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Making hedgerow and woodland wood-fuel resource assessments using remote sensing datasets.

A project carried out for the North Devon UNESCO World Biosphere Reserve Sustainable Energy Group

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Summary

This study attempts to explore remote sensing technology and publicly available data for making some biomass resource assessments. Various data sets have been used. The favoured one was the Environment Agency Geomatics LiDAR data given for a surface model and terrain model. Other data did not have the required accuracy.

From these data sets it seems likely that biomass assessments in hedgerows can be made. The figure derived for the 27.25 km2 study areas was 500 GWh of heat energy being available from almost 360Km of hedgerow.

The woodland assessment is more problematic with high errors and uncertainty in the data for the deciduous woodland areas. Conifer areas tend to be managed and the resource is probable better known. However most of the deciduous areas are not managed and this is where much of the resource can be exploited sustainably….if the volumes are known.

For the immediate future, on site sampling assessments for woodlands will be the most accurate and cost effective tool, until more work is done on the LiDAR processing.

Hedgerow assessments can be done using this technology, with more calibration.

Acknowledgements

The North Devon UNESCO Biosphere Reserve is grateful to the support from the EA Geomatics Group for providing the data free of charge as a trial of a methodology. We are also grateful to DCC data managers for the use of the GetMapping Data under licence. GIS Data in this report is based on OS data provided under licence to DCC and supported by a Public Service Mapping Agreement.

Brief:

The North Devon Biosphere Reserve Sustainable Energy group has carried out a number of surveys and reports for the energy use and possible solutions for reducing emissions from the Biosphere Reserve area generally. One of the key conclusions of the report was to reduce the emissions, to improve the local economy and to reduce fuel poverty was to increase the sustainable use of wood fuel heating. This needed to be coupled with the improvement of energy efficiency.

Work in recent EU funded Cordiale Programme indicated ways in in which hedgerows, with altered management regimes might be a useful source of wood fuel and as an income for the landowners.

The objective for this project is to identify ways that resources can be assessed using remote sensing data that might be available in various forms.

The Biosphere Reserve Sustainable Energy Group have identified a community based project in South Molton to explore the use of a district heating system to to heat the community owned swimming pool and other community buildings nearby. This project will explore how resources may be assessed in the surrounding area building on the experience gained from previous projects.

Wood fuel resource assessment methodologies to date:

There are trade-offs with the cost and level of accuracy of the estimates. However the more accurate the measurement, results in lower uncertainty and therefore a better standing price.

Direct Measurement

Foresters have been using a range of methods to measure standing resources of timber for decades. These have been both invasive and non-invasive.

The methods might range from measuring every tree; time consuming and very costly though to stratified sampling measures E.g. Tariff systems involve counting and measuring a sample of trees and a sub sample of these trees are felled to measure more precisely the volume of trees in various diameter at breast height (DBH) classes and relating these through statistical tables to provide an overall estimate of the standing volume of crop.

Generalised stand volumes that are approximated from crown height, basal area (the total surface area of the stems at DBH per Ha) and a form factor for the tree species.

Recent additions to the tool box for forest mensuration include the smart phone, with applications such as iHypsometer which effectively replaces the relascope, clinometer and clipboard.

More semi quantitative methods have been developed for unmanaged woodlands for landowners/managers to use as a ready reckoner to estimate Cordiale

Applying Hedgerow resource measurements

The recent work undertaken through Cordiale Project in the Tamar AONB [i] and more recent publications from the Devon Hedgerow Group provide some guidance on yields for hedges under different management/harvesting prescriptions and stages[ii]. These are reviewed below.

Remote Sensing

Stereographic aerial photogrammetry was a technique that has been used, that allowed some relative and absolute heights to be gained, as well as broad species group composition. The Improvement of photographic emulsions and latterly in to multispectral receivers meant that species can be identified also.

The recent additions of technology such as LiDAR (Light incidence detection and ranging) can provide a rapidly acquired data set used from a land based platform to give volumes in the forest, or from an aerial platform (light plane or satellite) to give canopy heights and through various processing.

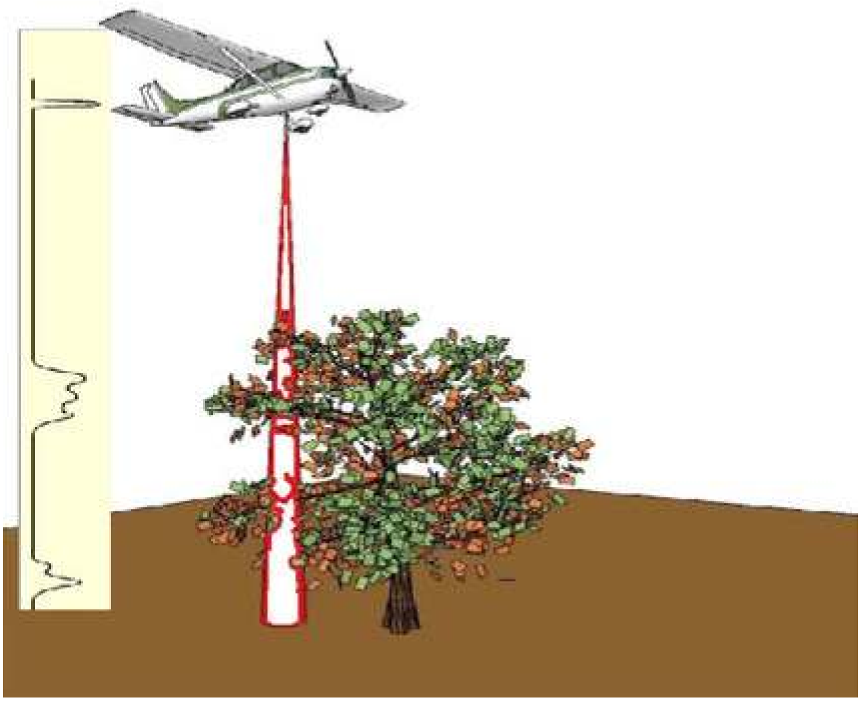


Figure 1 LiDAR scanning captures ground and canopy level reflections

Such radar or light based survey methods can yield 2 layers:

- The Digital Surface Model (DSM): this is the surface model generated by all of the highest readings over a cell area. It therefore includes all of the structures and features above the bare ground.
- The Digital Elevation Model (DEM); this is the model populated by the minimum heights acquired in the cell area. This effectively is the bare earth model of the area being investigated.

