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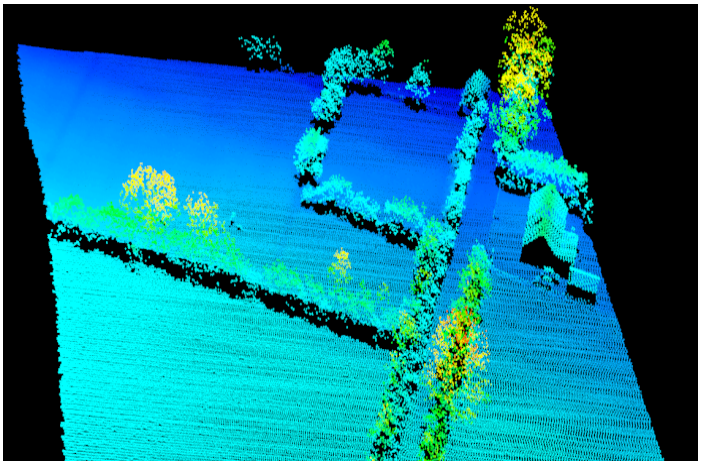
Using laser scanning to estimate carbon locked in hedgerows



Key external stakeholders:

Farmers, Department of Environment, Community and Local Government, Department of Agriculture, Food and Marine, Environmental Protection Agency, local authorities.

Practical implications for stakeholders:

This desk-based study indicates the potential of hedgerows to improve the carbon balance accounting of Irish agriculture: any future carbon foot-printing of Irish agricultural products can now take into account the beneficial sequestration function of any farm hedges and scrub.

Main results:

- Airborne LIDAR (Light Detection And Ranging) surveys can accurately measure the physical characteristics of hedges.
- These physical characteristics can be converted to carbon holdings for hedgerows.

Opportunity/Benefit:

- These hedgerow carbon sinks are potentially worth millions of Euros in European Trading Scheme (ETS) credits. The biomass held in hedgerows can now accurately be measured. Further field experiments are needed to convert biomass precisely to Carbon equivalents. The exact value depends on the current price of Carbon in ETS.
- A national ongoing inventory methodology for hedgerow and non-forest woody biomass utilising laser sensing has been shown to be cost effective.

Collaborating Institutions:

FERS Ltd., Dublin
Treemetrics Ltd., Cork

Contact Stuart Green Email: stuart.green@teagasc.ie.

Teagasc project team: Stuart Green (PI)
Niall Farrelly

External collaborators: Kevin Black, FERS Ltd.
Alex Poveda, Treemetrics Ltd.

1. Project background:

Hedgerows and woodland habitats are an important feature of the Irish landscape due in part to their roles in biodiversity, agricultural management and potential carbon sequestration. Greenhouse gas (GHG) emission reductions in the land use, land use change and forestry sector (LULUCF) are largely associated with forestry sinks. However, it is suggested that there could be possible GHG mitigation potential (sink potential) in grazing land or cropland following the introduction of the REPS scheme, which promoted the planting of indigenous trees and development of hedgerows.

Under the EU burden sharing agreement, Ireland will be committed to reduce its GHG emissions by 20% below the 2005 value by 2020 (5th National Communication, DoE). Additional measures or accountable sinks are required for the 20% target to be met for the non-emission trading sectors. Emissions and removals (Kyoto removal unit, RMUs) associated with the LULUCF sector can be used as a mitigation option under the Kyoto protocol mechanism. Article 3.4 of the protocol allows for the accounting of emission removals (sinks) associated with management or croplands, grazing land and forest management. Selection of these activities for the current commitment period of the protocol is voluntary, but likely to become mandatory post 2012. Ireland did not elect cropland and grassland land management for the first commitment period, due to uncertainty in the magnitude of emissions or sinks in this land use activity and a lack of methodology to report these activities on a national basis.

LiDAR (Light Detection And Ranging) remote sensing technology and ground truthing techniques could offer an ideal opportunity to utilise existing land use policies and incentives (e.g. agri-environment schemes) to realise the potential return of investment without any added cost, except for the implementation and testing of a compliance monitoring, reporting and verification (MRV) programme at a relatively low cost.

2. Questions addressed by the project:

- Is it possible to measure hedgerows using LIDAR to a sufficient accuracy that this could be used instead of a manual survey?
- Is it possible to convert physical measurement of hedgerows into an accurate estimate of their biomass and thus carbon holdings/sequestering potential?
- Can a cost effective national inventory be designed?

