Managing traditional hedges for biofuel

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Abstract: With around 700,000 km, hedges are the most widespread semi-natural habitat in lowland Britain. As well as being an important landscape feature in their own right, hedges fulfil many functions and are increasingly recognised for their importance in regulating environmental processes. However, the 2007 Countryside Survey found that just 68% of Britain's hedges are managed. Recent research has sought to address this by investigating the economic potential of using biomass from hedgerow management for local energy or heat production. This work has brought farm hedges back into focus and sought to answer questions about whether biomass can be sustainably and economically harvested from hedgerows, and as such, whether hedges can be a viable source of woodfuel?

Here we outline the results of trials carried out in Southern England to assess the efficiency, cost and viability of coppicing hedges as a local and sustainable source of woodfuel. Machinery and methods were tested at different scales and the impacts on the local environment assessed. Building on work in South West England and Northern France the trials demonstrated that that hedges can be managed effectively and economically to produce woodfuel of reasonable quality which meets industry standards. However, the introduction of coppice management of hedges for woodfuel is likely to have both positive and negative impacts on the wildlife of individual hedges and on biodiversity at a landscape scale. To address this, alongside the trials a protocol was developed to assess the likely impacts on biodiversity of managing hedgerows for woodfuel.

The biodiversity protocol enables landowners to carry out an assessment of their resource prior to carrying out any management, it identifies hedges suitable for harvesting woodfuel and those of potentially high biodiversity value as well as those in need of improvement and offers general management recommendations based on different indicators.

1. Introduction

With around 700,000 km, hedges are the most widespread semi-natural habitat in lowland Britain (Carey et al., 2008). As well as being a characteristic feature of the British countryside, hedges fulfil many functions, ecological and social and are increasingly recognised for their importance in regulating environmental processes (Wolton et al., 2014). The abundance of hedgerows in landscapes otherwise dominated by agriculture makes them a vital resource for biodiversity (Baudry et al., 2000). Biodiversity in British hedgerows has been well studied and hedgerows have been found to offer multiple micro-habitats, food sources, and ecological corridors for a diverse range of flora and fauna (Baudry et al., 2000; Vickery et al., 2009). However, despite the multifunctional nature of hedges and their importance in the provision of ecosystem services, the 2007 Countryside Survey found that just 68% of Britain's hedges are actively managed, with only 40% classed as being in good condition (Carey et al., 2008). The main threat to hedges and the services that they provide are changes in management practices related to agricultural intensification and a reduction in the perceived value of hedges to farmers (Oreszczyn and Lane, 1999). Of those hedges that are still actively managed the majority are repeatedly flailed at the same height, eventually creating gaps and leading to a decline in hedge condition, whilst those left unmanaged will ultimately develop into lines of trees. The results of both over and under management are detrimental to the structural integrity of the hedgerow (Garbutt & Sparks, 2002) and hence the quality of this important biodiversity resource. To maintain them into the future this imbalance in management needs to be addressed. Hedges need periodic rejuvenation actions, either by coppicing or hedge laying; however these management options are costly, time consuming and often missing.

Recent research (Chambers et al., 2015; Wolton, 2012) has sought to address this lack of appropriate management by investigating the economic potential of using biomass from hedgerow management activities for local energy or heat production. Coppicing or hedge-laying are both rejuvenation methods that can produce woodfuel as a by-product, either directly as logs or chipped for use in biomass boilers. Therefore management for woodfuel could provide an opportunity to rejuvenate old hedges, restoring not only their economic role but their value to the wider landscape. In some areas of northern France, hedgerows are coppiced and still provide an important fuel source, producing 4.4 million cubic metres of fuel per year and accounting for 11% of the total firewood used by households in 1997 (Lotfi, 2010). Recent trials in south west England investigated the relative costs and biomass production of hedge laying and coppicing, both carried out manually using a chainsaw. These trials showed that laying can retain up to 70% of material in the hedge and takes a lot longer (Wolton, 2012). Lessons from the continent combined with the work in south west England indicate that coppicing and chipping all the cut material is the most economic management method for woodfuel production (Wolton, 2012). However, hedge laying can also produce reasonable quantities of usable fuel wood and is the traditional UK management practice for producing a stock-proof field boundary. Given their significance in supporting biodiversity, if hedgerow coppicing is to be promoted as a management method for the provision of woodfuel, any potential impacts on biodiversity both within the hedgerow network and the landscape need to be assessed. In areas with specific landscape and biodiversity priorities hedge laying may be the most appropriate rejuvenation technique, especially where it is important that landscape connectivity is maintained.

