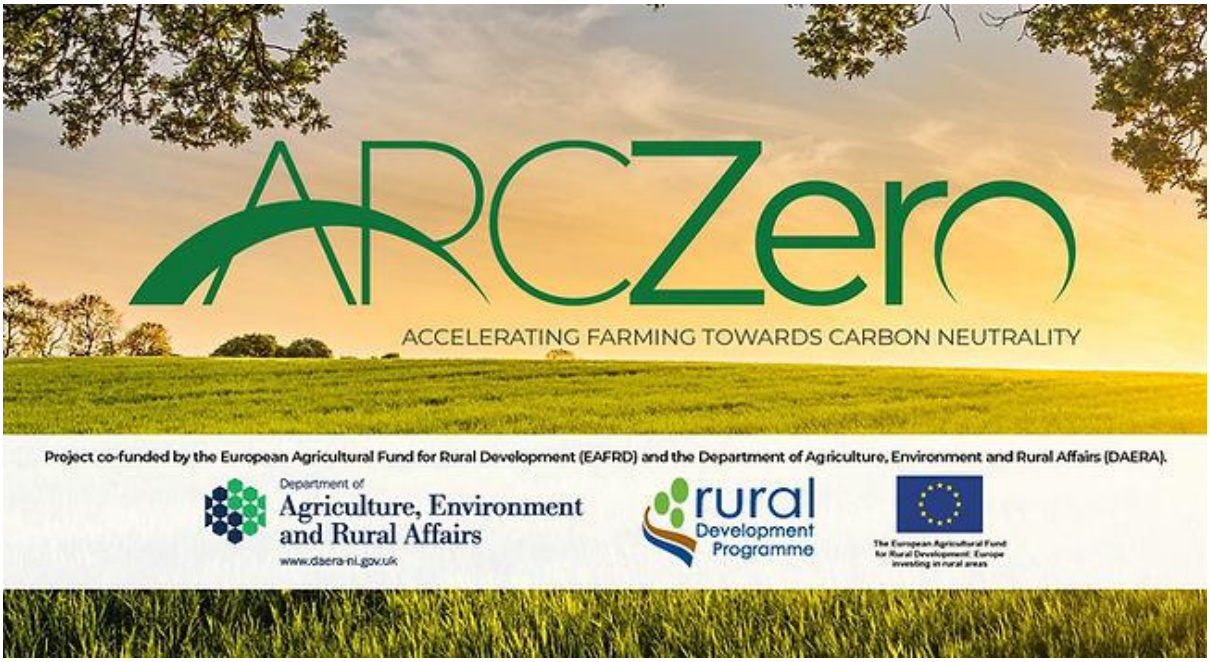

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Operational Group

ARC Zero

Website: www.arczeroni.org

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Abstract

Regardless of what media outlet you listen too, whether it be extreme weather events, or the demand for Net Zero, no one can escape from engaging in the journey towards Net Zero.

ARC Zero, (ARC being an acronym for Accelerating Ruminant Carbon) is an EIP Operational Group Project, funded jointly by the European Agricultural Fund for Rural Development and the Northern Ireland Executive, overseen by the Department of Agriculture, Environment and Rural Affairs (DAERA).

Core to the development of the EIP Operational Groups was the desire to empower practising farmers to lead innovation on farm.

ARC Zero is about seven such farmers who decided to face their responsibilities, embrace the need to find out “their carbon numbers,” carry it out with forensic detail, use it to inform and make better quality decisions on their farms, and deliver positive change in a way that embraces integrity and transparency.

Project Aims

The agricultural sector in Northern Ireland is the largest contributor to greenhouse gas emissions, producing about 27% of the total, in the form of methane from ruminant animals, nitrous oxide (largely from nitrogenous fertiliser) and carbon dioxide from combustion of fossil fuels and soil respiration. However the sector also has the unique ability to sequester and store carbon from the atmosphere in its soils and above ground vegetation, and hitherto this has not been recognised, measured or taken into account in the Greenhouse Gas national inventory. This issue has been brought into the front line by the passing of the Climate Change Act in June 2022 by the NI Assembly, with targets of a 48% reduction in emissions by 2030, and 100% reduction (i.e. Net Zero) by 2050. It is widely recognised, and acknowledged by the UK Climate Change Committee that this will be difficult, if not impossible for the agricultural sector to achieve, but that the industry must move significantly towards Net Zero if the overall target is to be reached.

The ARC Zero project, based on the premise that in order to manage a situation it is necessary to measure its parameters and establish a baseline, aimed to address these issues by:

- carrying out a detailed audit of the GHG emissions from the seven farms involved, using the accredited and independent SAC AgreCalc Life Cycle Assessment calculator.
- Measuring existing soil carbon stocks through a very detailed GPS soil sampling and analysis programme
- measuring above ground carbon through aerial LiDAR scanning at 40 scans per metre.
- adopting measures to both reduce the emissions of greenhouse gases and increase the rate of carbon sequestration on the farms
- repeating the Agrecalc audit at the end of the project to establish any change
- ensuring delivery of other environmental and agricultural benefits, including improved water quality and biodiversity, and more sustainable and profitable farming

Operational Group

The operational group was set up by John Gilliland, one of the seven farmers and a Professor of Practice at Queen's University Belfast. It was established to be representative of a range of farming enterprises, with a Northern Ireland-wide distribution covering different soil types and climatic conditions. Recruitment was achieved largely through the involvement of AgriSearch using their extensive contacts among progressive farmers. The seven farmers involved were:

• John Gilliland	Londonderry, Co Derry	Drystock and coppice willow
• Patrick Casement	Ballycastle, Co Antrim	Sucklers and sheep
• Hugh Harbison	Aghadowey, Co Derry	Dairy
• Roger and Hilary Bell	Kells , Co Antrim	Sheep and beef cattle
• Ian McClelland	Banbridge, Co Down	Dairy
• Simon Best	Poyntzpass, Co Armagh	Arable and beef
• John Egerton	Rosslea, Co Fermanagh	Sucklers and sheep

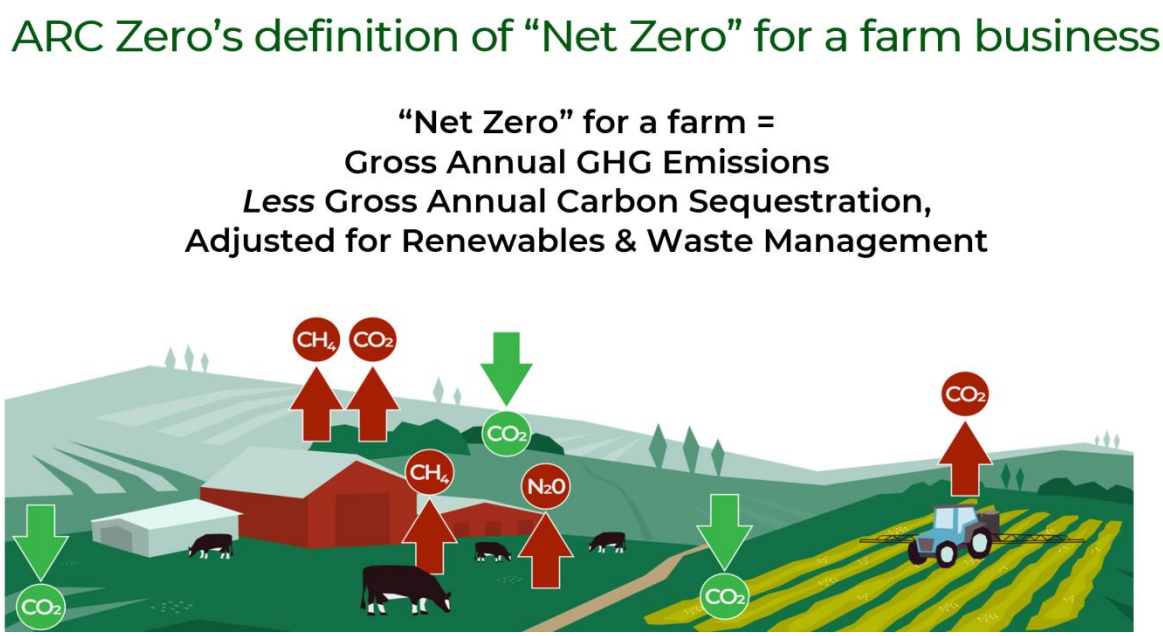
In addition to the farmers Birnie Consultancy was recruited to administer the project, AgriSearch (The Northern Ireland Agricultural Research and Development Council) was commissioned to manage Knowledge Exchange and communications, Devenish Nutrition was invited to share their experience of research carried out at their farm at Dowth, Co Meath, and Queens University Belfast, was brought in to assist with the scientific rigour and provide expertise on soil science. The Operational Group therefore consisted of the seven farmers, along with representatives of these four organisations. ARC Zero also established strong links with the Agri-Food and Biosciences Institute (AFBI) and with the Department of Agriculture, Environment and Rural Affairs College of Agriculture, Food and Rural Enterprise (CAFRE) at an early stage. John Gilliland was appointed Chairman of the group, with Patrick Casement as Deputy Chairman.

A smaller Management Group, comprising John Gilliland, Patrick Casement, Jason Rankin of AgriSearch along with Jonathan Birnie and Ashley Hassin of Birnie Consultancy, was established. It was agreed that the Operational Group would meet on a monthly basis, with the Management Group meeting every fortnight. Meetings were mostly held remotely via Zoom, but over the summer months the Operational Group also met in person, often on members' farms. In addition to discussing ARC Zero business we also invited specialist speakers to some meetings to give us the benefit of their expertise such as agroforestry, soil and animal health and their impacts on greenhouse gas emissions. At an early stage we visited Devenish Nutrition's farm at Dowth, Co Meath, where the pioneering work in carbon base-lining had been carried out. Attendance and engagement at all the meetings has been excellent.

Project Details

1. Establishing a definition for Net Zero

It was agreed at the outset that Net Zero for a farm was the Gross Annual Greenhouse Gas emissions less the gross annual carbon sequestration, adjusted for the use of renewable energy and waste management within the farm business.



Establishing this would involve using a life cycle assessment calculator to work out our farm emissions, measuring carbon stocks in our soils and above ground vegetation, and gaining some understanding of rates of sequestration.

