System Report: Agroforestry for Ruminants in England

Project name	AGFORWARD (613520)
Work-package	5: Agroforestry for Livestock farmers
Specific group	Agroforestry for ruminants in England
Deliverable	Contribution to Deliverable 5.13 (5.1): Detailed system description of a case study system
Date of report	30 October 2015
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Approved	Paul Burgess (11 April 2016)

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1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to Objective 2, Deliverable 5.13: "Detailed system description of case study agroforestry systems". The detailed system description includes the key inputs, flows, and outputs of the key ecosystem services of the studied system. It covers the agroecology of the site (climate, soil), the components (tree species, crop system, livestock, management system) and key ecosystem services (provisioning, regulating and cultural) and the associated economic values. The data included in this report will also inform the modelling activities which help to address Objective 3.

2 Background

New agroforestry systems integrating bioenergy crops (short rotation coppice: SRC) and livestock or arable production may help reconcile conflicting demands for land use, but are currently rare in the UK, and so there is a lack of information regarding the performance and potential of these systems. The stakeholder workshops held within work-package 5 identified that there is a need to get better estimates of the value of the woody vegetation for meeting the nutritional needs of the animals in relation to management of trees (e.g. impact of pollarding, cutting or grazing period etc. on the quantity or quality of this woody forage resource) (Hermansen et al. 2015). Building on previous research of the establishment phase of a novel silvopastoral system integrating short rotation coppice with livestock production, this project aims to investigate system productivity, pasture management and fodder value (Smith 2015).

3 Update on field measurements

Pasture productivity and biodiversity were measured in June 2015, and tree height assessed in August 2015, prior to cattle being introduced into the system. Cattle behaviour was monitored in August 2015 and tree damage assessed once the cattle had been moved out of the field in September. This report presents this data as well as providing a detailed description of the case study system.

4 Description of system

Table 1 provides a general description of silvoarable agroforestry systems. A description of a specific case study system is provided in Table 2. Missing data will continue to be sourced during 2015.

Table 1. General description of the silvoarable system

General description of system	
Name of group	Agroforestry for ruminants in England
Contact	Jo Smith
Work-package	5: Agroforestry for livestock farmers
Associated WP	4: Agroforestry for arable farmers (those growing SRC)
Geographical extent	Silvopastoral systems in the traditional sense are to be found throughout the UK e.g. parkland systems and grazed orchards or woodlands, but modern systems where trees are planted for bioenergy or tree fodder are very rare.
Estimated area	Very small nationally – probably less than 1000 ha. Examples include a fodder tree system for dairy cows in Shropshire (http://www.woodlandtrust.org.uk/publications/2013/05/how-trees-benefit-dairy-farms/) and a silvopastoral alley system, again in Shropshire: (http://www.silvaspin.org.uk/)
Typical soil types	Varied
Description	Silvopastoral systems that cultivate trees specifically for fodder include fodder bank systems, where trees and shrubs are planted at high densities and pruned regularly to maximize productivity, and alley pasture systems which further integrate livestock and tree production with rows of trees and shrubs separated by alleys of pasture, with perceived benefits to enhanced nutrient cycling and improved animal welfare (Ibrahim et al. 2005). In modern silvopastoral systems that seek to maximize resource efficiency, there is growing interest in exploiting tree fodder as an extra resource from trees planted for other purposes such as resource protection. For example, farmers in New Zealand have been exploring the value of willows and poplars planted for soil conservation to provide emergency feed during severe summer droughts (Anon. 1996). The value of tree fodder as a feed resource to buffer forage shortages is also increasingly appreciated in areas of seasonal droughts (Andrews 1998; Lefroy et al. 1992; Moore et al. 2003; Papanastasis et al. 2008b). This approach is new to the UK, and there is a need for demonstration systems and data on performance in order to increase awareness.
Tree species	SRC species: • Willow (*Salix viminalis*) • Poplar (*Populus*) • Hazel (*Corylus avellana*) • Alder (*Alnus glutinosa*)
Tree products	Woodchip for bioenergy and/or mulch/compost Tree fodder
Crop species	Grass species such as perennial ryegrass (*Lolium perenne*)
Crop products	Grass can be grazed directly by livestock or cut to provide animal feed (silage or hay).
Animal species	Cattle – dairy or beef
Animal products	Beef, dairy

