Silvopasture: a sustainable method to improve soil quality and productivity on farms in the North-West region of Ireland.

Rachel Connolly

The Research Project is submitted to Dundalk Institute of Technology in fulfilment of the requirements for B.Sc (Hons) in Sustainable Agriculture

DAFM Agriculture, Food and Animal Health
School of Health and Science

Principle Supervisor: Dr. Norma O'Hea

May 2020

1. Table of Contents

Contents

2. Table of Figures

3. Abstract

The FAO (2015) define agroforestry as a 'collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals'. The five main agroforestry practices that are recognised in the EU include riparian buffer strips, forest farming, home gardens and silvopastural and silvoarable systems (Mosqura-Losada et al. 2018).

The objective of this thesis was to obtain a greater level of understanding of agroforestry and its role in improving marginal land, with particular focus on farmer awareness of this practice in the North-West region of Ireland. The thesis aimed to determine factors which may restrict the uptake of agroforestry, and identify actions that could be taken to increase involvement. Another objective was to compare land occupied by agroforestry with grassland.

The survey distributed to farmers proved there is an appetite for agroforestry in the North-West of Ireland. However, work must be done by the government and the Department of Agriculture, Food and the Marine (DAFM) to incentivise this and make it attractive to those interested. More information must be made available as a lack of knowledge on the topic currently exists. Completing a soil sample analysis was very beneficial as it presented clear differences in the soils obtained from silvopasture and grassland sites. Silvopasture was superior in a number of areas including moisture content, porosity and earthworm populations. It was very evident that incorporating silvopasture into a grassland region can provide many benefits to the area.

Inconclusive of all data obtained, it is apparent that the presence of silvopasture provides the area with many benefits in comparison to grassland swards. Farmers in the North-West are open to considering silvopasture as a method of land and productivity improvement but additional funding and incentives are required alongside information sources.

4. Declaration of Originality

I hereby declare that this project entitled "Silvopasture: a sustainable method to improve soil quality and productivity on farms in the North-West region of Ireland" is entirely my own work.

__Rachel Connolly_____

Student Name

Date: 30th April 2021

5. Acknowledgements

First and foremost, I would like to take this opportunity to extend my sincere thanks to my thesis supervisor, Dr. Norma O'Hea. I am most thankful for the knowledge and expertise shared by Norma and the support, encouragement and attention given by Norma in helping me complete this project.

I would also like to express my gratitude to Prof. Jim McAdam who granted me permission to take samples from the grassland and silvopasture sites situated in ABFI Deerpark Farm. This allowed me to access primary research to present in my thesis and the findings were very beneficial.

I also offer thanks to the farmers who took part in my thesis by completing the surveys distributed online. Their cooperation made this research possible and for that I am very grateful.

Finally, I would like to thank the staff and lecturers in Dundalk Institute of Technology and Ballyhaise Agricultural College for all their help with this thesis and over the past four years.

My time in college completing this course has been very enjoyable and entertaining to say the least. As the saying goes; I was here for a good time, not a long time.

6. Introduction

Agroforestry was chosen as the topic for this thesis given its importance and the requirement for sustainable systems of production within agriculture is needed now more than ever.

Ireland's tree cover currently stands at 11% of the total land area. The Irish government plan to increase this figure to 18% by 2040 (Teagasc, 2017b). Given that tree cover throughout the country has risen by only 1% since 2006 (Teagasc, 2012), it is unlikely this target will be achieved unless greater focus is placed on increasing the number of trees planted in the near future.

Co. Leitrim currently stands as the county with the largest tree cover with 10.7% of it under forestry (Teagasc, 2020a). However, the planting of non-native Sitka Spruce under the Afforestation programme has caused much anger and disapproval among local communities, due in part to the loss of land for housing and environmental concerns (Carroll, 2019, Warnock, 2020).

In order for the government to meet the 18% tree cover target, the reluctance felt by those in the areas being planted must be removed and met with confidence and optimism instead. Within this thesis, the literature review will introduce agroforestry, outline the different forms of agroforestry and the benefits it provides. Agroforestry on a global level will be discussed and a number of case studies will be explored. Finally, the literature review will examine issues surrounding the practice and the schemes available within the EU and Ireland.

Following issues observed in regards to agroforestry, both qualitative and quantitative research was conducted based on the findings within the literature review. The field research compared soil characteristics between silvopasture sites and grassland sites located beside each other to identify if there were advantages to implementing silvopasture. A survey was also distributed to farmers in the North-West region of Ireland to identify the overall consensus towards agroforestry and what actions the government could take to increase Ireland's tree cover to meet the 2040 goal.

Data gathered from the soil analyses and questionnaire is demonstrated using charts and graphs, analysed and elucidated further into the thesis.

7. Literature Review

7.1 Introduction

Agriculture was the cause of one third of greenhouse gas emissions in Ireland in 2018 (Fig. 1). Most emissions derive from methane gas, a by-product of cattle rumination and cattle manure, and nitrous oxide which is released from fertilisers and cattle manure (Carbon Collective, 2018). In a bid to reverse environmental damage and prevent further global warming and climate change destroying more vulnerable natural resources, sustainable agricultural systems must be developed. One such system is agroforestry. Agroforestry is the method of linking agriculture and forestry which benefits both enterprises. Agroforestry allows farmers the option of grazing and harvesting silage off the land where trees exist in the same area (Teagasc, 2017b). There are numerous benefits associated with agroforestry, such as improvement in water quality, soil properties and greater carbon sequestration (Montagnini and Nair, 2004).
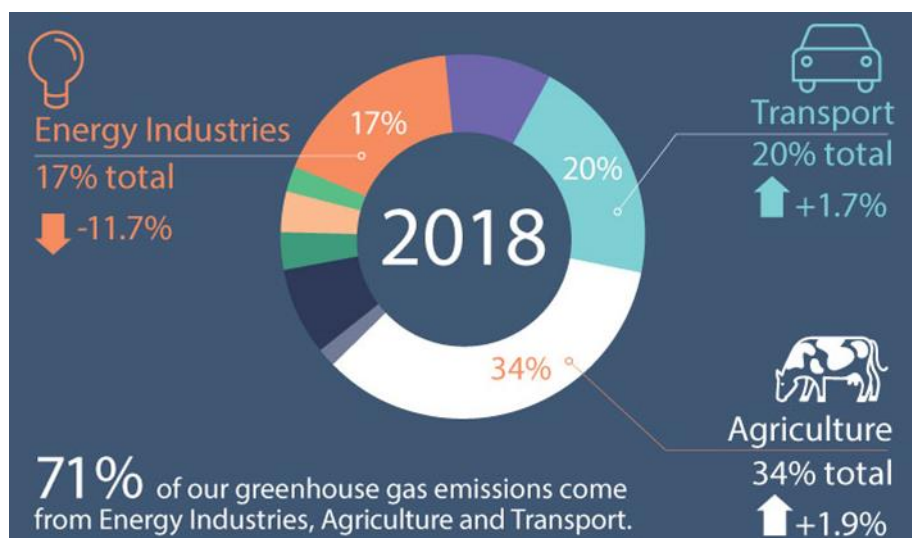
Fig. 1. Contributors to greenhouse gas emissions in Ireland (EPA, 2018).

7.2 Forms of agroforestry

The EU promotes five main agroforestry systems which are riparian buffer strips, forest farming, home gardens and silvopastural and silvoarable systems (Mosqura-Losada et al. 2018). Riparian buffer strips are the planting of forestry along the edges of lakes, rivers and other waterbodies. Forest farming is the cultivation of non-wood products. Crops like shiitake mushrooms are grown and harvested in forest farming systems (USDA, 2014). Home gardens are small plots of land around or in close proximity to dwellings. They typically consist of a variation of crops including fruit and vegetables, herbs, spices, medicinal and visually appealing plants (Galhena et al., 2013). Silvopasture integrates grazing livestock in the same area as the trees are planted whereas silvoarable is the practice of planting trees at a distance to allow for the growing of arable crops too (Wilson, 2019).

7.3 Benefits of implementing silvopasture

7.3.1 Farm benefits

Benefits of implementing agroforestry on a farm include the production of renewable energy, reduction in usage of unsustainable fossil fuels, improved drainage and prevention of nutrient run-off on sloped land. Land production per hectare is also increased due to the presence of both forage and trees. Costs attached to land management are reduced as less fertiliser and general machinery work is required (NSA, 2018). Diversifying into agroforestry increases the farmers income as grant aided

schemes are available at farmers disposal. Off-farm sales are also possible if tree products are sold i.e., bedding, mulch or logs for fire (Raskin, 2019).

7.3.2 Biodiversity benefits

Agroforestry has proven to create excellent habitats, improve biodiversity and can potentially enhance the landscape in which it is planted on (DAFM, 2018). Research carried out on an 8-year-old silvopasture system containing Ash trees in Loughgall, Co. Armagh, showed that biodiversity flourished here in comparison to other systems i.e., permanent grasslands (McAdam et al, 2006). The report stated a number of findings including:

1. More spiders were obtained in the silvopasture site than in grassland or woodlands (Johnston, 1996).
2. A greater number and diversity of Carabid beetles were found by Cuthbertson and McAdam (1996) and Whiteside et al. (1998).
3. In the silvopasture, the number of young earthworms was greater than that in a pasture (Whiteside et al., 1998).
4. More birds were sighted by Toal and McAdam (1995) on both lowland and upland silvopasture in the summer and winter months than in grasslands or in forests.

7.3.3 Environmental benefits

Numerous studies have proven that silvopasture is the superior option for farming sustainably when compared against grassland farming (Project Drawdown, 2015). Research has shown silvopastural systems can sequester 5-10 times more carbon than grassland pastures. It is estimated 1-2t carbon/ha/year is sequestered by grassland whereas silvopasture sequesters 3-8t/ha/year. Lands dedicated to silvopasture have the capacity to store approx. 250 t/ha whereas grasslands are only capable of retaining 30-50t/ha of carbon (Toensmeier, 2016). In 2016, 2,709,200 hectares of the 4,883,600 hectares under agriculture in Ireland occupied permanent pasture. If 20% of this land was converted into silvopasture, a further 4t/ha/yr. of carbon would be sequestered, resulting in an additional 2,167,360 tonnes of carbon being stored in the land each year. In addition to this, growing trees convert consumed carbon into wood. Trees are also excellent at improving water quality. Trees absorb suspended solids in rivers and streams, and collect nitrogen and phosphorus run-off, preventing them from entering waterways. By slowing down water flow, trees often prevent mass flooding during times of increased waterfall.

7.3.4 Livestock benefits

Generally, trees contain more micronutrients and tannins than grasses so therefore, animals grazed in forestry areas are less likely to become deficient in certain micronutrients. This can also reduce parasite related problems. In times of drought and increased heat, trees provide animals with forage whereas grass will quickly scorch. Providing shelter against the harsh elements, this prevents a drop in productivity that would otherwise occur. One particular study carried out showed a positive impact in the relationship of a farmer and his cows as the animals were more content in areas where forestry was present (Raskin, 2019).

Benefits also exist for sheep. Temperatures in forested areas can be up to 5 degrees warmer than bare areas, giving farmers the option to lamb outdoors. This provides extra protection to young weak lambs, increases lamb survival rates and improves maternal bonding and colostrum intake (NSA, 2018). In a study conducted in Australia, a lamb mortality rate reduction of 50% was witnessed in areas where tree shelter was available for the lambs (Raskin, 2019). Shade during warmer months also reduces ewe energy expenditure in regulating body temperature. Improved feed conversion ratios have also been observed.

Agroforestry improves animal health. Trees increase land drainage providing a drier area unsuitable for snail survival and therefore liver fluke issues are prevented. Cold weather leads to teat lacerations which, too, are avoided through the shelter trees provide. Lower mastitis incidents are a knock-off effect of this (NSA, 2018). It is estimated lameness costs the Irish sheep industry €5 million each year (Agriland, 2018). As wet soils are one of the main causes, tree presence increases land drainage and prevents the soil holding water, therefore reducing lameness (NSA, 2018).

7.4   Agroforestry worldwide

Just under one billion hectares of agricultural land holds a tree cover of ≥10%. A further 1.6 billion hectares has the capacity to be transformed into agroforestry in the future (Nair and Garrity, 2012). Although a study carried out by Zomer et al. (2016) mentioned the regions with the highest tree cover (over 45%) included areas in Asia, America and Africa, agroforestry is most commonly carried out in the tropics and sub tropics. Ortolani (2017) describes, how in tropical regions, the standard intensive agricultural practices are often unsuccessful at providing the population with the required security for their produce (i.e., coffee, bananas etc) due to international trade dictating prices. Agroforestry, however, is more productive as it is less sensitive to international trade trends and also suppresses deforestation, mitigates global warming and maintains soil structure.