2. Selecting a Carbon Calculator.

We decided that we should only use a carbon calculator that met the following criteria:

- It should be independent, and not involved in carbon trading

- It should be accredited to BSI PAS2050 Standard

- It should cover the whole farm and not just single enterprises

- It should report methane emissions to both GWP100 & GWP methodologies

- It should include carbon sequestration

- It should be backed by a globally credible science-based Institute

3. Running the Carbon Calculator

This involved the seven farmers providing very detailed information twice: firstly at the start of the project in 2021, and then again at the conclusion in 2023. This included details of their operations, covering stock numbers, including ages, purchases and disposals, animal performance, feed inputs, fuel usage, fertiliser applications, utilisation of animal manures, electricity consumption and fodder conservation. This was a challenging process and we were grateful to SAC who provided an invaluable one-to-one assistance and mentoring service, and constructive discussion of the results with recommendations on the most appropriate and cost-effective mitigations that might be undertaken.

4. Soil Analysis

As part of establishing a baseline we carried out an extremely detailed analysis of the soils on our farms. This involved dividing each farm into 2ha blocks, including on-farm woodland, then soil sampling 25 cores per 2 hectare block, to a depth of 7.5cm in grassland and 15cm in arable fields, with each sample site recorded on GPS. To ensure that the process had complete integrity and quality control the sampling was carried out by an independent company, RPS. The samples were then analysed for:

- pH
- Phosphate
- Potassium
- Calcium
- Magnesium
- Soil Organic Matter, measured by Loss on Ignition

This analysis was carried out by NRM, the UK's largest independent provider of agronomic and environmental soil analyses.

5. Land management descriptions

The Arc Zero farmers provided details of past land management on each 2 hectare block or field based on the following criteria:

- Grassland, multi-species sward, arable, woodland, silvopasture, willow coppice
- Slurry, farmyard manure or compost applied
- Grassland grazed, cut or both
- Level of soil organic matter – 0-10%, 10-20%, 20-30%, >30%.

This gave a total of 86 different land management categories across the seven farms.

6. More detailed measurement of soil carbon and soil bulk density

Across the seven farms a more targeted soil sampling was undertaken based on the management categories in an attempt to discover whether past management influenced the levels of carbon in the soil. This involved sampling to a depth of 30 cm, with five cores being taken at each chosen site, and a cylinder of soil removed to establish the bulk density of the soil in situ to compare with a measurement made by NRM based on re-constituting the core samples. Measuring bulk density is essential if one is to establish the total amount of carbon in the soil rather than simply the percentage of carbon present. At the same time as measuring soil carbon and bulk density a soil textural analysis was carried out, measuring the relative proportions of clay, silt and sand.

This second sampling resulted in 465 sites being sampled in total.

7. Measurement of above ground carbon stocks

Light Detection and Ranging (LiDAR) has been widely used as a tool in archaeological surveys and for accurate measurement of buildings, but in 2012 the EPA in Ireland commissioned Teagasc to evaluate a method of using it to measure above ground carbon. We therefore commissioned BlueSky International to carry out LiDAR scanning at 40 scans per square metre, and orthographic photography surveys of our farms over the winter months of 2020-21 when the deciduous trees and hedges were without leaf cover. We then engaged AFBI to calculate the carbon levels in the above ground vegetation in a similar manner to what Teagasc had delivered for the EPA.

8. Run-off Risk Mapping

The same LiDAR survey data, when analysed using different software, can also be used to establish ground level pathways where rain water will flow across fields and ultimately into watercourses, often carrying soil and nutrients such as phosphates, particularly during heavy rainfall. Combining this information with the phosphate indices for the fields involved will give a clear picture of the high risk areas on a farm which will lead to soil and phosphate enrichment of watercourses and water bodies. We commissioned AFBI to create run-off risk maps of our seven farms to provide insight into how we might manage these areas through remedial actions. This was intended to deliver environmental benefits beyond the core aims of the project as well as ensuring the most efficient use of phosphate fertiliser and our own organic manures.

9. Additional soil carbon measurement

During the course of the project we discovered a company, Agricarbon, who offered a unique soil carbon and bulk density analysis service to a depth of up to one metre at a very competitive price. We commissioned them to carry out a trial on our farms, repeating the sampling carried out at (6) above at one in every five sample sites, with an additional whole farm survey on three of our farms using their sampling strategy. Their sampling technique

produces a core which can be subdivided at four different depths, 0-15cm, 15-30cm, 30-60cm, and 60cm +, providing greater insight into carbon distribution, and enabling very accurate measurement of bulk density at all the different depths. The resulting figures for soil carbon levels are significantly more accurate than other methods of measurement can provide, and show clearly the benefits of sward/tree diversity, which in turn leads to diversity of root architecture and the laying down of additional carbon across these four depths.

10. Mitigation actions

- Liming - fields identified with low pH were limed to bring them to a pH of 6.5 for optimal growth of legumes and uptake of nutrients.
- Reduction in nitrogenous fertiliser use – levels of fertiliser were reduced to cut down emissions of nitrous oxide.
- Clover stitching in – clover seed was sown into ryegrass swards to provide nitrogen through fixation, replacing artificial fertiliser.
- Multi-species swards – a range of mixtures of grasses, herbs and legumes were used to reseed ryegrass swards. These swards require significantly less nitrogen, improve soil structure and porosity and have positive effects on animal performance as well as biodiversity.
- Tree planting – the run-off risk maps identified areas that were appropriate for planting trees to slow down the run-off of excess rainfall and mop up surplus phosphate. This included riparian strips. Other unproductive areas were also identified and trees planted to improve carbon sequestration.
- Hedge management – hedges were allowed to grow taller and wider, and new cutting regimes introduced to increase sequestration.
- Grazing management – the introduction of multi-species swards meant that grazing regimes needed to be adjusted with longer intervals between grazings and higher stocking rates for each grazing period.
- Animal genetics – reductions in cow size were introduced, both by buying in alternative breeds or by careful bull selection.
- Grazing of coppice willow – indications from *in vitro* experiments that a diet of willow leaves reduced methane production from ruminants were tested in a field trial.

11. Re-running of Carbon Calculator to measure progress

The Agrecalc carbon calculator was run for a second time at the end of the project on five of the seven farms to measure progress towards net zero. The other two farms had already reached net zero and so the calculation was not repeated.

12. Farm Walks

A series of seven farm walks were planned across the ARC Zero farms, with each walk focusing on a different aspect of the project. The schedule was as follows:

May 2022, Roger and Hilary Bell – introduction to the project. Carbon measurement.

June 2022, Simon Best – managing carbon on an arable farm.

June 2022, John Egerton – grazing management. Multi-species swards.

September 2022, Hugh Harbison - multi-species swards. Cow genetics.

April 2023, Ian McClelland - animal health and carbon. Wooded riparian strips.

May 2023, Patrick Casement – pH and clover. Biodiversity.

June 2023, John Gilliland - cattle diet and methane reduction. Renewable energy.

13. Lectures and presentations

As the project proceeded considerable interest was raised and requests were made for presentations and lectures to a very wide range of bodies and audiences across Northern Ireland, Great Britain, and Europe.

14. Conferences

Two conferences were hosted:

- March 2023 - *Barriers to Net Zero* in partnership with Institute for Global Food Security, Queen's University, Belfast.
- June 2023 - EIP Closing out conference. An end-of-project summing up of the findings and conclusions of the ARC Zero project, to be held at John Gilliland's farm, Brook Hall, Londonderry.

15. Workshops

A number of workshops were planned, both on line and in person, to discuss a range of topics relevant to our work.

16. Capital expenditure

The following purchases were planned:

Item	Cost
Weather Station	£6,653.00
Variable rate fertiliser spreader	£21,900
2 no. Tractor GPS units	£2,900
Low emission slurry tanker	£33,500

Funding Expenditure

Project:

The following items of expenditure were planned:

- Soil Sampling
    - 0-7.5cm for grassland fields, 0-15cm for arable with a core diameter of 1.5cm
    - Each soil sample represents a two-hectare parcel, taken in a 'W' shaped traverse across the field
- Soil Analysis to UKAS (ISO 17025) accreditation standard with certification for
    - pH (in water, 1:2.5 volume ratio of soil to water)
    - Phosphorous (Olsen) (1:20 volume ratio of soil to sodium bicarbonate)
    - Potassium (1:5 volume ratio of soil to ammonium acetate or ammonium nitrate)
    - Magnesium (1:5 volume ratio of soil to ammonium acetate or ammonium nitrate)
    - Organic Matter by Loss on Ignition (LOI)
- LiDAR Aerial Survey
    - 40ppm LiDAR with RGB Orthoimagery
    - 25cm resolution DTM/DSM
    - Classified LAS data
    - Accuracy +/- 50mm RMSE
    - Survey to be undertaken while leaves are off in Spring 2021 – suggested period 15 th February to 30 th April 2021
- Hydrological Mapping
    - Hydrological runoff modelling and generation of runoff risk maps following the methodology of Thomas et al. (2016)
    - Provision of colour-indexed field nutrient maps with the appropriate index-based colour scales for pH, phosphate, potash, calcium and magnesium and soil organic matter.
- Above ground Biomass quantification
    - Analysis of LiDAR data to generate quantification of above ground biomass (AGB) (hedgerows, free standing trees and plantations)
    - Production of farm maps illustrating the distribution of the AGB around the farm and produce estimates of total AGB at farm, land unit and per different AGB category
- Life Cycle Assessment Calculator
    - Must be able to appraise the total farm business including fixed costs
    - Must be accredited to the BSI PAS2050 Standards to at least TIER II, and be in a position to help adopt TIER III factors where possible
    - Must be able to differentiate methane emissions within their calculator so that if/when IPCC and UNFCC recognise Oxford Work on GHGP* results can

be adjusted to reflect the decision.
    - Must be from an internationally recognised centre of excellence
    - Must have a track record of coming on farm and providing a one-to-one walk through of the results and benchmarking
- Project finance and administration
- Provision of communication services
- Provision of farm-walks

Projected Cost

Item	Cost
Soil Sampling	£21,709.84
Project Management	£11,083.93
Financial Administration	£3,000
LiDAR Survey	£36,339.80
Carbon Calculator	£15,729.98
Hydrological Mapping and Biomass	£10,534.02
Workshop Provision	£229.76
Knowledge Transfer	£ 19,373.08

Funding Sources:

- EIP
    - EIP project funding
    - EIP Capital funding
- Private funding – contributions from ARC Zero members
- The seven farmers' own time

Project Results and Outcomes

1. Establishing a definition for Net Zero

As described above the following definition was agreed:

"The Gross Annual Greenhouse Gas emissions less the gross annual carbon sequestration, adjusted for the use of renewable energy and waste management used within the farm business."

