Farm carbon stocks monitoring, reporting and verification

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1. Introduction

Measurement, reporting and verification (MRV), are the tools that allow actions by farmers to reduce greenhouse gas (GHG) emissions and increase carbon (C) sequestration to be turned into trusted impacts. Without measurement, the size of the impact will not be known; without reporting, the source of the impact will be unrecognised and without verification the measured, reported impact will not be trusted. MRV can be done at national statistical scale for inventory reporting or it can be done at the farm level: scaling up for national inventory or staying at the farm gate for C farming or credits. MRV can come from data provided by the farmer or producer or they can acquired remotely using sensor technology. MRV approaches are particularly important with respect to C stocks on the farm – how much carbon is already stored in the soil and in hedgerows, value and credit will only flow from an increase in these stocks. The C stocks can increase due to actions being taken by the farmer (e.g. straw incorporation), and the measurement and verification of these actions is sufficient for reporting. This would be known as an action based approach to carbon farming. The second approach would be results based – demonstrating that a specified increase carbons stocks has been achieved. The MRV methods for results based schemes rely on measuring or modelling of carbon stocks before and after the period over which the scheme was to be run.

2. State of Knowledge

The suite of technologies and methods used in MRV have been explored and developed within the Teagasc research program looking at both action and results based approaches.

Within the Teagasc Signpost Programme, baselines of carbon stocks in soils and above ground carbon have been created. As part of the Signpost Programme, over 100 farms have been selected for comprehensive soil sampling and measurements of soil organic carbon sequestration. Signpost strategically chooses spatially distributed locations that comprise a variety of soil types, land uses, and management scenarios in order to measure SOC stocks, analyse distribution patterns, and identify factors influencing SOC stability. C fractionation measures are included at depth to identify the different carbon pools and understand the quality and persistence carbon present in soil. These measures are critical for understanding the potential for soils to sequester carbon. Changes in carbon stocks over the lifetime of the Signpost programme can be made, directly linking recommended actions with results on the farm. Combining these approaches improves quantification of soil carbon dynamics.

Cutting edge laser scanning technologies are used to give accurate estimates of above and below ground carbon stored in woody biomass. Teagasc has been researching the importance of hedgerows for carbon and habitat for many years and published the first national hedgerow map in 2010. A number of projects since then have developed methods to estimate volume and carbon of hedgerows from laser scanning, photogrammetry and satellites. Hedgerows are now mapped routinely by DAFM, Tailte **Éireann** and private companies. Teagasc developed the methodology to detect automatically hedgerow removal, in the BRIAR project and estimated approximately a net removal of hedgerows between 1995 and 2015 of between 0.16-0.3% pa. The FarmCarbon project created the first Irish allometric models to convert hedgerow volume to biomass C. The project found that hedgerows typically contain ~58 tC/ha and, if allowed to grow, increase this amount by 1-2 tC/ha/yr (Black et al, 2023). The project also found a net removal of hedgerows in Waterford/ Wexford between 2015-2020 meaning that hedgerows were a source of GHG emission not a sink. Every farm in signpost will have full carbon inventories created, see figure 1, and a new PhD (in the AGNAv cluster) is developing methods of tracking change over time.