Despite increasing interest in managing hedges for woodfuel and the potential benefits, there is limited data and knowledge regarding the productivity, logistics and potential impacts of such systems. Here we outline the results of trials carried out by the Organic Research Centre (ORC) at two sites in southern England (Chambers et al., 2015) as part of the European project Towards Eco-Energetic Communities (TWECOM; www.twecom.eu). The trials assessed the feasibility of mechanising the process of coppicing hedges and processing the resultant material as a local and sustainable source of woodfuel.

2. Methods

The trials were carried out during winter 2014/15 at two sites: Elm Farm, Newbury, West Berkshire (51.23°N; 1.24°W) and Wakelyns Agroforestry, near Diss, Suffolk (52.36°N 1.36°E). Three different hedges were used, representing a range of physical characters but all at a suitable stage for coppice management. In addition, in winter 2013, three small plot trials were established at Elm Farm (Table 1).

Table 1. The trial hedges at Elm Farm and Wakelyns Agroforestry

Site	ID	Length of coppiced section	Hedge description	Approximate hedge dimensions
Wakelyns Agroforestry	Hedge 1	100 m	Mixed species, small field maple trees, hawthorn and some blackthorn, dogwood. Left to grow for c.20 years	7.5 m high, 3.5 m wide
	Hedge 2	20 m	Predominately hazel coppice with several small multi-stemmed field maple trees. Last coppiced c.15 years ago.	4 m high, 2 m wide
Elm Farm	Hedge 3	170 m	Predominantly mature hazel coppice plus substantial blackthorn outgrowth. Last coppiced c.28 years ago.	6 m high, 3-5 m wide
	Blackthorn small plot	15 m	Predominantly very overgrown blackthorn, internal ditch. Blackthorn stems c.40 years old.	5.5 m high, 4 m wide
	Hawthorn small plot	15 m	Predominantly mature hawthorn with some willow on one bank, internal ditch. Hawthorn stems c.40 years old	5 m high, 4 m wide
	Hazel small plot	15 m	Predominantly mature hazel coppice, deep internal ditch. Last coppiced c.15 years ago.	6.5 m high, 6 m wide

Machinery and methods were selected to represent a range of machinery sizes, cutting mechanisms, cost, and availability. Machinery was classified as small-, medium- and large-scale, and one machine of each scale was trialled at each site. The large-scale harvesting machinery trialled were hydraulic shears and a felling grapple with integral chainsaw; medium-scale were assisted fell (manual fell using a chainsaw and excavator) and tractor-mounted circular saw; and small-scale was manual felling at both sites. Two sizes of chippers were also trialled: a large drum chipper and a small disc chipper. All machinery was operated by experienced contractors.

The trials assessed: the costs associated with each machinery option and the time taken to coppice or chip a pre-determined length of hedge; the biomass productivity of each hedge; the chip quality in terms of moisture and ash content, calorific value and particle size distribution (ÖNORM and BS EN standards). At Elm Farm, coppice regrowth and stool survival was also monitored for Hedge 3 during the summer following coppicing and again at the end of the growing season to ascertain the impact of different cutting methods on stool health and regrowth. Monitoring plots of 15 m length were measured out in each of the five hedgerow coppicing trial sections: hydraulic tree shears (left as cut), hydraulic shears (with short chainsaw finish), hydraulic tree shears (with long chainsaw finish), assisted fell, and manual fell. Both the number of shoots and the height of the five tallest stems were recorded for each stool within these 15 m plots.

2.1 Small plot trials

The aim of the small plot trials, which were carried out prior to the machinery trials, was to refine non-destructive methods to assess the volume of biomass in a hedgerow; to quantify coppice re-growth and survival rates between different hedgerow species; and to assess the impact of coppicing on biodiversity, microclimate and soil carbon dynamics. Paired 15 m cut and uncut plots were established in three different hedgerow types: blackthorn, hawthorn and hazel dominated (Table 1). Coppicing was carried out in winter 2013 by hand and all material was chipped, bagged and weighed. Regular regrowth measurements were carried out on the cut stools.