2. Selecting a Carbon Calculator.

Only one calculator out of many available in the UK met all of the set criteria. This was Agrecalc run by Scotland's Rural College (SRUC). We therefore contracted them to carry out our carbon audits at the start and finish of the project.

3. Running the Agrecalc Carbon Calculator

The results from the initial Agrecalc Carbon Calculator were as follows:

Gross Emissions for the seven ARC Zero farms:

2021 AgReCalc Analysis	Enterprises	Gross Emissions
Ian McClelland	Dairy	1,125t/yr
Hugh Harbison	Dairy	2,012t/yr
John Egerton	Beef	1,404t/yr
Roger & Hilary Bell	Sheep with Beef	820t/yr
Simon Best	Arable with Beef	1,799t/yr
Patrick Casement & Trevor Butler	Beef & Sheep	492t/yr
John Gilliland	Willows with Dry Cows	151t/yr

Gross sequestration for the seven ARC Zero farms (using TIER 1 module):

2021 AgReCalc Analysis	Enterprises	Gross Sequestration
Ian McClelland	Dairy	309t/yr
Hugh Harbison	Dairy	550t/yr
John Egerton	Beef	442t/yr
Roger & Hilary Bell	Sheep with Beef	455t/yr
Simon Best	Arable with Beef	738t/yr
Patrick Casement & Trevor Butler	Beef & Sheep	549t/yr
John Gilliland	Willows with Dry Cows	156t/yr

Net Carbon as a Percentage of Gross Emissions (using TIER 1 Module)

2021 AgReCalc Analysis	Enterprises	Gross Emissions	Gross Sequestration	Net Emissions	% Reduction
Ian McClelland	Dairy	1,125t/yr	309t/yr	816t/yr	27%
Hugh Harbison	Dairy	2,012t/yr	550t/yr	1,462t/yr	27%
John Egerton	Beef	1,404t/yr	442t/yr	962t/yr	31%
Roger & Hilary Bell	Sheep with Beef	820t/yr	455t/yr	365t/yr	56%
Simon Best	Arable with Beef	1,799t/yr	738t/yr	1,061t/yr	59%
Patrick Casement & Trevor Butler	Beef & Sheep	492t/yr	549t/yr	-56t/yr	112%
John Gilliland	Willows with Dry Cows	151t/yr	156t/yr	-5t/yr	103%

Benchmarked farms against average

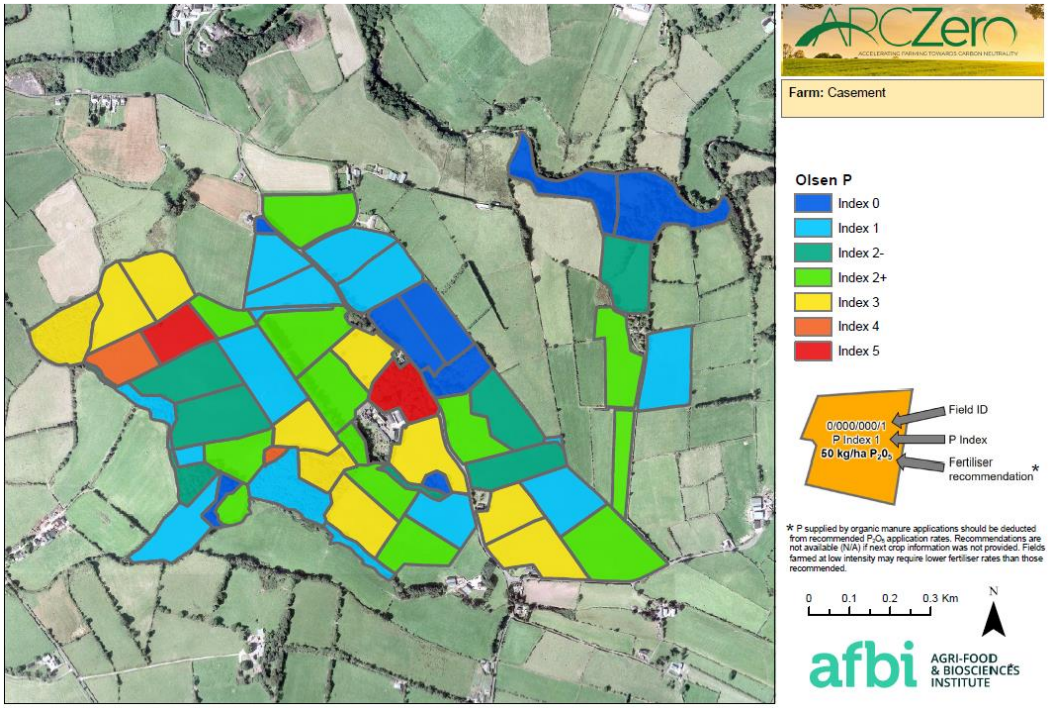
2021 AgReCalc Analysis	Enterprises	Actual Emissions	Benchmark Average
Ian McClelland	Dairy	1.3kgCO2e/kg FPC Milk	1.3kgCO2e/kg FPC Milk
Hugh Harbison	Dairy	1.25kgCO2e/kg FPC Milk	1.3kgCO2e/kg FPC Milk
John Egerton	Beef	32.8kgCO2e/kg dwt	37.6kgCO2e/kg dwt
Roger & Hilary Bell	Sheep with Beef	21.9kgCO2e/kg dwt	28.4kgCO2e/kg dwt
Patrick Casement & Trevor Butler	Beef & Sheep	24.6kgCO2e/kg dwt	41.9kgCO2e/kg dwt

Conclusions:

- ARC Zero farms were already at, or well above average in their GHG performance.
- No two farms are the same.
- Two of the seven farms have already reached Net Zero.
- Net Zero for the farming sector will be realised when the mean of farming businesses reach Net Zero. Some farms will find it easier than others, some will exceed Net Zero, while some will never get there. A mechanism to allow farmers to trade carbon between themselves will accelerate the sector's journey to Net Zero.

4. Soil Analysis

The detailed soil analysis produced a huge amount of data which cannot be presented here in any meaningful way. Initially the results came from NRM in the form of tables, which we judged to be quite difficult to interpret without lengthy study. We therefore determined to present the data in graphic form, using colour coded maps for each nutrient/category. These were generated with the assistance of Rachel Cassidy of AFBI and distributed to each farmer who was then able to tell the status of any field at a glance. Examples of these maps are shown below:



5. Land Management descriptions

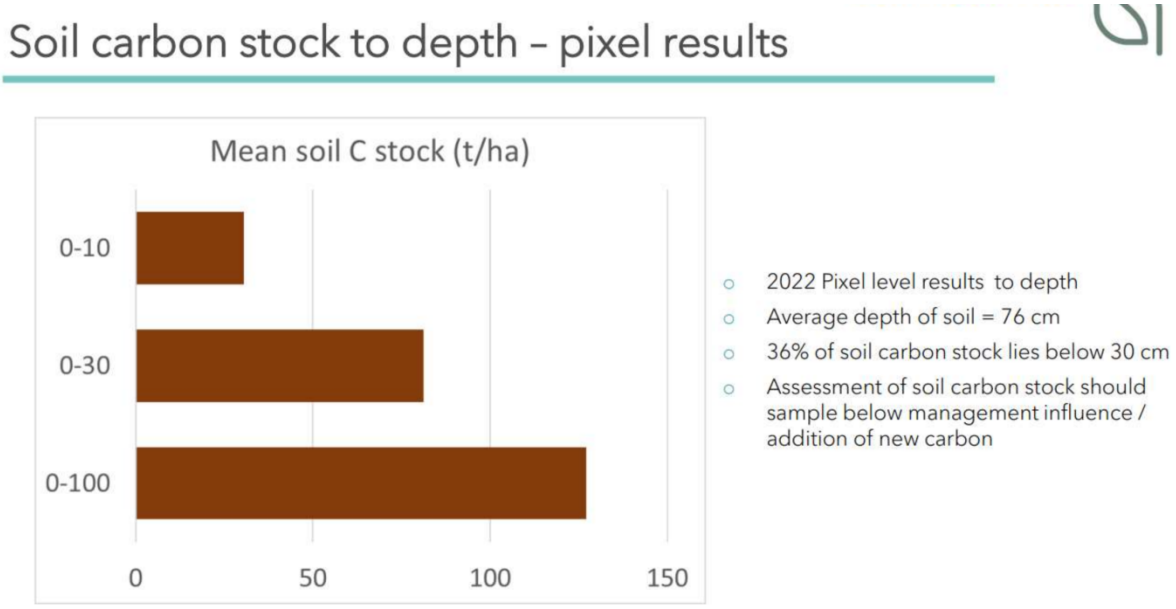
The following land management categories were identified:

- Permanent Grass, no slurry/FYM, only grazed
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, slurry, only grazed
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, FYM, only grazed
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, no slurry/FYM, cut and grazed
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, slurry, cut and grazed
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, no slurry, cut only
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Permanent Grass, slurry, cut only
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Multispecies sward, no slurry, grazed only
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter
    - 20-30% Soil Organic matter
    - >30% Soil organic Matter
- Multispecies sward, slurry, grazed only
    - <10% Soil Organic matter
    - 10-20% Soil Organic matter

        - 20-30% Soil Organic matter
        - >30% Soil organic Matter
- Silvopasture
        - <10% Soil Organic matter
        - 10-20% Soil Organic matter
        - 20-30% Soil Organic matter
        - >30% Soil organic Matter
- Deciduous Woodland
        - <10% Soil Organic matter
        - 10-20% Soil Organic matter
        - 20-30% Soil Organic matter
        - >30% Soil organic Matter
- Mixed Woodland
        - <10% Soil Organic matter
        - 10-20% Soil Organic matter
        - 20-30% Soil Organic matter
        - >30% Soil organic Matter
- Coniferous Woodland
        - <10% Soil Organic matter
        - 10-20% Soil Organic matter
        - 20-30% Soil Organic matter
        - >30% Soil organic Matter