Other provisioning services	
Regulating services	The trees can provide shade for livestock in summer and shelter from wind in the winter. The cattle can promote nutrient cycling. Above-ground, the trees will increase carbon storage. The tree rows support functional biodiversity that regulate pollination, pest control and decomposition services. Nitrogen-fixing trees such as alder can increase soil fertility.
Habitat services and biodiversity	Tree species such as willow can provide additional resources for invertebrates such as bumblebees early in the season. The tree row represents a stable habitat so can provide shelter and resources for animals, as well as acting as corridors linking up other (semi)natural habitat patches. These species may be beneficial, neutral or detrimental to provisioning services.
Cultural services	Introducing trees into a livestock system may increase job opportunities and skills with regards tree management. The landscape also changes from an open pastoral landscape to a partly wooded environment depending on design of the system. This landscape change can be both an improvement and degradation depending on the context and individual preferences.

Table 2. Description of the specific case study system

Specific description of site	
Area	3.5ha
Co-ordinates	51°23’14.19” N; 1°24’08.34”W
Site contact	Jo Smith
Site contact email	jo.s@organicresearchcentre.com
Example photograph	 Figure. 1. Cattle in the silvopastoral system August 2015

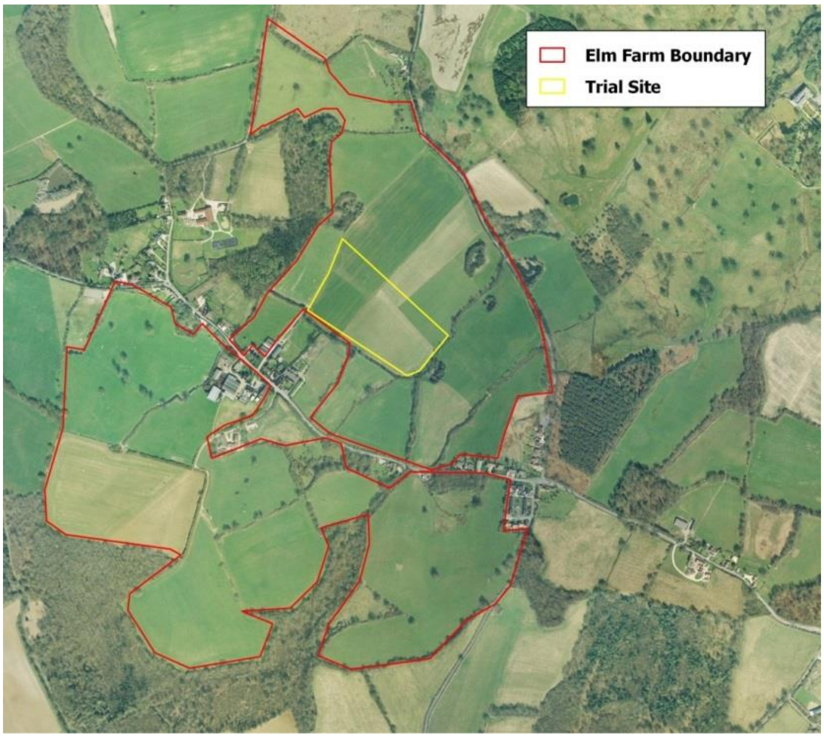
<table>
<tr><td>Map of system</td><td>

Figure 2 Aerial view of Elm Farm and silvopastoral trial site

Figure 3. Aerial view of the silvopastoral trial site (photo by Daria Eric)</td></tr>
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Figure 4. Silvopastoral system design, Flatbottom Field, Elm Farm, Hamstead Marshall, UK (not to scale)

Possible modelling scenarios	
Comparison	Organic SRC production with different species (willow, alder, mix of willow and alder) integrated with cattle production.
Climate characteristics	
Mean monthly temperature	10.7°C
Mean annual precipitation	672 mm
Details of weather station (and data)	Met Office weather station at Oxford, accessed from the Met Office website on 25 March 2015 (www.metoffice.gov.uk/public/weather/climate-historic).
Soil type	
Soil type	Wickham series, changing from heavy clay loam at top of slope to sandy loam at bottom
Soil depth	
Soil texture	
Additional soil characteristics	
Aspect	South