7.5   Research reports

7.5.1 Global research

Udawatta et al. (2009) assessed how the soil enzyme activity and physical properties in a watershed compared when managed under four different systems- agroforestry (using pin oak, grass buffer, grass waterway and crop area) – in the USA. They compared the four systems for soil bulk density and water-stable aggregates, soil carbon and soil enzyme activities. The crop area had the lowest bulk density with a 0.10g cm^3 difference between it and agroforestry. Agroforestry had a significantly higher impact on water stable aggregates, so the soil had a greater ability to resist structural change, hence less soil erosion would occur when agroforestry is planted in the area. Soil carbon was also higher in the area planted with trees. A watershed with 10% grassland pastures and agroforestry would contain just under 23Mt Carbon/ha in the top 10cm of the soil. This translates to 1.8% more carbon compared with a single crop system. In terms of soil enzyme activities, agroforestry had a greater rate of activity for three of four enzymes tested when compared to the crop area. Overall agroforestry had a significant positive impact on the quality of soil within a decade of being planted.

7.5.2 European research

Mosquera-Losada et al. (2018) studied how agroforestry could be used as a management tool to mitigate climate change. It evaluated the impact and benefits of the presence of silvopasture, silvoarable, home gardens, forest farming and riparian buffer strips. Silvopastural practices are present on 12% of areas occupied by grassland throughout Europe, with the majority located in Southern European countries. It does exist in Northern European countries but huge potential is still present for growth in countries like Ireland. The authors stated that of the 19.77 million hectares of agroforestry in Europe, 90% of this was in the form of silvopasture and existed primarily in Southern Europe.

In southern countries practicing silvopasture, goats and sheep reap the most benefits as the vegetation supplies feed in times of drought and extends the grazing season due to the shade it provides (Mosquera-Losada et al., 2018). In some countries, silvopasture systems are integral to promote rural community stabilization and prevent the abandonment of dwellings and farms which can lead to devastation as was seen to occur in 2006 when bush fires broke out on deserted land in Galicia, the North-Western region of Spain. The prevention of these wild fires is essential to prevent further emission of damaging gases. Another benefit stated is the impact silvopasture has when

planted amongst herbaceous plants. Less soil erosion occurs due to the constant presence of non-wood stemmed plants which would be incapable of surviving without the presence of the shade supplied by the trees. This also increases migration of carbon in the area due to the increased addition of organic matter. Animals farmed in these ecosystems encourage nutrient cycling as forage consumed is converted into nutrients for the land. This reduces the requirement of inorganic fertilisers (Mosquera-Losada et al., 2018).

7.6   Current issues regarding agroforestry in Ireland

The Republic of Ireland has only 11% of forestry cover nationwide, leaving it the second lowest in the EU. The average tree cover throughout the EU is currently 30% (DAFM, 2017). A goal of 18% forest cover in Ireland by 2040 has been set by the Government. In order to reach this target, more farmers need to diversify into agroforestry and 8,000 hectares per annum needs to be planted (Carroll, 2019). As part of the Conifer Afforestation Programme 2014-2020 ran by the Government, Leitrim was chosen for blanket afforestation by Sitka Spruce. However, this planting caused outrage within the local community for a number of reasons. For example, in Kiltyclogher Co. Leitrim, the planting of trees made the land unavailable for residential and unusable for farming purposes. The lower population here then resulted in the closure of a school and other local amenities. The *Save Leitrim* campaign argues that it is not opposed to farmers planting their own land and integrating agroforestry by planting native species, but given that over 18% of Leitrim is already occupied by trees, the planting of blanket non-native forests is unnecessary and would spoil the area (Save Leitrim, 2020).

Carroll (2019) in The Guardian argued that Ireland is planting the wrong species of trees. Although a fast growing and tall tree, Sitka Spruce is indigenous to North America and does not provide the same habitat that trees native to Ireland do. The *National Forestry Accounting Plan 2021-2025* (DAFM, 2019) stated that Ireland's method of planting trees could be a source of emissions rather than acting as a carbon sink if the forests are managed incorrectly. Although trees absorb carbon and reduce carbon emissions to the atmosphere, soil disturbance caused by afforestation and tree-felling causes a large release of carbon from the soil.

The DAFM and Government are aware a more sustainable way of increasing Ireland's forest cover needs to be developed. This is where silvopastural systems could play an integral role.

7.7   Schemes and initiatives to support the adoption of agroforestry practices

7.7.1 European Union

Agroforestry is supported by the current Common Agricultural Policy (CAP) 2014-2020 under Pillar II. Article 23 in the new Rural Development Programme is designated to agroforestry and the systems which can be practiced to support the inclusion of agroforestry at farm level. Currently, those who enrol in agroforestry practices receive support for the establishment and maintenance of the plantations for five years, at an 80% rate for eligible items. Payments are given on a land area basis. The size of plantation required for this scheme is dictated by each Member State as is the approach taken to implement it (EURAF, 2020).

7.7.2 Ireland

The *Forestry Programme 2004-2020* (DAFM, 2014) stated that a forest cover of 18% by mid-century is a primary objective. Currently four schemes exist to encourage farmers towards planting land. These schemes include Afforestation, Establishment of Native Woodlands, Forestry for Fibre, and Agroforestry (Conroy, 2020). Under these schemes, 80% of eligible costs are paid. Grants of €6,220/ha with an annual premium of up to €660/ha are available for scheme participants (O'Brien, 2019).

The rate of payments is allocated on a fixed grant basis. The duration of the payments is five years and covers the cost of maintenance.

7.8 Overview

Agroforestry has many benefits for farmers, livestock, soil and the environment but is not widely practised in Ireland. This project will examine farmers perceptions to agroforestry, with the main focus on silvopasture to identify factors that are making farmers reluctant to plant trees on their land and how to overcome this. Using an experimental trial, silvopasture sites will be compared with adjacent grassland pastures for a range of soil characteristics, and soil benefits within the silvopasture, if any, will be identified.

8. Methodology

8.1 Introduction

With the fundamental areas of agroforestry and silvopasture examined in the literature review, the purpose of the experimental work was to assess key differences and superiorities that exist in the silvopasture site against the grassland site. The questionnaire was designed to collect data from farmers in regards to implementing silvopasture in the North-West, areas that may be restricting its growth and identify methods to improve this.

8.2 Site description

Deerpark Farm is located in Lough Gall, Co. Armagh and is operated by the Agri-Food and Biosciences Institution (AFBI)

Loughgall is one of seven sites owned and managed by AFBI in Northern Ireland. This lowland farm, approximately 30m above sea level, spans across 124.08 hectares and is split into three blocks: Church field (25.08ha), Manor Estate (51.68ha) and Deerpark Farm (47.32) where the soil sampling and earthworm population was carried out. The farm is located on Drumlins and is south facing. The area receives approximately 816mm of precipitation annually and has an average monthly temperature of 3.4℃ to 15.1℃. The farm lies on Carboniferous Limestone till parent material and the soil type here is brown earth, red limestone till.

A silvopasture experimental site was established at AFBI Loughgall in 1988. The grassland fields were reseeded in 1988 (plate. 1). *Lolium perenne* (Barlenna and Morenne), a low growing perennial ryegrass, was sown at a rate of 30kg/ha. In 1989, in the silvopasture research sites, trees were planted at a density of 400 trees/ha. The trial sites in Loughgall were chosen randomly with 18 experimental plots, each 1 hectare in size, divided into three blocks. Each block consisted of a control field (grassland with no trees present) and fields with either sycamore or ash trees growing. Trees were planted at 100 and 400 trees/ha. Hedgerows run along the boundary of the trial site which create an additional habitat for biodiversity present.

8.3 Soil sampling

Each soil sample was taken from a depth of 100mm and from several areas of the fields.

In the silvopasture site, samples were taken randomly around each of three 1ha site (beside a random tree, 2 metres from the tree and 4 metres from the tree). This was carried out three times in total using other trees selected randomly in two other silvopasture sites to ensure a good representation of the area was achieved.

In three grassland sites adjacent to the silvopasture sites, soil samples were collected using the 'W sampling method'. The fields were walked through in a 'W' shape and samples were collected using the soil corer at 1.5m distances. Areas of poaching, field entrances and drinking troughs were avoided. Soil was mixed and placed into a labelled plastic bag.

8.4 Determination of earthworm population

Capsaicin solution was prepared 1 day prior to fieldwork. 38g of ground mustard was placed into a container and 100ml of tap water was added. The container was sealed with the plastic lid and inverted continuously for 2 minutes to ensure the water and mustard was mixed thoroughly. The container was set aside to rest for 24 hours. The mustard solution was diluted with 4 litres of tap water in a large 12L bucket. It was then divided into 4L bottles for easy transport and handling. The bottle was inverted a few times to mix the solution. In both the agroforestry and pasture sites, a quadrat was randomly thrown onto the ground. Any leaves, branches or stones present within the quadrat area

were removed. The mustard solution was mixed again before being poured within the quadrat. The quadrat area was then observed for 5 minutes as earthworms began appearing. After all earthworms present in the sample area had emerged from the soil, they were counted (Jove, 2021) (Pelosi et al., 2020).

8.5 Soil sample preparation

Methods for soil sample preparation and laboratory analysis followed methods in Lynch (2020) and DkIT (2020).

Soil samples were placed in individual, clean trays. Surface vegetation, roots, large stones and pebbles were removed from all samples. The soil was mixed and formed into a cone. It was then divided into three equal sections.

8.6 Calculation of soil moisture content

A crucible was weighed to 3 decimal places. It was filled with field moist soil and reweighed. It was placed in the oven at 105°C for 24 hours. It was then reweighed. Soil moisture was calculated using the following equation.

Percentage moisture = <u>Weight of fresh soil (-crucible weight) - weight of dry soil (- crucible weight)</u> x 100

Weight of dry soil

8.7 Measurement of soil pH

A clean 100ml beaker was taken and filled to the 50ml mark with field moist soil. Distilled water was added until it reached the 100ml mark and then stirred to mix the solution. Following calibration of the meter with pH4 and pH7 buffer solutions, the pH probe was rinsed with distilled water and placed in the first soil solution. Once the meter had stabilised, the pH reading was recorded. The remaining samples pH were recorded using the same method.

8.8 Soil porosity

The beaker containing $50cm^3$ soil from the previous experiment was placed on a balance and set to zero. Tap water was added slowly to the beakers. Once the soil pores were full with water, the addition of water was stopped. The soil was left to sit for a few minutes to allow all pores to fill with water. Excess water present on the soil was removed. The weight of the beaker with soil plus water was recorded. The volume of water in the soil was then calculated using the following calculation:

% Soil porosity = (cm^3 added water/50 cm^3 soil) *100

Note: 1 mg water = 1 cm^3 water.

8.9 Questionnaire methodology

A questionnaire was constructed using SurveyMonkey and was distributed to farmers in the North-West of Ireland via email. The objective of this was to understand farmers perceptions towards agroforestry, silvopasture in particular, and why uptake of silvopasture has been low in this region. Options that would possibly increase interest and uptake of planting trees on farms was explored.

A copy of the survey, the participation consent from and information leaflet are in the Appendix.

8.10 Questionnaire analysis

A total of 51 responses were collected. Data were inputted and analysed using Microsoft Excel. Descriptive statistics and other analyses including a t-Test were used to summarise experimental data.

9. Results

9.1 Questionnaire

The following information presents an analysis of the data gathered from the online survey.