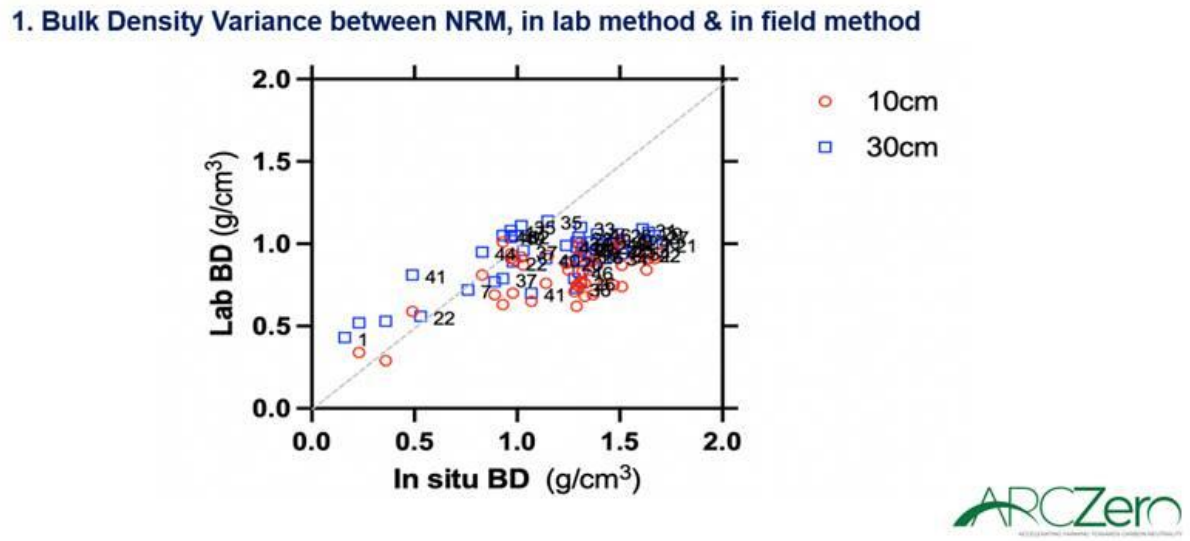
6. The detailed measurement of soil carbon and soil bulk density

The results from this measurement indicated that the level of soil carbon varied widely, depending on the soil type and vegetation. However it was clear that there was still a significant but diminishing amount of carbon at depths down to at least 30cm, indicating that sampling to a depth of 7.5cm does not give a true reflection of the total soil carbon. This was confirmed subsequently by the Agricarbon sampling down to the soil's C Horizon which was at an average depth of 76cm across the seven ARC Zero farms. The amalgamation of their results across the seven farms is shown below:



H. Black, Agricarbon, 2023

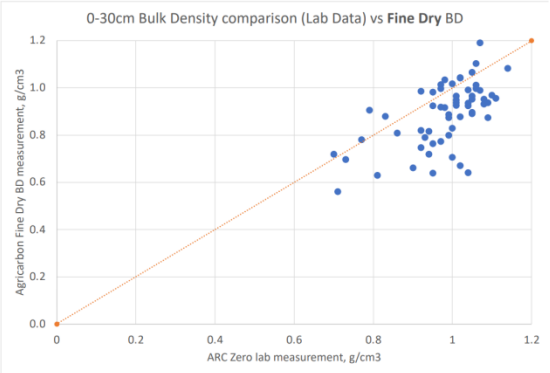
Analysis of the results for bulk density carried out by Dr Paul Williams of Queen's University Belfast showed a considerable difference between the two initial methods of measurement, with the figures for the in situ measurement being significantly higher than those for NRM's laboratory reconstituted technique. The latter appeared to plateau at about 1g/cm³, while there were many measurements of a higher value from in situ measurement. This is clearly shown on the graph below:

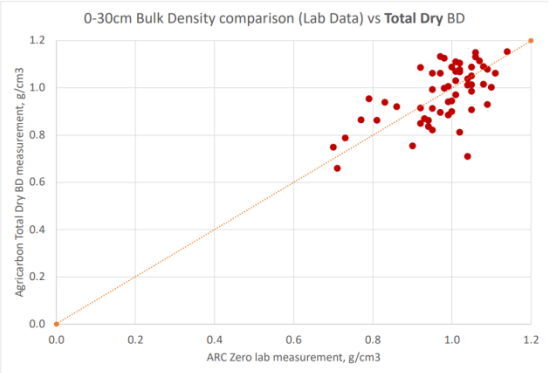


P. Williams, QUB,2022

Subsequent discussions with Dr Helaina Black of Agricarbon gave us greater understanding of the discrepancy: the in situ samples included stones, which should be removed and thereby excluded from the calculation.

Bulk Density Correlation, lab measures 0-30

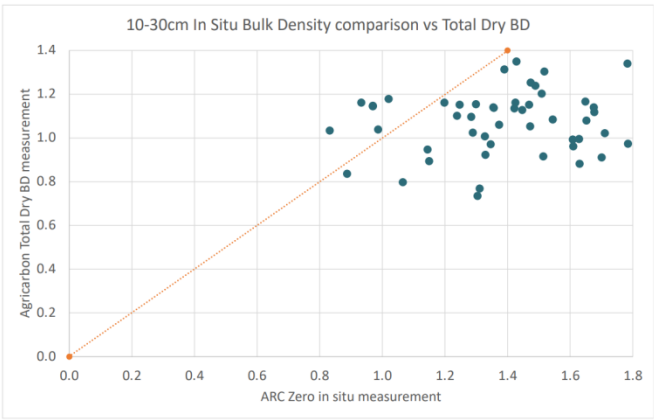




- Each point represents one sampling location (5 cores)
- Lab results are a better match with the Total Dry Bulk Density calculation
  - For these, centred around the y=x line
  - Whilst many points are close to the line (average distance < 10%), some points are more distant

H. Black, Agricarbon, 2023

Bulk Density Correlation, in-situ measures



- In situ measurements (for 10-20 cm depth) generally have a higher bulk density than the Agricarbon measurements (for 10-30 cm)

H. Black, Agricarbon, 2023

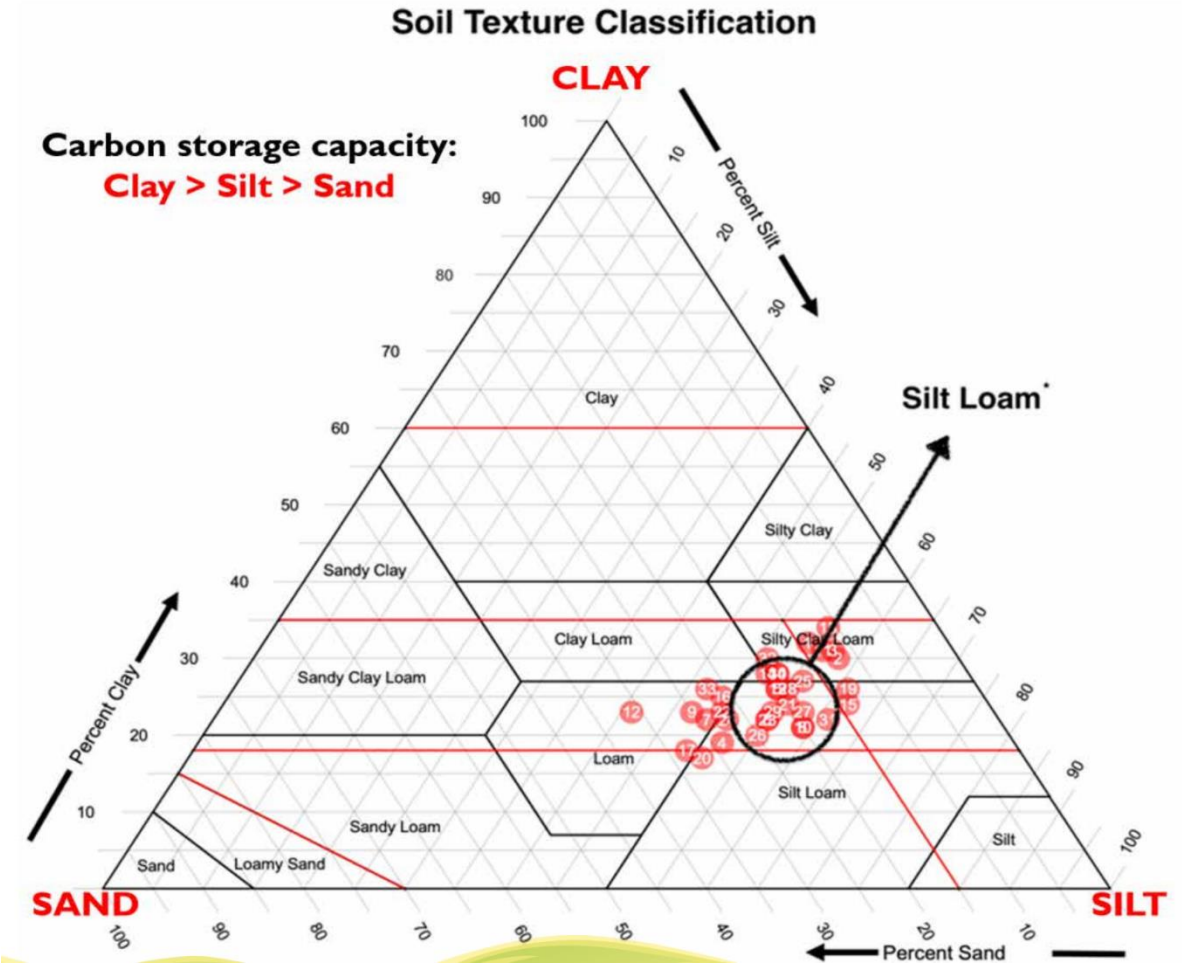
It was agreed, in the absence of Agricarbon's more detailed bulk density measurements across all seven farms, that we should use the more conservative NRM bulk density results to establish levels of soil carbon stocks. This was done for all management categories on each farm, which combined with the area of each category gave the total amount of carbon stored in the top 30cm of soil.

