped hierarchically into four categories dairy, pig, poultry, or beef/sheep enterprises dependant on the farm enterprises reported.

Farm type	Number of respondents
Poultry	69
Beef/Sheep	37
Pig	26
Dairy	16
Grand Total	148

5.2 Relative advantage of the practice - planting trees to capture ammonia

As noted in the semi-structured interviews there was a wide range of scores assigned to each question by respondents. The average for all farm sectors was similar with some differences for certain indicators (Figure 2). *Profit orientation* and *Risk orientation* were seen as moderate motivators (Q2 & Q4) while *Environmental orientation* (Q3 - *How important is protection of the environment a motivation for you to plant trees to capture ammonia?*) was a strong motivator for dairy and poultry producers. For *Enterprise scale (Q5)* then planting for ammonia mitigation was seen to support a large enterprise for dairy farmers but less so for beef and sheep farmers. All farmers have long term management horizons of 10-20 years being the common response (Q6 *Do you have a long-term management horizon*?). Finally, *Short-term financial constraints* were present for all farmers but were not a major influencing factor (Q7 *Do you have a severe short-term financial constraint that may influence you planting trees on your farm for ammonia mitigation? [1=yes to 5=not an issue]*).

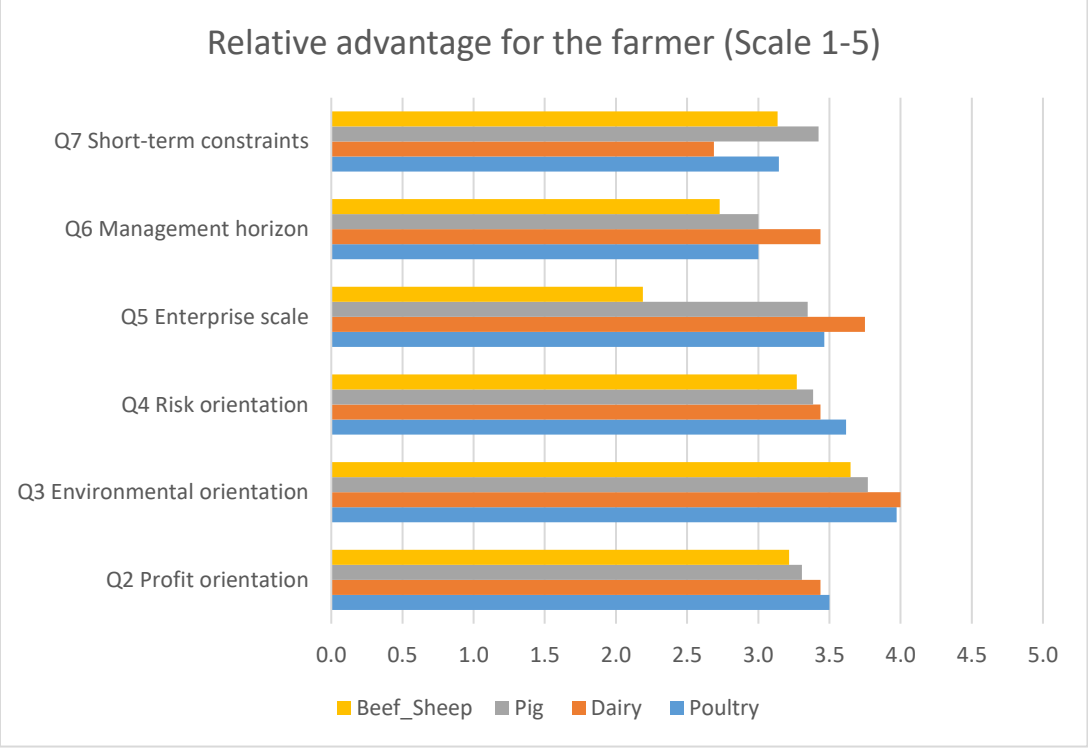

Figure 2: Relative advantage indicators for planting trees on the farm for ammonia mitigation for four livestock s

5.3 Effectiveness of the process of learning about the practice

The average scores were lower in this section. Trialing of incorporating trees on the farm for ammonia mitigation was deemed as difficult but trialable with some modifications (Q8). Scores were lower for observing the benefits and understanding the practice of carrying out planting (Q10 and Q9). Poultry famers (blue) were more positive, likely due to many of them having already carried out some level of tree planting for free-range birds. Similarly, The practical side of planting and establishing a treebelt (Q9) was seen as 'difficult' or 'difficult but can be overcome by guidance' especially for non-poultry farmers.

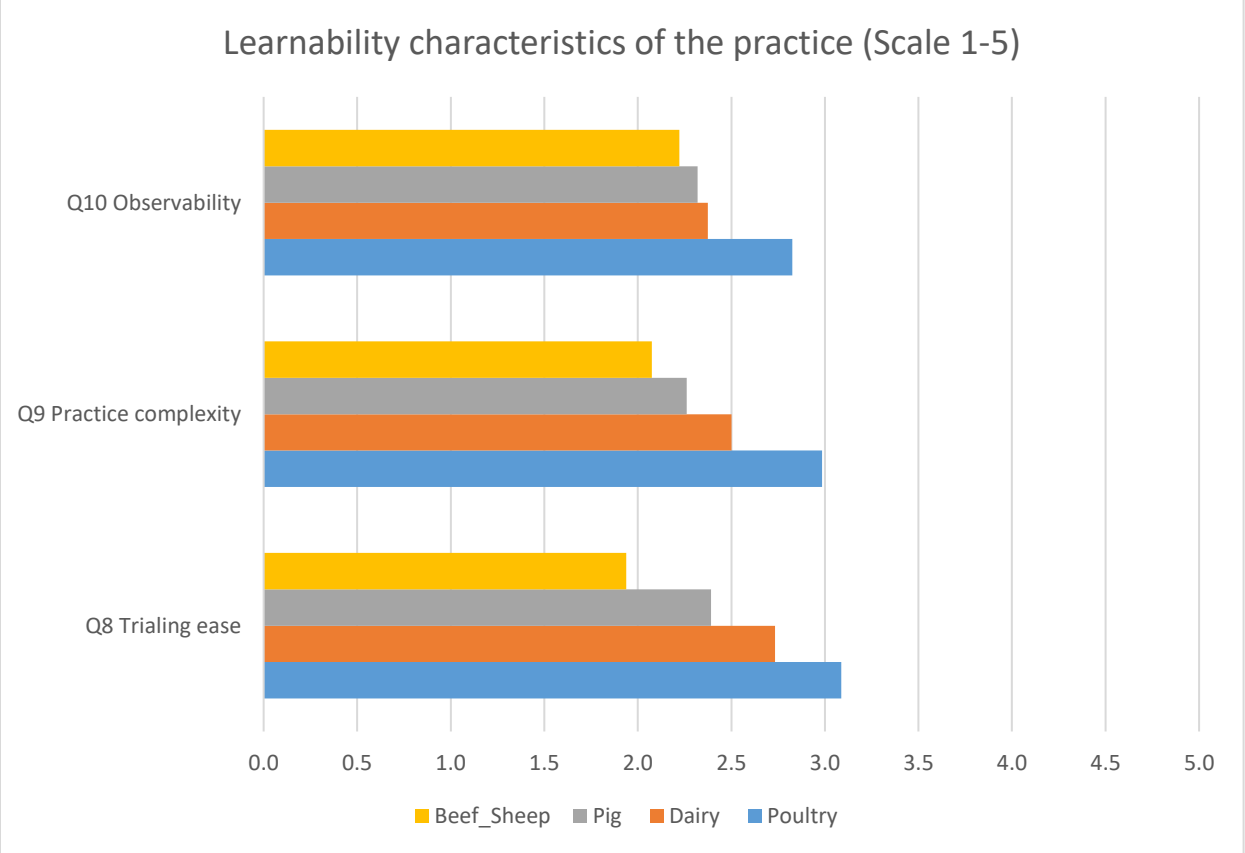

Figure 3: Learnability characteristics of the planting trees for ammonia mitigation for four farmer groups assessing ease of trailing, complexity of carrying out the practice and observability of the benefits.

5.4 Specific influences on the ability to learn about the practice

There were strong indications that farmers make 'occasional' use of farm advisors (Q11) and use of several local group networks (Q12). Relevant experience of planting trees for ammonia mitigation were as expected low for most farmer groups (Q13 2=very limited knowledge), while poultry farmers (blue) had 'some knowledge'. Moreover, there was low awareness of the practice being carried out in their area (Q14 *2=i've heard of one case*). Interestingly diary farmers (blue) had experienced the practice more than the other framing groups.