3. Results

3.1 Harvesting and chipping costs

Both harvesting and chipping costs per metre were calculated by dividing the day hire cost including haulage by the length of hedge each machine can harvest or chip in one day, to give the maximum efficiency of each option. The harvesting and chipping cost and time taken per metre varies depending on hedge type and length coppiced and variability within methods was seen depending on the hedge (Table 2). For example, manual fell was generally the most time consuming method but the time taken to coppice 1 m of hedge varied between 10.8 and 12.8 minutes depending on the hedge. Assisted fell was found to have the lowest harvest cost per metre (£2.26) and was also one of the least costly options. Haulage increased the cost of the large-scale machinery options. On average it was found to be cheaper and quicker to use large scale chippers; of the chipping options trialled the Jenz drum chipper had the lowest processing cost per metre (£2.44), followed by the Heizohack drum chipper (£3.21) and the Timberwolf disc chipper had the highest processing cost (£5.01), however these figures are dependent on the amount of material to be processed.

Table 2. The harvesting and chipping cost and time taken per metre for each machinery option at Elm Farm and Wakelyns Agroforestry

Machinery option	Hedge/ location	Cost per metre of hedge	Minutes per metre of hedge
10” Dymax tree shears	Hedge 3	£6.78	2.78
		£8.06[a]	3.30[a]
Gierkink felling grapple	Hedge 1	£6.28	2.64
Tractor mounted circular saw	Hedge 1	£7.46	5.40
	Hedge 2	£4.00	2.90
Assisted fell (chainsaw and excavator with land rake)	Hedge 21	£2.26	1.58
Manual fell (2 person team with chainsaw)	Hedge 21	£6.85	12.85
	Hedge 1	£8.24	10.81
Heizohack fuel grade chipper	Elm Farm	£3.21	1.48
Jenz drum chipper	WAF	£2.44	1.63
6” Timberwolf chipper	Elm Farm	£5.01	5.01

[a]: with chainsaw finish

The energy cost of hedgerow woodchip ranged from 1.6 to 3.5 pence per kWh depending on machinery options and hedge type. This compares relatively favourably with the cost of commercially produced woodchip from forestry roundwood which retailed at 3.43 pence per kWh in 2015 (Forest Fuels, 2015).

3.2 Biomass

Biomass data was collected from six different hedges, the three machinery trial hedges and three small plot trials at Elm Farm. Average biomass production per metre hedge, at 30% moisture content, was 82 kg, or 8.2 tonnes per 100 m. Production ranged from 4 to 13 tonnes per 100 m depending on hedge species, structure and age, with the blackthorn small plot showing the highest biomass production (Figure 1).