Total Soil Carbon Stocks across ARC Zero farms……

Farm	Total Soil Carbon Stocks (tonnes CO 2 equivalent)
Ian McClelland	31,813
Hugh Harbison	68,054
John Egerton	31,813
Roger & Hilary Bell	50,819
Simon Best	237,915
Patrick Casement	54,556
John Gilliland	19,468
TOTAL	**494,438 tonnes**

From this we could only conclude that farmers are custodians of much of the nation's carbon, and that we needed to help them to build additional carbon stocks.

Finally the results for soil texture classification were presented in graphic form as shown in the example below:



Brook Hall Estate, Soil Texture Classification, Buffara, WUR, 2023

As with the soil nutrient level maps these diagrams give an immediate understanding of the soil texture on each farm. The soil texture gives a good idea of the potential for carbon storage: clay soils have much greater ability to store carbon as the fine soil particles and chemically active, whereas sand particles are almost completely inert and therefore unable to bind carbon or most nutrients effectively.

It should be noted that most of the farms showed significant variations in soil types between fields and often within fields or within very short distances. This appears to be a feature of farms in Northern Ireland, and makes it difficult to make generalisations about soil carbon or develop models to predict levels. Once again discussions with Dr Helaina Black indicated that this is further complicated by the frequent presence of organo-mineral soils in the province, where organic soils (originating from peat) and mineral soils are mixed together. These soils fall outside of conventional soil classifications and present problems when trying to prescribe management to enhance carbon stocks.

Variability of soil over short distances – results

- The table below shows the standard error / mean, averaged over all locations

Average SE / mean	0-10cm	0-30cm
Total Dry Bulk Density	20%	13%
Fine Dry Bulk Density	19%	14%
SOC%	22%	20%
Carbon stock	26%	20%

Key points:

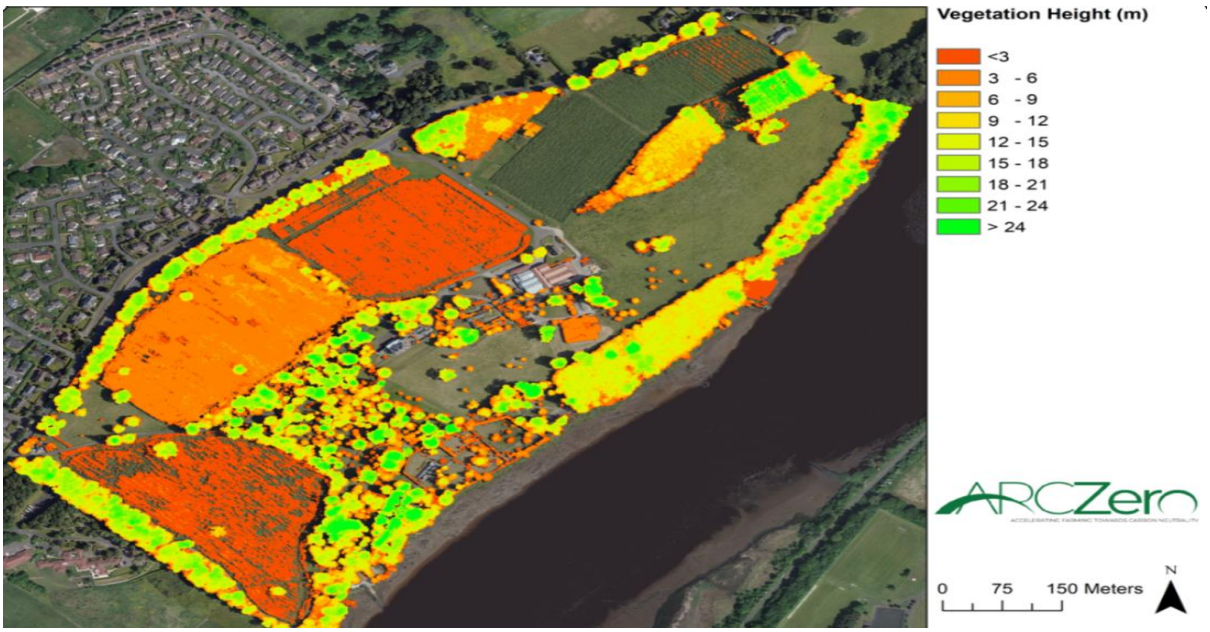
- Even across short distances, soil measurements are quite variable
- There is lower variability for 0-30cm than for 0-10cm
- Bulk density is less variable than SOC%

H. Black, Agricarbon, 2023

7. Measurement of above ground carbon stocks

LiDAR scans were completed over the winter of 2020-21, but because the orthographic photography requires very clear skies opportunities were limited and by the time the last three farms were scanned there were some leaves on the trees. As a result these farms were scanned again in November 2021.

The scans were analysed by Alex Higgins of AFBI, who produced colour maps depicting the above ground vegetation (principally trees and hedges) coded according to height. A typical map is shown:



Brook Hall Estate, A. Higgins, AFBI, 2021

From the above, a Carbon Asset Register of the above ground carbon was created.

	Brook Hall Estate Totals					
Vegetation type	Hedge Length (km)	AGB (t)	C (t)	BGB* (t)	C (t)	Total C (t)
Hedge 0-4m	0.78	14.92	7.1	2.86	1.3	**8.5**
Hedge 4-7m	0.35	6.36	3.0	1.22	0.6	**3.6**
Hedge 7-10m	0.25	10.32	4.9	1.98	0.9	**5.9**
Hedge >10m	1.00	156.17	74.5	29.99	14.1	**88.6**
Total Hedges	**2.38**	**187.77**	**89.5**	**36.05**	**16.94**	**106.49**
	Canopy Area (ha)					
Single Trees	1.87	494.78	236.0	95.00	44.6	**280.6**
Deciduous Woodland	17	1352.74	645.1	259.73	122.1	**767.2**
Coniferous Woodland	0.09	6.17	2.9	1.27	0.6	**3.5**
Biomass	28.96	337.61	161.0	64.82	30.5	**191.5**
Total	**47.92**	**2,379.07**	**1,134.6**	**456.8**	**214.7**	**1,349.3**

Brook Hall Estate, A. Higgins, AFBI, 2021

The totals of above ground carbon for the Arc Zero farms were:

Farm	Above ground carbon	% of total
Ian McClelland	1,310 tonnes	4%
Hugh Harbison	1,969 tonnes	3%

John Egerton	1,310 tonnes	2%
Roger &Hilary Bell	688 tonnes	4%
Simon Best	6,493 tonnes	3%
Patrick Casement	4,022 tonnes	7%
John Gilliland	4,937 tonnes	20%
TOTAL	20,729 tonnes	

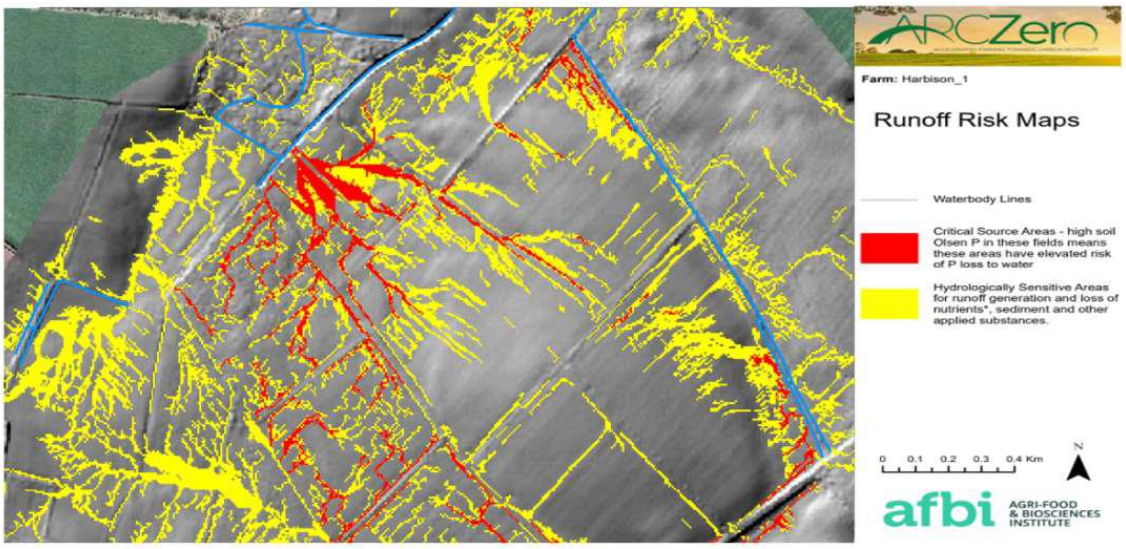
These results highlight the low proportion of stored carbon that is held in above ground vegetation compared with the amounts that are stored in our soils. Even on farms with high tree cover (eg the Casement farm with c.20% tree cover, plus hedges) the percentage of carbon stored in those trees and hedges only constitutes a small proportion of the total. This in turn leads to the conclusion that it is essential, even in soils under trees, that we manage our soils in a manner which both protects the stored carbon and also increases the rate of sequestration in order to actively remove carbon from the atmosphere. This is particularly important as our work shows that soil pH drops significantly under most areas planted with trees, an effect most marked under conifers. Planting trees will, of course, also result in above ground, carbon sequestration, but we cannot rely on this alone to make a significant difference without taking large areas of land out of food production.