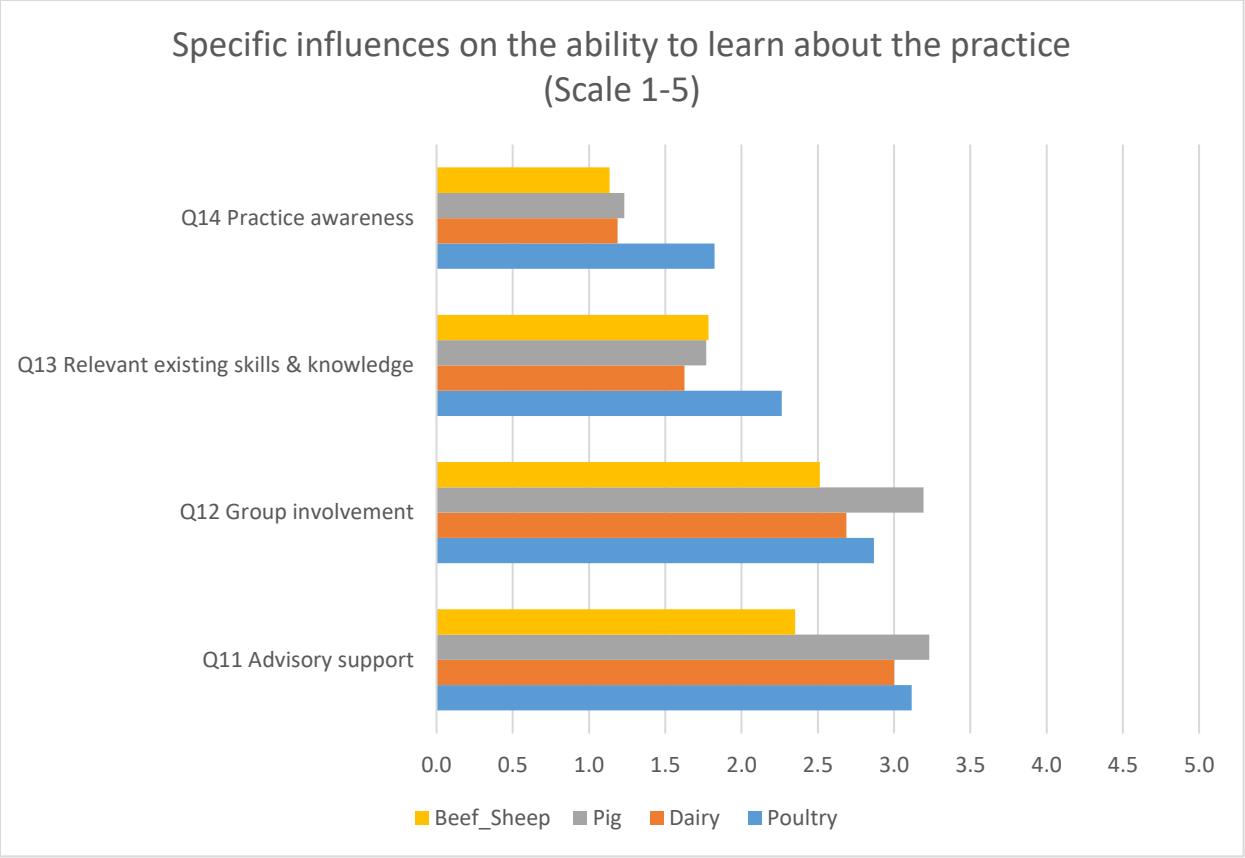

Figure 4: influences on the ability to learn about planting tree for ammonia mitigation

5.5 Relative advantage of the practice (Scale 1-5)

For Q15 and Q16 the investment and reversibility were sored low by all farmer groups (Figure 5). The investment to design and plant trees was deemed as a 'medium investment' while the reversibility was judged as 'very difficult' to reverse. This may not come as a surprise as planting trees is a long term change in land use. There were very high scores for Q17 and Q18 which indicated that benefits to both on farm profit and the environment would not be realised until at least 8 years.

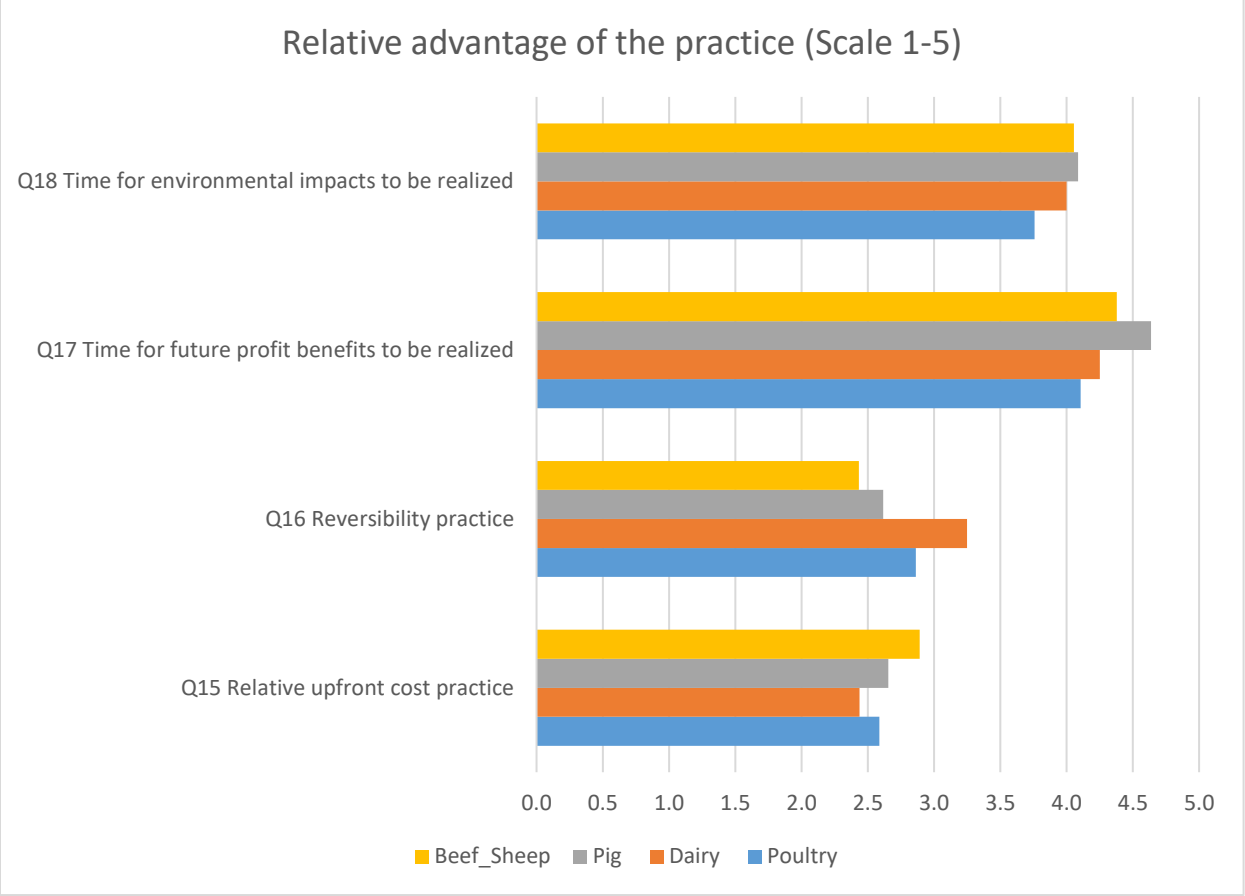

Figure 5: Relative advantage of the practice of planting trees for ammonia mitigation for four farm sectors.

Questions 19 to 23 scored indicators across the scale from -3 to +4. This helped show clear negative and positive responses from each of the farm sectors for profit, risk, environment and ease of implementation as presented in Figure 6. Negative score of -3 represented 'Large disadvantage' while +4 was a 'Large advantage'. Form the bar-chart profit and ease and convenience of implementation all on average had negative scores, all be it only slightly negative (< -1), while environment and risk were scored positively. It is interesting that risk scored positively (some reduction in risk) while profit was negative. The dairy sector was neutral on risk and environmental impact while most strongly negative for ease of convenience of implementation possibly representing some of the advance that the pig and poultry industry have already put into ammonia mitigation.