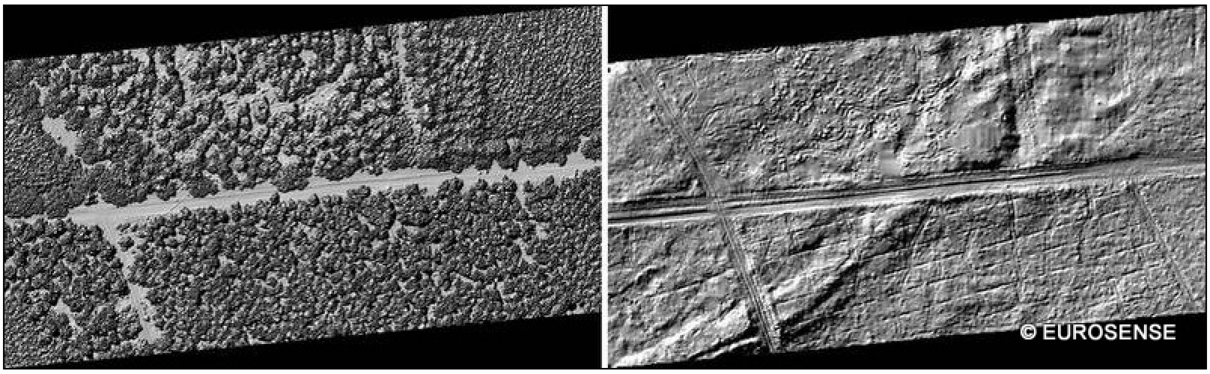


Figure 2 Difference between DSM (left) and DTM

LiDAR can be expensive to acquire and so it must be considered for multiple uses when it is gathered. However it is getting cheaper to acquire. Similarly since the data capture excursions are the most expensive element, other remote sensing should be carried out simultaneously if possible. This might be high resolution aerial images and other Hyperspectral receivers to maximise the data capture and expand the types of analyses available; for example Infrared, to show moisture content, plant health, etc.

As will be shown in this trial, having contemporaneous data capture means that verification between data points can be more certain. For example comparing LiDAR and aerial photographs taken even one year apart will be impacted by forest or hedgerow management cycles.

Methods deployed over a landscape area

The Tamar Valley AONB undertook a hedgerow assessment using aerial images in a pioneering programme to interpret the resource available and published the methodology[iii]. The method uses 5 classifications of hedges that were easily identifiable from aerial and on farm surveys. These are mapped using GIS and linked database to provide the resource assessment. The methodology is participative, which has the benefits of direct engagement with the landowners, but was very time consuming (6 months with a specialist)

The Cordiale Project also produced a ready reckoner for non-specialists for hedgerows and small woodlands[iv]. The tools provide 17 classifications of hedges from which the volume of extractable biomass is estimated. The same classification system is used in the tool developed for specialist/professionals[v] which uses more intensive sampling methods for DBH measurements and height measurements of sample plots as applied in standard forest mensuration. The specialist tool was derived from the work undertaken by the Forestry Commission.[vi]

The most recent iteration of hedgerow assessment provides a classification of the hedges into 6 typologies and gives and estimated energy value of the chips after seasoning. There are variations due to species composition. It is assumed that the wood to bark ratio in the harvested volume is taken into consideration in the energy estimates.

This project will test a few publicly available remote sensing data sets and methodologies using off-the-shelf technologies to analyse the data. The contract time for this project was less than 10 days. Therefore by necessity, the assessments are going to be rapid.

The Project Area

The area chosen for the assessment is in the South Molton area and slightly to the north. It was chosen because of the proposed renewable heat project for the swimming pool. The area to the north of the A361 has been chosen to focus the work on because

- it includes a number of woodland sites that are Plantations on Ancient Woodland Sites (PAWS) and these will need some management that will be supported to re-instate to native woodland cover
- there are blocks of woodland deemed to be in management and others not deemed to be in management.
- there appears to be a variety in hedgerow structures across the farms in that area.

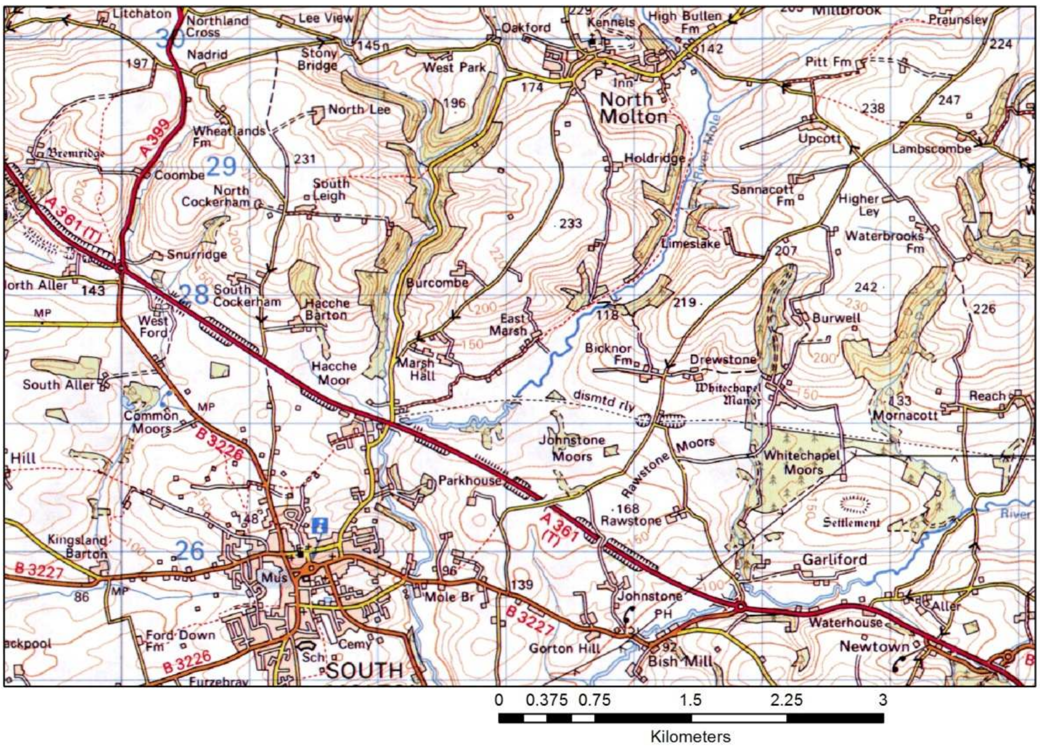


Figure 3 Map of the project area

Data sets available:

- FC National Forest Inventory 2013 (publicly available). The polygon data includes an estimate of forest type (e.g. conifer, broadleaved, Mixed, Scrub, Coppice, open ground).
- Defra Rural land Registry Field Parcels (under licence to the Biosphere Reserve). This data set can be used to generate field boundary layers that are more likely to be hedges, since the OS Master Map layer is hard to separate agricultural boundaries from others.
- Bing aerial imagery automatically streamed through Arc GIS
- Get Mapping Digital surface model and Digital elevation model (DCC licensed)

- LiDAR coverage 2m resolution (limited cover) available in JPG and ASCI Grid for different prices. Both data types are in DSM and DTM. (under licence/purchased from Environment Agency/Geomatics).