Putting the figures for soil carbon and above ground carbon together we get the following results:

Total ARC Zero CO2e Stocks	Soil Carbon	Tree Carbon	Total Carbon	% C in Soil
Ian McClelland	31,813t	1,310t	33,123t	96%
Hugh Harbison	68,054t	1,969t	70,023t	97%
John Egerton	31,813t	1,310t	33,123t	96%
Roger & Hilary Bell	50,819t	688t	51,507t	98%
Simon Best	237,915t	6,493t	244,407t	97%
Patrick Casement & Trevor Butler	54,556t	4,022t	58,578t	93%
John Gilliland	19,468t	4,937t	24,405t	80%
		Total	**515,166t**	

8. Over Environmental Benefits, Improving Water quality through Run-off Risk Mapping

Rachel Cassidy from AFBI processed our LiDAR data to produce run-off risk maps, showing the lines of greatest run-off risk as shown below:



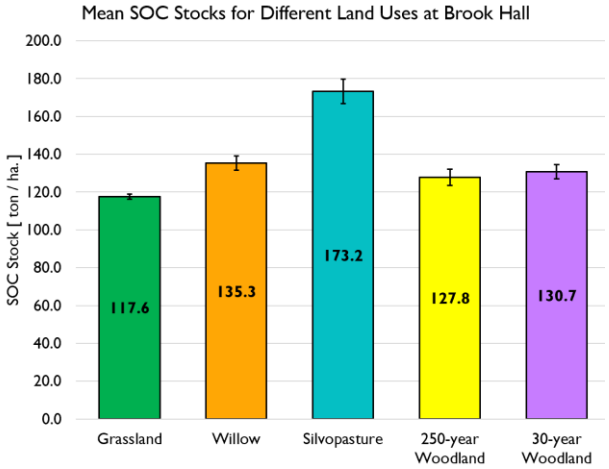
H.Harbison farm, R.Cassidy, AFBI, 2021

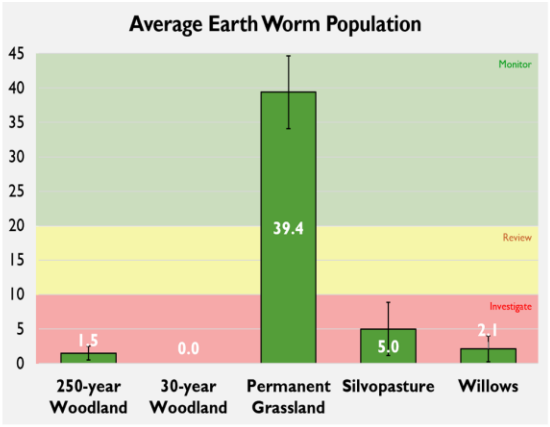
The yellow and red lines show the hydrologically sensitive areas for run-off generation and the loss of nutrients and sediment. The red lines show critical source areas where high levels of soil Olsen P in these fields produce elevated risk of P loss to water courses. The water courses are shown in blue.

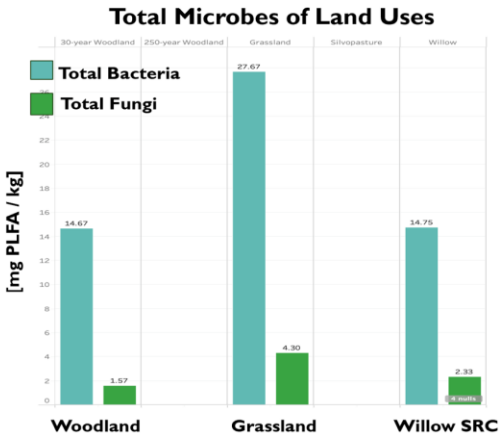
These maps enable farmers to target preventative measures to ensure that Phosphate and soil run-off to water courses is minimised. These might include reduced Phosphate application in the these fields, planting of multi-species swards with better water infiltration rates, or the planting of riparian strips of woodland beside the water course. The most effective action would be to plant trees at the source points for the runoff, though this may not always be practical.

9. Other Environmental Benefits, Measuring Soil Biodiversity across different land uses

In March 2023, ARC Zero hosted the placement of Wageningen University & Research Master's student, Ricardo Buffara. Ricardo focused at looking at the impacts on Soil Health and Soil Organic Carbon by different long-term land uses at Brook Hall Estate, where five totally different long term land uses have been used. Their impact on soil organic carbon stocks and soil biodiversity can be seen below







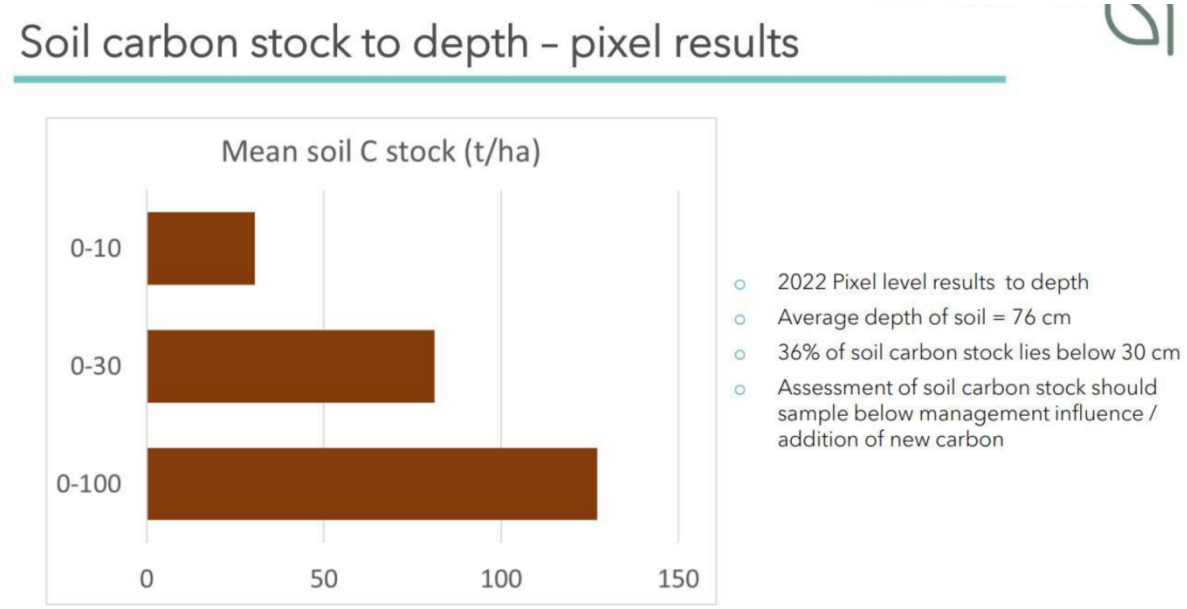
R. Buffara, WUR, 2023

This work highlighted the beneficial role of big animal agriculture defecating on the soil and inoculating the soil biology; and the exemplar role that a hybrid of land uses, such as silvopasture, can play to accelerate our improvement of soil health and building carbon stocks.

10. Additional soil carbon measurement

Agricarbon used the equipment shown to take soil samples down to one metre depth or the C-horizon, whichever came first. These samples were taken from one in five of the sample points used in the initial soil carbon measurement, located using the GPS co-ordinates recorded by RPS. The machine extracts a core, 3.6 cm in diameter, encased in a clear plastic cylinder, which can then be divided into different lengths (eg 0-15cm, 15-30cm, 30-60cm, >60cm) for separate analysis. The analysis is carried out automatically, measuring soil carbon percentage and fine bulk density to give totals of carbon in each sample.

The average of the results across the seven farms is shown below:



H.Black, Agricarbon, 2023

11. Mitigation actions

A significant number of mitigation actions were taken by the seven farmers involved, depending on their perceived issues and desired outcomes, influenced by their farm enterprises, soils, and personal preferences. These included:

- Optimisation of soil pH, achieved by the application of lime. This has had multiple benefits including:
    - Improved nutrient uptake
    - Improved clover production and contribution to nitrogen availability
    - Improved soil structure through influence of calcium ions
    - Improved earthworm populations

- Reduction in nitrogenous fertiliser use. This has partly been a consequence of massive price increases, but has also been driven by improved clover performance. Nitrogenous fertilisers are the principal source of emissions of Nitrous Oxide, the most potent greenhouse gas.
- Clover stitching in. The addition of clover to swards of perennial ryegrass has a major impact on the requirement for nitrogenous fertiliser.
- Multi-species swards. Four of the seven farms introduced these swards, using several techniques for establishment, with mostly excellent results. The benefits of multi-species swards have been demonstrated clearly at Dowth and elsewhere, and include:
    - Improved soil structure
    - Higher soil organic matter
    - Improved soil porosity
    - Improved animal performance
    - Improved biodiversity, both above and below ground
- Grazing management. The grazing of clover-rich swards and multi-species swards requires some adjustment to grazing regimes, generally requiring a longer rest period between grazings, shorter grazing periods but with higher stock levels, and a greater bulk of vegetation before grazing. This has sometimes proved quite difficult to manage where there is only a limited area of these swards among predominantly ryegrass swards. This points to a requirement to create significant grazing blocks of these swards to accommodate the stock grazing them.
- Animal genetics. Two of the farms involved have taken the step of reducing cow size by either investing in a different breed of cow (eg Salers sucklers) or breeding replacements with a smaller sire (eg Jersey crosses from Holstein cows). Some work by SRUC suggests that this could reduce greenhouse gas emissions by about 15% without significant reduction in productivity.
- Tree planting. While trees store significantly less carbon than soils they provide a number of other benefits:
    - Active carbon sequestration, particularly with young trees
    - Shelter from livestock, from both wind and hot sun
    - Biodiversity opportunities
    - Farm fuel
    - Landscape enhancement
    - Phosphate removal

Areas of unproductive and awkward land such as rushy corners of fields may be well suited to growing trees, as well as riparian strips which can protect watercourses from run-off pollution. Two ARC Zero farms have planted areas of woodland, one on wet, unproductive land and the other as a riparian strip.

- Hedge management. Hedges can sequester surprising amounts of carbon if well managed, particularly when they are young. The ideal management regime is to cut only every 2-3 years, to le the hedge grow slightly taller each year and then reprofile it after 10-15 years, and to let it grow wider. Older, ‘leggy’ hedges can be either coppiced or laid. Several of the ARC Zero farms have moved towards better management, and on one farm an overgrown hedge has been laid.

- Grazing of short rotation coppice willow.

12. Re-running of Carbon Calculator

The results from five of the seven farms are shown below:

Farm	Enterprises	2021 Emissions (CO_2e per kg product)	2023 Emissions (CO_2e per kg product)	% Reduction
Ian McClelland	**Dairy**	**1.3kg**	**1.1kg**	**13%**
Hugh Harbison	**Dairy**	**1.25kg**	**1.2kg**	**4%**
John Egerton	**Beef**	**32.8kg**	**25.6kg**	**22%**
Bells	**Lamb**	**22kg**	**15.7kg**	**28%**
Simon Best	**Cereals**	**0.99kg**	**0.47**	**53%**

All five of these farms achieved a reduction in their emissions within a two year time frame. The other two farms were not run through Agrecalc for a second time as they had already achieved Net Zero and in the absence of any incentive for them to go further in their carbon journey.