Tree characteristics	
Species and variety	Willow (*Salix viminalis*: mixed varieties) Common alder (*Alnus glutinosa*) Mixed willow and common alder
Date of planting	From April 2011
Intra-row spacing	1175 trees/ha planted as twin rows 0.7 m between twin rows 1.0 m within rows
Inter-row spacing	24 m between centre of twin rows
Tree protection	None. Weed control approaches trialled in years 1-3 (fabric mulches vs woodchip)
Typical tree yield	No harvest to date.
Typical increase in tree biomass	To be determined
Crop/understorey characteristics	
Species	Grassland, including cocksfoot (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) and clover (*Trifolium repens, Trifloium pratense*)
Management	Silage cut in June annually. Cattle introduced for the first time in August 2015.
Typical grass yield	Average from 2011-2015 = 2330 kg ha^{-1} $year^{-1}$ (oven dry weight)
Fertiliser, pesticide, machinery and labour management	
Fertiliser	Cattle grazing from 3rd August 2015 Composted manure spread autumn 2015 (estimated 50 t/ha as no inputs in last few years)
Pesticides	None (organic)
Machinery	Tractor and mower, rake, and loader wagon for silage harvest Alleys were subsoiled on 2 October 2015
Manure handling	Not necessary in the field
Labour	Animals checked daily when in field
Fencing	Field has boundary fence and hedge on two sides, and electric fence on other two sides. Electric fencing was erected along each tree row prior to cattle entering field.
Livestock management	
Species and breed	14 Cattle. The two bulls are Friesian x shorthorns, born March 2014; the cows are Friesian x Jersey heifers, born March 2013, in calf with dairy replacements.
Description of livestock system	Cattle are outdoors from March/April to Oct/Nov depending on weather and soil conditions. The animals are part of an organic dairy/beef enterprise, with the dairy cows and milking unit on the main farm (Eling Farm), and Elm Farm used for grazing dairy replacements and occasionally for sucklers.
Date of entry to site	3 August 2015.
Date of departure from site	The field was divided in half (north/south) and cattle had access to the southern half for four weeks and then moved to the northern half for four weeks until end of September.
Stocking density	14 cattle had access to 4 ha (agroforestry trial plus headlands) for 8 weeks.
Animal health and welfare issues	None. Coppice could provide shelter from wind and shade in the summer. Also trees used as rubbing posts.
Requirement for supplementary feed	No supplementary feed

Technical data, livestock	
Production volume	14 cattle maintained for 8 weeks
Herd performance	Not determined
Feed consumption	Not determined
N-balance,	Slightly negative (no supplementary feed and moderate gain in livestock)
Financial and economic characteristics	
Costs	A Net Present Value calculation has been carried out for this system. The results suggest an NPV for the agroforestry system at Elm Farm of £31,296 over the 20 year lifetime of the willow, or £1302 per year. Since the agroforestry system covers 3.5 ha this gives a value of £8942 per ha for the twenty years and an annual income of £372 per hectare from the system. It is worth noting that there were a large number of assumptions involved in these calculations and these could alter the figures to improve or reduce the final income available from the system. More details will be available in Smith et al. (2015) by the end of December 2015.

5 Pasture productivity and biodiversity

As part of the FP7 project Sustainable Organic and Low Input Dairying (SOLID: www.solid.eu), productivity of the pasture was assessed annually from 2011 to 2015 before the first silage cut was taken (Smith et al (in prep)). To standardise timings between years, sampling was timed to occur during peak seed head production of cocksfoot (*Dactylis glomerata*). Sampling took place on transects running across the alleys and in pasture-only controls. The herbage within each 1 m^2 quadrat was cut to 5 cm above ground in June each year. Herbage was collected into a polythene bag and sealed to prevent water loss. After weighing for fresh weight, a sub-sample from each sample was oven dried at 100°C until a stable weight was reached (oven dried mass: ODM). To identify changes in species composition in the five years following establishment, species percentage cover within 1 m^2 quadrats (same quadrats as for ley productivity assessments) was assessed each year immediately before the herbage cut. Biomass production averaged 233 g m^{-2} over the five years with the lowest production in 2011 (162 g m^{-2}) and highest in 2014 (321 g m^{-2}). Linear mixed model analyses of biomass from 2011-2015 found no statistically significant effects of tree planting on pasture productivity, indicating that the impact of tree planting on pasture production within the first five years was minimal (Figure 5).