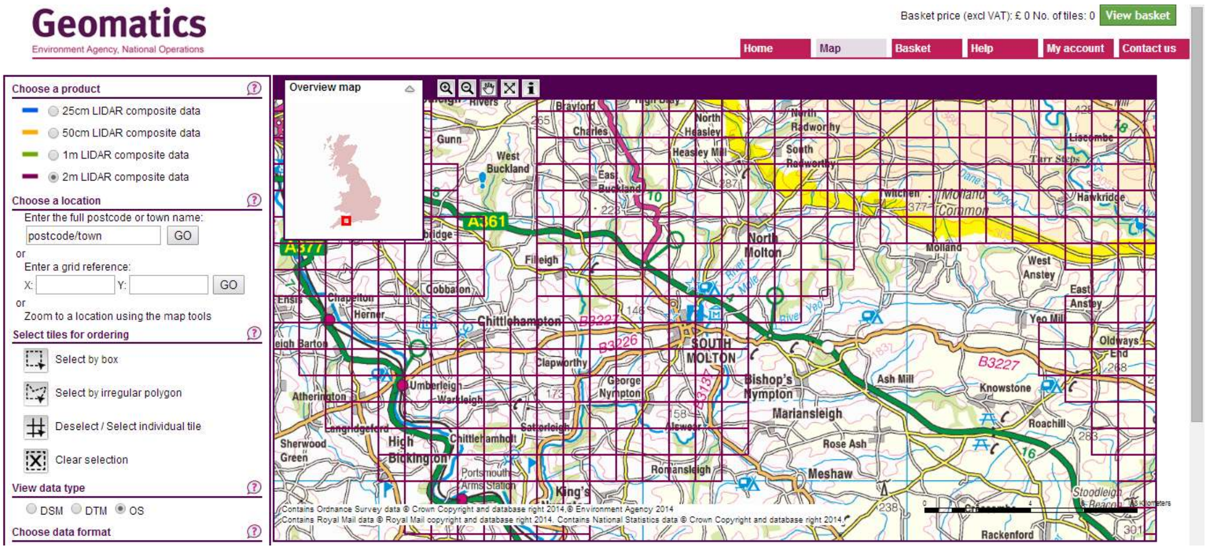


Figure 4 Indication of LiDAR coverage. Source EA Geomatics-Group.co.uk

As can be seen from the screen shot above, LiDAR coverage is not complete. This data has been identified as 2013 composite layer. This doesn't necessarily mean that the flight was taken in 2013. It therefore draws in a level of uncertainty. To professionally acquire the data for analysis for this project for the ASCI grid would cost £5900 plus VAT. In JPG version the same areas is £1500 plus VAT.

- Get Mapping 2006 25cm Aerial photography (DCC Licenced). This can be used as in the early stages of the Cordiale Project on hedgerow identification.

Figure 5 Sample images of the 25cm resolution aerial ortho-rectified imagery.

DSM DTM Analysis.

The principle approach for early quality testing of the data source is to subtract the DEM from the DSM. If the quality is adequate for further work, the resulting raster image will reflect all the above ground structures, with plausible heights.

Get Mapping Data

The GetMapping DSM and DTM Tiles SS80 were provided by DCC. These tiles were to the south of the study area but were provided for a trial of the methodology and feasibility of using this dataset. The raster resolution is 5m pixels, which can be adequate for forest purposes for identifying canopy height but might be dubious for individual tree recognition. The width of hedgerows is 5 m or less therefore picking-up hedgerows would be uncertain.

The following page shows the DTM (figure 7), DSM (figure 8) and the residual above ground images Figure 9). As can be seen the residual layer picks out the hedgerows and woodland, however the lines are not continuous.

Furthermore, there are values in the residual layer that are negative. The range is from -13.03 to +30.3. It is suspected that this error was from the original data capture where the steep slopes and woodlands might present false values, especially within the valleys.

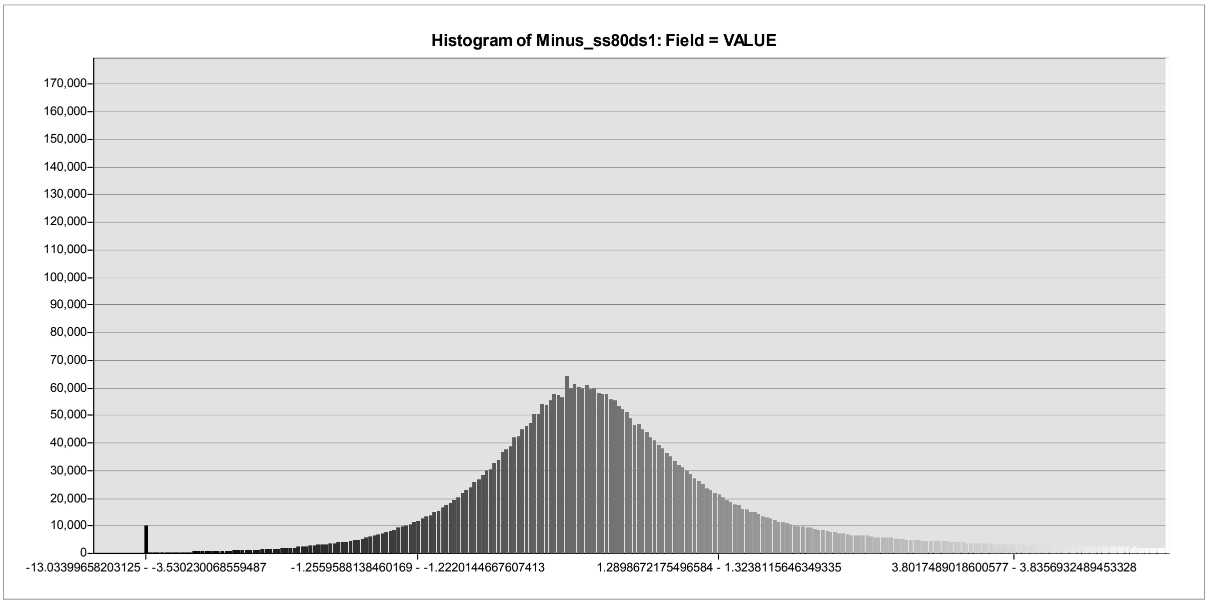


Figure 6 Histogram of points of the residual raster of Get Mapping

For reasons of high uncertainly and low resolution, this data set was discarded.