The majority of respondents (> 35%) own/manage 51-100 acres. Just under a quarter own or manage 101-150 acres, under 20% farm on 1-50 acres. Just over 20% also manage or own farms over 151 acres (Fig.2).
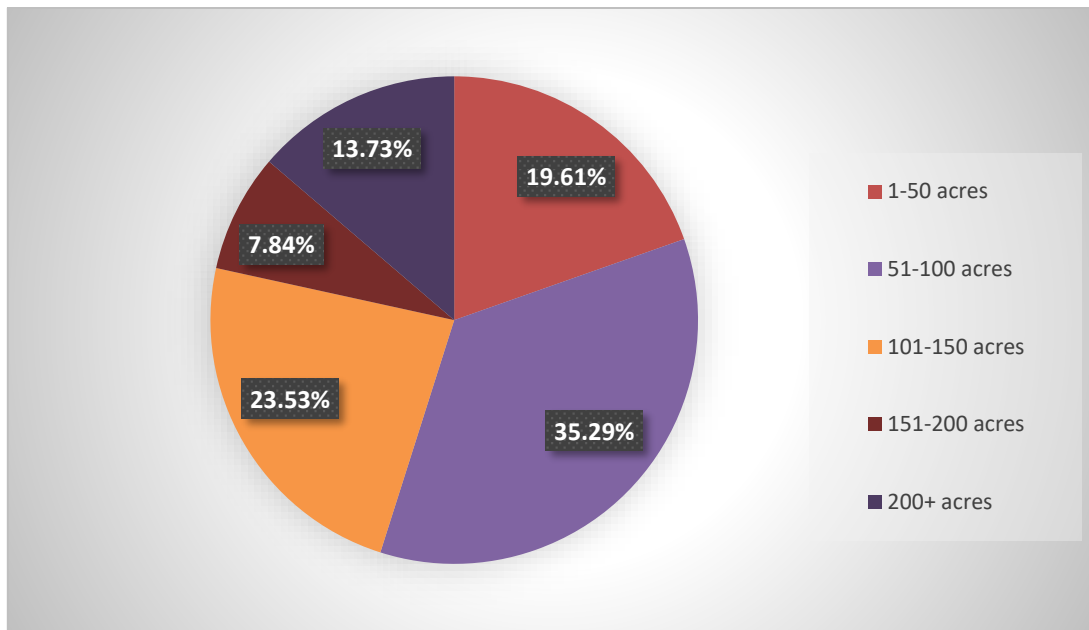

Fig. 2. A breakdown of farm size of farmers in the North-West of Ireland who completed the survey.

In terms of age profile, almost 40% of respondents were aged between 18-25, approximately 37% were in the 26-40 age bracket, followed by 21.57% who were aged between 41-60 and less than 2% who were over the age of 61 (Fig.3).
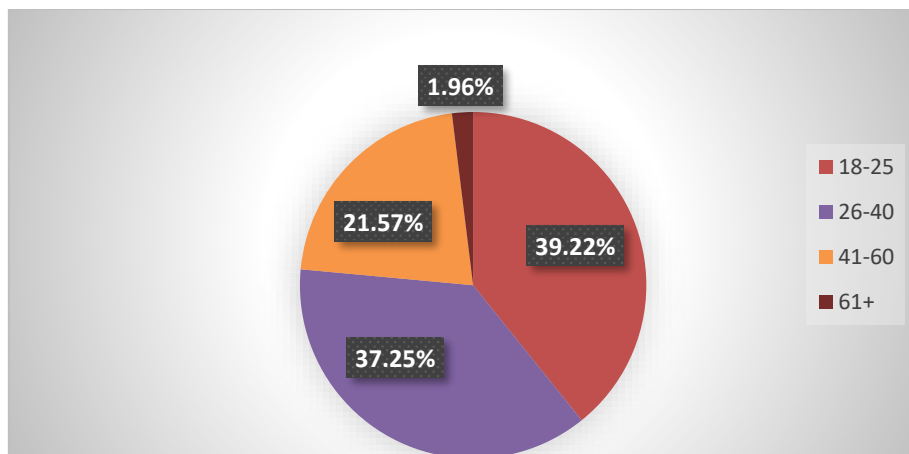
Fig. 3. Age category of respondents.

Thirty-five respondents had sheep farms while twenty-nine farmed beef. Five had a combination of the above enterprises. Four farmers own dairy farms and three people were involved in alternative enterprises. Tillage was not represented (Fig 4).
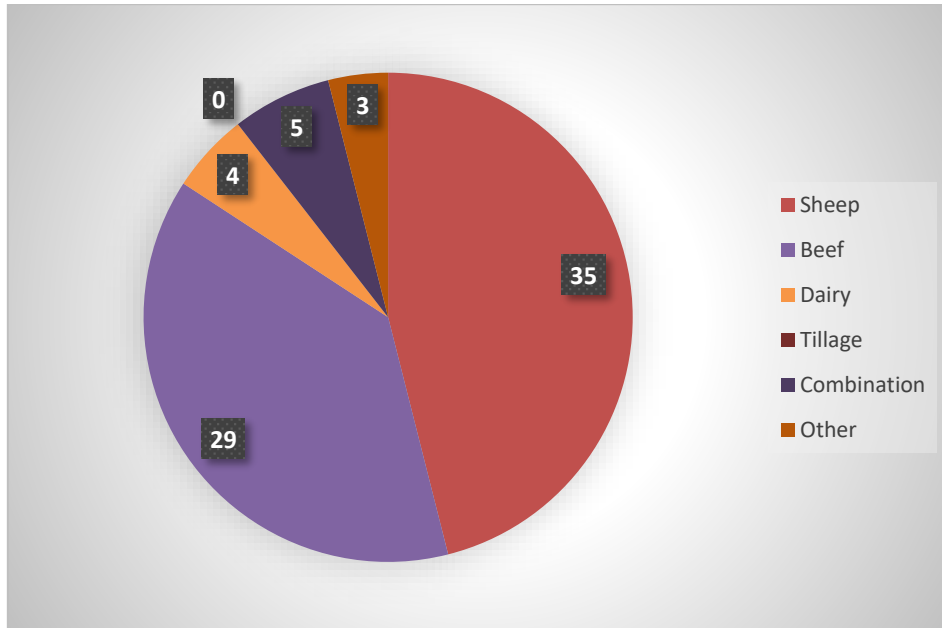
Fig. 4. Enterprises farmed by the farmers who completed the survey.

When questioned on what future plans include, increase production on the farm was the most common answer. Another goal was to introduce new systems of production in the future. A few farmers who answered the survey hope to diversify into a new enterprise. Fewer than 2% planned to discontinue farming and decrease levels of production (Fig. 5).
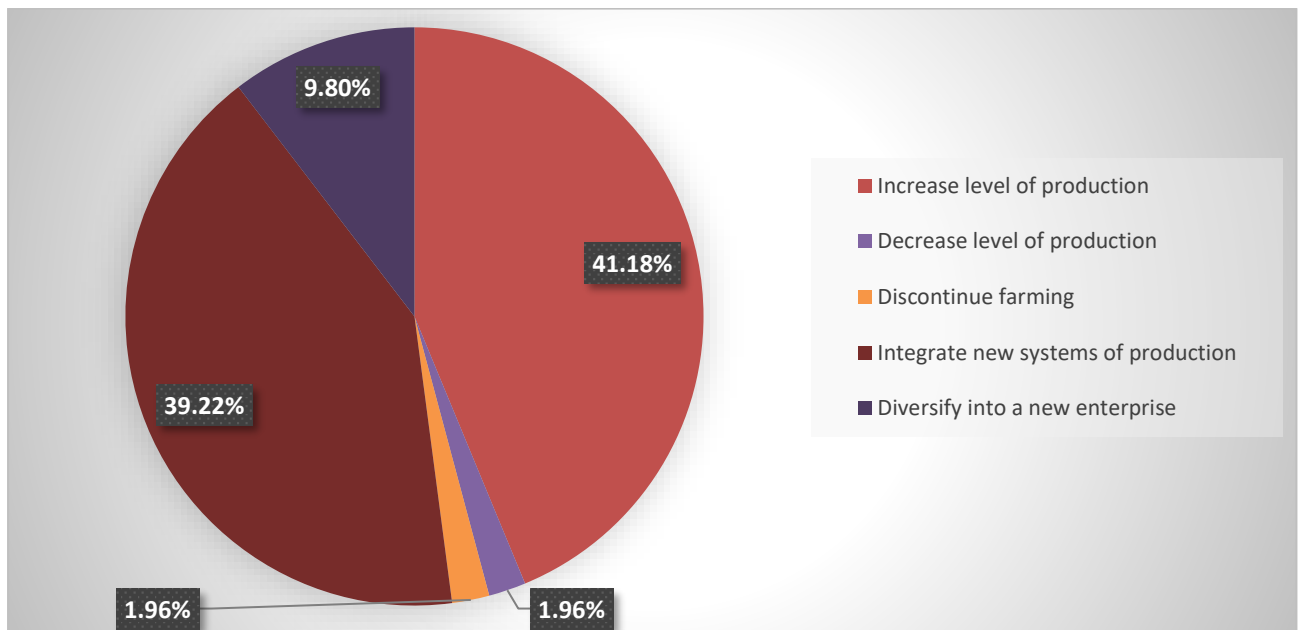
Fig. 5. Future plans of the survey participants.

When asked if the contribution of the agricultural sector to climate change was a concern, approximately 49% of people stated "No" while approximately 51% admitted it does (Fig. 6).
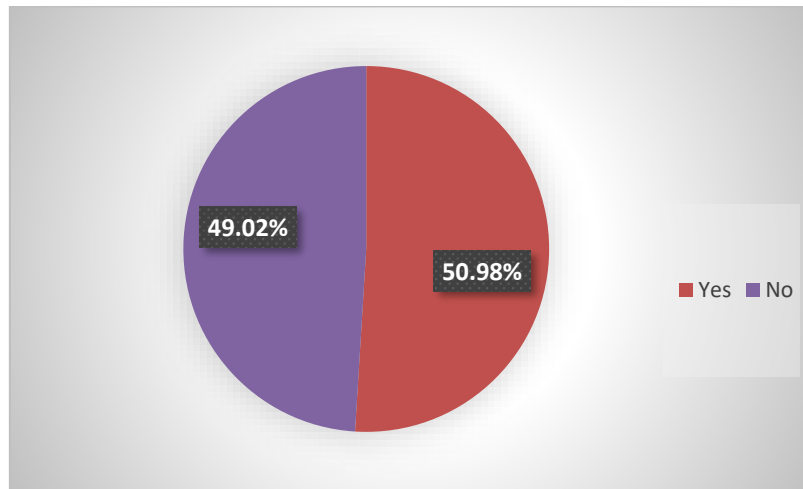
Fig. 6. Indication of concern about agricultures contribution to climate change.

When participants were asked if they were aware of anyone who had incorporated silvopasture onto their farms, 72.55% stated they were not aware whereas 27.45% claimed they did know someone.

When asked to rate the importance of trees in the environment, 41.18% stated trees are very important, 35.30% feel trees are important and 11.76% believe the presence of trees in the environment is neither important nor unimportant. 5.88% believe them to be not very important and 5.88% also believe they are not important at all (Fig.7).
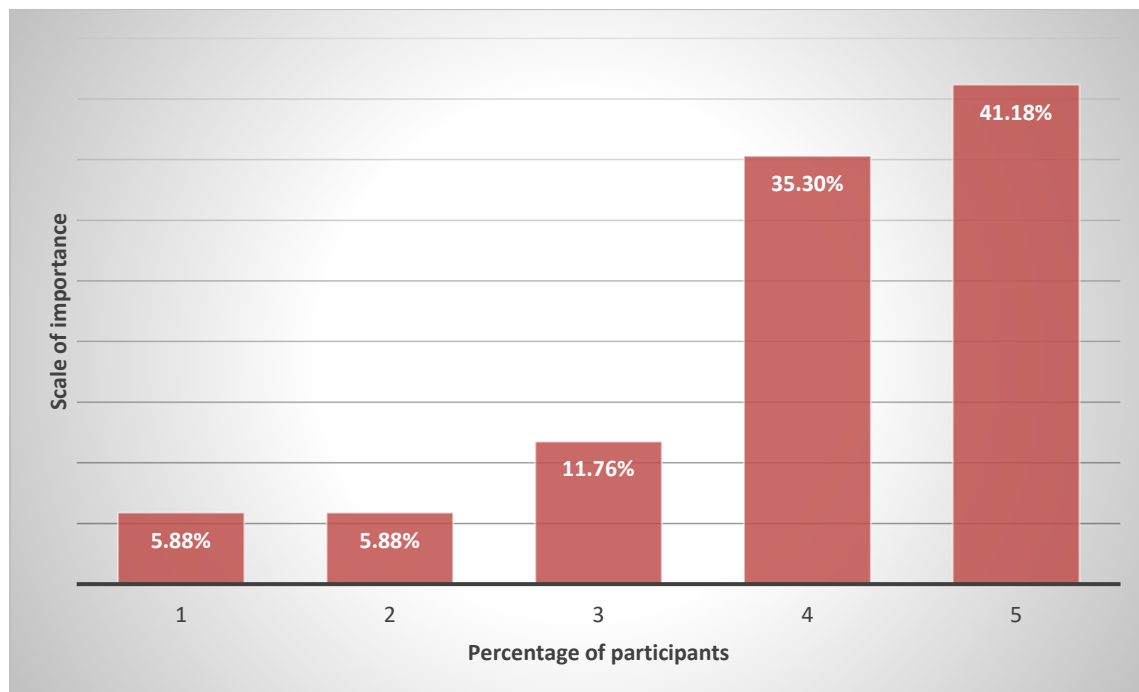
Fig. 7. A scale of importance regarding the presence of trees on farms in Ireland (1 = not important, 5 = very important).