The pasture community was dominated by *Dactylis glomerata*, with high densities of *Ranunculus repens* in certain areas of the field. Other common species included the grasses *Agrostis capillaris* and *Holcus lanatus*. There were no statistically significant differences between the treatments with regards to changes in the species percentage cover over the five years with all canonical axis (Axis 1 to 3) accounting for just 2% of the variance in the species cover data (Sum of all canonical eigenvalues = 0.02, F-ratio = 1.491, p-value = 0.124; bi-plot not shown). RDA analysis of the agroforestry-only data to identify spatial variation in species % cover indicated no significant differences in species composition within the alleys (sum of all canonical axes = 0.188, F-ratio = 0.598, p=0.908; bi-plot not shown). Therefore there is no evidence yet of any edge effects caused by competition between the trees and pasture.

Figure 5. Pasture production in different agroforestry treatments from 2011 to 2015.

6 Tree height

Trees were measured in August 2014 and July 2015 (prior to cattle being introduced). Tree height data from 2014 and 2015 were analysed using ANOVA, with tree species as the fixed factor. Alder and willow growing within the 'mixed species' treatment were included as separate 'species'. Post hoc testing to compare means was carried out using the Tukey HSD test. There were no significant differences in tree height between the different species in 2014 ($F = 0.644$, $p>0.05$). In 2015, there was a statistically significant difference between species ($F = 15.73$, $p = 0.001$), and alder was significantly taller than both the willow grown as a single species and as a mix (Figure 6).

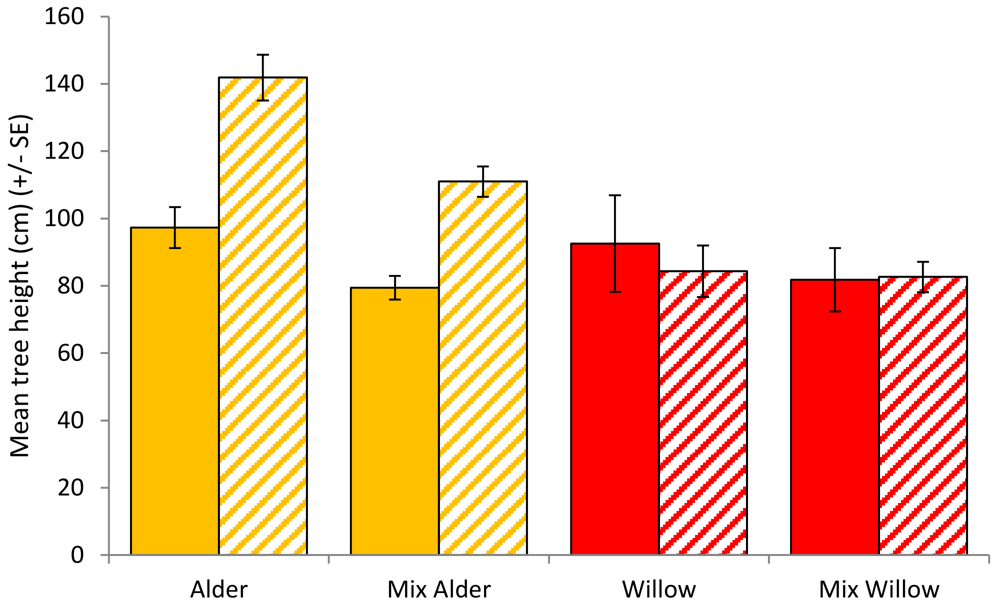

Figure 6. Tree height in 2014 (full bars) and 2015 (striped bars)