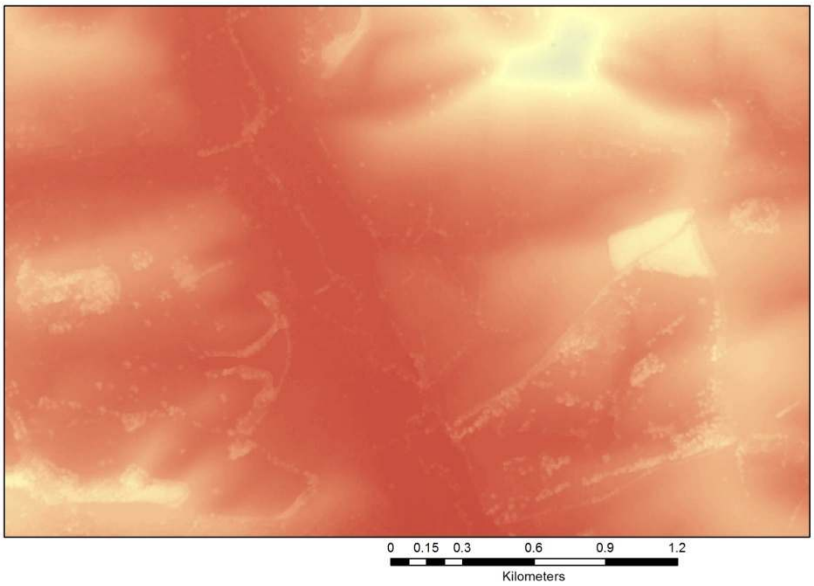


Figure 7 DTM of Get Mapping product

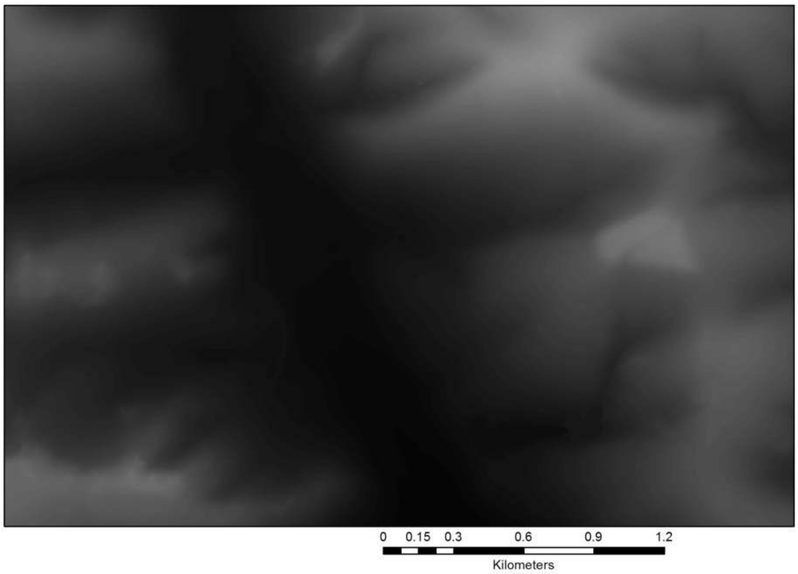


Figure 8 DTM of GetMapping

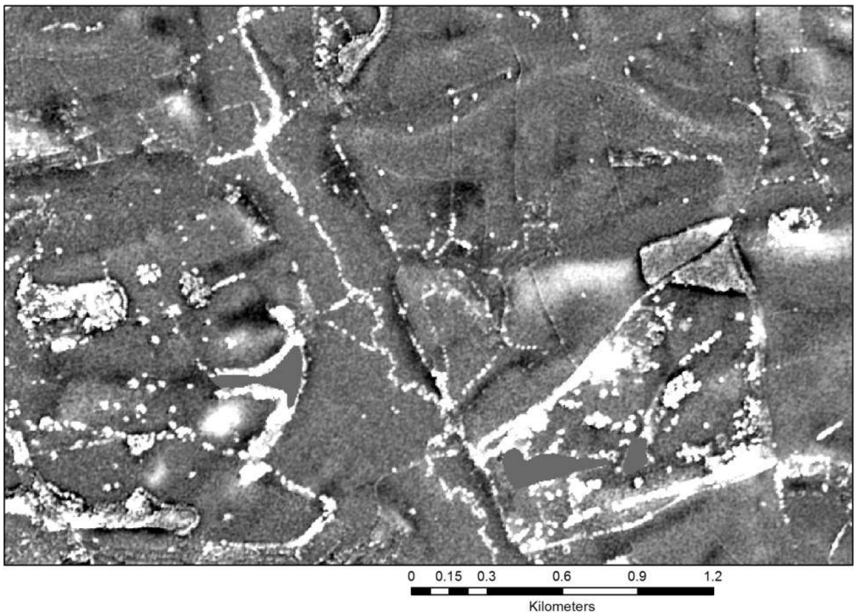


Figure 9 Residual layer of Get Mapping SS80. Note the discontinuity of the hedgerows.

Figure 10 Google Earth image for same site (the image source is Get Mapping 2010).

LiDAR Data

The LiDAR data available does not give complete coverage of the area. This is due to the reason for which the flights are originally commissioned. To date it has been largely used for modelling hydrology and flood zones. The image below shows the extent of the data used in this analysis.

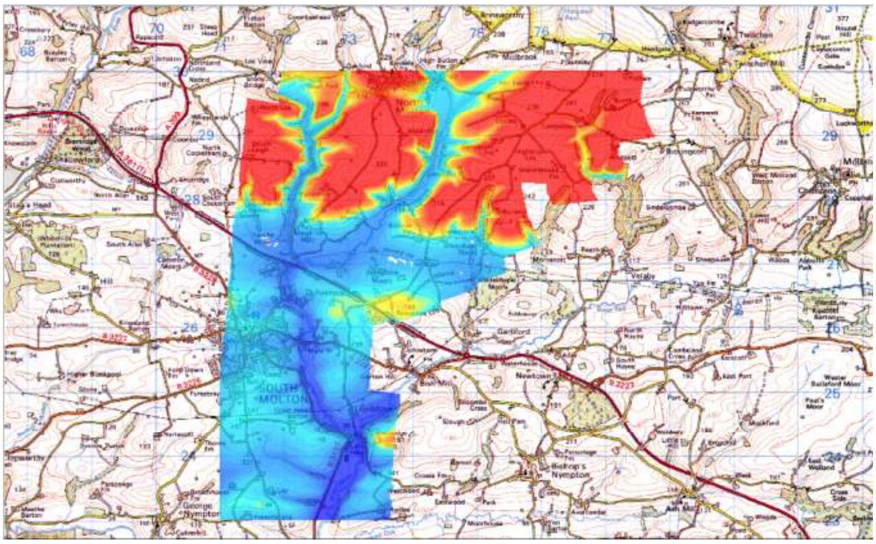


Figure 11 LiDAR Data coverage for the project area

Jpg Format.