Answering the question regarding should the planting of trees be made compulsory in the next CAP, almost half who answered this question said no, a third said yes and 17.65% ticked the other box which allowed them to share their opinion in words on what they believe should be done. Some opinions shared include:

➢ 'Some Compulsory afforestation scheme'.
➢ [It should be] 'an option'.
➢ 'I feel agroforestry is probably important but I think farmers should be educated and well informed and encouraged into this type of practice. In other words, they should give incentives monetary and otherwise as well as training. Programmes that are made compulsory are normally met with resistance and cynicism. You get better buy in with informing and incentivising the participants.
➢ 'Yes, but not compulsory across the board as not all land types may be suitable, however it should be encouraged and paid on'.
➢ 'It should be on a case-by-case basis. Places it works, places it doesn't. If you cut out too much sunlight nothing will thrive in it'.
➢ 'It should be incorporated the same a previous REPS schemes. Such as wind breaks as previously used as a substitute for livestock housing'.
➢ 'Have it as an option'.
➢ 'Not compulsory but should incentivized'.
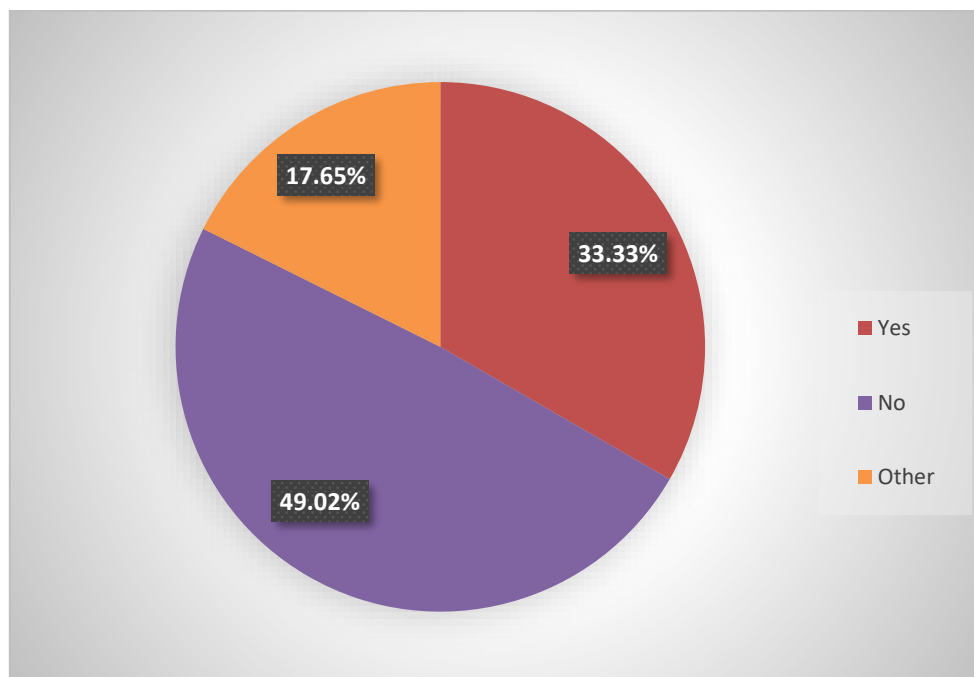
Fig. 8. Proportion of respondents that agree/disagree/have an alternative opinion on whether agroforestry should be a mandatory action in the next CAP.

When asked about awareness of the Agroforestry scheme (2014-2020) and associated grants, almost 60% of respondents stated they were aware of the grants available while just over 40% of farmers admitted they were not.

When participants were asked if increasing the duration and payments of a scheme would encourage them to plant trees, almost 75% of respondents agreed they would be enticed to plant trees on their farm if the duration of the previous agroforestry scheme was increased for more than 5 years. Just over 25% stated they would not be.

When questioned on the importance of some aspects of farming, a range of responses was observed.

Opinions shared on the importance of farming in a sustainable manner included over 60% of respondents agreeing that this is very important, under a third believed it to be important and less than 10% regarded it as neutral or least important.

Regarding importance of level of production in farming, under a third of the participants thought of this as most important. The majority (52.90%) viewed it as important, only a small number (13.73% and 3.92%) believed this to be neutral and less important respectively.

While 20% of respondents believe the continuation of the farming practices that was carried out before and during their time on the farm is important, less than half found it to be of neutral importance, followed by 22% viewing it as less important.

The planting of trees is an activity regarded as very important as it received the majority vote (40%). This was followed by 30% who believe it is important. 16%, 10% and 4% viewed it as neutral, not very important and not important respectively.

When asked to rate how important achieving a healthy work-life balance in the future is, 53.90% stated this is very important. 36.25% thought of this to be important, followed by 9.80% who believe it to be neither important nor unimportant (Fig. 9).
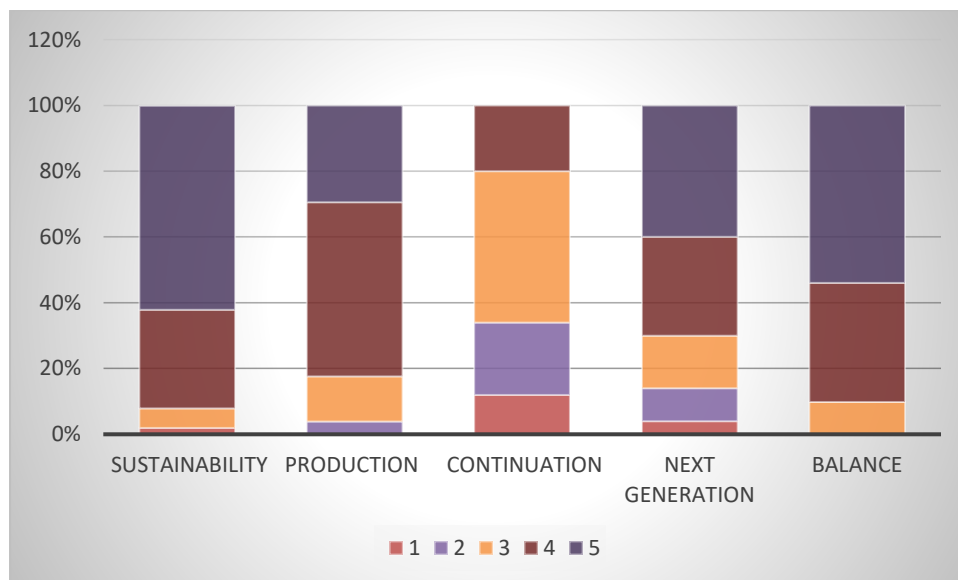
Fig. 9. Importance of factors (sustainability/production/continuation/planting for next generation/work-life balance) for farmers in their outlook. Sustainability = sustainable farming, Production = level of production, Continuation = continuation of the same farming practices (e.g. dairy with no diversification), Next generation = planting of trees for the next generation, Balance = better work-life. Factors were graded on a scale of 1-5: 1-not important, 2-less important, 3-neither important nor unimportant, 4-important and 5-very important.

Over 60% stated silvopasture to be an option they would consider, followed by slightly over 30% who would consider the use of riparian buffer strips and lastly approx. 6% voting for forest farming. Silvoarable was not chosen by any respondent (Fig. 10).
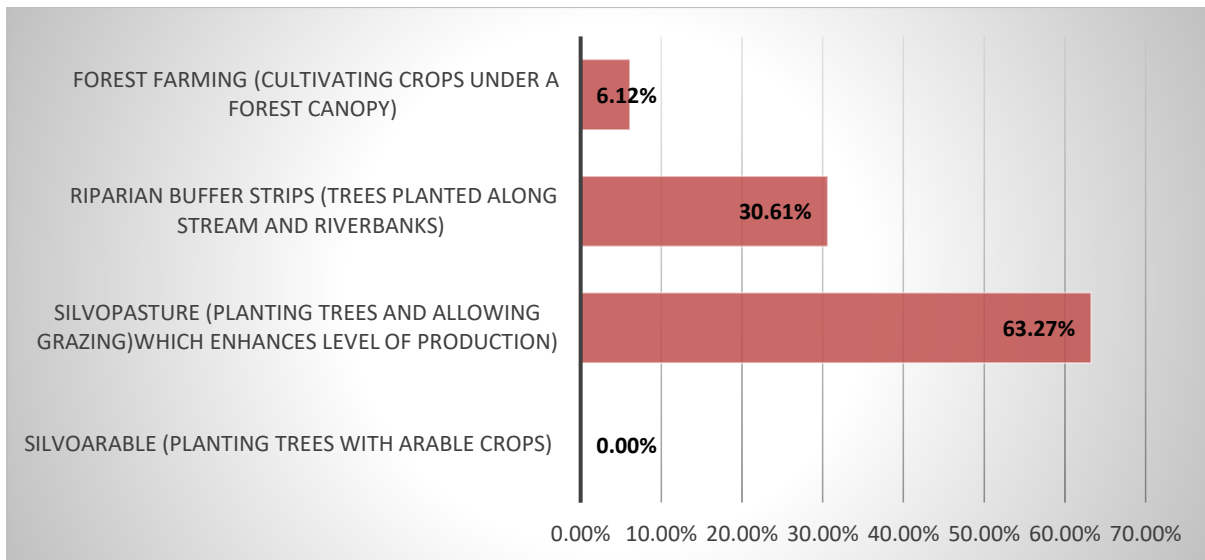
Fig. 10. Practice's respondents would be most open to integrating onto their farms.

When asked what trees they would prefer to plant if they were to diversify towards agroforestry, 30 voted for native wood-producing species. 18 votes were casted for a combination of all options, 9 voted for fruit-producing species and 4 people voted for nut-producing species. The least common answer with only 3 votes was fast-growing non-native trees (Fig. 11).
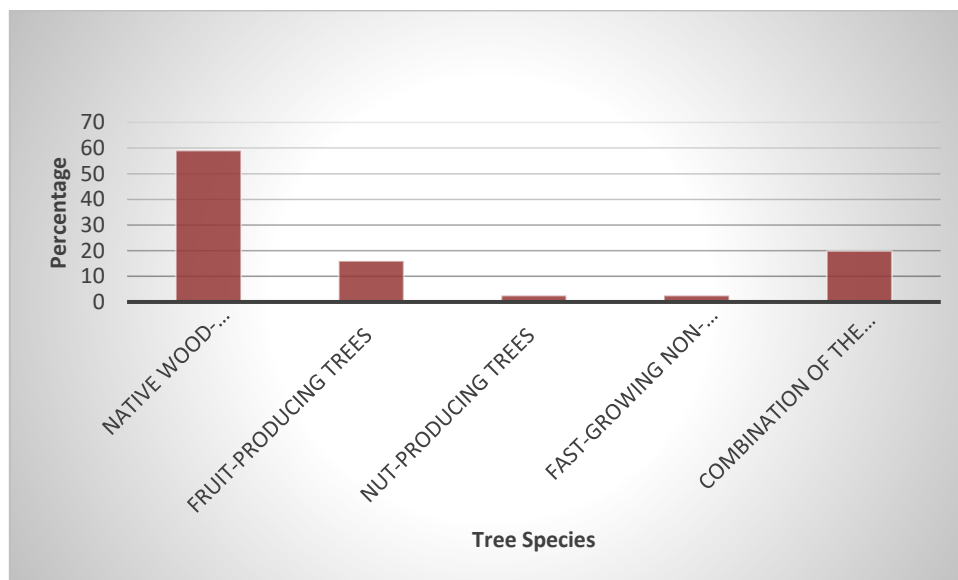
Fig. 11. Tree species favoured by respondents.