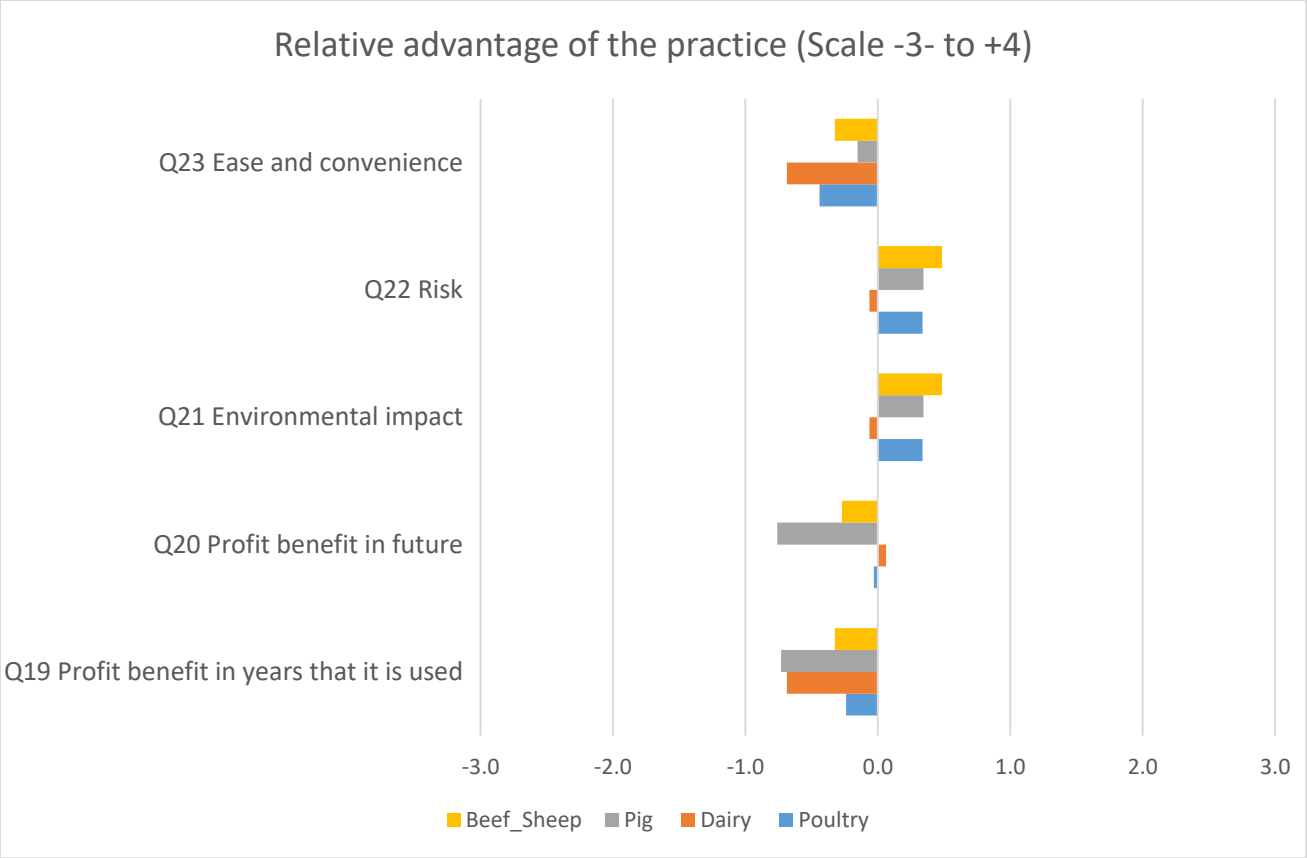

Figure 6: Sliding scale of -3 to +4 for advantages of planting trees for ammonia mitigation for profit, risk, the environment and ease of implementation.

5.6 Planting trees for other reasons

Questions 24 to 26 were free-text boxes to gain further understanding of willingness and motivation around tree planting. Table 3 shows the breakdown by farmer type to the question around the consideration of planting treebelts for other benefits apart from ammonia reduction. Additionally, Figure 7 shows the responses in a pie-chart. 56% responded positively (n=83), while 6% have already planted trees (n=16). Only 11% were negative in this response with others 'unsure' (16%) or 'possibly' (5%).

Table 3: Question 24 'Would you consider planting a tree shelter belt on your farm for other benefits (apart from ammonia reduction)?' split by farmer type.

Category	Beef_Sheep	Dairy	Pig	Poultry	unknown	Grand Total
Blank	1		1	5		7
No	6	2	1	7		16
Possibly		3	2	2		7
Unable		1				1
Unsure	6		5	13		24
Yes	23	9	15	35	1	83
Already	1	1	2	7		11
Grand Total	**37**	**16**	**26**	**69**	**1**	**149**

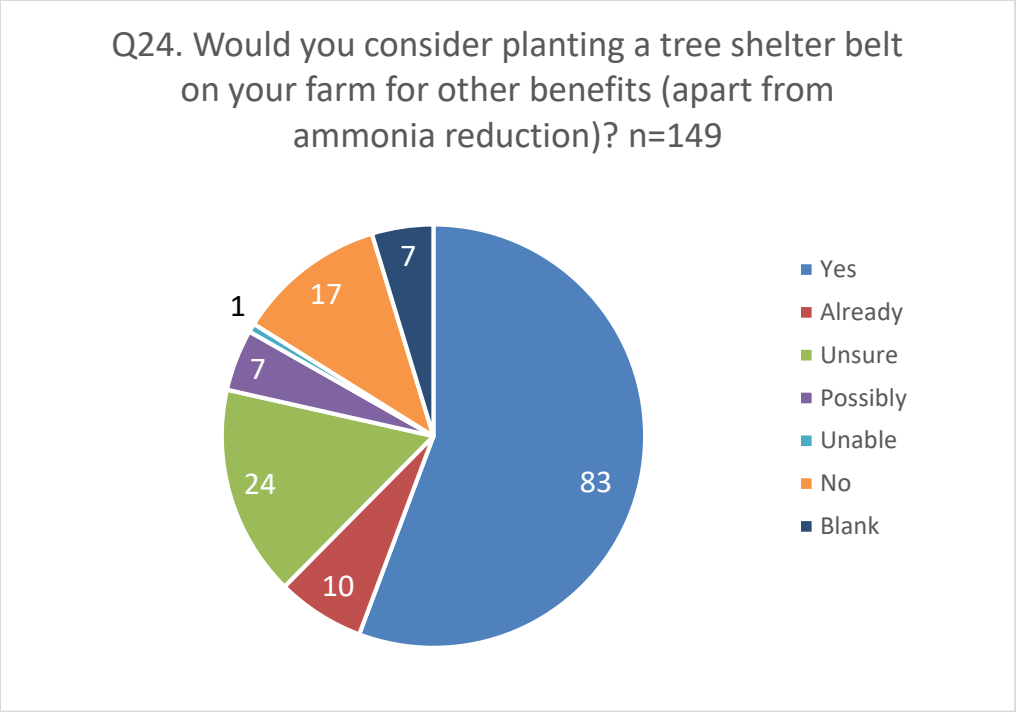

Figure 7: Answers based on the question 'Would you consider planting a tree shelter belt on your farm for other benefits (apart from ammonia reduction)?'

Question 25 asks about the benefits farmers would expect to see on their farm after planting treebelts (Table 4). From Figure 8 the majority (54%) suggested that environmental benefits were the main benefit. This included biodiversity/wildlife, carbon sequestration, and ammonia reduction as the main environmental benefits. Animal welfare through ranging and sheltering were seen as the next best benefit from treebelt planting (13%). Animal welfare was mainly mentioned by poultry farmers (Table 4).

Table 4: Question 25 'What benefits would you expect to see from planting trees on your farm?' split by farmer type.