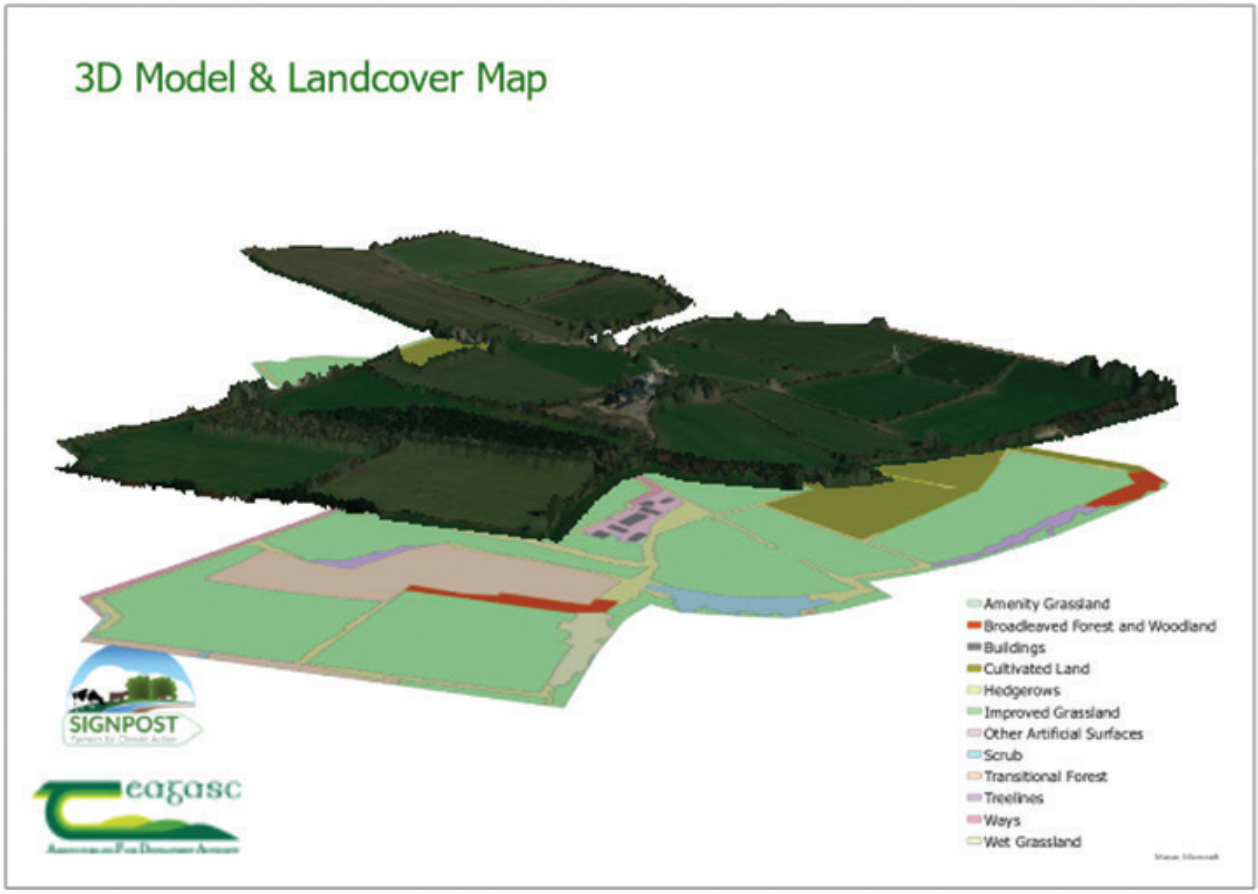

Figure 1: Laser Scanning of signpost farms allows us to very accurately estimate the C content of hedgerows, trees and forest and to create a biodiversity baseline map for the farms.

Teagasc (funded by DAFM, the Agricultural Catchment Programme and SFI VistaMILK) recently established the National Agricultural Soil Carbon Observatory (NASCO) network to measure the greenhouse gas emissions from a 28 sites representing a range of land-uses and soil types across Ireland (Murphy and Bondi, 2024). These towers create vast amount of data but also need a lot of other support data on management activity, crop growth, weather and soil. The Maynooth University/Teagasc SFI/Microsoft funded TerrainAI project created a digital platform for the collation and analysis of all this data. Besides tower data, remote sensing data from drone surveys, aircraft flights and satellites were captured and analysed. This large array of data is being used on the platform to model emissions at farm and national scales and is being used to developed explicit MRV tools.

Ireland has implemented various soil sampling schemes to monitor and estimate soil C stocks at national level. While these schemes provide valuable insights, their accuracy can be further enhanced by considering additional factors such as the depth of sampling and precise measurements of soil organic carbon. The Signpost Programme serves as a valuable resource for informing national soil sampling schemes on strategies to enhance accuracy by addressing aspects crucial for precise C stock estimation. Teagasc research has shown that up to 40 t C/ha was found below 30cm (Simo et al. 2019) and different soil bulk density measurement can over estimate C stocks by up to 310% (Fenton et al., 2024). Thus robust soil MRV methods are needed and a gold standard method for accurate calculation of C stocks needs: 1. depth of a soil layer, 2. representative bulk density and 3. representative organic carbon. Soil carbon content can vary significantly across different landscapes and even within the same field. Sampling schemes that do not account for this spatial variability may not provide accurate national estimates of C stocks. Standardized methods are essential for obtaining accurate and comparable results. For the Tower sites in TerrainAI extensive soil sampling was carried out to provide a spatial assessment of the true small scale variation in soil properties across the tower footprints.

TerrainAI used satellites to map different types of grassland management and grassland productivity. These products act as verification of the adoption of grassland management as action to reduce emissions. Verification of grassland management is also verification of agricultural activity and the paddock detection tool has been adopted by DAFM as an input into its CAP payments system. In Tillage, the planting of winter green cover is an important measure for GHG mitigation and water quality; using Sentinel 1 satellites (that can see through cloud), Teagasc in TerrainAI has developed a method to detect green cover at field scale in November and December.