Referring to Fig. 12, the majority of respondents viewed trees as important as a source of firewood, improved drainage, carbon sequestration, animal shelter, improved water quality and increased biodiversity. Aesthetic value/ pleasant to look at was mostly thought of as of neutral importance.
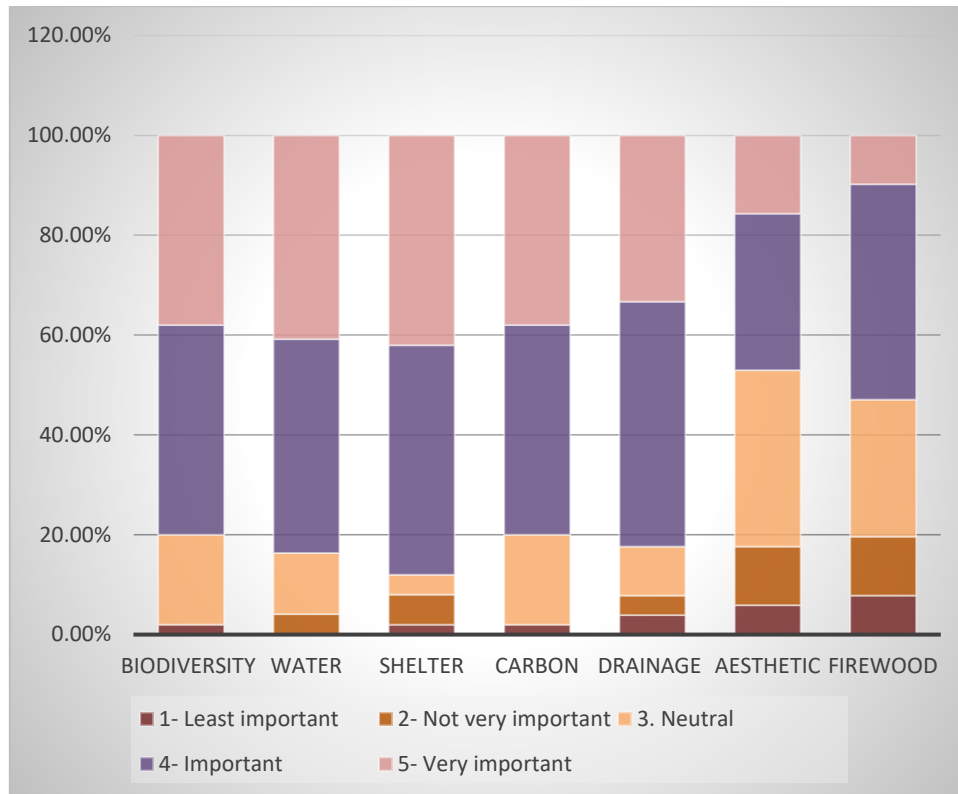
Fig. 12. Importance of services provided by trees. Biodiversity = increased biodiversity, Water = improved water quality and Shelter = animal shelter, Carbon = greater carbon sequestration, drainage = increased drainage, aesthetic = aesthetic value, firewood = source of firewood. Factors were graded on a scale of 1-5: 1-not important, 2-less important, 3-neither important nor unimportant, 4-important and 5-very important.

Lastly, farmers were asked to rate how encouraging each factor would be to motivate them to plant agroforestry on their land. The majority, 66.67%, voted allowing farmers the ability to choose the tree location themselves as very important. 43.14%, 49.02%, 36% and 43.14% voted ability to use the by-products from trees as an additional source of income, increased payments, increased variety of trees to choose from and scheme last longer as important respectively (Fig. 13).
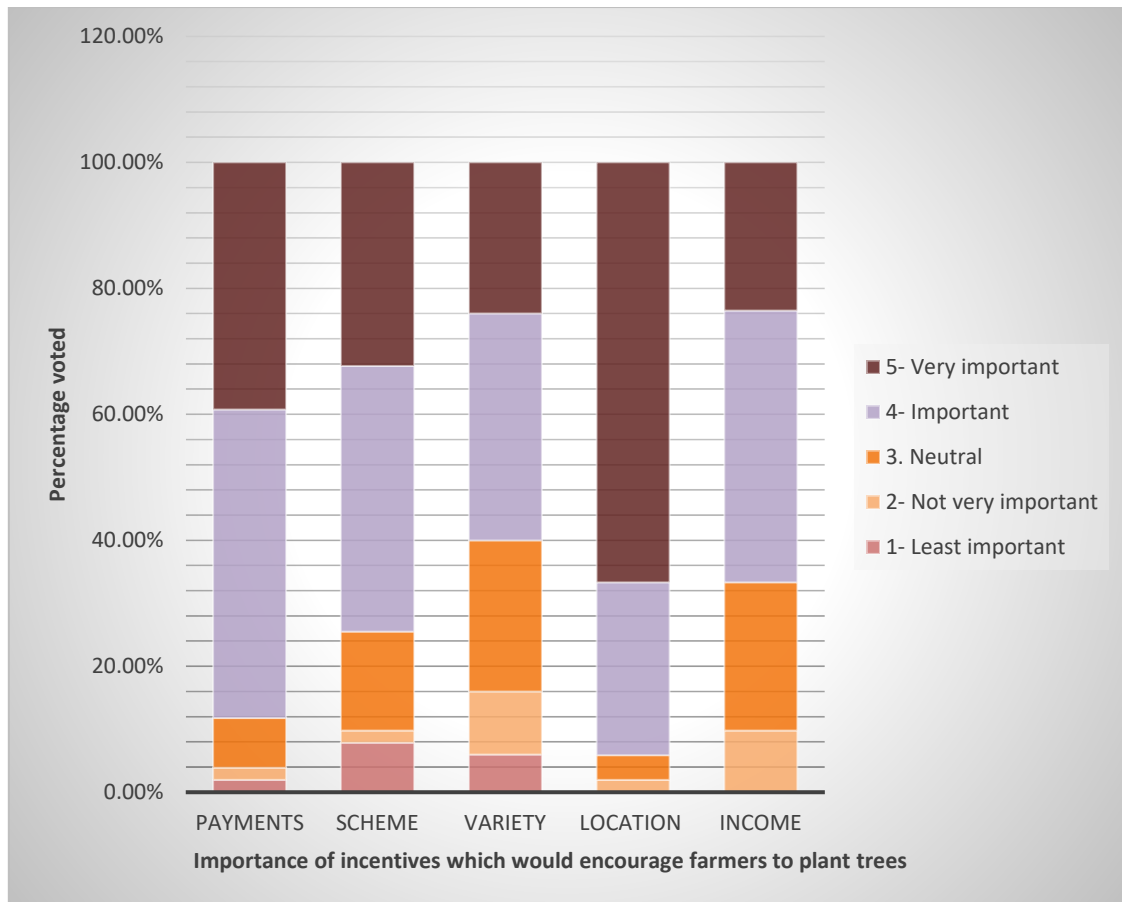
Fig. 13. Importance of different incentives to encourage tree-planting. Payments = increased payments, Scheme = longer-duration scheme, Variety = increased variety of trees to choose from, Location = ability to choose tree location yourself, Income = ability to use by-products from trees as an additional source of income. Factors were graded on a scale of 1-5: 1-not important, 2-less important, 3-neither important nor unimportant, 4-important and 5-very important.

9.2 Soil analysis

9.2.1 Soil moisture

Fig. 14. shows the comparison in moisture content between the silvopasture and grassland samples. Moisture content is substantially lower in the silvopasture implying the grassland pastures have poorer drainage properties.
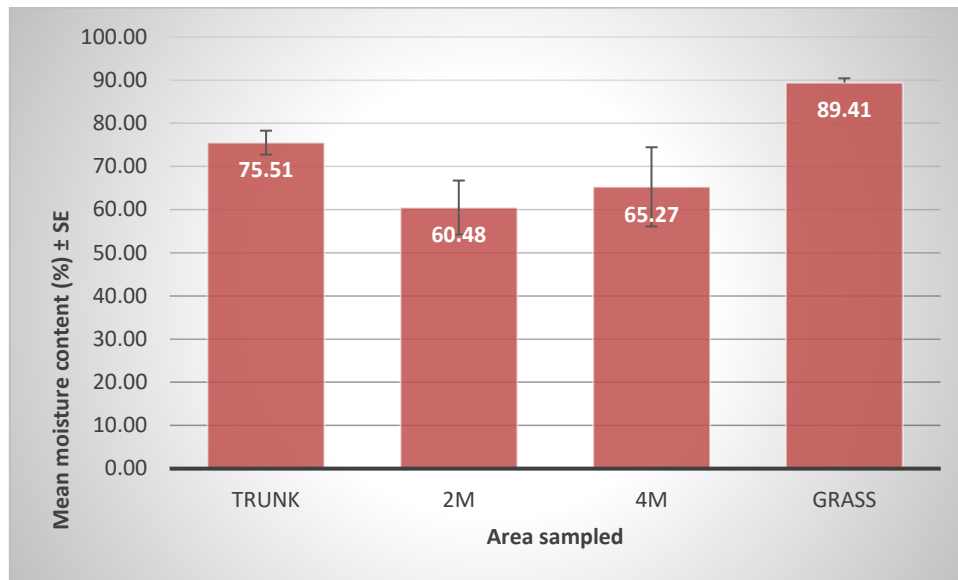
Fig. 14. Mean ± Standard error (±S.E.) moisture content for locations in silvopasture sites (at Trunk, 2m and 4m from trunk) and in grassland sites (n=3).

9.2.2 Soil pH

The mean pH is closer to being neutral in the silvopasture sites whereas the mean pH in the grassland sites is slightly more acidic (Fig. 15)
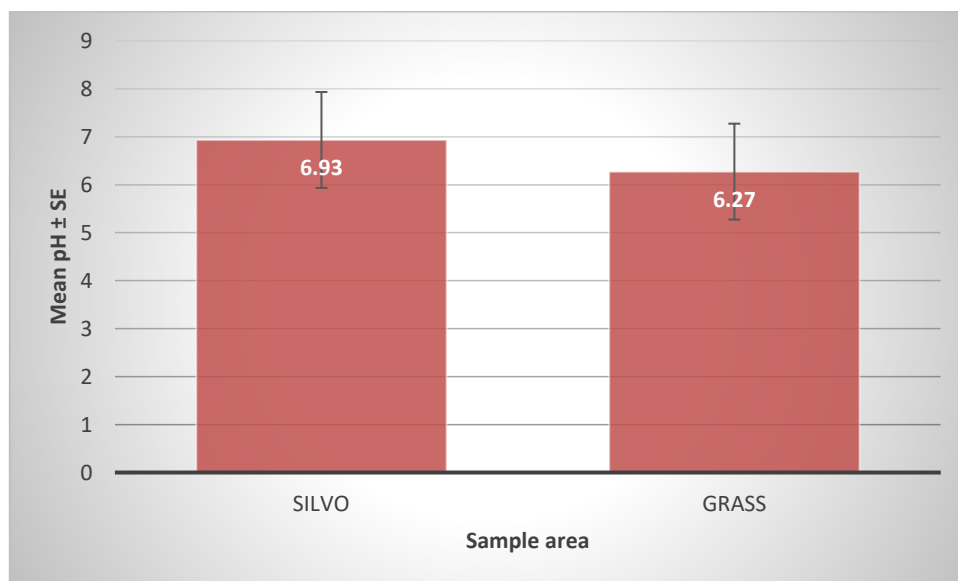
Fig. 15. Mean (± S.E.) pH for silvopasture sites and grassland sites (n=3).

9.2.3 Soil porosity

As presented in Fig. 16, porosity declines as the distance from the tree increases. In contrast to the silvopasture sites, the porosity within the grassland soils is a lot lower. Reduced porosity within a soil results in soils becoming waterlogged and inhibits water, air and nutrients being conducted within the soil (Indoria et al. 2020). As expressed by Bingqin et al. (2018) who carried out research on tree root density and its effect on porosity, they recorded root density decreasing from 1m away from the tree trunk had a direct impact on the porosity of the soil in that area.
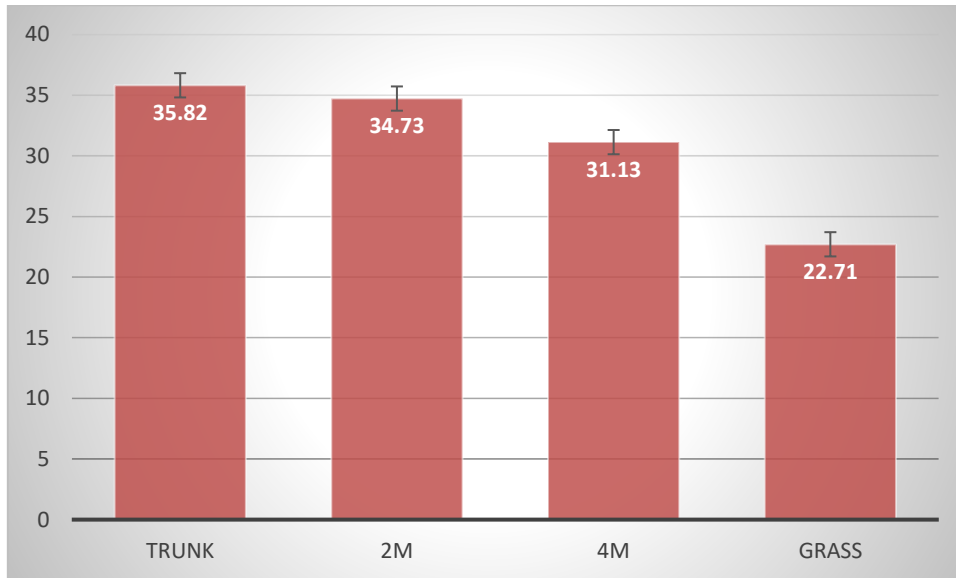
Fig. 16. Mean (± S.E.) porosity for locations in silvopasture sites (at Trunk, 2m and 4m from trunk) and in grassland sites (n=3).