The same process as above was carried out on the LiDAR data provided by Geomatics for the study area. This is the cheaper of the 2 LiDAR products.

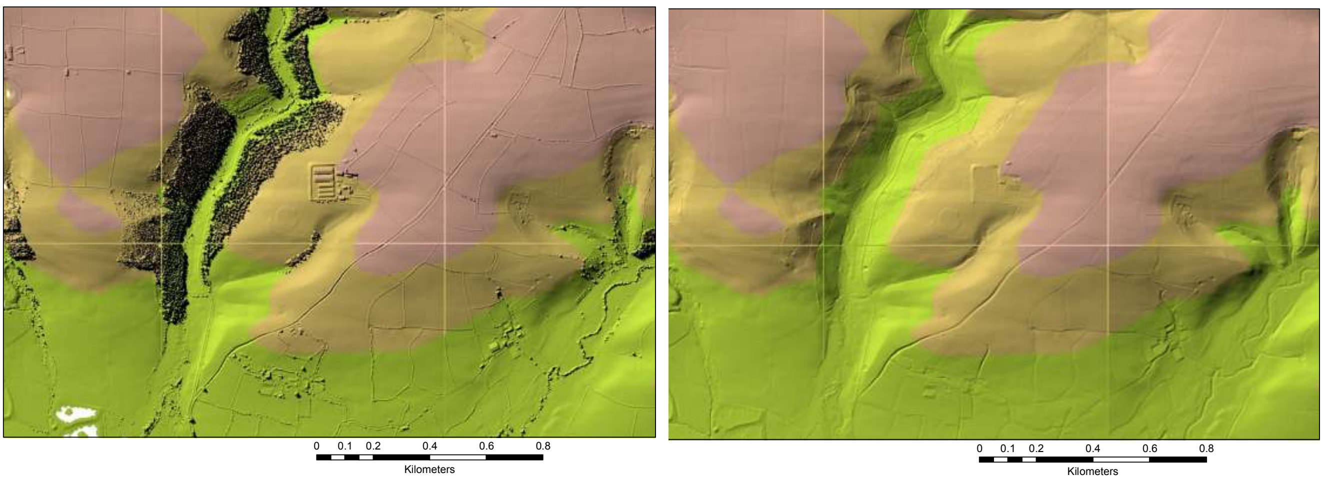


Figure 12 Presentation of LiDAR JPG data

Since the layers are Red Green Blue channels that include hill shading, the subtraction process results in a single band raster, that shows the features, but there is no meaningful extractive data than can be reverted back into any absolute heights. The JPG files are good for illustrative measures but not good for any analysis work. This data set was also discarded.

LiDAR DATA ASCI Grid Format

The same process was applied to the ASCI grid LiDAR data and the results can be seen below.

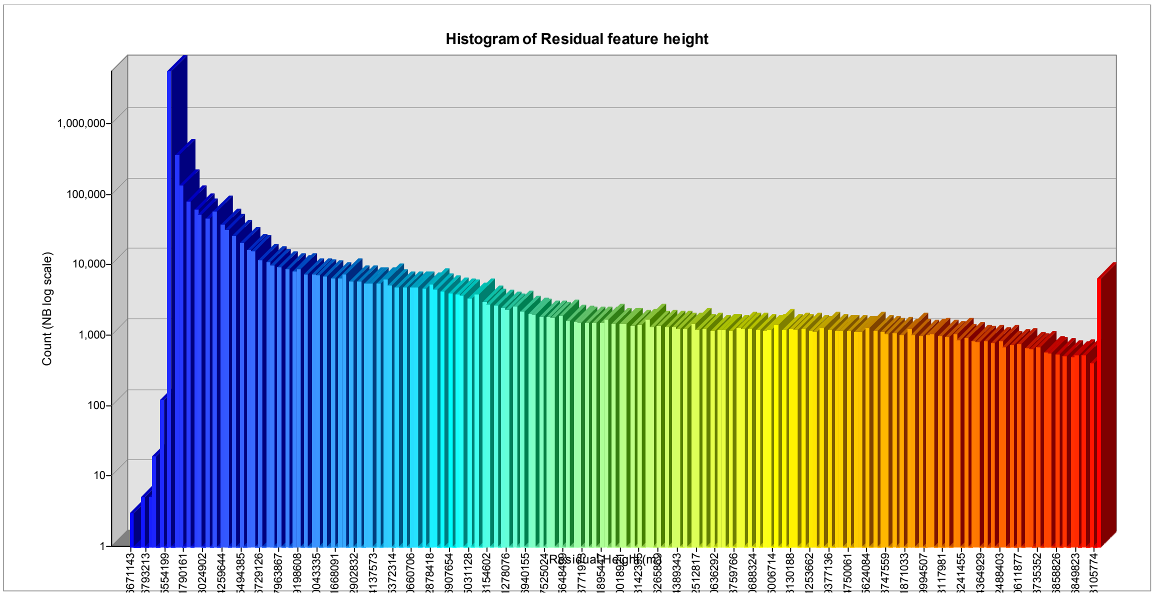


Figure 13 Histogram of heights in LiDAR residual feature height data. NB very few negative height values