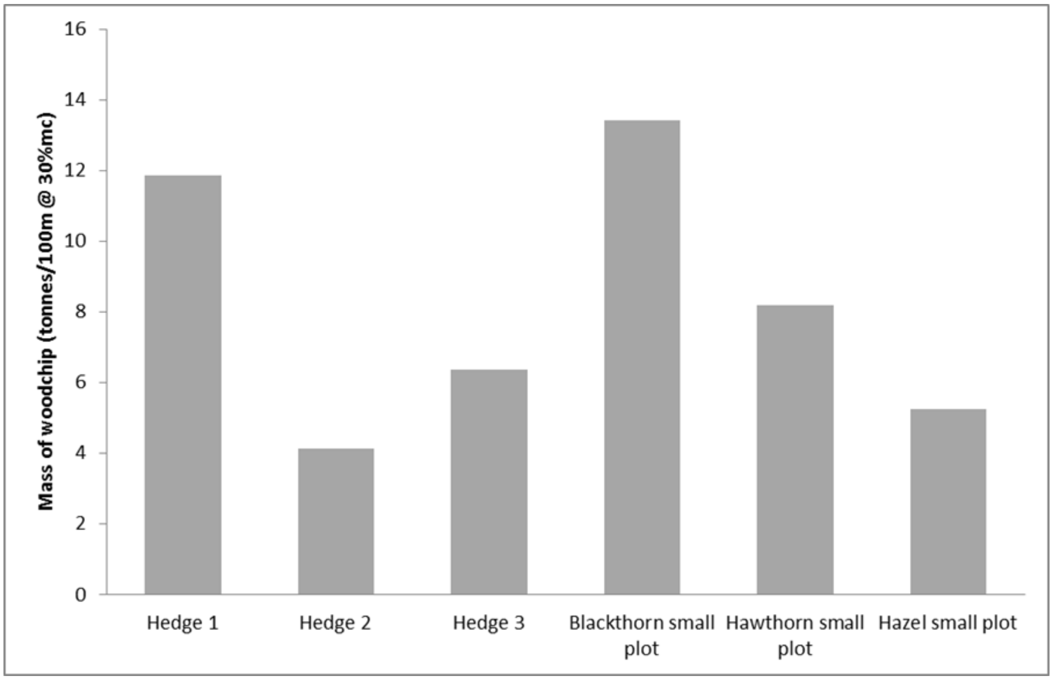

Figure 1. Mass of woodchip produced by each of the different hedges (tonnes per 100 m at 30% moisture content)

3.3 Chip quality

It was expected that the large drum chippers with integral screens would produce higher quality woodchip than the smaller disc chipper. However, when tested there was no difference in chip quality between the different chippers. The woodchip quality analysis found that all the hedgerow samples passed the BS EN standards and ÖNORM G30 standards for particle size distribution, indicating that a suitably high proportion of the hedgerow woodchip was greater than 30 mm in diameter, and therefore saleable on the open woodchip market. They did however all fail the ÖNORM G50 standards; this was due to the generally smaller diameters found in hedgerow material. There was very little variation in calorific value between the three different hedges sampled. However the drying method appeared to affect both the ash content and the moisture content of the woodchip. The ash content of hedge material that had been left to air-dry in the field for three months ranged from 2.06% to 2.93% and the average moisture content was 24%. However where the material was chipped green the ash content was significantly higher at 3.58% and the moisture content after three months was 31%.

3.4 Regrowth

Two of the three sections cut with the hydraulic tree shears were finished with a chainsaw (long and short finishes) to tidy them up and remove the split stems produced by the shears. In Hedge 3 an average of 1.1 m regrowth from hazel coppice stools was seen after seven months, increasing to1.5 m by end of first growing season, re-establishing a green roadside and landscape feature, and habitat continuity and wildlife corridor. No significant difference in regrowth was seen between the different cutting methods (Figure 2). The plots coppiced using the assisted fell and tree shears (both long and short chainsaw finishes) had the highest average number of shoots per stool, at 89.9 and 85.9 respectively, followed by manual fell with 77.4 and then the tree shears (left as cut) which only had 60.5 shoots per stool on average. This variation between plots may be due to variation in growing conditions and stool sizes along the hedge or the health of the stools before coppicing.