9.2.4 Earthworm population

A greater mean abundance of earthworms can be observed in the silvopasture sites in comparison to the grassland fields sampled. The lowest number of earthworms counted in the silvopasture sites was 31 earthworms/m^2 (silvopasture site 2) whereas the grassland sites remained in the high teens with the exception of grassland site 2, which recorded 20 earthworms per m^2. The average number of earthworms in the silvopasture site is 36 earthworms/m^2 whereas the average number of earthworms in the grassland site is only 18 earthworms/m^2.
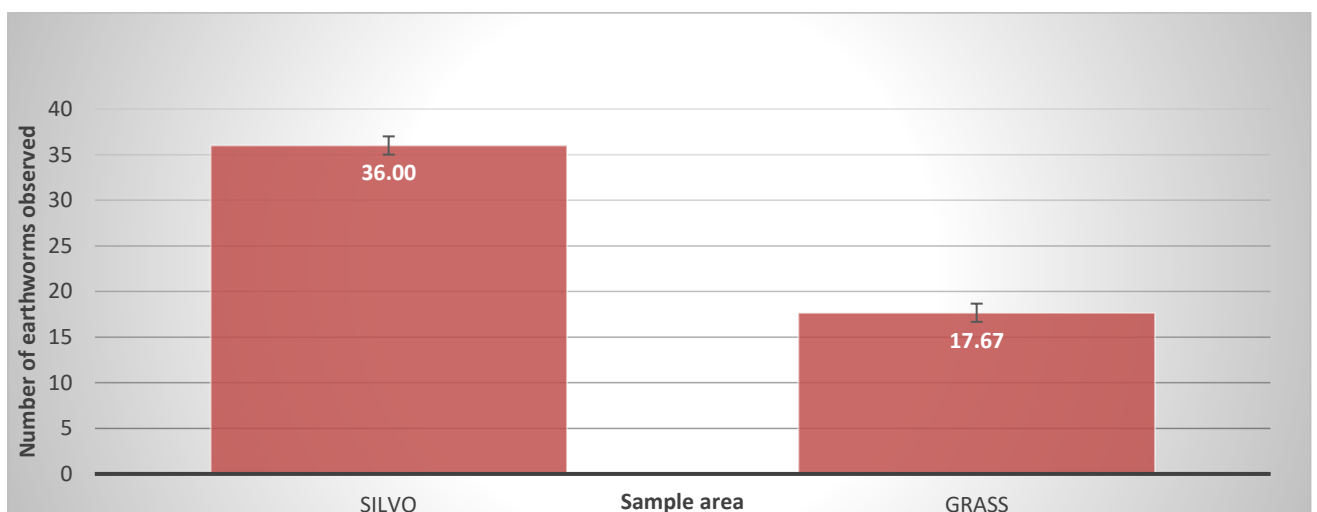
Fig. 17. Mean (± S.E.) earthworm count for silvopasture and grassland sites (n=3).

25

Earthworm abundance consists of non-normal data so to compare sites, data was square-root transformed to approximate normality. Following transformation, a t-test was used to compare data. There was a very significant difference in mean earthworm abundance between the silvopasture site and the grassland site (t=6.409, 4df, p<0.01) (Table 1).

Table 1 Summary results of t-test comparing earthworm abundance in silvopasture (Variable 1) and grassland (Variable 2) sites. Data were square-root transformed.

t-Test: Two-Sample Assuming Equal Variances		
	Silvopasture	*Grassland*
Mean	5.990296	4.19841386
Variance	0.174527	0.059981588
Observations	3	3
Pooled Variance	0.117254	
Hypothesized Mean Difference	0	
Df	4	
t Stat	6.409005	
P(T<=t) one-tail	0.001523	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.003045	
t Critical two-tail	2.776445	

Table 1. t-Test analysis on earthworm population.

10.   Discussion

10.1 Questionnaire

With regards to the survey farmers in the North-West of Ireland were asked to complete, some interesting observations were made.

It is clear that there is a large variety in farm sizes of those that completed the survey. The majority owned and rented farms ranging from 51-100 acres, closely followed by farm sizes of 101-150 acres and thirdly 1-50 acres. Under 22% of the respondents worked farms of 151+ acres. This is a good representation of farm sizes in the North-West of Ireland.

The majority of respondents were in the age range 18-25 and 26-40. According to most recent figures released from the CSO (2018), the average age range of farmers in Ireland is 65+ years old. Given the surveys were distributed via email due to Covid-19, a younger democracy was more capable of completing the questionnaire.

Almost two thirds of the respondents hailed from sheep farming backgrounds (68.63%). This result was anticipated as the landscape in the North-West is heavily suited to farming sheep. Beef farming closely followed after. No tillage farmers answered the survey which is not surprising given the North-West is not heavily populated with these systems of farming.

It is obvious that the majority of those surveyed hope to increase levels of production in the future. These are likely to be in the younger age bracket and have a long life of farming ahead of them. 39.22% of respondents stated they would like to introduce new systems of production onto their farms. New enterprise e.g., agroforestry could allow for an increase in production and profit which would make farming more viable. Only 9.8% of respondents want to convert to a completely new enterprise.

When asked if agriculture contribution to climate change concerns them, a 50:50 response to yes: no was observed. This is alarming as it is clear the agricultural sector needs to become more sustainable and reduce its carbon footprint in order to prevent environmental damage. Given that the majority of responses received were from a younger cohort, it was expected the 'Yes' vote would have been substantially higher which was not the case. This could have been due to an unwillingness to admit ownership of a problem or it could be genuinely felt agriculture is becoming increasingly sustainable.

Almost 40% of farmers who answered the survey had already included silvopasture on the land they farm. The majority (60.78%) had not. Given that there is very little emphasis placed on this system of agroforestry farming, this was not surprising but satisfying to see that almost 40% had. Reasons for farmers having not yet planted agroforestry included lack of knowledge, awareness and education on the agroforestry system, farm size not large enough yet, perceived inconvenience for harvesting silage and hay, possible loss of payments, planning for future uptake and intensifying other systems of production instead. With the majority saying no, there is room for education on the benefits, and expansion, of agroforestry and silvopasture in particular in this region.

It is clear that a lack of awareness regarding the practice of silvopasture was prevalent within those who completed the survey. With less than 30% of those who filled out the survey having contacts in the local area that are practicing silvopastural systems on their farm, the majority claim they knew no one who has integrated it onto their farm.

Although there is a deficit of farms with agroforestry plantations present, 41.18% of those surveyed believe it is very important that trees exist on farms. With the majority (76.48%) acknowledging it is either important or very important for trees to be planted on farms, it is clear that farmers are aware of the important role trees play in the environment and how they are beneficial for ecosystems.

Although the majority of farmers who completed the survey acknowledged trees should be present on every farm, almost half (49.02%) stated no when asked should agroforestry be included in the next CAP. Although they are aware of trees' importance, this result suggests that making every farmer plant trees is not suitable and a different action should be taken.

It could be argued a lack of knowledge of the current schemes and incentives cannot be blamed for the lack of uptake/participation in agroforestry as 58.82% stated they were aware of the Forestry Programme 2014-2020 but there was still over 40% who were not aware of its existence and may have utilised it if increased awareness was raised.

Almost three-quarters of those who completed the survey stated that a longer-lasting scheme would encourage them to join and plant trees. This could be considered in the future by the DAFM as one possible measure to increase the number of farmers partaking in agroforestry-based schemes and increase the forested land area. As over a quarter still stated they would not be inclined to plant trees, it is clear other measures would be needed to increase uptake.

As so many farmers acknowledge that farming sustainably is of huge importance, this suggests they may be more open to considering agroforestry on their farms in the future. Presenting them with options such as diversifying towards agroforestry to reduce their farm carbon footprints could be a successful action.

While the level of production on-farm is important to farmers, given they understand how important sustainability is, it could be that production is only important when being done sustainably and protecting the environment.

Continuation of farming practices was of little to low importance. This shows that continuing previous practices is not a factor that is preventing farmers from planting agroforestry.

Farmers in the North-West are aware of the roles trees play in an ecosystem and the results from this survey question reflects this. With this in mind, it would suggest that a properly-designed scheme would be attractive to farmers as they already understand the importance of including trees on a farm.

Although most farmers would say they enjoy farming and couldn't see themselves doing anything else, it is clear that a better harmony between living and pursuing other passions alongside farming is something many would like to achieve as almost 55% stated a better work-life balance in the future is very important. It is possible agroforestry could provide those with this balance as systems like silvopasture can reduce labour requirements once established by allowing sheep to lamb outdoors, allowing animals to be let out to grass earlier in spring and indeed some animals can be outwintered removing the requirement to house livestock at all.

It is apparent silvopasture is the most attractive options for farmers who are considering planting land in the North-West region. The convenience of being able to graze livestock and harvest silage/hay while also having the benefits from planting trees would suit farms in the North-West.

When being given the option of different species of trees to plant, the most common answer was the native wood-producing species. Planting this variety of trees would allow farmers to source additional income from the by-products of the trees if allowed in a scheme. Regarding fast growing non-native tree species (the least common answer), previous agroforestry schemes have run into opposition throughout the country. If native trees had been considered, the schemes may have been more successful.

This survey has indicated what farmers in the North-West deem as valuable when planting trees. Factors like improved drainage, increased biodiversity, carbon sequestration, improved water quality

are important not just for farmers but for the land they are farming and the greater environment. These aspects are what will make farming sustainable in the future.

The final question paints an image of what is required to incentivise farmers to plant trees. It is clear allowing farmers to choose the area being planted is paramount as 66.67% voted this as most important. Increasing payments, increasing the longevity of the scheme and allowing farmers to use by-products (e.g., timber, wood shavings etc) as a source of additional income is also important and would encourage them to partake in agroforestry schemes. Although the majority (36%) viewed choosing the variety planted as important, 26% and 6% voted this as of neutral and least importance respectively. By focusing on payments, scheme length and by-products, the North-West and possibly further afield, may see an increase in those planting land and making use of agroforestry schemes.

10.2 Soil analysis

The grassland sites have a higher mean moisture content (89%) than the silvopasture (75%) meaning they hold more water and have poorer drainage. Compaction causes increased bulk density which in turn increases the water retention capacity of the soil resulting in a greater moisture content percentage (Dobson, 1995). This may contribute to the higher moisture content in the grassland sites.

The mean pH of the silvopasture sites is 6.93, almost neutral whereas the mean grassland pH was 6.27. As all areas received the same treatment in regards to liming, fertiliser etc., this result could be due to a greater nutrient holding capacity in the silvopasture sites due to the existence of trees. Mentioned by Nidzgorski and Hobbie (2016), tree roots can prevent and reduce nutrient run-off on the land whereas the grassland soils have a much more limited ability to do so.

Soil compaction is an issue on Irish farms and leads to soil deterioration which should be avoided at all costs (Teagasc, 2020b). The soil porosity was greater in the silvopasture site in comparison to the grassland sites sampled. A mean porosity of 35.82%, 34.72% and 31.13% was recorded for the trunk, 2m and 4m samples respectively. In contrast to this, the mean porosity within the grassland site was significantly lower at 22.71%. This is possibly due to the presence of roots leading to greater aeration within the silvopasture. Porosity decreased the further away from the tree trunk soil samples are taken. This may be because tree roots disperse further apart the further away from the trunk and have a reduced effect on porosity.

There was a greater abundance of earthworms in the agroforestry plots than in the area occupying grassland. From the three silvopasture sites tested, a mean number of 36 earthworms/m^2 were counted. In comparison, in the grassland sites, a mean of 18 earthworms/m^2 was recorded. It was apparent that agroforestry was superior in terms of earthworm abundance. This is likely due to the soil environments in the silvopasture sites having superior soil drainage, suitable pH and adequate moisture levels as measured in the experimental trial. Trees also provide much material (leaves, branches) for decomposition by soil invertebrates (Whiteside et al., 1998).