Category	Beef_Sheep	Dairy	Pig	Poultry	unknown	Grand Total
Animal welfare/Shelter	4	2	1	12		19
Environmental/Biodiversity	24	10	15	32		81
Grant incentives	1			3		4
Increased income	1		1	5		7
No benefits	2	2	1	3		8
Screening	1		2	1		4
Timber products	1		1	1	1	4
Unanswered	3	2	5	12		22
Grand Total	**37**	**16**	**26**	**69**	**1**	**149**

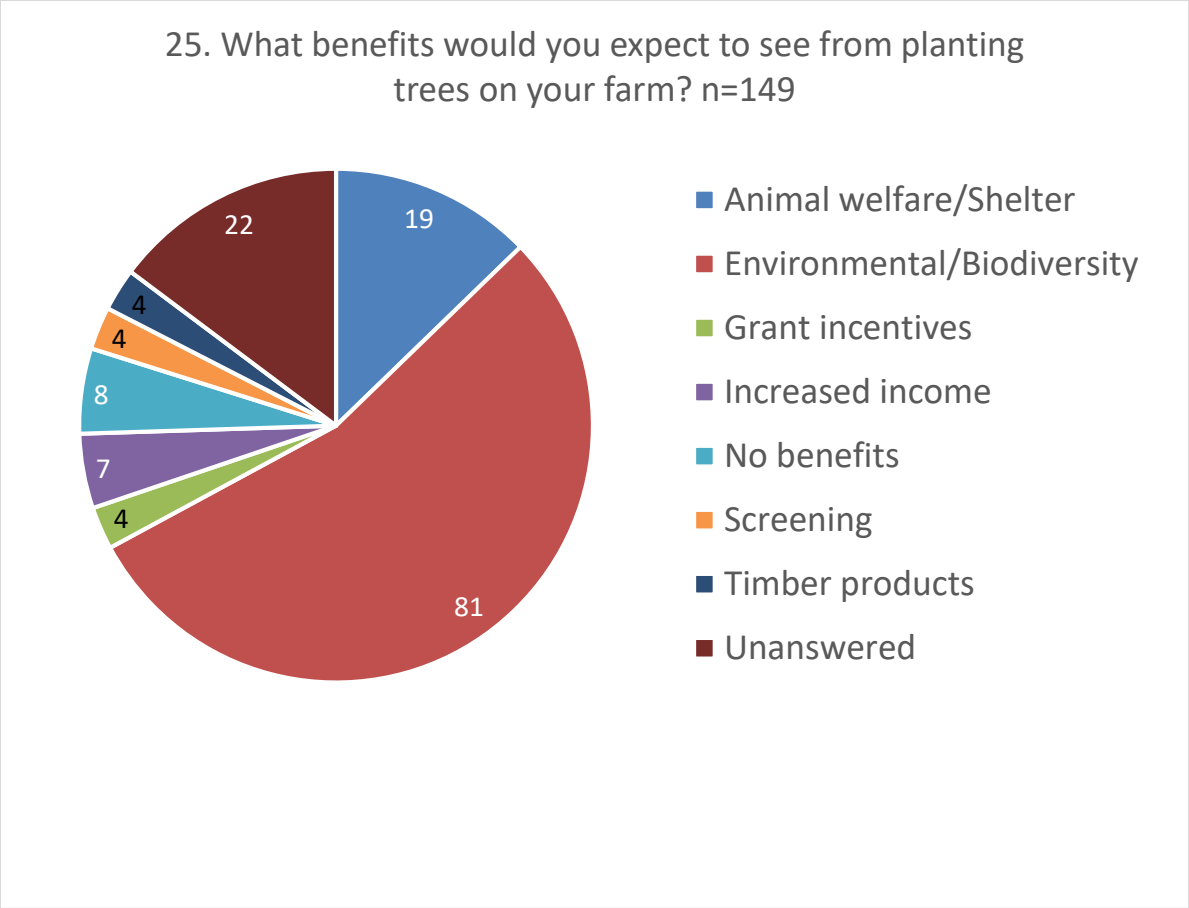

Figure 8: Answers based on the question 'What benefits would you expect to see from planting trees on your farm?'

Question 26 concerns the motivation behind farmers planting trees on their farm. Table 5 shows the breakdown of answers by famer type. From Figure 9 the overwhelming motivation concerned financial support (61%) to carry out tree planting either via grants, payment for capital costs or incentives.10% were motivated by the environmental benefits and 5% had already planted trees on their farm. A small number were motivated by animal welfare reasons (all of them poultry farmers) while 3 would be motivated by better guidance and evidence of benefits. A total of 24 respondents declined to answer this question (16%).

Table 5: Question 26. What would motivate you to plant a tree shelter belt or woodland on your farm? split by farmer type.

Category	Beef_Sheep	Dairy	Pig	Poultry	unknown	Grand Total
Already planted	1	1	2	4		8
Animal welfare				3		3
Environmental benefit	2	2	2	9		15
Grant/Finance/Incentives	26	10	17	37	1	91
Improved planning permission			1	1		2
No motivation to plant	2			1		3
Better guidance	1	1	1			3
Unanswered	5	2	3	14		24
Grand Total	**37**	**16**	**26**	**69**	**1**	**149**

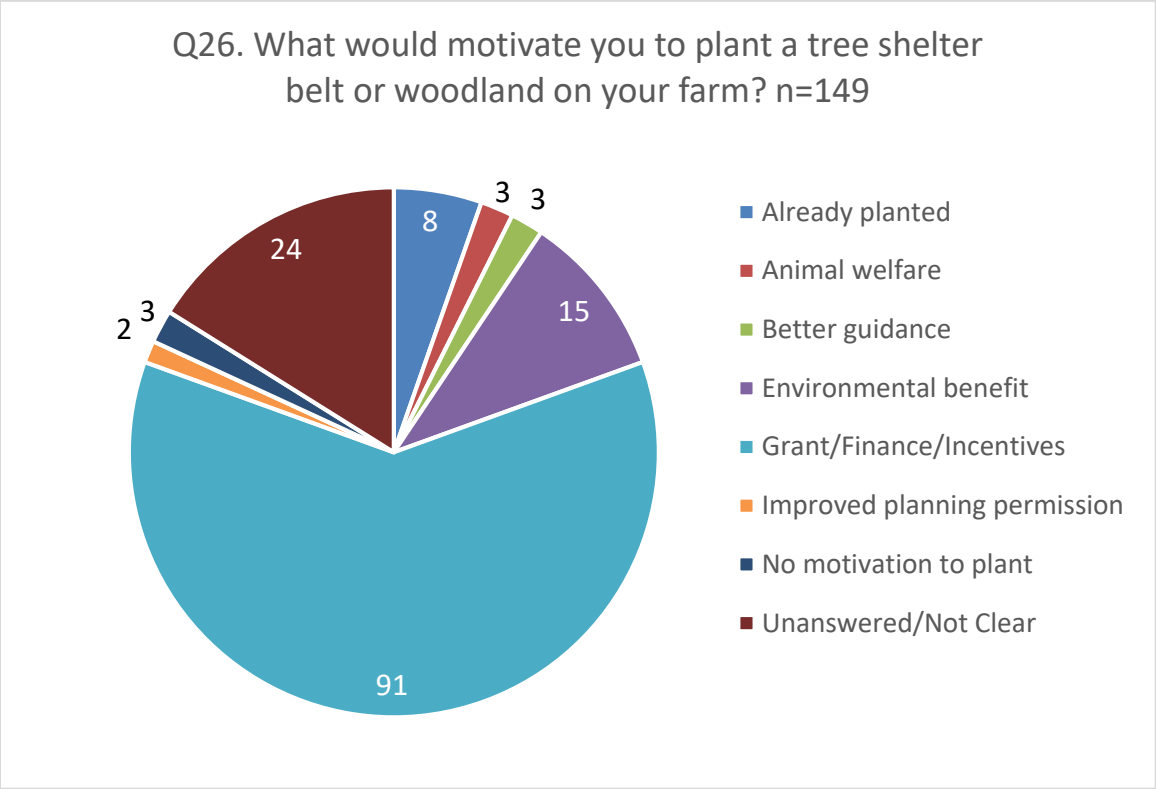

Figure 9: Answers based on the question 'Q26. What would motivate you to plant a tree shelter belt or woodland on your farm?'

5.7 APODT

5.7.1 ADOPT Model predictions

Using the online data the ADOPT model predicts a 'Time to Near Peak Adoption Level' and a 'Peak Adoption Level' for all 4 farm sectors for the practice of planting trees for ammonia mitigation (Figure 10). A summary in of the results Table 6 shows that the model predicts poultry farmers likely to adopt the practice slightly quicker (15 years) than other sectors 17-19 years), but a low adoption predicted for all sectors of only 2%.