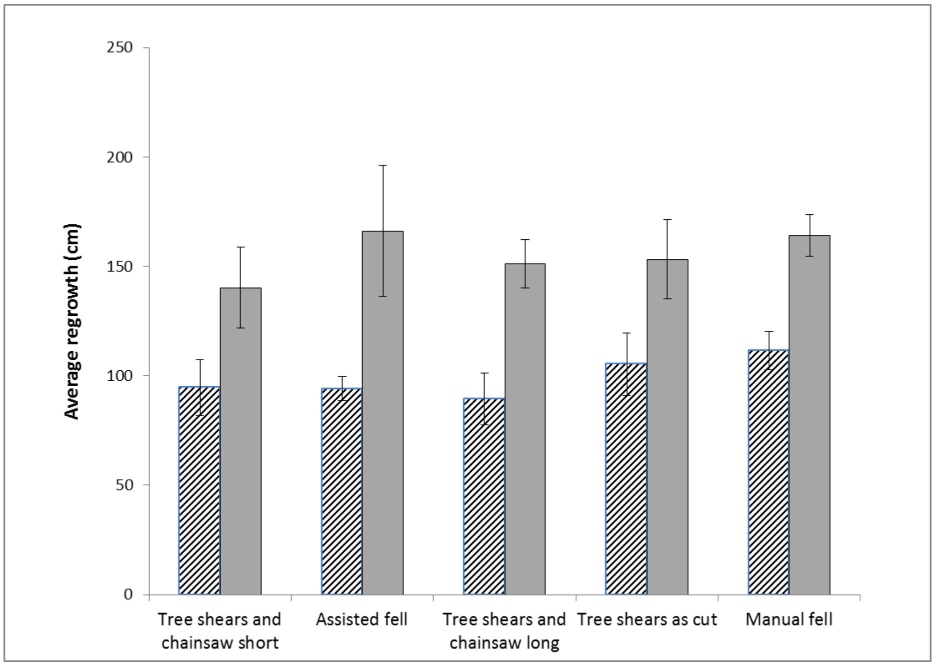

Figure 2. Average regrowth (± SE) of different treatments in Hedge 3 plots, diagonal shading measured in June 2015, solid shading in November at the end of the growing season

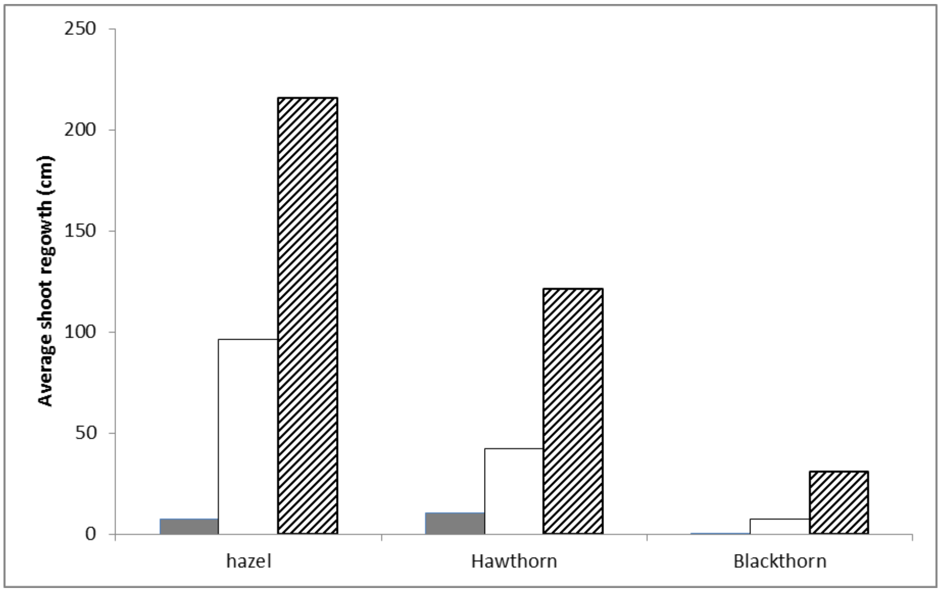

Figure 3. Average shoot regrowth in cm of small single species plots at Elm Farm, solid shading was measured in May 2014, unshaded bars were measured in July 2014 and diagonal shading measured in July 2015.

Regrowth in the small plot trials showed large differences in average regrowth between different hedge species (Figure 3). Blackthorn stools were very slow to regrow, many cut stems did not show any regrowth at all, and much of the regrowth that was recorded was from underground suckers. By contrast the regrowth in the hazel plots was strong, with an average of 1.21 m by July 2015; the hawthorn stools also showed strong regrowth.

3.5 Biodiversity impacts

Change in management adopted on any scale has potential impacts and the introduction of coppice management to hedges for woodfuel is likely to have both positive and negative impacts on the wildlife of individual hedges and on biodiversity at a landscape scale. Potential impacts include an alteration of the hedge microclimate, changes in hedge structure, plant species composition, and landscape connectivity. It is expected that the introduction of coppice management cycles will tend to make hedgerow systems more dynamic increasing the habitat heterogeneity within a landscape. With different species and communities associated with different ages of regrowth, this may lead to an increase in overall biodiversity at a farm or landscape scale. However there are also likely to be some trade-offs, for example, reduced connectivity between patches of semi-natural habitat for species that use the hedgerows as corridors, such as dormice (*Muscardinus avellanarius*) which have been found to be gap adverse (Bright, 1998) and may be adversely affected by coppicing.