11.   Conclusions

This thesis focused on silvopasture as a sustainable method of improving productivity within farms in the North-West while also improving the quality of the soil. When considering enterprises for farms to diversify into, agroforestry is not one many give thought to and this project focuses on the benefits of doing so.

Results obtained from the survey distributed to farmers within the North-West farming community stated there is a lack of knowledge and awareness of the practice and this had led to poor uptake. An appetite for agroforestry does exist so increased information talks and events hosted by advisors and members of the Department could see a greater involvement in introducing silvopastural systems onto farms in this part of the country. Clear benefits for land, livestock and the farmer exist when incorporating this practice onto farms including improved soil drainage, reduced nutrient loss, a reduction in labour and greater animal welfare by means of shelter provided by the trees.

Outcomes from the soil analysis displayed a clear contrast in soil characteristics within the grassland and silvopastural sites sampled. Overall, the forested area had a greater porosity percentage and lower moisture content meaning it has superior drainage qualities which would act in favour of the farm in terms of parasitic control, as fluke is less likely to exist in drier areas (NSA, 2018). The higher soil porosity in the silvopasture sites would convey that the presence of tree roots under the ground has offset any compaction issues that were seen to occur in the grassland sites. The grassland sites were also inferior in regards to earthworm population. This proves that trees encourage biological diversity as they act as an excellent habitat and source of food for soil biota.

11.1 Recommendations

➢ The Department must focus more on improving the knowledge base of farmers with regards to agroforestry and its place in the environment.
➢ Greater incentives must become available for farmers who would like to incorporate agroforestry onto their farms.
➢ Making the inclusion of trees on Irish farms a requirement in the next CAP could be an option to increase the land area occupied by trees but allowing farmers to choose the tree location is paramount.
➢ Policies like the Conifer Afforestation Programme 2014-2020, where non-native trees were planted in land areas, is not the correct method of increasing Ireland's tree population and has upset many communities.

11.2 Future work

If this thesis were to be advanced further in the future, areas of increased focus would include:

➢ Distribution of surveys. Given safety regulations with Covid-19, an online platform to collect surveys was used but created issues for collecting data from farmers in the 61+ age category. If a survey were to be conducted again, paper forms would be used instead of/ in addition to the online tool.
➢ More sample sites. More silvopasture sites like Loughgall would be included in the research to provide more information to draw a more definite comparison. Unfortunately, in light of the pandemic, travel was restricted and only one site visit was feasible.
➢ Given the lab restrictions, the number of tests carried out on the soil samples were limited. In future, if this thesis were to be expanded, more aspects of the soil would be assessed i.e., soil bulk density and organic matter, mineral content, nutrient content, CO_2 levels etc.

12.   References

Agriland. (2018). *Lameness: a critical issue for the sheep industry in Ireland.* [online]. Available at: https://www.agriland.ie/farming-news/lameness-a-critical-issue-for-the-sheep-industry-in-ireland/https://www.agriland.ie/farming-news/lameness-a-critical-issue-for-the-sheep-industry-in-ireland/ [accessed 22 October 2020].

Apuri, I., Peprah, K. and Achana, G.T.W., 2018. Climate change adaptation through agroforestry: The case of Kassena Nankana West District, Ghana. *Environmental development*, *28*, pp.32-41.

Ban Bloodsports. (2007). *The facts about sheep mortality on Irish farms.* [online]. Available at: http://www.banbloodsports.com/sheep.htm [accessed 21 October 2020].

Bingqin, Y., Changkun, X., Shize, C., Yan, C., Yongpeng, L., Zulan. M., Tianlei, L., Zhiwen, Yang. (2018). *Effects of Tree Root Density on Soil Total Porosity and Non-Capillary Porosity Using a Ground-Penetrating Tree Radar Unit in Shanghai, China*. [online]. Available at: file:///C:/Users/HP/Downloads/sustainability-10-04640.pdf [accessed 11 April 2021].

Bridgeman, L. (2020). *Intensive agriculture: impact on humans, animals, and the planet.* [online]. Available at: https://sentientmedia.org/intensive-agriculture/ [accessed 24 November 2020].

Canopy. (n.d.). *Benefits of trees.* [online]. Available at: https://canopy.org/tree-info/benefits-of-trees/ [accessed 8 April 2021].

Carbon Collective. (2018). *Silvopasture: A carbon sequestering solution for Ireland?* [online]. Available at: https://medium.com/@ronan.atkins/silvopasture-a-carbon-sequestering-solution-for-ireland-2abab80eb803 [accessed 24 November 2020].

Carroll, R. (2019). The wrong kind of trees: Ireland's afforestation meets resistance. *The Guardian.* [online]. 7 July 2019. Available at: https://www.theguardian.com/world/2019/jul/07/the-wrong-kind-of-trees-irelands-afforestation-meets-resistance [accessed 2 November 2020].

Central Statistics Office. (2018). *Statistical yearbook of 2018*. [online]. Available at: https://www.cso.ie/en/releasesandpublications/ep/p-syi/psyi2018/agri/farmsandfarmers/ [accessed 27 February 2021].

Clatterbuck, W.K. (n.d.). *Identification of and corrective action for poorly drained soils in the landscape.* [online]. Available at: https://agrilife.org/treecarekit/tree-identification-selection/identification-of-and-corrective-action-for-poorly-drained-soils-in-the-landscape/ [accessed 11 April 2021].

Conroy, L. (2020). Agroforestry. *Ecofuel blog* [online], January 24. Available at: https://www.ecofuel.ie/blogs/read/agroforestry [accessed 19 October].

Cuthbertson, A. and McAdam, J. (1996). The effect of tree density and species on carabid beetles in a range of pasture-tree agroforestry systems on a lowland site. In *Agroforestry Forum (United Kingdom)*.

Department of Agriculture, Food and the Marine. (2014). *Forestry Programme 2014-2020: Ireland.* [online]. Available at:

https://www.agriculture.gov.ie/media/migration/forestry/forestryprogramme2014-2020/IRELANDForestryProgramme20142020230215.pdf [accessed 10 December 2020].

Department of Agriculture, Food and the Marine. (2017). *Agroforestry policy in Ireland.* [online]. Available at: https://foresteurope.org/wp-content/uploads/2017/08/BudapestPP.pdf [accessed 2 November 2020].

Department of Agriculture, Food and the Marine. (2018). *Agroforestry.* [online]. Available at: https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2016/6AgroforestryRPC010894ENPRL1150319.pdf [accessed 19 October 2020].

Department of Agriculture, Food and the Marine. (2019). *Irelands National Forestry Accounting Plan 2021-2025.* [online]. Available at: https://www.agriculture.gov.ie/media/migration/ruralenvironment/climatechange/IrelandsNationalForestAccountingPlan20212025Dec2019201219.pdf [accessed 24 November 2020].

DKIT. (2020) *Soil and Water Management Module.* Dundalk Institute of Technology.

Dobson, M. (1995). *Tree root systems.* [online]. Available at: https://www.trees.org.uk/Trees.org.uk/files/61/6181f2b7-e35d-4075-832f-5e230d16aa9e.pdf [accessed 10 April 2021].

Environmental Protection Agency. (2018). *Irelands greenhouse gas emissions.* [image online]. Available at: http://www.epa.ie/pubs/reports/air/airemissions/ghgprovemissions2018/9145_EPA_greenhouse_gas_emissions_Infographic_2018_CA7_FINAL.pdf [accessed 24 November 2020].

European Agroforestry Federation. (2017). *Lobbying in Brussels for Agroforestry.* [online]. Available at: https://euraf.isa.utl.pt/action/policy/Lobbying_in_Brussels_for_Agroforestry [accessed 9 December 2020].

European Agroforestry Federation. (2020). *Agroforestry Policy Briefing? Why?* [online]. Available at: https://euraf.isa.utl.pt/news/policybriefings_why [accessed 12 November 2020].

Food and Agriculture Organization of the United Nations. (2015). *Agroforestry definition.* [online] Available at: http://www.fao.org/forestry/agroforestry/80338/en/ [accessed 8 April 2021].

Fruit and Nut. (2015). *Agroforestry.* [online]. Available at: http://fruitandnut.ie/agroforestry.html [accessed 19 October 2020].

Galhena, D.H., Freed, R. and Maredia, K.M. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. *Agriculture & food security*, *2*(1), p.8.

Gardiner, M., & Ryan, P. (1969). A New Generalised Soil Map of Ireland and Its Land-Use Interpretation. *Irish Journal of Agricultural Research*. [online]. 8(1), 95-109. Available at: http://www.jstor.org/stable/25555514 [accessed 8 April 2021].

Global Forest Atlas. (2020). *Agroforestry.* [online]. Available at: https://globalforestatlas.yale.edu/land-use/agroforestry [accessed 19 October 2020].

Gold, A. (2017). *Agroforestry.* [online]. Available at: https://www.britannica.com/science/agroforestry [accessed 19 October 2020].

Indoria, A., Sharma, K., Reddy, K. (2020). *Hydraulic properties of soil under warming climate.* [online]. Available at: https://www.sciencedirect.com/science/article/pii/B9780128180327000187 [accessed 26 April 2021].

Johnston, R. (1996). The effect of tree density and species on spiders in a range of lowland pasture-tree agroforestry systems. *Unpublished thesis. Queen's University of Belfast, UK.*

Jove. (2021). *Analysis of earthworm populations in soil.* [online]. Available at: https://www.jove.com/v/10002/analysis-of-earthworm-populations-in-soil [accessed 2 February 2021].

Karki, Amrit S. (n.d.). *Agroforestry and its benefits.* [online]. Available at: https://en.reset.org/knowledge/agroforestry-and-its-benefits [accessed 8 April 2021].

Kent, T., Short, I.J. (2004). *Agroforestry: A land-use system with potential on Irish farms.* [online]. Available at: https://www.teagasc.ie/media/website/crops/forestry/research/Agroforestry-presentation-for-IT-colloquium.pdf [accessed 19 October 2020].

Lynch, J. (2020). *Soil Science Module.* Dundalk Institute of Technology.

McAdam, J., Short, I., Hoppé, G. (2006). *Opportunities for silvopastoral systems in Ireland.* [online]. Available at: http://www.coford.ie/media/coford/content/publications/projectreports/small-scaleforestryconference/McAdam.pdf [accessed 24 November 2020].

Montagnini, F. and Nair, P.K.R. (2004). Carbon sequestration: an underexploited environmental benefit of agroforestry systems. *In New vistas in agroforestry* (pp. 281-295). Springer, Dordrecht.

Mosquera-Losada, M.R., Santiago-Freijanes, J.J., Rois-Díaz, M., Moreno, G., den Herder, M., Aldrey-Vázquez, J.A., Ferreiro-Domínguez, N., Pantera, A., Pisanelli, A. and Rigueiro-Rodríguez, A. (2018). Agroforestry in Europe: A land management policy tool to combat climate change. *Land Use Policy*, *78*, pp.603-613.

Nair, P.K. & Garrity, Dennis. (2012). *Agroforestry - The Future of Global Land Use*. 10.1007/978-94-007-4676-3. [accessed 19 October 2020].

National Geographic. (2011). *Agriculture.* [online]. Available at: https://www.nationalgeographic.org/encyclopedia/agriculture/ [accessed 10 Nov 2020].

National Sheep Association. (2018). *The role of trees in sheep farming.* [online]. Available at: https://www.nationalsheep.org.uk/workspace/pdfs/nsa-sheep-and-trees-for-website.pdf [accessed 22 October 2020].

Nidzgorski, D., Hobbie, S. (2016). *Urban trees reduce nutrient leaching to groundwater*. [online]. Available at: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/15-0976 [accessed 20 April 2021].

O'Brien, B. (2019). *'Substantial grants available for agroforestry'- Doyle.* [online]. Available at: https://www.agriland.ie/farming-news/substantial-grants-available-for-agroforestry-doyle/ [accessed 24 November 2020].

Ortolani, G. (2017). *Agroforestry: An increasingly popular solution for a hot, hungry world.* [online]. Available at: https://news.mongabay.com/2017/10/agroforestry-an-increasingly-popular-solution-for-a-hot-hungry-world/ [accessed 19 October 2020].

Owen, J. (2005). *Farming claims almost half of earths land, new maps show.* [online]. Available at: https://www.nationalgeographic.com/news/2005/12/agriculture-food-crops-land/ [accessed 10 November 2020].