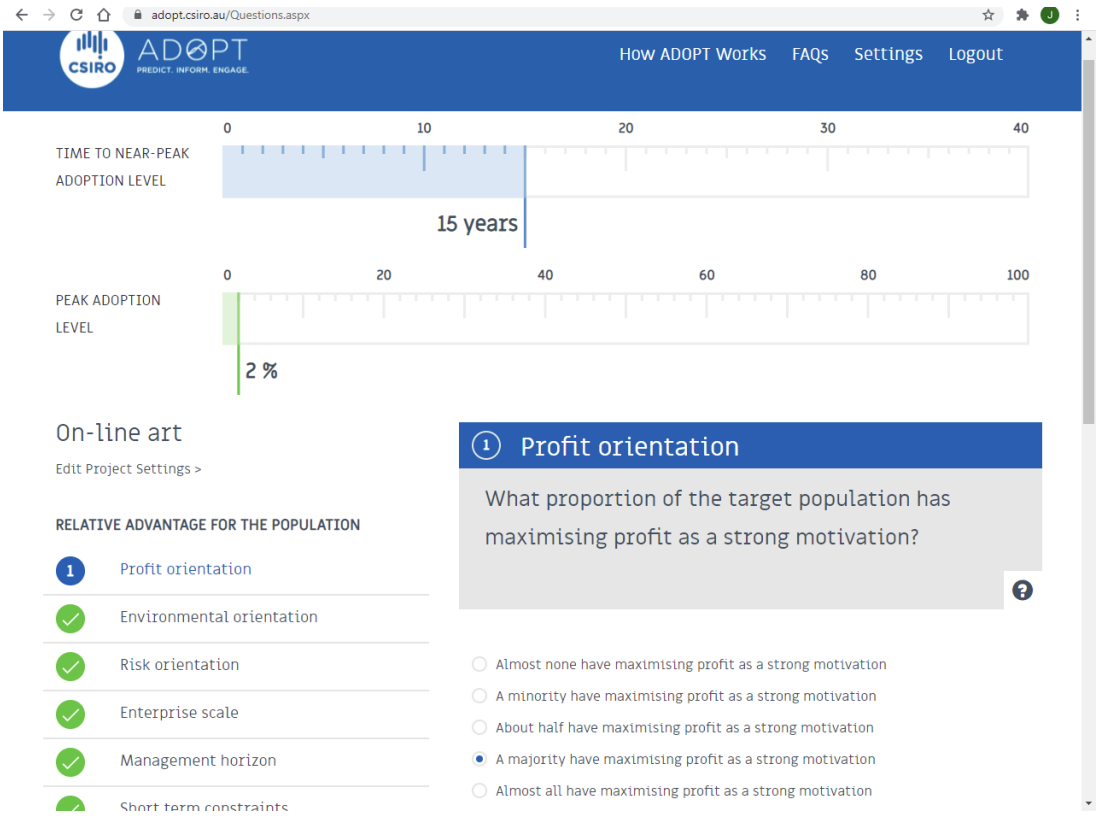

Figure 10: ADOPT model 'dashboard' showing the time to near-peak adoption level and peak adoption level percentage.

Table 6: Time to near-peak adoption across all four farm sector (in years) and the peak adoption level for each sector (%).

	Poultry	Dairy	Pig	Beef_Sheep
Time to near-peak adoption (years)	15	17	17	19
Peak adoption level (%)	2	2	2	2

5.7.2 Comparison with online survey and 'face to face' 2nd Interview

Figure 11 shows the ADOPT comparison of scores for poultry farmers only between the online survey (blue) and the 2nd interviews with the Case Study farmers (one to one via phone/video). The scoring between the online and 2nd interview famers is consistent for most of the questions. The questions that have a score difference of greater than two are: Q12 How would you rate your knowledge about how to design planting trees to capture ammonia?; Q13 how common is tree planting to capture ammonia in your district; Q19 How large a profit disadvantage do you consider planting trees to capture ammonia would be on your farm in the future? (-3 to +4); Q20 How large an environmental disadvantage do you view planting trees to capture ammonia?; Q21 How large an increase in risk do you consider planting trees to capture ammonia (-3 to +4).

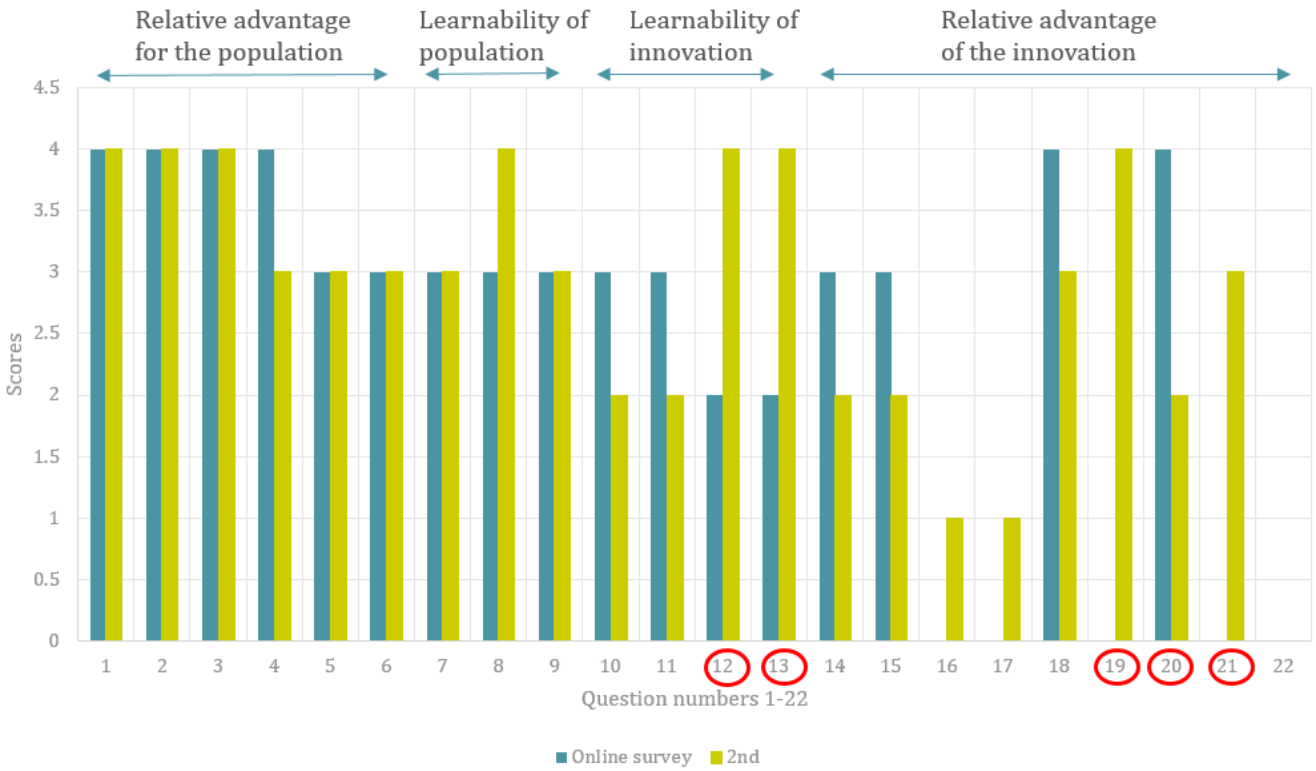

Figure 11: Difference in ADOPT between second interview and on-line survey using the results from the poultry farmers only. Questions with a score difference of 2 or greater are highlighted red. Where bars are missing an ADOPT score of zero. Note the order of the questions Q1-22 are represented as Q2-23 in the online survey (see Annex 4).

6 Predicted farmer adoption of tree planting to capture ammonia

An aim of this study was to determine if providing farmers with ammonia capture data from their farm, an ammonia calculator tool that estimated ammonia uptake by shelterbelts and guidance on planting shelterbelts could increase the probability of farmers adopting the practice of planting tree shelterbelts close the ammonia sources on their farm.

Parameterising the free trial version of the ADOPT model (https://adopt.csiro.au) with estimates from the first and second interviews (Appendix 3) results in a suggested increase from 45% uptake by farmer to 85% and a reduction in time to near-peak adoption levels from 18 years to 10 years. The 40% increase in likely uptake estimated after provide new knowledge to farmers is presented here only as indicative because the sample size is very small (n=4) and the data on ammonia capture was collected directly on the interviewees farm. It is likely that overall the UK poultry and dairy farming community the uptake and time to peak adoption would be different unless a very strong positive incentive via any land management scheme or via negative economic leavers aimed at reducing the impact of ammonia production from UK agriculture was instigated. The online survey bears this out as based on the survey a peak uptake of only 2% was realised and a 15 year time to near-peak adoption (similar to the 1st interviews).

7 Conclusions

The 22 questions of the ADOPT model was found useful in this study as they provided a structured framework that incorporated and highlighted factors, information and principles known to be important to adoption outcomes of agricultural practises in developed countries.

Analysis of the questions and the informal discussion at the first interview revealed that all farmers considered that they could not tell if tree planting was effective at capturing ammonia and were keen to see the data and learn more.

All interviewees made the point that each farming business was unique depending primarily on land type, land ownership, the age and succession strategy of the farmer, etc. and therefore they wished knowledge in order to make farm specific decisions.