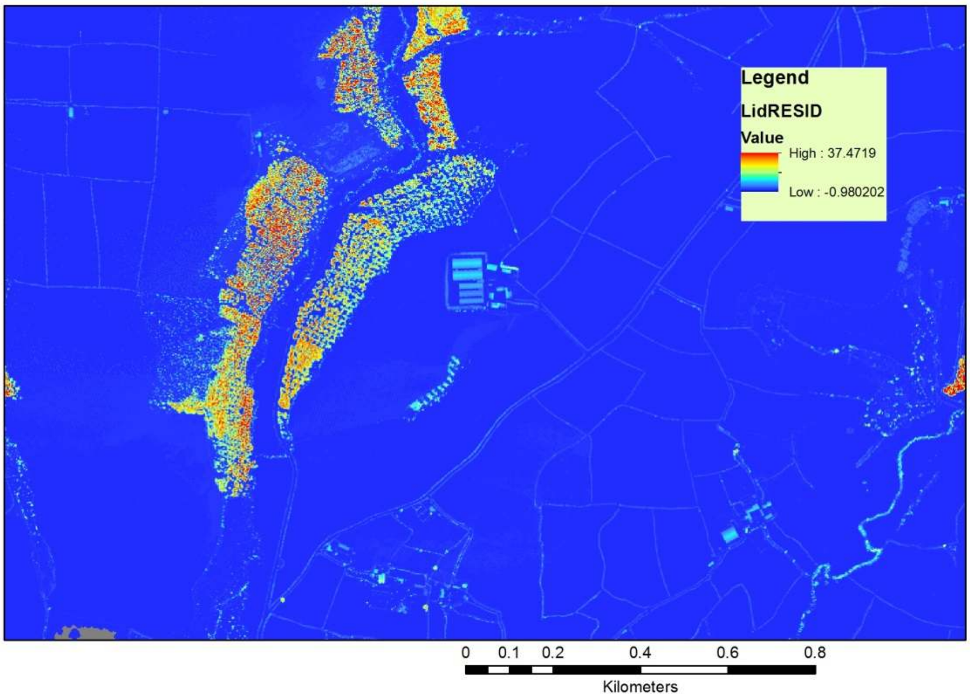


Figure 14 Sample of the LiDAR residual feature height mapping

Based on these results the ASCI data was taken to the next stage of analysis.

Resource Assessment

Extracting the Height data for the areas of interest.

The treatment for woodland data and hedgerow data needs to be different due to the structural nature of the features. The variance that one might expect between woodlands of different management status, stocking density and species coupled with the variance one would expect with hedges would render any statistical analysis ineffective.

The process for both however involves isolating the LiDAR data to polygons of woodland (generated form the NFI data) and polygons for the hedgerow data. For the latter the field polygons used in Single Farm Payments are used, converted to poly lines, given a 2.5 metre buffer. Using this methodology firstly ensures that only farmed hedges are assessed and that there is no double capture of the data. Each raster data set captured in the polygons is subjected to statistical analysis to identify any groupings.

Results Analysis: Woodland

Observed Data Limitations for the woodland.

There are areas of forest that do not appear to have been filtered correctly to account for the tree cover in the LiDAR DSM layer; this will lead to under estimation of volumes in those patches. On initial investigation, it is the broadleaf wooded areas that are underestimated. This might be a more likely occurrence if the flight is done after the leaves have fallen in autumn and bud burst in the spring. Without the leaf area to reflect the scanning beam, a higher percentage of beams will strike the ground, giving an appearance of less dense or even no woodland.

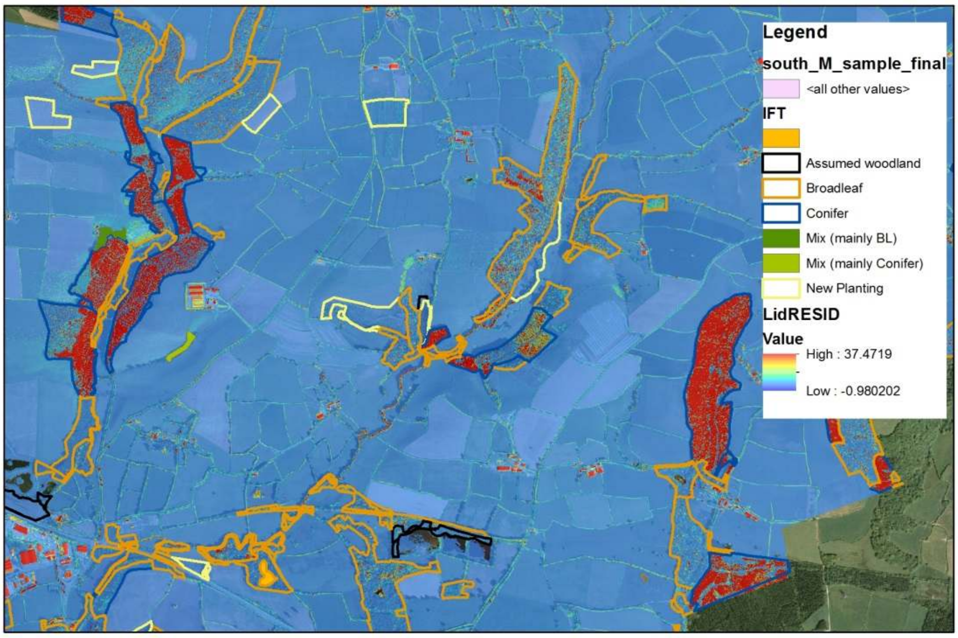


Figure 15 Indication of under measuring over broadleaf woodland areas in filtered LiDAR data

Despite the above data issue, some effort was made to attempt to make some analysis from the information.

The best that could be drawn from the data are the maximum heights within the various woodland blocks. Normally one would use the relative proportion of ground readings compared to elevated canopy readings to give an estimation of woodland cover/density. This does not give the stem density (i.e. stems per hectare) .

In an effort to measure stem density (Number of stems per hectare) the triangular information network was created. (this process along took 28 hours of computing time.) A manual count from the TIN and a manual count from the same area of young conifer stand led to an underestimate of total stems by almost da factor of 2.