13. Farm Walks

The seven farm walks were duly held over the summers of 2022 and 2023. The schedule was as follows:

Date	Host	Subject
May 2022	Roger and Hilary Bell	Introduction to the project Carbon measurement
June 2022	Simon Best	Managing carbon on an arable farm

June 2022	John Egerton	Grazing management
September 2022	Hugh Harbison	Multi-species swards Cow genetics
April 2023	Ian McClelland	Animal health and carbon Wooded riparian strips
May 2023	Patrick Casement	pH and clover Biodiversity
June 2023	John Gilliland	Cattle diet and methane reduction Renewable energy

For each walk a series of display boards were prepared to illustrate the points being made by a range of speakers at a series of stops on a circuit round the farm. Speakers included the host farmer, other members of ARC Zero, advisers from CAFRE, researchers from AFBI and Queen's University Belfast, and members of other EIP Operational groups. In each case a booklet was also produced, containing images of the display boards and other relevant information. At each stop discussion was encouraged, and at the end of each walk there was an opportunity to discuss issues with the speakers and ARC Zero members.

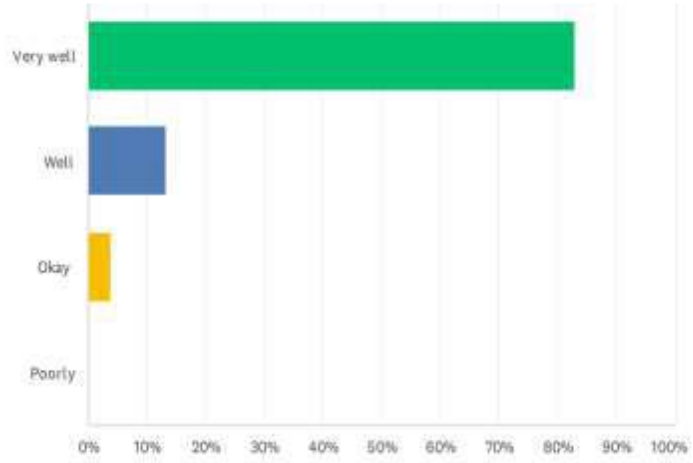
Attendances were good:

Farm	Numbers	Comment
Roger and Hilary Bell	90	
Simon Best	145	Held jointly with the Ulster Arable Society and ITLUS
John Egerton	90	
Hugh Harbison	250	
Ian McClelland	100	
Patrick Casement	50	
John Gilliland	160	Took place following close-out Conference

After the event we sought feedback from attendees and received a considerable number of responses. These can be summarised as follows:

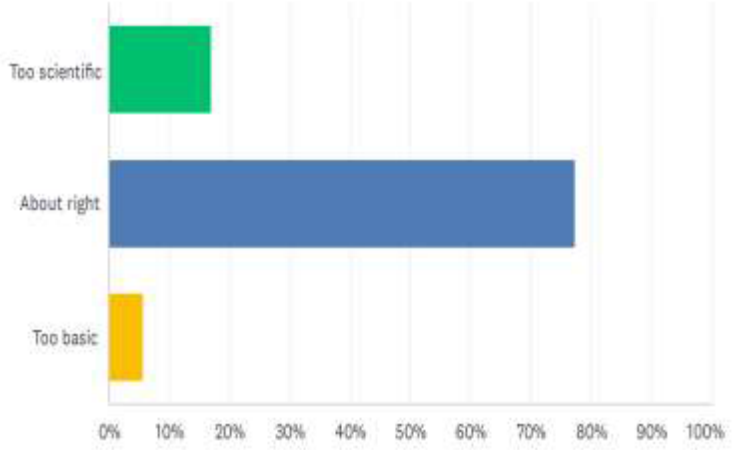
Q3 How well do you think the event was organised and run?

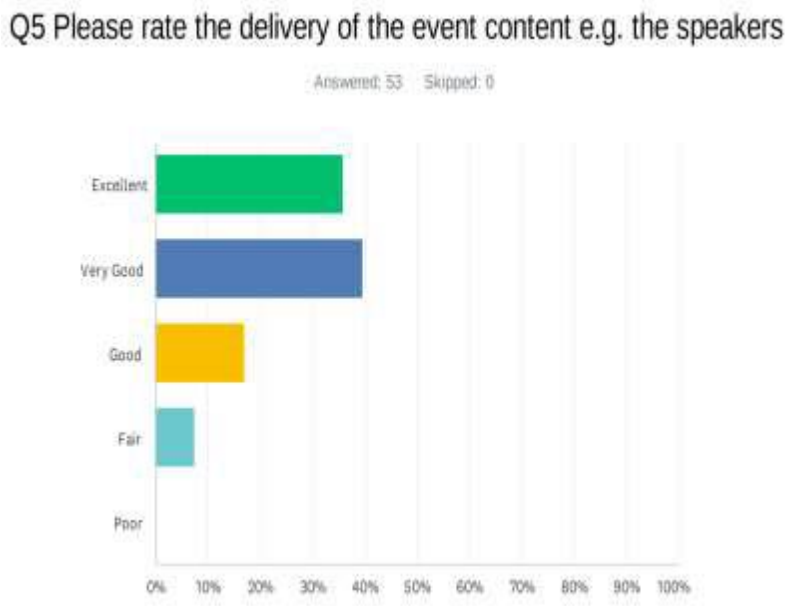
Answered: 53 Skipped: 0



Q4 Please rate the content of the event?

Answered: 53 Skipped: 0





Mainly qualitative comments were submitted at the same time and the following sums up the majority.

"Found the walk to be very current, interesting & informative. Speakers were clear to the point, no waffles, helped by having a host who is walking the walk and not talking the talk. Excellent farm walk."

14. Lectures and presentations

The following lectures, presentations and farm visits were made over the course of the project:

- NI
  - DAERA Chief Science Adviser (John Gilliland)
  - AFBI (John Gilliland)
  - Barclays Bank (4 times) (John Gilliland, Simon Best, Hugh Harbison)
  - NI Historic Houses Association (John Gilliland)
  - Young Farmers Club of Ulster (x2) (John Gilliland)
  - Mid and East Antrim Borough Council (John Gilliland)
  - Ulster Grassland Society (Hugh Harbison)
  - CAFRE Advisers team (John Gilliland)
  - RPS (John Gilliland)
  - DAERA Climate Change conference (John Gilliland)
  - Lakeland Creameries Dairy team (John Gilliland)
  - NI Soroptimists (Patrick Casement)
  - CAFRE Environmental BDG (Patrick Casement)
  - South West College (John Gilliland)
- UK
  - LEAF (x3) (Simon Best and John Gilliland)

- UK Net Zero Bus Tour (David Gilliland)
- UK Climate Change Committee) (John Gilliland)
- UK Agricultural Partnership (Patrick Casement)
- Video at COP 26 in Glasgow
- British Nutrition Foundation (John Gilliland)
- Groundswell 2022 and 2023 (John Gilliland)
- UK Institute of Agricultural Management (x4) (John Gilliland)
- Hybu Cig Cymru (John Gilliland)
- Presentation to Princess Royal at Dowth (Patrick Casement and Ian McClelland)
- AHDB Board (John Gilliland)

- Republic of Ireland
  - Irish Tillage and Land Use Society (Simon Best, John Gilliland, Patrick Casement)
  - Irish Guild of Agricultural Journalists (John Gilliland, Simon Best)
  - National Economic and Social Council (John Gilliland)
- European Union
  - Wageningen University (Simon Best, John Gilliland)
  - EU Commission DG Clima (John Gilliland)
  - EU Commission DG Ag (John Gilliland)
  - EU Parliament webinar (John Gilliland)
  - FEDIOL (John Gilliland)
  - European Milk Forum (John Gilliland)
  - European Dairy Association (John Gilliland)
  - EIT Food annual conference (John Gilliland)
- International
  - International Dairy Forum (John Gilliland)
  - UN Economic Commission of Europe (John Gilliland)
  - Good Meat Summit, Sydney, Australia (John Gilliland)

15. Conferences

The two planned conferences were duly held:

Barriers to Net Zero in partnership with Institute for Global Food Security, Queen's University, Belfast, took place on 23rd to24th March 2023.

Day 1: 23rd March 2023

13:00 – 14:20 Lunchtime Talk by Professor Gideon Henderson, Chief Scientific Adviser at DEFRA & Q&A
14:40 – 14:50 Chair's welcome, Prof Nigel Scollan
14:50 – 15:05 'Setting the Scene – A View from a Practitioner' - Prof John Gilliland
15:05 – 15:15 Initial Reflections

15:15 – 16:00 Speed Session, Chair Prof Nigel Scollan
16:00 – 16:15 Break
16:15 – 18:00 Speed Session, Chair Prof Nigel Scollan
19:10 – 20:00 Keynote Address:

'A Pathway to Carbon Neutral Agriculture in Denmark: Lessons Learned': Prof Jorgen Oleson, Head of Department, Department of Agroecology, Aarhus University.

Day 2: 24th March 2023

09:30 – 09:40 Welcome, Prof John Gilliland
09:40 – 09:50 'A European Perspective'
09:50– 10:00 Şeyda Ozkan, FAO: A Global Livestock Perspective
Case Studies: Overcoming Barriers to Net Zero
10:00 – 10:15 Prof Gary Lanigan, Principal Research Officer (Teagasc): Challenges and opportunities for moving to Tier 2 Emission and Land-Use Factors
10:15 – 10:30 Prof Neil Ward, University of East Anglia: Harnessing Interdisciplinary Science for Net Zero Policy Design
10:45 – 11:00 Dr Florian Freund, Thunen Institute of Market Analysis: The effects of a planetary health diet on agricultural incomes and greenhouse gas emissions in Ireland and Denmark.
11:00 – 11:15 Agri-Food & Biosciences Institute Northern Ireland (AFBI): Delivering water quality improvements at catchment scale – a case study from the Upper Bann Catchment Platform
11:15 – 12:30 'Focus group' Discussions and Synthesis on the three Barriers to achieve Net Zero in Agriculture and Food, Facilitated by Prof John Gilliland (and individual chairs)
13:15 – 14:15 Discussion: Barriers to Achieve Net Zero in Agriculture and Food,
14:15 – 14:30 Wrap Up/Agreement of Outputs, Prof John Gilliland
14:30 – 14:40 Close and thanks, Prof Nigel Scollan

Attendance at this conference was 64**,** with representation from :

- NI (AFBI, DAERA, QUB, FFCC, UFU, RSPB, Devenish, AgriSearch and RSPB)
- England (DEFRA, AHDB, Universities of Reading and East Anglia)
- Ireland (DAFM, Teagasc, Irish Farmers' Journal)
- Scotland (SRUC, Agricarbon)
- Germany (Thünen Institute)
- Netherlands (Wageningen University)
- Denmark (Aarhus University)

EIP Closing out conference, 20th June 2023.