Following presentation of ammonia data from their farms, the ammonia calculator and the guidance document, the farmers were convinced that their trees did in fact capture ammonia. The responses to the second interviews revealed farmers viewed the advantages of tree planting to capture ammonia more positively. Parameterised with the data from the first interview the ADOPT model estimates that 45% of farmers would take up the practice. However, if the positive attitude resulting from increased knowledge was replicated thought out the population the ADOPT model predicts that adoption of the practice would peak at 85% of the population. Time to near peak adoption level would reduce from 18 years to 10 years with increased knowledge. The online survey gave similar (often the same) ADOPT scores across the 22 questions but scored much lower represented by higher risk, lower knowledge and lower profit advantage. As a consequence the adoption peak level was only 2% with a 15-19 year time to near peak adoption period.

The farmers commented that woodland creation was multi-purpose and planting designs should have multiple purposes and considered incentive schemes should enable flexibility so farmers can maximise the benefit of tree planting to their specific environment and to fit their business objectives.

8 Acknowledgements

Jan Dick is very grateful to all the interviewees for giving so freely of their knowledge, opinions and time and for making the process fun. She learnt a great deal and was pleased that at least one farmer commented at the first interview *I wasn't looking forward to it but it has not been too bad.* While another ended the second interview positively commenting *thanks, it was great I like learning.*

How to cite this document: Dick, J & Bealey W.J. (2021) Farmers views on practicalities and farm business benefits of tree planting to capture ammonia from hen or dairy units (UKCEH Project: 07555; UKCEH, Wallingford).

9 Annex 1. Participant Information and Consent Sheet for semi-structured interviews

Ammonia Reduction by Trees project (ART)

You are involved the ART project and in addition to the collection of greenhouse gas data from your farm you have agreed, in principle, to be interviewed by the research team.

This *Participant Information and Consent Sheet* explains the procedure. Before you decide whether you wish to participate in the interviews, it is important that you read the information provided below. This will help you to understand why and how the research is being carried out and what participation will involve. Please contact Dr Jan Dick (jand@ceh.ac.uk), who will conduct the interview, if anything is unclear or you have any questions.

You can refuse and withdraw at any stage during the interviews. Please note that information from the interviews will be anonymised and incorporated into a single report of all participating farmers. Consequently, your views cannot be withdrawn after the interview is complete and the data analysed.

9.1.1 Who is conducting the research?

This project is a partnership between CSF Agricultural, Natural England, Environmental Agency the UK Centre for Ecology and Hydrology (UKCEH) and Forest Research. The key contacts from the project team are Philippa Mansfield, Natural England and Bill Bealely, UK Centre for Ecology and Hydrology.

9.1.2 Who is funding the research?

This project has been funded by Defra via Natural England

9.1.3 What is the purpose of the research?

Aims of ART project are:

- to provide evidence to help us target tree planting to reduce ammonia emissions from livestock housing impacting protected sites

- to get better field evidence of the effectiveness of trees shelter belts for ammonia capture

- to communicate messages to farmers and hear their views

- to improve ELMs grants

9.1.4 Do I have to take part?

No. Taking part in this knowledge sharing activity is completely voluntary and deciding to not take part will not disadvantage you in anyway. You are free to withdraw from the interview at any time without explanation or penalty. The best way to withdraw from the interview is to alert Dr Jan Dick conducting the interview that you wish your contributions removed. Withdrawing your contributions once they have been anonymised and summarised will not be possible.

9.1.5 What will happen if I take part?

Participating will entail two interviews of approximately one hour each (October 2020 and February 2021) scheduled at a time mutually agreed with Dr Jan Dick (weekend and evening interviews are possible if you desire).

The purpose of the interviews is to understand your motivation for tree planting on your farm and you perceptions of it in terms of farm business, environmental benefits and any issues, practicalities or problems needing to be overcome. Your feedback will also be gathered on the need and usability of the guidance and tool provided by UKCEH; suitability of the design for your farm including practicalities and any constraints that may affect the selection of tree species and final planting plan/location.

The interview is designed around 22 questions and you will be asked to provide a numerical score for each and a short narrative of your thoughts and reasons. The interview will be recorded to enable Dr Jan Dick to check when she writes the report that she is correctly representing the views you express. If individual quotes are used, they will not be attributable to an individual farmer.

The second interview following the training on the UKCEH tool and results of the ammonia measurements conducted on your farm will follow the same format.

9.1.6 Are there any risks in taking part?

There are no risks to taking part in the interview, which the research team can foresee. The research team are not part of the UK regulatory agencies.

9.1.7 What are the possible benefits of taking part?

There are no immediate direct benefits to taking part in this project; however, we hope that following the results of the ART project you will have a better understanding of the potential benefits of planting trees to capture the ammonia from your hen or diary enterprise. The interviews in part are designed to identify challenges and opportunities of farmers planning trees to capture ammonia from livestock housing.

9.1.8 Will my taking part in this project be kept confidential?

Yes - UKCEH will present the minimum, maximum and average scores of the participating farmers (hopefully 5) and summarise the main points raised without mentioning individuals. All output will be anonymised to ensure no identifiable data is made public. Dr Jan Dick will be managing your contact details to ensure you are invited to both interviews and will keep those contact lists secure. There will not be any records linking your contributions back to your name or contact details.

9.1.9 What will happen to the information I provide?

The information you provide will be captured electronically and via a recording of the interview. The data will be stored to support analysis and a future publication documenting this co-production process. We intend to archive the anonymised data for future research use; however, there will be no way for these data to be linked to project participants. If you wish to withdraw your contribution, this must occur during the interview, when UKCEH will still be able to identify your statements and remove them from the analysis. Once the report has been anonymised, it will not be possible to withdraw your contribution. If you are interested to access any of the results of the project, you can contact Dr Jan Dick (jand@ceh.ac.uk).

9.1.10 *Data Protection*

The personal data that will be collected and processed in this study are your name and contact details, solely for facilitating the arrangements for the interviews and will not be used for any analysis or reporting.

The UKCEH asserts that it is lawful for it to process your personal data in this project, as the processing is necessary for the performance of a task carried out in the public interest (contacting you to arrange interviews). Following the completion of the ART project (March 2021) Jan Dick will delete the file with your contact details.

The UKCEH respects your rights and preferences in relation to your data and if you wish to update, access, erase, or limit the use of your information, please let us know by emailing Dr Jan Dick (jand@ceh.ac.uk). Please note that some of your rights may be limited where personal data is processed for research, but these occasions do not relate to this project. If you wish to complain about the use of your information please contact the UKCEH's Data Protection Officer in the first instance (email: Quentin Tucker, Data Protection Officer quetuc@ceh.ac.uk). You may also wish to contact the Information Commissioner's Office (https://ico.org.uk/).

10 Annex 2. Invitation to second interview

From: Dick, Jan
Sent: 18 February 2021 20:36
To:
Subject: RE: Cumbria Farms - Ammonia and Trees - Farmer Interview Introduction

Dear

Following from our telephone conversation last November I am contacting you to arrange a convenient time for our second interview – I hope you are still willing to chat. Please drop me a line suggesting a suitable time when in the next two weeks would suit you (weekends and evening possible if that easier for you).

It has not been possible for Bill Bealey to arrange a workshop as originally planned to explain the ammonia calculator tool so he has created a video (accessed here https://www.farmtreestoair.ceh.ac.uk/ammonia-calculator--video) and general guidance advise which can be accessed here (https://www.farmtreestoair.ceh.ac.uk/sites/default/guidance/index.html) and a short report which I attach to this email that provides some specific data for your farm.

You can also access the calculator and guidance via the homepage https://www.farmtreestoair.ceh.ac.uk see below.

It would be great if you could read the attached and play with the Ammonia Calculator Tool before we chat. Bill has only provided data for a limited number of tree species for your farm but you may want to play and consider other species and adding a backstop (i.e. evergreen trees furthest from the shed) to see the increase of ammonia that could be captured in your situation. The tool is a prototype so I am sure you will have many comments to improve it ☺