7 Livestock browsing trial

While the SRC was establishing cattle were restricted from grazing in the agroforestry area although the alleys were harvested for silage. It should also be noted that local wild deer did access the area and browsed the willow in particular. In the summer of 2015 it was decided to give the cattle access to the agroforestry system for the first time. To investigate measures which farmers could take to restrict browsing in such a system two types of electric fencing were investigated (single strand and two strands of electric wire) along with a no-fence control. To record the impact that this had, observations were made of cattle behaviour with regards to browsing of the trees and reactions to the fencing. The cattle were 16 dairy/beef cattle: 14 cows and two bulls. Two cows were removed from the field shortly after the observations began (for Tuberculosis testing) and the remaining 14 cattle stayed in the field for the duration of the period. The two bulls are Friesian x short horns, born March 2014; the cows are Friesian x Jersey heifers, born March 2013, in calf with dairy replacements. All occurrences of the key behaviours that were observed (i.e. to carry out behaviour sampling; Martin and Bateson 2007) were recorded. Observations took place over an hour and one-zero time-sampling techniques were used (Martin and Bateson 2007): the hour was split into 60 intervals of one minute and at the end of each minute it was recorded whether or not the behaviour pattern had occurred during the last minute. The observer also noted how many animals had carried out the key behaviour during that period.

Figure 7. Cattle browsing on alder

The key behaviours were defined as:

1. Browsing – defined as animals' heads being in the tree line and ideally animals being observed to eat the leaves, twigs, etc. of the trees.
2. Aversive behaviour triggered by the electric fences e.g. animals jumping and pulling away from the tree line, animals showing signs of caution in approaching the tree line.
3. Damaging trees e.g. walking through trees, scratching against trees.

With regards to browsing behaviour, at the start of the three week observation period the browsing that was observed was either browsing of the mature boundary hedge or browsing of the willow within the agroforestry system. The first observation of cattle browsing on alder was of them browsing on a branch that had been cut five days before and was dead. This occurred on 5 August 2015. It is suggested that this may have been due to reduced tannins in the dead alder making it more palatable (Gonzalez, personal communication, 2015). However, later on in the 3 week observation period cattle were also observed browsing on alder (Figure 7). Samples of leaves were taken from both the alder and willow trees on the same day as browsing was observed, oven dried at 40°C until constant weight was achieved. These will be analysed for nutritional value in collaboration with other work-package 5 partners.

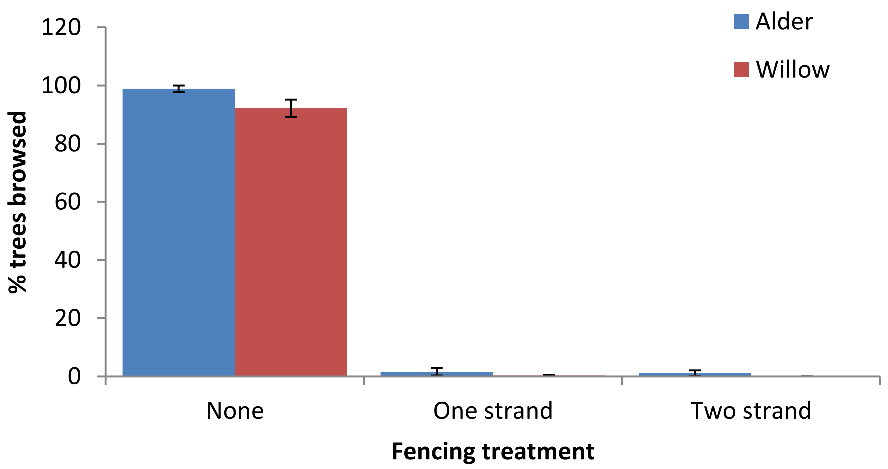

Figure 8. Tree browsing within different fencing treatments

Post-grazing, assessments were made of all trees for signs of browsing by cattle (Figure 8). Analysis of variance identified a statistically significant difference in the proportion of trees browsed by cattle in the different levels of fencing (alder: F-value = 2594, df = 2, $p < 0.0001$; willow: F-value = 529, df = 2, $p < 0.0001$). Unsurprisingly, the highest level of browsing occurred in the no-fence control. However there were no differences in levels of browsing between the single and double strand fencing treatments, indicating that a single strand of electric fencing is sufficient to protect the trees from cattle.

8 Plans for 2016

The pasture alleys will be ploughed and reseeded in spring 2016 with diverse sward mixtures. Pasture establishment, biodiversity and productivity, tree growth and cattle behaviour will be assessed in 2016.

9 Acknowledgements

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