3. The experimental studies:

1) Literature review of existing hedgerow accounting in Ireland (e.g. County Surveys) and on the use of LIDAR in non-forest biomass estimation. The review found limited literature on LIDAR scanning of hedgerow and woodlands. Internationally there are published guidelines on field surveys and some estimates of hedgerow density and length for different countries. Data on hedgerows in Ireland is contained in separate county surveys (though not all are covered). The nearest to a national estimate of occurrence of hedgerows in Ireland is to be found in the European LUCAS survey (2009, conducted by the EEA). Analysis of the report based on this survey shows Ireland has double the occurrence of hedgerow than our nearest neighbour, Great Britain.
2) Re-analysis of an existing LIDAR survey: A pilot study was conducted using existing LIDAR data from Frenchpark, Co Roscommon, to develop a hedgerow classification and sampling system to assess biomass and carbon (C) sequestration by adopting a range of geo-processing techniques and empirical models. Direct modeling of LIDAR metrics, such as intensity and percentiles of 1st and 2nd laser returns, were used to accurately (RMSE ±7.3 to 19 tC ha^{-1}) estimate hedgerow and non-forest woodland biomass.
3) Applying conventional forest plot approaches to estimating biomass and carbon budget from physical measurements. Above-ground biomass measurements were derived using an algorithm developed from harvested broadleaves as described in the CARBWARE forest model. The algorithm was refined to provide above-ground biomass based on tree height (H) derived from the segmentation of tree crowns or randomly sampled tree heights. A second approach to derive biomass directly from laser metric data based on regression analysis against biomass estimates was

Contact Stuart Green Email: stuart.green@teagasc.ie.

also investigated.

4) A cost benefit analysis looking at estimated costs of a national LIDAR survey for hedgerows (based on known costs of LIDAR surveys) against conventional methods and value of the carbon inventory in the Kyoto accounting mechanism.

4. Main results:

This desk study was initiated to demonstrate the use of Light Detection And Ranging (LIDAR) remote sensing technology and terrestrial laser scanning (TLS) for assessing hedgerow biomass with the aim of developing a cost effective and efficient national hedgerow carbon inventory.

A pilot study was conducted using existing LIDAR data from Frenchpark, Co. Roscommon, to develop a hedgerow classification and sampling system. In order to assess biomass and Carbon (C) sequestration by hedgerows, a range of geo-processing techniques and empirical models were adopted. Direct modelling of LIDAR metrics, such as intensity and percentiles of 1st and 2nd laser returns, were used to accurately (RMSE ±7.3 to 19 tC ha^{-1}) estimate hedgerow and non-forest woodland biomass. Optimisation of LIDAR sampling techniques suggest that the minimum laser return sample density for detecting hedgerow biomass could be set at 5 returns per m^2 without influencing the performance of model estimates, thereby reducing survey costs.

Following optimisation of sampling and processing requirements, guidelines and costs for developing a national LIDAR based inventory were established. It is estimated that the total annual cost of a national hedgerow inventory could be between €80,000 and €100,000, ameliorated over a six-year reporting cycle. However, the financial impact could be substantially reduced if the acquisition and processing cost for LIDAR data is shared by governmental bodies interested in the use of LIDAR for other applications.

Preliminary estimates suggest that hedgerow and non-forest woodlands could sequester 0.66 to 3.3 tCO_2 ha^{-1} yr^{-1}. These estimates exclude potential emissions associated with hedgerow management or disturbance. However, the reported estimates are within the range reported by other hedgerow studies. If these estimates are representative of national hedgerows and non-forest woodlands, this could potentially result in a net removal of 0.27 to 1.4 M tCO_2 per year, which would increase the total land use change and forestry (LULUCF) sink estimate by ca. 8 to 28%. However, under the current accounting framework for Article 3.4 of the Kyoto Agreement, claimed emission reductions are calculated using a net-net approach. This is done by comparison of the net removal in a given year with the net removal or emission in a reference year. For the cost benefit analysis, the year 2000 was selected as the base year using available statistics on increases in hedgerow area to derive a net-net removal estimate of 3,000 to 17,000 t CO_2 per year. Based on the estimated cost of a hedgerow inventory and the expected accountable removals, it is estimated that a national inventory would be cost neutral at a CO_2 market price of €6 per t CO_2. Under the 2012 market conditions and Kyoto accounting mechanism, a national hedgerow inventory would offer no cost benefit. However, it is plausible that the market demand for CO_2 and the value of Kyoto RMUs would increase when new emission reduction and burden sharing targets come into effect post 2020.

5. Opportunity/Benefit:

In conclusion, a national LIDAR-based inventory of hedgerows is feasible and cost effective (pending future internationally agreed accounting modalities). It is recommended that additional research and inventory capacity is required to include hedgerows into a fully compliant LULUCF inventory. For example, extensive validation and ground-truthing of LIDAR and TLS biomass estimates are required to ensure estimates are robust and defensible in the international review process. In addition, national institutions and government departments should develop cohesive LIDAR survey, dissemination, and inventory policies, compatible with the INSPIRE directive, so that the costs of acquiring and processing LIDAR data for multiple users can be reduced.

6. Dissemination:

Work presented at the 5th and 6th symposia on Irish Earth Observation Research.

Stakeholder workshop held in Ashtown, November 2012. Hosted by Teagasc with EPA and national and international stakeholders.

Main publications:

Black K., Green S., Mullooley G. and Poveda A., 2012. Towards a national hedgerow biomass inventory for the LULUCF sector using lidar remote sensing, Final Report. EPA Climate Change Research Programme, EPA, Ireland. http://erc.epa.ie/safer/reports2

7. Compiled by: Stuart Green

Contact Stuart Green Email: stuart.green@teagasc.ie.

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