Looking forward to hearing from you

Jan

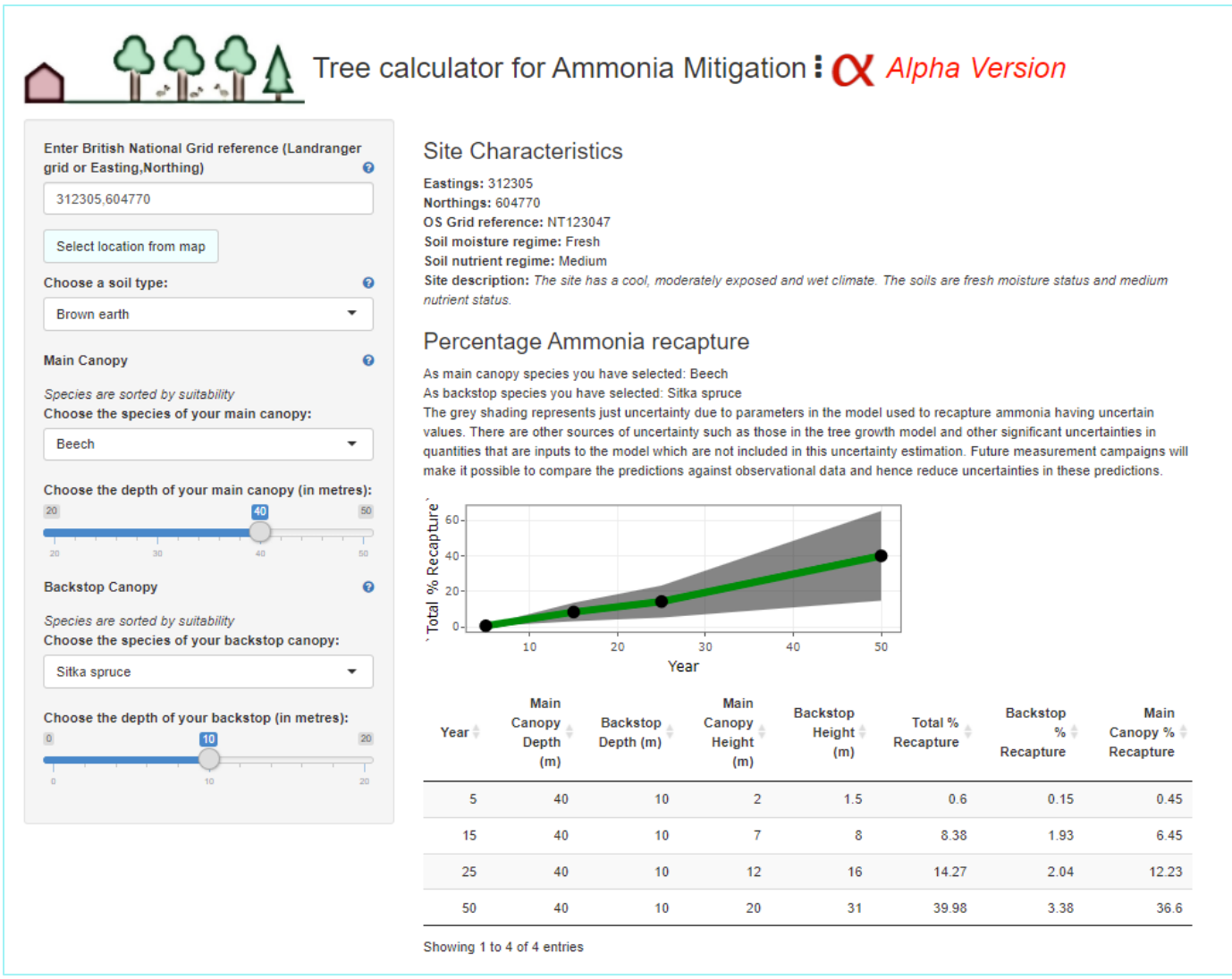

Figure 12: Ammonia tree calculator https://www.farmtreestoair.ceh.ac.uk/ammonia-reduction-calculator

11 Annex 3. Parameterisation of ADOPT model from interviews

The underlying data and two parameterisations of the ADOPT model, hosted by CSIRO in Australia (https://adopt.csiro.au/); dark green base model parameterisation and light green the improved scores follow the second interview (blank means model parameterisation not changed).

Q#	ADOPT Variable	Question	Farmers Score Interview #1 & #2										Mean Interview 1 (n=4)	ADOPT Parameters	Mean Interview 2 (n=4)	ADOPT Parameters
1	Profit orientation	How important is maximising profit a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	4		3		3		4				3.50	4.00	3.50	
2	Environmental orientation	How important is protection of the environment a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	2	5	5	5	2	4	5	3			3.5	3	4.25	4
3	Risk orientation	How strong is risk minimisation a motivation for you to plant trees to capture ammonia (1= zero 5= strong motivation)	3	3	4	5	1	5	4	3.5			3	3	4.13	4
4	Enterprise scale	If tree planting found to be beneficial would it benefit a major enterprise on your farm (1= very small enterprise 5 = major enterprise)	4		5		1		2				3	3	3.00	
5	Management horizon	Do you have a long-term management horizon (1= no i.e. less than 1 year, 5= yes i.e. more than 50 years)	5		5		5		2				4.25	4	4.25	
6	Short-term constraints	Do you have a severe short-term financial constraint that may influence you planting trees on your farm (1= yes, 5 = not an issue)	5		5		5		2				4.25	4	4.25	
7	Trialing ease	Do you think it would be possible to have a trail before fully committing to incorporating tree planting to capture ammonia for your hen or dairy enterprise (1=not trialable 5=Very easily trialable)	2	4	4	4	3	4	2	2			2.75	2	3.50	3
8	Practice complexity	Do you think it will be easy to evaluate the effects of tree planting on ammonia capture from your hen/dairy enterprise due to complexity of understanding the practice (which tree species to plant, the planting design etc.) (1= very difficult, 5= not at all difficult, easy, not complex)	3	4	1	4	4	5	2	4.5			2.5	2	4.38	4
9	Observability	Do you think the benefits of the woodland planting will be easily observed (1= Not observable at all, 5= Very easily observable)	4	5	1	2	4	4	1	3.75			2.5	2	3.69	3
10	Advisory support	How much do you rely on farm advisors (1= Almost never use a farm advisor 5 = often use an advisor)	1		2		1		5				2.25	2	2.25	
11	Group involvement	Are you involved in any groups that discuss farming (1=no only my mates , 5= yes several industry groups and/or associations that discuss aspects of farming that interest me)	1		5		2		1				2.25	2	0.00	
12	Relevant existing skills & knowledge	How would you rate your knowledge about how to design planting trees to capture ammonia (1- currently have no skill or knowledge 5= I do not need any new skills or knowledge to design effect tree planting to capture ammonia)	1	4	4	4	2	4	1	4			2	2	4.00	4
13	Practice awareness	How common is tree planting to capture ammonia in your district (1= tree planting to capture ammonia never used or trailed in my district 5= common I am fully aware of the practice/trail in my district)	1	5	2	3	2	3	2	4			1.75	2	3.75	4
14	Relative upfront cost practice	How large an investment would you judge designing and planting trees to capture ammonia would be on your farm (1= large investment 5=no initial investment required)	4	3	2	4	3	3	1	1			2.5	2	2.75	
15	Reversibility practice	How reversible would you judge planting trees on the farm to capture ammonia from your chick or dairy enterprise (1= not reversible at all 5= very easily reversed)	3	4	2	3	3	4	2	2			2.5	2	3.25	
16	Profit benefit in years that it is used	How large a profit disadvantage do you consider planting trees to capture ammonia would be on your farm (-3= large profit disadvantage in years that it is used +4 = Very large profit advantage in years that it is used	0	3	4	4	3	2	-2	-3			1.25	1	1.50	
17	Profit benefit in future	How large a profit disadvantage do you consider planting trees to capture ammonia would be on your farm in the future (-3= large profit disadvantage in years that it is used , +4=Very large profit advantage in years that it is used (+ 4)	-1	1	4	4	3	4	-2	-3			1	1	1.50	
18	Time for future profit benefits to be realized	How soon do you think the profit benefits would be realized (1= 1 year, 2=2 years 3= 4 years, 4= 8 years 5= 16 years or more)	1	4	2	4	1	5	5	5			2.25	1-2yrs	4.50	
19	Environmental impact	How large an environmental disadvantage do you view planting trees to capture ammonia (-3= Large environmental disadvantage, +4= Very large environmental advantage	3	4	4	4	4	4	4	3			3.75	3	3.75	4
20	Time for environmental impacts to be realized	When do you expect the environmental impacts would be realized (1= 1 year, 2=2 years 3= 4 years, 4= 8 years 5= 16 years or more)	3	4	3	4	4	3	1	1			2.75	3-5yrs	3.00	
21	Risk	How large an increase in risk do you consider planting trees to capture ammonia (-3= Large increase in risk , +4=Very large reduction in risk	3	4	4	4	4	4	4	3			3.75	2	3.75	3
22	Ease and convenience	How large a decrease in ease and convenience in your work is associated with tree planting to capture ammonia (-3= Large decrease in ease and convenience , +4= Very large increase in ease and convenience (+ 4)	-2	2	0	2	0	0	1	-2			-0.25	0	0.50	

12 Annex 4: Online Survey: Planting trees on the farm to reduce ammonia

Page 1: About this survey

About this survey:

You are invited to take part in this survey to inform future farm advice and support for treeplanting on farms to improve air quality through using treebelts to capture ammonia. The majority of the question are tick-box type and should take you 10-15 minutes to complete. No location or personal details are collected within the survey.