An end of project summing up of the findings and conclusions of the Arc Zero project, held at John Gilliland's farm, Brook Hall, Londonderry.

Welcome	Dr Jonathan Birnie, Birnie Consultancy
Keynote address	Professor John Gilliland, ARC Zero
Panel Session 1	ARC Zero farmers, Ian McClelland, Hugh Harbison, John Egerton and Patrick Casement Led by John McLenaghan, UFU
Panel Session 2	ARCZ Zero farmers, Simon Best, Roger Bell and John Gilliland Led by John McLenaghan, UFU
Reflections	Norman Fulton, DAERA Deputy Secretary (Food and Farming Group)
Summary	John McLenaghan, UFU
Thanks and acknowledgements	Professor John Gilliland, ARC Zero

Attendance at the conference was about 160 people from a very wide range of organisations as well as individual farmers:

- NI – DAERA, CAFRE, AFBI, QUB, UFU, LMC, Devenish, National Trust, Rural Support, Dept of Finance, AgriSearch, Bank of Ireland, Barclays Bank, Danske Bank, Ulster Bank, Tesco, BBC, NIMEA, Derry and Strabane Council, United Feeds, B9 Energy, Gibson Trust, Foyle Food Group, FFCC, Blakiston Houston Estates, Abercorn Estate, and Larchfield Estate.
- RoI – Teagasc, TCD, Dunbia, Irish Farmers' Journal, Dublin City University, Irish Agroforestry Forum.
- England - DEFRA, AHDB, Farming Carbon.
- Scotland - Agrecalc, Agricarbon.

16. Workshops

A series of workshops were held over the course of the project:

- Soil improvement 13/5/21 – an on-line workshop for ARC Zero members with David Atherton, a ruminant nutritionist and soil scientist, covering:
    - Physical improvement – principally soil aeration
    - Chemical improvement – addressing the Calcium:Magnesium ratio in the soil
    - Biological improvement – using slurry additives to digest slurry and increase its nutrient value

- Nutrient Planning 26/1/22 Held at Greenmount College with CAFRE advisers. This covered the use of the CAFRE Nutrient Management software.

- Agrecalc 17/2/22 Held at Loughry College, with Jonathan Bell of Agrecalc, ARC Zero farmers and their CAFRE advisers. This covered the results of the first run of AgreCalc, and also looked at some possible mitigation scenarios.

- Soil Bulk Density 1/4/22 An on-line discussion between ARC Zero, Alistair Carson (DAERA Chief Scientific Adviser), AFBI, Teagasc and NRM. This explored the issues around soil Bulk Density focussing on its measurement.

- Soil Carbon Measurement 11/1/23 Held at AFBI, New Forge Lane, involving ARC Zero farmers, Annie Leeson, Stewart Arbuckle and Helaina Black of Agricarbon, Alistair Carson, Peter Scott, and Brendan Gilroy of DAERA, and Elizabeth Magowan and Jan-Pieter Schon of AFBI. This covered:
    - The background to Agricarbon:
        - Science – accuracy, depth of measurement, intensity of sampling
        - Service – detailed sampling strategy, standardised collection, automated analysis and cost effectiveness.
    - The results from detailed sampling of Hugh Harbison's farm.
    - Putting soil carbon data to work:
        - The need for independent data
        - Measurement, Reporting and Validation
        - Carbon markets

- Animal Health and Greenhouse Gas Emissions 8/3/23 An on-line workshop with Jonathan Statham chair of Bishopton Veterinary Group and Chief Executive of RAFT Solutions Ltd, covering:
    - Effects of poor animal health:
        - Reduced productivity
        - Inefficient production
        - Higher overheads
        - Higher GHG emissions per unit of output
    - Case studies:
        - Pregnancy diagnosis
        - Bovine Viral Diarrhoea
        - Calf pneumonia
        - Mastitis
    - Marginal Abatement Cost Curve for the control of endemic disease in dairy cattle which showed the benefits (in terms of both cost and GHG emissions) of a wide range of animal health interventions.

17. Capital expenditure

The following purchases were made:

Weather Station	£6,653.00
Variable rate fertiliser spreader	£21,900
2 Tractor GPS Units	£2,900
Low emissions slurry tanker	£33,500

Building bridges between farmers, the research and development community and others supporting the agriculture sector

From the very start of the ARC Zero project we have initiated and developed strong links to a range of bodies involved in research, development, advice and training. Several of these bodies are associates of ARC Zero, and have played an important role in our work. These include:

- AgriSearch, the farmer-funded, production orientated research organisation covering the beef, dairy and sheep sectors. They have been running three other EIP projects on multi-species swards, anthelmintics and leatherjackets as well as being closely involved in ARC Zero. Their Director, Jason Rankin, sits on our Management Group and has been an invaluable source of intelligence around the whole agricultural sector. Their staff have been closely involved in organising our communications and running our farm walks.
- Birnie Consultancy, a solutions driven agri-food consultancy working with the entire food chain. Their clients include DAERA, AFBI, CAFRE, NI Food and Drink, Queen's University, AHDB, NFU, Quality Meat Scotland and the Isle of Man Government.
- Devenish Nutrition, a multi-national feed company based in Northern Ireland. They pioneered the work that we have picked up on at their farm at Dowth, Co Meath, have been generous in sharing information and insight.
- Institute for Global Food Security, Queen's University, Belfast. The IGFS is one of four interdisciplinary Global Research Institutes at Queen's University Belfast, established to address the key, international challenges of the integrity of our food systems. The Director of IGFS, Professor Nigel Scollan sits on our Operational Group, while several members of his staff and students have been involved in analysing our data on soils.
- College of Agriculture Food and Rural Enterprise (CAFRE) provide advice and education to the agri-food sector. They are also the body through which our funding flows, and run the EIP Forum. As well as keeping them abreast of the progress of the project we have established strong links to several of their advisers, who have given presentations at all of our farm walks, focusing on the bigger picture of carbon balances and the need for sectoral action. Many other advisers have attended our events.
- Agrifood and Biosciences Institute (AFBI), the leading provider of scientific research and services to government, non-governmental organisations and commercial organisations. We have worked very closely with Rachel Cassidy and Alex Higgins in particular, who gave us great help on producing maps of nutrient levels, above ground carbon measurement, and run-off risk mapping. This has tied in closely with their work on the Soil Nutrient Health Scheme. They have also spoken at several of our farm walks, presenting the results of their work for us in clear and accessible language.
- Other EIP projects – Through the EIP Forum and our association with AgrisSearch we have established close contact with the other EIP projects, particularly the Multi-species Swards group and the Ruminant High Health Group. Sam Strain from the

latter group spoke at one of our farm walks, stressing the relationship between animal health and greenhouse gas emissions.

- Food, Farming and Countryside Commission (FFCC) and GrowIn – FFCC was set up to look at future solutions for a more sustainable food and farming system post-Brexit. In Northern Ireland it has established a subsidiary, GrowIn, which acts as a focal point for organisations and individuals interested in and involved with regenerative and innovative agriculture. ARC Zero has been involved with GrowIn from the start, and they have publicised our farm walks and wider activities.
- Northern Ireland Environment Link (NIEL) the umbrella body for environmental NGOs. We have been able to publicise our activities on their fortnightly member update which is widely read in the sector. In addition we have established links with their Rural Resilience Project co-ordinator.

18. Conclusions

- If you empower farmers with really good data about their own farm, they will change their behaviour positively, to deliver the journey to Net Zero Carbon, while also delivering other public goods, such as improvements in water quality and biodiversity.
- In order to manage farm GHG emissions and carbon stocks effectively, it is first necessary to establish a baseline a rigorous, repeatable and verifiable methodology. ARC Zero has worked hard with a range of partners and contractors to develop such a methodology to establish baselines for the seven farms involved.
- The seven ARC Zero farms hold 515,166 tonnes of CO_2 equivalent within their total area of 930 ha. This figure gives an idea of the vast amount of carbon stored in Northern Ireland's farmland. Our farmers are unquestionably the guardians of the nation's carbon.
- The bulk of this carbon (average 97%) is held in the soil, rather than in the above ground vegetation.
- Our soils are extremely varied, in terms of their structure, texture and carbon content. Significant variation occurs over short distances, and further complexity is added by the common occurrence of organo-mineral soils, where mineral soils and peat are mixed together.
- Different soils have very different abilities to sequester and store carbon. Clay soils can sequester and hold carbon much better than sandy soils due to the chemical interactions that can take place on the surface of their particles.
- To achieve a MRV of soil organic carbon it must be measured to depths beyond 30cm, to see the full benefit of creating diversity in the plants grown in the soil. As well, the sampling density in the initial survey must be done at a level that allows the minimum detectable difference to be measured with statistical significance, when the sampling is repeated after five years.
- ARC Zero has explored a range of measures to move their farms towards NetZero. These include:
    - Liming
    - Reduction in nitrogenous fertiliser use
    - Clover stitching in
    - Multi-species swards
    - Tree planting
    - Hedge management
    - Grazing management
    - Animal genetics
    - Grazing of coppice willow

These have all shown considerable potential to either reduce emissions, or increase sequestration, or both. Five of the farms have shown improvements of between 4% and 53%.

- Each farm has adopted a different suite of measures, depending on the principal issues identified by Agrecalc and their farming operations. It is apparent that there is no universal simple formula for achieving NetZero, but rather a suite of options from which individual farmers can select the most appropriate for their circumstances.
- Net Zero is achievable for the NI farming sector, but only where farmers are empowered by the transparency of the results from detailed baselines of their GHG emissions and their carbon stocks.
- Two of the ARC Zero farms are already beyond Net Zero

Notwithstanding the private cash and the time of the seven farmers invested in ARC Zero, the success of ARC Zero would not have been possible if it wasn't for the initial public funding support. This initial support helped to create and catalyse ARC Zero into action. All the participants in ARC Zero are indebted to the EIP Programme of the European Agricultural Fund for Rural Development and the Northern Ireland Executive, and for the leadership and administration of the Department of Agriculture, Environment and Rural Affairs.