To address this alongside the practical trials a biodiversity protocol was developed by ORC (Crossland et al., 2015) to assess the likely impacts on biodiversity of managing hedgerows for woodfuel. This protocol provides a simple methodology to enable landowners to assess the biodiversity status of a hedge network prior to changes in management. It gives baseline data for comparison whilst also identifying hedges that are home to key species with specific management requirements. The protocol is based on a set of indicators selected to provide quantitative links between, for example, habitat quality or structural diversity and biodiversity (Dauber et al., 2003). In order to make the results widely relevant, the methodologies developed to measure each indicator were based on existing surveys such as the DEFRA hedge survey (DEFRA, 2007) and the British Trust for Ornithology’s breeding bird survey. The main indicators included in the protocol are: hedge connectivity, hedge network density, the density of hedgerow trees, hedge structural diversity, the percentage of hedges in favourable condition, and the percentage of hedges providing a good food resource. After carrying out the survey these indicators are scored and the results represented visually using a radar diagram (Figure 4). This gives an overall picture of the biodiversity value of a hedge network and the relative value of individual hedges within the network. Using data collected in the survey the protocol also identifies hedges suitable for harvesting woodfuel as well as those in need of improvement and offers general management recommendations based on different indicators.

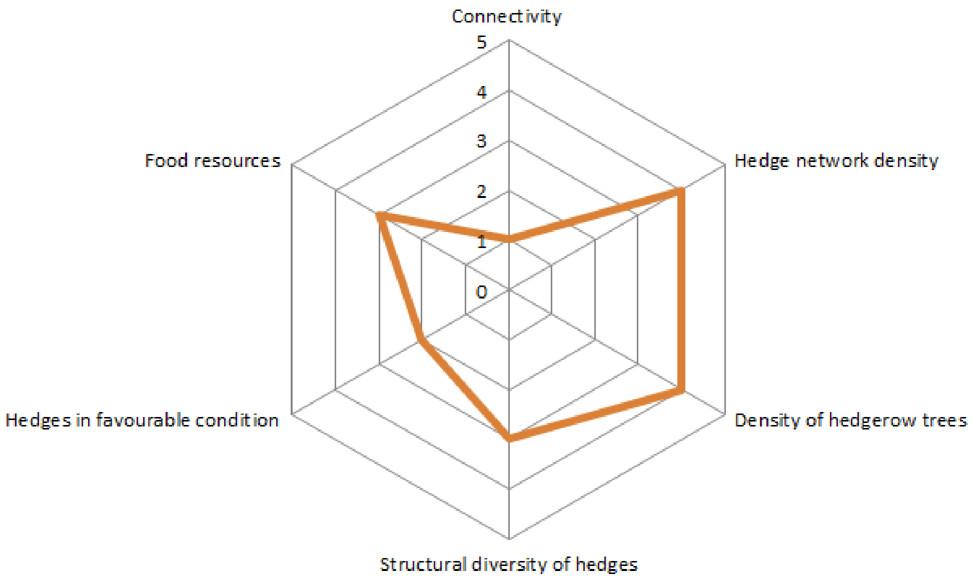

Figure 4. An example radar diagram of the biodiversity protocol hedge survey indicator results.

However the protocol has not been fully tested to date and represents just one approach to quantifying hedgerow biodiversity. There are many other assessment methods and potential indicators which were not included. Through future use, the protocol could be further developed and improvements made to the indicators and how they are calculated and scored. The protocol is available online at http://tinyurl.com/TWECOM.

4. Conclusions

The ORC trials have demonstrated that hedges can be managed effectively and economically to produce woodfuel of reasonable quality which meets industry standards at an energy cost competitive with other fuel types. The economic case for managing hedges for woodfuel is further strengthened when additional savings in reduced costs of annual flailing are taken into account, plus the potential government support via environmental stewardship payments.