One of the significant measures for land-based mitigation could be controlling of the water table in agricultural peat soil settings. Significant research is underway nationally as summarised by Saunders et al.(2024) all of which will create new MRV tools for agricultural peat soils. These are being developed within the Teagasc D-TECT project.

Grassland and sward management can play a significant role in reducing greenhouse gas emissions and increasing soil carbon sequestration. Remote methods to detect use of clover or multi-species swards at farm scale have been developed within VistaMILK. Detection of growing and grazing season have also been explored within Teagasc.

Internationally tools for MRV in relation to forestry are significantly more advanced than those for agriculture. In Ireland, statistical knowledge of plantation and native forestry is good and remote sensing tools for detecting forest health and the impact of forest fires are being created. A number of flux towers are located on forestry to improve our knowledge of the impact of management on forest carbon sequestration or emission factors. Within Teagasc the role of farm forestry in achieving farm net reductions is that farm forestry contributes significantly to carbon sequestration, helping to offset emissions from agricultural activities. By planting trees on farms, farmers can sequester carbon in the biomass and soil, which helps in mitigating climate change.

3. Implications for Stakeholders

MRV as tool for the support of carbon farming and the possible development of carbon markets is quickly developing. There are yet no agreed standards in Ireland for the MRV of carbon credits and there are already a small number of firms attempting to offer different standards of MRV at farm scale. MRV for measures that impact the national inventory for agriculture have different accuracy and utility needs than those for reporting on farm scale actions.

There is a robust national hedgerow baseline and methods for measuring change at both farm and national scale. The automatic detection of hedgerow removal will soon become common place – farmers need to be aware that hedgerows and trees represent an important carbon store. Even if hedgerows are replanted it will take up 30 years for the new hedgerow just to absorb the carbon that was lost when the old hedgerow was removed. Farmers can be confident that any trees planted on the farm or within hedgerow will be accounted for both nationally and at farm scale.

For soil carbon, the data analysed within the NASCO project will massively improve the accuracy of national net estimates of carbon emission from agriculture. Within a carbon farming context action based approaches are easier to verify and some of the Teagasc research is allowing this to be done in areas such as grassland management, hedgerow management, winter green cover and the extent of agricultural peat lands.

MRV for results based carbon farming can be more difficult. Monitoring the establishment and growth of farm forestry is now routine- but also loss of biomass thought clearance, deforestation, natural disaster (forest fires, storms etc.) is also possible – results based markets could lead to loses for farmers if a forest is destroyed for example. MRV for changes in soil carbon is largely dependent on "before and after" soil sampling – but soil carbon accumulation occurs over decades.

The modeling tools developed around emission profiling of actual sites rather than generalised factors associated with particular soil/land use combinations can in fact be a cause of uncertainty for the land manager in results based schemes. Some sites may be a sink in some years and source of GHG in others due to seasonal weather impacts largely out the control of the farm manager. Financial support for farmers to adopt measures that are likely to improve net GHG budgets (action based approaches) do not suffer from this uncertainty.

4. Future Research Needs

The continued support of the NASCO network of towers is vital if specific factors for Irish land uses and soils in all seasons are to be created. Without these factors, international data will used in there stead, making in some cases poor approximations of the reality. Work will continue in the development of MRV tools that allow for actions by farmers to be translated into trusted national level statistics.

In Table 1 are selected measures from the Teagasc marginal abatement cost curve, MACC, advices. Measures such as hedgerow management have technical solutions to measuring, reporting and verification by remote systems and are ready to be included in national inventories. Some such as extended grazing need a small amount of research and technical development to be ready whilst options such as water table management are only now being researched in the context of MRV.

Table 1: MACC measures that are amenable to remote MRV - the table indicates whether the technology is ready for measuring, reporting or verification.

Measure	Measuring	Reporting	Verification
Grassland Management	Yes	Yes	Yes
Cover Crops	Yes	Yes	Yes
Prevent Deforestation	Yes	Yes	Yes
Afforestation	Yes	Yes	Yes
Hedgerow	Yes	Yes	Yes
Clover & Multispecies Swards	Yes	No	No
Extended Grazing	Yes	No	Yes
Soil Drainage	Yes	No	Yes
BIRCH (wetlands)	Yes	No	No
Agro-Forestry	Yes	No	No
LESS (low emission slurry spreading)	No	No	No
Mean Annual Increment (farm forestry)	No	No	No
Water Table	No	No	No
Straw incorporation	No	No	No

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