Palma, J.H., Graves, A.R., Bunce, R.G.H., Burgess, P.J., De Filippi, R., Keesman, K.J., van Keulen, H., Liagre, F., Mayus, M., Moreno, G. and Reisner, Y., (2007). Modeling environmental benefits of silvoarable agroforestry in Europe. *Agriculture, ecosystems & environment*, *119*(3-4), pp.320-334.

Paul, C., Weber, M. and Knoke, T. (2017). Agroforestry versus farm mosaic systems–Comparing land-use efficiency, economic returns and risks under climate change effects. *Science of the Total Environment*, 587, pp.22-35.

Pelosi, C., Baudry, E., Schmidth, O. (2020). *Comparison of the mustard oil and electrical methods for sampling earthworm communities in rural and urban soils.* [online]. Available at: https://link.springer.com/article/10.1007/s11252-020-01023-0 [accessed 21 April 2021].

Pingali, P. (2012). Green revolution: Impacts, limits, and the path ahead*. Proceedings of the National Academy of Science of the United States of America.* [online]. 109 (31). Available at: https://www.pnas.org/content/109/31/12302 [accessed 10 December 2020].

Poore, J., Nemecek, T. (2018). *Global Greenhouse gas emissions from food production.* [image online]. Available at: https://science.sciencemag.org/content/360/6392/987 [accessed 10 November 2020].

Project Drawdown. (2015). *Silvopasture.* [online]. Available at: https://www.drawdown.org/solutions/silvopasture [accessed 24 November 2020].

Raskin. (2019). *Silvopasture: The benefits of integrating livestock and trees.* [online]. Available at: https://sustainablefoodtrust.org/articles/silvopasture-the-benefits-of-integrating-livestock-and-trees/ [accessed 2 November 2020].

Ritchie, H. (2019). *Food production is responsible for one-quarter of the world's greenhouse gas emissions.* [online]. Available at: https://ourworldindata.org/food-ghg-emissions [accessed 10 November 2020].

Save Leitrim. (2020). *About us.* [online]. Available at: https://saveleitrim.ie/business/ [accessed 2 November 2020].

Schmidt, H. (2014) The use of biochar as building material. *The Biochar Journal 2014*. [online]. 2297-1114. Available at: https://www.biochar-journal.org/en/ct/3#:~:text=These%20properties%20mean%20that%20biochar,ratio%20of%20up%20to%2080%25. [accessed 10 November 2020].

Teagasc. (2012). *The Second National Forest Inventory.* [online]. Available at: file:///C:/Users/HP/Downloads/109394_b9b5f7c8-2d5f-4333-a041-72ea2f6cdebb.pdf [accessed 8 April 2021].

Teagasc. (2017a). *County Soil Maps*. [online]. Available at: https://www.teagasc.ie/crops/soil--soil-fertility/county-soil-maps/ [accessed 10 April 2021].

Teagasc. (2017b). *Agroforestry.* [online]. Available at: https://www.teagasc.ie/crops/forestry/grants/establishment-grants/agroforestry/ [accessed 19 October 2020].

Teagasc. (2018). *Fact sheet on Irish Agriculture.* [online]. Available at: https://www.agriculture.gov.ie/media/migration/publications/2018/January2018Factsheet120118.pdf [accessed 10 November 2020].

Teagasc. (2020a). *Forest Statistics Ireland 2020.* [online]. Available at: https://www.teagasc.ie/media/website/crops/forestry/advice/Forest-Statistics-Ireland-2020.pdf [accessed 8 April 2021].

Teagasc. (2020b). *Trafficking intensity index for soil compaction management in grassland.* [online]. Available at: https://www.teagasc.ie/publications/2020/trafficking-intensity-index-for-soil-compaction-management-in-grassland.php#:~:text=In%20Ireland%2C%20soil%20compaction%20has,structural%20damage%20threats%20in%20grasslands.&text=Livestock%20treading%20may%20also%20cause%20damage%2C%20through%20poaching%20or%20pugging. [accessed 15 April 2021].

Toal, L. and McAdam, J.H. (1995). Avifauna in establishing silvopastoral systems in Northern Ireland. In *Agroforest Forum* (Vol. 6, No. 2, pp. 25-30).

Toensmeier, E. (2016). *The Carbon Farming Solution: A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security.* Vermont: Chelsea Green Publishing.

Udawatta, R., Kremer, R., Garrett, H., Anderson, S. (2009). *Soil enzyme activities and physical properties in a watershed managed under agroforestry and row-crop systems.* Volume 131, Issues 1–2. [online]. Available at: https://www.sciencedirect.com/science/article/pii/S0167880908001783 [accessed 10 December 2020].

USDA National Agroforestry Centre. (2014) *An overview of Agroforestry.* [online]. Available at: https://www.fs.usda.gov/nac/assets/documents/agroforestrynotes/an01g01.pdf [accessed 11 November 2020].

Warnock, J. (2020). Interview on: *Ocean FM.* [radio]. 12 October 2020, 12.45.

Whiteside, L., Bell, A.C. and McAdam, J.H. (1998). The effect of trees on the biodiversity of grassland. In *Agroforest Forum* (Vol. 9, No. 1, pp. 28-34).

Wilson, B. (2019). *Biodiversity and Agroforestry.* [online]. Available at: https://www.celtnet.org/blank [accessed 19 October 2020].

Zomer, R., Neufeldt, H., Xu, J., Ahrends, A., Bossio, D., Trabucco, A., Noordwijk, M., Wang, M. (2016). Global Tree Cover and Biomass Carbon on Agricultural Land: The contribution of agroforestry to global and national carbon budgets. *Scientific Reports.* [online]. 6, 29987 (2016). Available at: https://doi.org/10.1038/srep29987 [accessed 19 October 2020].

13.   **Appendices**

13.1 Example of completed participant consent form

Sample of Participant Consent Form that was distributed to farmers in the North-West of Ireland.

Participant Consent Form

Study title: Assessing silvopasture as a sustainable method of improving soil quality whilst mitigating climate change.		
I have read and understood the Information Leaflet about this research project. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	Yes X	No ☐
I understand that I don't have to take part in this study and that I can opt out at any time. I understand that I don't have to give a reason for opting out and I understand that opting out won't disadvantage me in any way.	Yes X	No ☐
I have been assured that information about me will be kept private and confidential.	Yes X	No ☐
I have been given a copy of the Information Leaflet and this completed consent form for my records.	Yes X	No ☐
Storage and future use of information: I give my permission for information collected about me to be stored or electronically processed for the purpose of research and to be used in <u>related studies or other studies in the future</u> but only if the research is approved by a Research Ethics Committee.	Yes X	No ☐

Joe Bloggs | *Joe Bloggs* | 12-3-2021

Participant Name (Block Capitals) | Participant Signature | Date

To be completed by the Researcher:

I, the undersigned, have taken the time to fully explain to the above participant the nature and purpose of this study in a way that they could understand. I have explained the risks involved as well as the possible benefits. I have invited them to ask questions on any aspect of the study that concerned them.

Rachel Connolly | BSc. Sustainable Agriculture | *Rachel Connolly* |12-3-2021

Name (Block Capitals) | Qualifications| Signature | Date

13.2 Participant information leaflet

Silvopasture: a sustainable option to improve soil quality and productivity on farms in the North-West region of Ireland.

Hello. My name is Rachel Connolly and I am a fourth year student currently studying BSc. Sustainable Agriculture in Dundalk Institute of Technology. As part of my final year, I am undertaking a thesis. The subject I have chosen to focus my project on is assessing silvopasture as a sustainable option which could improve soil quality in tandem with increasing production levels in farms located in the North-West of Ireland.

One aspect of my project involves examining the perceptions of farmers located in the North-West region of Ireland towards agroforestry. I hope to discover whether an appetite for silvopasture exists, what reasons are responcible for the lack of involvement in the practice and what could be done to improve participation of planting trees on farms in the future.

I would be very grateful if you would take a couple of minutes to fill out this confidental and anonymous survey and answer the questions included. Your participation in my work is greatly appreciated. If you have any further questions, please do not hestitate to contact me via email or mobile on 086 0516088.

Kind regards,

Rachel.

Study title: Assessing silvopasture as a sustainable method of improving soil quality whilst mitigating climate change.

Researcher Name: Rachel Connolly

Research Supervisor Name: Dr. Norma O'Hea

You are being invited to take part in a research study being carried out as part of a fourth-year undergraduate project at Dundalk Institute of Technology (DkIT).

Before you decide whether or not you wish to take part, you should read the information provided below carefully and, if you wish, discuss it with your family and friends. Take time to ask questions – don't feel rushed and don't feel under pressure to make a quick decision.

You should clearly understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. This process is known as 'Informed Consent'.

You can change your mind about taking part in the study any time you like. Even if the study has started, you can still opt out. You don't have to give a reason. If you wish to withdraw you need only send me an e-mail confirming that you wish to withdraw.

Why is this study being done?

This research study is taking place to determine farmers' current attitudes towards, and knowledge of, agroforestry and their openness towards diversification into silvopasture.

Who is organising and funding this study?

Rachel Connolly is conducting this research project to fulfil requirements for the B.Sc. (Hons) in Sustainable Agriculture

Why am I being asked to take part?

You are a farmer who has yet not diversified into agroforestry. Your views are important because they will provide insight into the views of farmers throughout Ireland and what could be done to improve uptake of agroforestry and silvopasture in particular.

How will the study be carried out?

This study will take place from December 2020 to May 2021. It will involve participants taking part in a survey online.

What will happen to me if I agree to take part?

If you agree to take part, you will be asked to complete an anonymous questionnaire. Your name will not be recorded and will not appear in the final report. If your views should be quoted you will not be identified directly.

What are the benefits?

There are no specific benefits to you for taking part in this study. I hope that the results will provide a better understanding of farmers' attitudes towards agroforestry as a sustainable method of farming ad what could be done in the further to encourage more farmers to plant trees on their farms.

What are the risks?

There are no risks involved with this study. You will be asked to take approximately 5 to 10 minutes to complete the survey.

Is the study confidential?

The questionnaire will be confidential and anonymous. All data collected will be stored in a secure, confidential and anonymous manner on a password protected PC. I will make the final report available to all participants upon request.

Where can I get further information?

If you have any further questions or if you want to opt out of the study now or at any time in the future, please contact:

Name: Rachel Connolly   Address: rachelxconnolly@hotmail.co.uk

Sample of survey which was shared to farmers in the North-West of Ireland via email to complete.

13.3 Example of completed questionnaire

1. What size farm do you own/manage?

200+ acres

2. What age category do you belong to?

26-40

3. What enterprises do you farm?

Beef

4. In the future, do you plan to:

Increase your level of production

5. Does the agricultural sector's contribution to climate change concern you?

No

6. Have you incorporated silvopasture practices onto your farm?

Yes

7. If no, what are your reasons for not considering silvopasture?

Respondent skipped this question

8. Do you know anyone in your local area who has incorporated silvopasture onto their farm?

Yes

9. In your opinion, how important is it for trees to be planted on Irish farms? 1- not important 2- not very important 3- neutral 4- moderately important 5-very important

4

10. Do you believe agroforestry should become a compulsory action in the next CAP?

Yes

11. Were you aware of grants available in the Forestry Programme 2014-2020, funded by the Government, for farmers who diversified into Agroforestry?

Yes

12. Would increasing the duration of a scheme similar to the 2014-2020 agroforestry scheme and the payments encourage you to plant trees on your farm?

Yes

13. How do you rate the importance of each of the following?

Sustainable farming
5- Very important

Level of production
5- Very important

Continuation of the same farm practices e.g. dairy with no diversification
2- Not very important

Planting trees for the next generation
5- Very important

Better work-life balance
4- Important

14. What practice would you be most open to integrating onto your farm?

Silvopasture (planting trees and allowing grazing)

15. What tree species would you opt for planting?

Combination of the above

16. In your opinion, rate the importance of each service provided by trees to a landscape:

Increased biodiversity
3- Neutral

Improved water quality
4- Important

Animal shelter
4- Important

Carbon sequestration
4- Important

Improved drainage
4- Important

Aesthetic value/Pleasant to look at
2- Not very important

Source of firewood
3- Neutral

17. How would these encourage you to plant trees on your land?

Increased payments
5- Very important

Schemes last longer
5- Very important

Increased variety of trees to choose from
4- Important

Choose tree location yourself
5- Very important

Ability to use by-products from trees as an additional source of income
4- Important

18. If you have any remaining comments, please state them below:

Respondent skipped this question