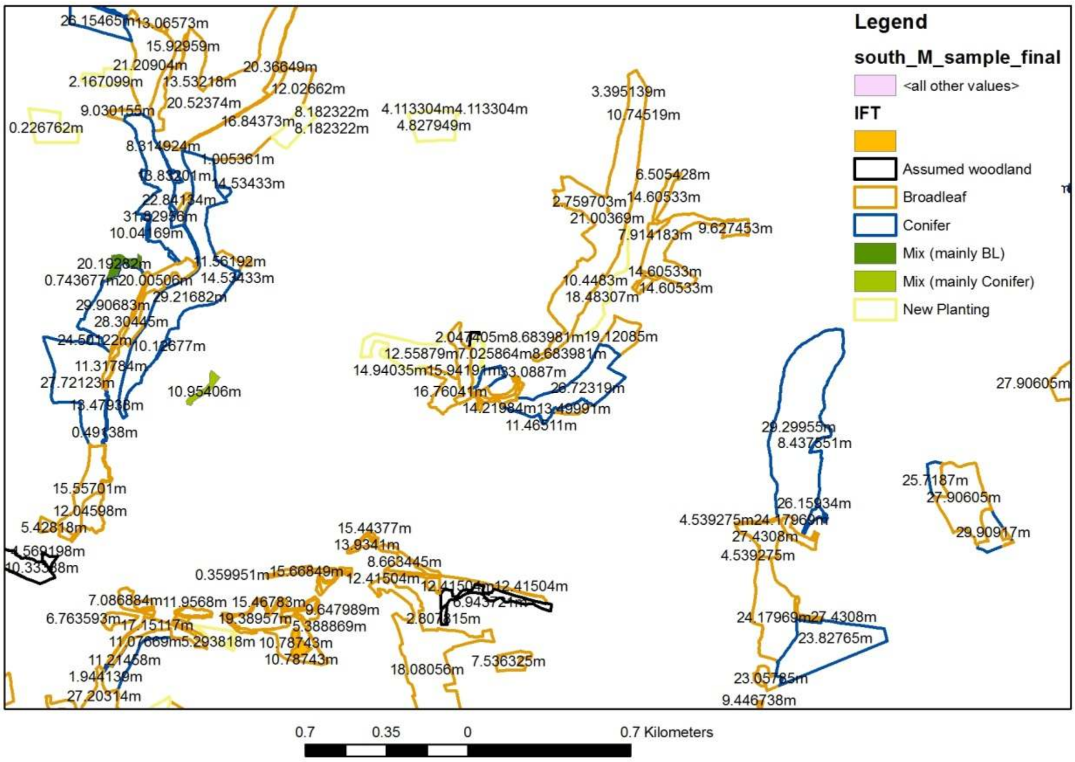


Figure 16 Woodland blocks and the registered maximum feature height from LiDAR data

No meaningful volumetric measure can be derived from this data as it is presented and with the current software. A more reliable measure would be the mean height of the highest 20% of the readings in the polygons. A better analysis might be done with the LiDAR data if the unfiltered data was available.

Results Analysis: Hedges:

The polygons were treated to a statistical analysis of the LiDAR data contained within them for maximum height, mean and median height, coefficient and variance and volume. After various multivariable analyses, the bulk volume per unit length was derived as the best method to create classifications. There adjustments made to the classes by the mean and maximum height measurements.

The classifications were sampled at random at inspected against the 2006 aerial photography. There appeared a reasonable correlation. However the 2006 aerial image data was the most recent photographic data available as a layer on the GIS. This data is 7 years out of sync with the LiDAR data and therefore the verification cannot be entirely relied upon.

Figure 17 Hedge Data processed and interim classified according to Walton, 2014

Figure 18 Zoomed in view of Hedgerow mapping and classification

The following table indicates the heat energy potentially available within the footprint of the LiDAR data acquired (27.25 Km^2). Under normal circumstances one would try to produce some statistical qualification and error margins.

The results were ground trothed by visiting 2 farms which indicated a range of hedge volume classes.

The hedges were measured and classified against the system proposed in the Devon Hedge Group publication.

The data were also refined by adjusting the outlier data points of extreme high values and negative values.

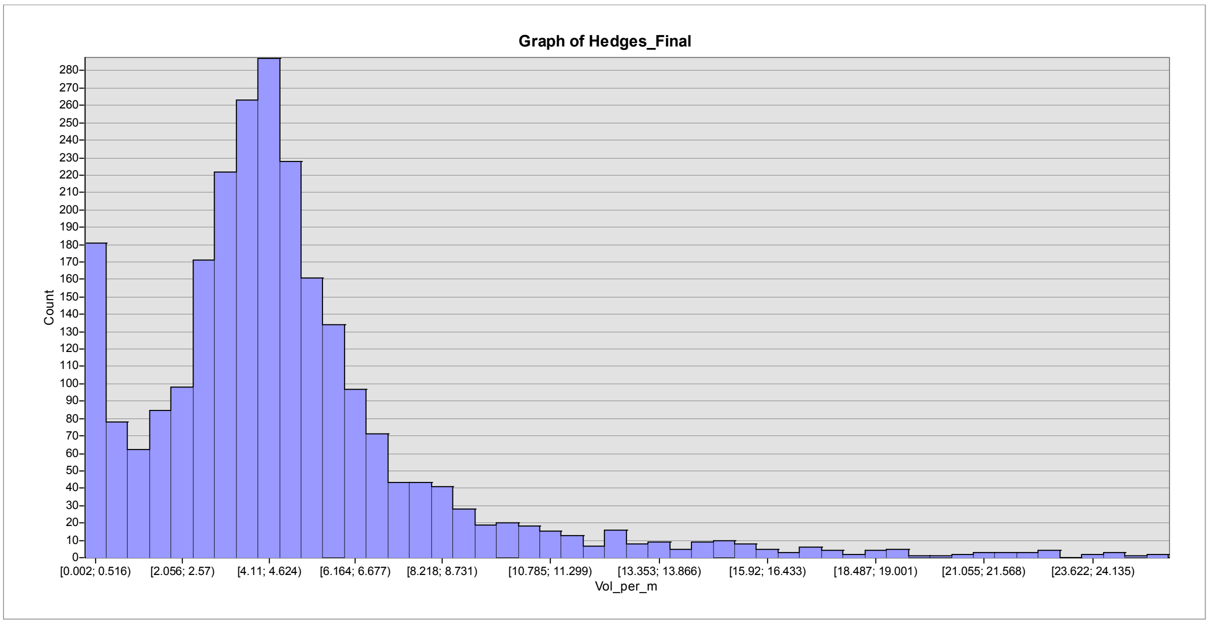
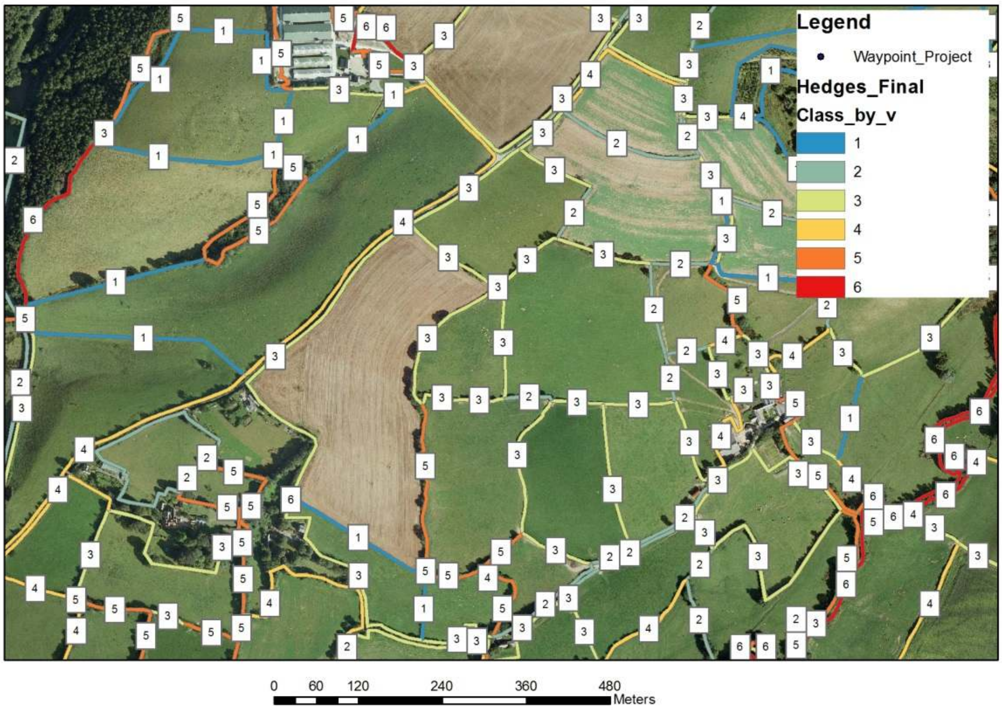