A key conclusion from the ORC trials is that each hedge is unique and has to be assessed and managed on its own merits and the most appropriate machinery or methods will depend on the hedge itself and the priorities of the landowner or farmer. In these trials the harvesting and chipping options were used on different hedge types and as such it is difficult to make direct comparisons between the machines. However some general conclusions can be drawn. Assisted fell and large chipper was the most cost-effective harvesting and processing combination of all the machinery methods trialled when at least 280 m of hedge was coppiced. Smaller sections are likely to be more suited to manual fell techniques and smaller chippers. Both the hydraulic shears and felling grapple appeared better suited to large-diameter single-stemmed material with single-blade circular-saws optimally designed for small-diameter material. The assisted-fell and manual-fell methods have the flexibility to work on most sites and hedges. As shown by the variation in maximum efficiency of the circular-saw and manual-fell options when used on different hedge types, the nature of the hedge material being coppiced can have a significant effect on the performance of harvesting options.

The biodiversity protocol provides a mechanism with which to assess a hedge network prior to management in order to identify hedges suitable for harvesting woodfuel, those with high biodiversity value, as well as those in need of improvement. These trials demonstrate that managed correctly the use of traditional farm boundary hedges for woodfuel can be both economically viable and beneficial not only in terms of energy production, but also make sense environmentally, for example, in terms of improving the long-term viability of hedges, connectivity in the landscape and carbon sequestration.

The next step is to investigate how to increase the quality of the woodchip from hedgerows and the potential for other new products from the woodchip such as landscaping mulch, compost, or livestock bedding. Starting in March 2016, 'SustainFARM' is a new EU funded project which will look further into these other provisioning services as well as model the agronomic, environmental and economic performance of these and other integrated food and non-food production systems.

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6. References

Baudry, J., Bunce, R.G.H. & Burel, F. (2000). Hedgerows: An international perspective on their origin, function and management. *Journal of Environmental Management* 60: 7-22.

Bright, P.W. (1998). Behaviour of specialist species in habitat corridors: arboreal dormice avoid corridor gaps. *Animal Behaviour* 56: 1485-1490.

Carey, P.D., Wallis, S., Chamberlain, P.M., Cooper, A., Emmett, B.A., Maskell, L.C., McCann, T., Murphy, J., Norton, L.R., Reynolds, B., Scott, W.A., Simpson, I.C., Smart, S.M. & Ullyett, J.M. (2008). Countryside Survey: UK Results from 2007. CEH Project Number: C03259, 105 pp.

Chambers, E.M., Crossland, E.M., Westaway, S. & Smith, J. (2015). Hedgerow harvesting machinery trials report for TWECOM. The Organic Research Centre. http://tinyurl/TWECOM

Crossland, E.M,, Westaway, S., Gerrard, C. & Smith, J. (2015). Hedgerow Biodiversity Protocol 2015. User Guide. A protocol for monitoring the impacts of harvesting hedges for woodfuel. The Organic Research Centre. http://tinyurl/TWECOM

Dauber, J., Hirsch, M., Simmering, D., Waldhardt, R., Otte, A. & Wolters, V. (2003). Landscape structure as an indicator of biodiversity: matrix effects on species richness. *Agriculture, Ecosystems and Environment* 98: 321–329.

DEFRA (2007). Hedgerow Survey Handbook. Available from: https://www.gov.uk/government/publications/hedgerow-survey-handbook

Garbutt, R.A., Sparks, T.H. (2002). Changes in the botanical diversity of a species rich ancient hedgerow between two surveys (1971 – 1998). *Biological Conservation* 106: 273–278.

Lofti, A., Javelle, A., Baudry, J., Burel, F. (2010). Interdisciplinary analysis of hedgerow network landscapes' sustainability. *Landscape Research* 35:415–426.

Oreszczyn, S. & Lane, A.B. (1999). How hedgerows and field margins are perceived by different interest groups. *Aspects of Applied Biology* 54: 29-36.

Vickery, J.A., Feber, R.E. & Fuller, R.J. (2009). Arable field margins managed for biodiversity conservation: A review of food resource provision for farmland birds. *Agriculture, Ecosystems and Environment* 133: 1-13.

Wolton, R.J., Pollard, K.A., Goodwin, A. & Norton, L. (2014). Regulatory services delivered by hedges: the evidence base. Report of Defra project LM0106. 99 pp.

Wolton, R.J. (2012) The yield and cost of harvesting wood fuel from hedges in South-West England. Unpublished report to the Tamar Valley and Blackdown Hills AONBs. Locks Park Farm, Hatherleigh, Okehampton, Devon, EX20 3LZ