Treebelts planted downwind of livestock housing have been shown to capture ammonia by around 5-20% depending on the age, species, height and design of the treebelt A tooland guidance have already been developed and can be found at the Farm Trees to Air website.

This survey is part of the Ammonia Reduction by Trees (ART) project to gather farmer'sviews on how tree shelter belts/woodlands fit specifically for ammonia capture with the farm business, pros/cons and practicalities, constraints and farmer motivations for tree planting for ammonia capture.

We are aware that trees are planted on farms for many reasons, but here we focuson ammonia capture with trees.

The ART project partners include Natural England (Catchment Sensitive Farming), theUK Centre of Ecology and Hydrology, Forest Research, Environment Agency, Lakes Free Range Eggs company and Cumbria Farm Environment Partnership (CFEP).

The ART project partners have carried out extensive ammonia monitoring and measurements on farms in Cumbria to testing how effective tree shelter belts and woodlands are for capturing ammonia emissions from farming. The evidence from fieldmeasurements, survey and farm case studies will be used to develop tools, advice andgrant options for farmers through environmental land management schemes.

Page 2: Your operations

1. What are your farming livestock operations. Many options can be checked

- ☐ Poultry - Layers
- ☐ Poultry - Broilers
- ☐ Poultry - Pullets
- ☐ Dairy
- ☐ Beef
- ☐ Pig - breeding sows
- ☐ Pigs - fatteners
- ☐ Other

1.a. If you selected Other, please specify:

Page 3: Relative advantage?

2. How important is maximising profit a motivation for you to plant trees to capture ammonia [1=Zero motivation | 2=Very little motivation | 3=Some motivation | 4=A strong motivation | 5=An extremely strong motivation]

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

3. How important is protection of the environment a motivation for you to plant trees to capture ammonia? [1=Zero motivation | 2=Very little motivation | 3=Some motivation | 4=A strong motivation | 5=An extremely strong motivation]

- 1
- 2
- 3
- 4
- 5

4. How strong is risk minimisation a motivation for you to plant trees to capture ammonia? [1=Zero motivation | 2=Very little motivation | 3=Some motivation | 4=A strong motivation | 5=An extremely strong motivation]ion]

- 1
- 2
- 3
- 4
- 5

5. If tree planting for ammonia mitigation is found to be beneficial would it benefit a major enterprise on your farm? [1= very small enterprise to 5 = major enterprise]

- 1
- 2
- 3
- 4
- 5

6. Do you have a long-term management horizon? [1=no i.e. less than 1 year | 2=yes i.e. 5-10 years | 3=yes i.e. 10-20 years | 4=i.e. 20-50 years | 5=yes i.e. more than 50 years]

- 1
- 2
- 3
- 4
- 5

7. Do you have a severe short-term financial constraint that may influence you planting trees on your farm for ammonia mitigation? [1=yes to 5=not an issue]

- 1
- 2
- 3
- 4
- 5

Page 4: Learnability characteristics

8. Do you think it would be possible to have a trial before fully committing to incorporating tree planting to capture ammonia for your hen or dairy enterprise? [1=not trialable | 2=trialable, but difficult | 3= trialable with some modifications | 4=easily trialable | 5=Very easily trialable]

- 1
- 2
- 3
- 4
- 5

9. Do you think it will be easy to evaluate the effects of tree planting on ammonia capture from your hen/dairy enterprise due to complexity of understanding the practice (which tree species to plant, the planting design etc.) ? [1= very difficult | 2=difficult | 3=difficult but can be overcome with guidance | 4=quite easy | 5= not at all difficult, easy, not complex]

- 1
- 2
- 3
- 4
- 5

10. Do you think the benefits of the woodland planting for ammonia capture will be easily observed? [1=Not observable at all | 2=partly observable | 3=observable for some benefits | 4=quite observable | 5=Very easily observable]

- 1
- 2
- 3
- 4
- 5

Page 5: Specific influences on the ability to learn about the practice

11. How much do you rely on farm advisors? [1=Almost never use a farm advisor | 2=Somewhat infrequently | 3=Occasionally | 4=Somewhat frequently | 5=very often usean advisor]

- 1
- 2
- 3
- 4
- 5

12. Are you involved in any groups that discuss farming? [1=no only my friends and/or neighbours | 2=yes but only one local group | 3=yes several local groups | 4=yes butlocal

and national groups | 5= yes several industry groups and/or associations that discuss aspects of farming that interest me]

- 1
- 2
- 3
- 4
- 5

13. How would you rate your knowledge about how to design planting trees to capture ammonia? [1=currently have no skill or knowledge | 2=very limited knowledge | 3=someknowledge | 4=a fair bit of knowledge | 5=I do not need any new skills or knowledge to design effect tree planting to capture ammonia]

- 1
- 2
- 3
- 4
- 5

14. How common is tree planting to capture ammonia in your district? [1=tree planting to capture ammonia never used or trialled in my district | 2=i've heard of one case | 3=I've heard of a couple of trialled | 4=fairly common in my district | 5=common I am fully awareof the practice/trail in my district]

- 1
- 2
- 3
- 4
- 5

Page 6: Relative advantage of the practice

15. How large an investment would you judge designing and planting trees to capture ammonia would be on your farm? [1=large investment | 2=medium investment | 3=small investment | 4=very small investment | 5=no initial investment required]

- 1
- 2
- 3
- 4
- 5

16. How reversible would you judge planting trees on the farm to capture ammonia from yourlivestock enterprise? [1= not reversible at all | 2=very difficult | 3=difficult | 4=quite easily reversed | 5=very easily reversed]

- 1
- 2
- 3
- 4
- 5

17. How soon do you think the profit benefits would be realized? [1=1 year | 2=2 years | 3=4years | 4=8 years | 5=16 years or more]

- 1
- 2
- 3
- 4
- 5

18. When do you expect the environmental impacts would be realized? [1=1 year | 2=2 years | 3=4 years | 4=8 years | 5=16 years or more]

- 1
- 2
- 3
- 4
- 5

19. How large a profit disadvantage do you consider planting trees to capture ammonia wouldbe on your farm? [-3= large profit disadvantage in years that it is used +4 = Very large profit advantage in years that it is used]

- -3
- -2
- -1
- 0
- +1
- +2
- +3
- +4

20. How large a profit disadvantage do you consider planting trees to capture ammonia wouldbe on your farm in the future? [-3= large profit disadvantage in years that it is used , +4=Very large profit advantage in years that it is used]

- -3
- -2
- -1
- 0
- +1
- +2
- +3
- +4

21. How large an environmental disadvantage do you view planting trees to capture ammonia? [-3= Large environmental disadvantage, +4= Very large environmental advantage]

- -3
- -2
- -1
- 0
- +1
- +2
- +3
- +4

22. How large an increase in risk do you consider planting trees to capture ammonia? [-3=Large increase in risk , +4=Very large reduction in risk]

-3	-2	-1
0	+1	+2
+3	+4	

23. How large a decrease in ease and convenience in your work is associated with tree planting to capture ammonia? [-3= Large decrease in ease and convenience , +4= Very largeincrease in ease and convenience]

-3	-2	-1
0	+1	+2
+3	+4	

Page 7: Planting trees for other reasons

24. Would you consider planting a tree shelter belt on your farm for other benefits (apart from ammonia reduction)?

25. What benefits would you expect to see from planting trees on your farm? (includefarm business, environmental benefits and other perceived benefits).

26. What would motivate you to plant a tree shelter belt or woodland on your farm?

27. Is there anything else you would like to tell us? Please add below.

Page 8: Final page

Many thanks for taking part!

BANGOR
UK Centre for Ecology & Hydrology
Environment Centre Wales
Deiniol Road
Bangor
Gwynedd
LL57 2UW
United Kingdom
T: +44 (0)1248 374500
F: +44 (0)1248 362133

EDINBURGH
UK Centre for Ecology & Hydrology
Bush Estate
Penicuik
Midlothian
EH26 0QB
United Kingdom
T: +44 (0)131 4454343
F: +44 (0)131 4453943

LANCASTER
UK Centre for Ecology & Hydrology
Lancaster Environment Centre
Library Avenue
Bailrigg
Lancaster
LA1 4AP
United Kingdom
T: +44 (0)1524 595800
F: +44 (0)1524 61536

WALLINGFORD (Headquarters)
UK Centre for Ecology & Hydrology
Maclean Building
Benson Lane
Crowmarsh Gifford
Wallingford
Oxfordshire
0X10 8BB
United Kingdom
T: +44 (0)1491 838800
F: +44 (0)1491 692424

enquiries@ceh.ac.uk

www.ceh.ac.uk