Figure 19 Distribution of bulk volume per unit length of the hedges

The final energy analysis after re-calibrating form the ground truthing is as follows:

Hedgerow Class	Sub-total length (m)	Subtotal Energy MWh
1	62589	0
2	43166	10813
3	107342	80604
4	64692	97289
5	64432	203654
6	16887	106075
Totals	**359,110**	**498,437**



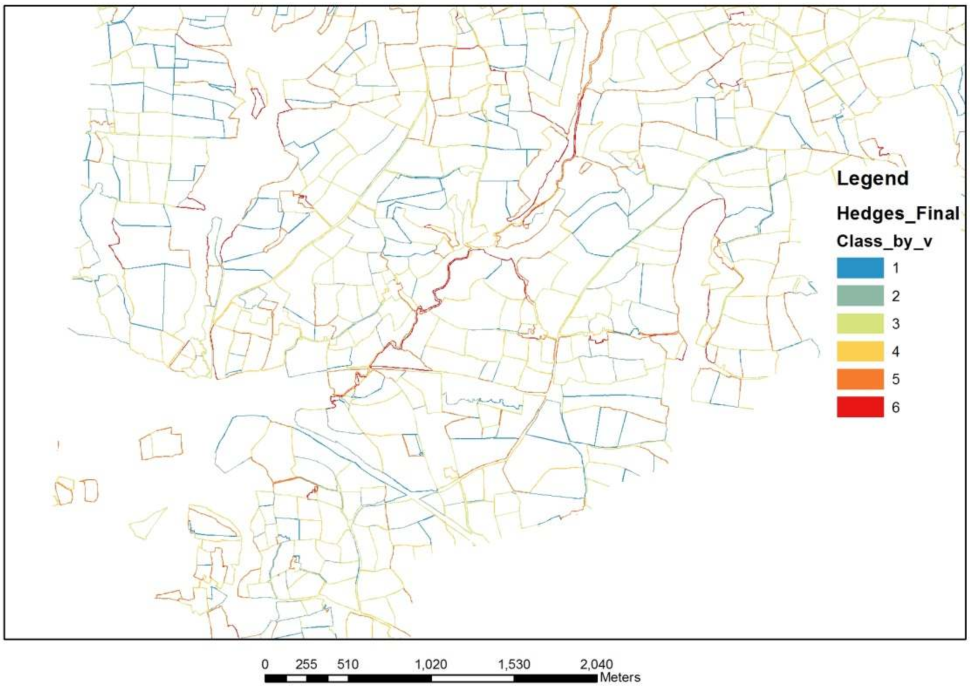


Figure 20 Mapping of the reclassified hedges

Conclusions of the study:

The figures are quite impressive, with over 360Km of harvestable hedgerow potentially yielding 500GWh of heat if chipped and dried. This is just a snap shot and does not give an indication of maximum sustainable annual yield. Such a calculation would need to take into account biodiversity needs etc. Many of the much higher yielding hedges are either next to the woodlands or are alongside the river banks. Both of these are essential ecological components providing shade and connecting habitat.

Given that the same data set seems to be under representing the deciduous woodland, the gross volumes occupied by the trees in the hedgerows may also be under presented.

To sum up;

- The study has explored the use of various remote sensing data available to public bodies to assess the resource available in the landscape.
- LiDAR data appears to be the most suitable data for its horizontal resolution and vertical accuracy. Raster data with pixel sizes more than 2 metres will not be able to give a suitable estimate.
- The season within which the data is gathered will impact on the accuracy of the assessment.
- LiDAR can be a very suitable tool for the assessment of hedgerow resources in an area. Some ground truthing will be needed to ensure the model is calibrated correctly.
- Conifer woodland measurements are likely to be more accurate than deciduous woodland.
- Onsite measurements of height, DBH and or Basal Area are needed to support any information gathered by the Environment Agency with LiDAR on an aerial platform for woodlands.
- The snap shot given by this type of analysis does not show the age structure and what the long term annual sustainable yield will be from the landscape from neither the hedgerows nor the woodlands.

Further work recommended:

- Field measurements of the woodlands.
- Seek to acquire the raw LIDAR data to explore better bespoke filtering for woodlands.
- Further field measurements of the hedges to calibrate the model more precisely.
- Engage with the landowners in the possible market opportunities for harvesting.

REFERENCES and END NOTES

[i] http://www.hedgelink.org.uk/wood-fuel.htm
[ii] Wood Fuel From Hedges, ISBN 978-1-84785-042-3
[iii] http://www.cordialeproject.eu/en/toolkit/tools/tool_01_hedgerows_mapping_methodology/
[iv] http://www.cordialeproject.eu/images/uploads/toolkit-tools/12_b1-Calculation%20of%20biomass%20volume%20from%20woods%20and%20hedges%20for%20non-specialists_Farm%20toolkit.pdf
[v] http://www.cordialeproject.eu/en/toolkit/tools/tool_12_feasibility_assessment_tools_for_woodfuel_production_and_woodfuel_b/
[vi] http://www.biomassenergycentre.org.uk/portal/page?_pageid=74,373197&_dad=portal&_schema=PORTAL and http://www.forestry.gov.uk/fr/INFD-7SUE6F