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INTERACTIONS BETWEEN TREES, CROPS AND ANIMALS: EXPERIENCES IN A NOVEL BIOENERGY-LIVESTOCK SYSTEM IN THE UK

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Abstract

Managing the interactions between trees, crops and animals is an on-going challenge for agroforestry farmers. This paper reports on interactions between trees, crops and both wild animals and livestock in the establishment years of a novel UK agroforestry system combining short rotation coppice for energy production with livestock production. Our trials suggest that in the first six years there is no significant impact of trees on the alley crops (pasture and whole crop oat silage) in this system. Protecting the trees from livestock damage is essential in the early years; with cattle, our results show that it this is possible using a single stranded electric fence. Patterns of biodiversity varied between taxa; earthworm abundances were higher in the tree rows, which represent an undisturbed stable habitat, while the more active ground beetles were in greater abundances in the crop alleys which may reflect higher levels of prey within the crop.

Keywords: silvopastoral systems; biodiversity; competition; tree protection; earthworms; Carabidae

Introduction

A central hypothesis in agroforestry is that productivity is higher in agroforestry systems compared to monocropping systems due to complementarity in resource-capture i.e. trees acquire resources that the crops alone would not (Cannell et al. 1996). Interactions between the tree and crop/livestock components can be positive or synergistic, leading to complementarity between the systems components; negative or antagonistic, resulting in competition; or neutral, with no direct interactions (Jose et al. 2004). As agroforestry systems are dynamic, these interactions are likely to change over time, so that there may be complementarity between the components in the early stages which then shifts into competition for resources as the tree component reaches maturity (Jose et al. 2004). This paper reports on interactions between trees, crops and both wild animals and livestock in the establishment years of a novel organic bioenergy agroforestry system in the UK.

System description

An agroforestry system combining bioenergy and livestock production was established on Elm Farm in Berkshire in the UK in 2011 (51°23’14.19”N; 1°24’08.34”W), with the aim of assessing the potential impacts of utilising agroforestry for low-input and organic dairy systems. A replicated plot trial incorporating short rotation coppice (SRC) and pasture was planted in April 2011 using an alley-cropping design with tree rows running north/south (Figure 1). Willow was chosen as a SRC species as it has a dual value as both a bioenergy source and a livestock fodder; a mixture of five bioenergy varieties of *Salix viminalis* was planted. Common alder (*Alnus glutinosa*) was chosen as a second species to test; its value as a fodder crop was unknown, and while it coppices well, it is not a common species for SRC bioenergy production. However, it is one of only a few temperate tree species that fixes nitrogen, and so is of interest in an organic system. Trees were planted in twin rows, 0.7 m between twin rows and 1.0 m between trees within rows. Tree rows are roughly 3 m wide, with 24 m between tree row centres (i.e. about 21 m of pasture alley). A silage cut was taken once or twice a year for the first four years, and cattle were introduced in August 2015 for two months. A break crop of oats for whole crop silage was sown on 10 October 2016 (at a rate of 185 kg seed per hectare) ahead of re-seeding of pasture in Spring 2018.

Figure 1. Alder short rotation coppice with oats in the 21 m wide alley (May 2017)

Tree: animal interactions

In the summer of 2015 cattle were given 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. The cattle were 14 dairy/beef cattle: 12 cows and two bulls. The two bulls were Friesian x short horns, born March 2014; the cows were Friesian x Jersey heifers, born March 2013, in calf with dairy replacements. At the start of the three week observation period the browsing that was observed was either of the mature boundary hedge or of the willow within the agroforestry system. However, later on in the three week observation period cattle were also observed browsing on alder. Post-grazing, assessments were made of all trees for signs of browsing by cattle. 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 (willow 92.2% browsed; alder 98.7%). 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 (single strand: willow 0.3% and alder 1.5%; double strand: willow 0% and alder 1.1%).

Tree: crop interactions

Pasture productivity

Productivity of the pasture was assessed annually before the first silage cut was taken from 2011 to 2015. 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 from tree row to tree row, and in pasture-only controls. The herbage within each 1 m^2 quadrat was cut to 5 cm above ground in June each year and oven dried at 100°C. 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.

Growth and cover of oats

Due to the tree harvesting rotation, it was possible to study the effects of tree height on the oat crop in the alley. Three tree rows were coppiced in February 2016, and three more in January 2017, leaving the three remaining rows un-harvested. The impact of tree growth on the oats in the adjacent alleys was investigated by assessing growth stage, percentage cover and height of oats from April to June. Assessments were carried out at 4 m, 8 m and 12 m from the centre of the tree row, on two transects in each of the willow and alder plots (1st year regrowth; 2nd year regrowth; un-harvested). Full details are given in Deremetz (2017). A more detailed study of crop height was carried out in the alley with the oldest trees to identify any impact of the tallest trees on the crop. The height of a main stem was recorded at eight points spaced 4 m apart on transects parallel to the tree rows, at distances 2.5, 4, 8 and 12 m from the tree rows both east and west of the tree row.

There were significant differences in terms of some growth stages, in response to age of the tree re-growth, and the interaction between tree re-growth age and distance from the tree row: timing of second nodes (Tree age: $X^2 = 10.671$, $p=0.005$ and interactions: $X^2 = 19.174$, $p = 0.014$) and timing of ear emergence (Age: $X^2 = 7.360$, $p = 0.025$). The timing of these growth stages was later in the second year of regrowth, compared to both the first year regrowth and the unharvested tree plots, so the delay can't be directly attributed to the effects of shading by the trees. It may be that the trees are too small, even the oldest, to significantly influence the timing of growth stages.

There were significant differences in percentage cover of the oats in response to the age of tree regrowth (21 April: F = 4.285, p = 0.020; 5 May: F = 6.404, p = 0.004; 12 May: F = 4.565, p = 0.017). However, similar to the effects on growth stages, percentage cover of oats in the second year regrowth plots were significantly lower from the first year regrowth and unharvested plots (38% compared to 51% and 47% respectively), suggesting that shading from the trees alone was not the driving factor. There were no significant influences of the distance from the tree row and the interaction of distance and age of the trees on the cover of oats.

Focusing in more detail on the tree row alleys with the unharvested trees, there were significant differences between the distance (F = 64.521, p < 0.001) and orientation of the alley (West and East of the tree row; F = 21.251, p < 0.001) and their interaction (F = 3.300, p = 0.022) (Figure 2). Crops were tallest adjacent to the tree rows with a decrease with increasing distance from the tree row; this effect was more noticeable on the east side of the tree rows. This may reflect the shading effect causing greater stem elongation in those plants closes to the tree rows. The impact of trees on the microclimate, enrichment of nitrogen by the fine tree roots, leaf litter and biological nitrogen fixation by the alders may also contribute to this effect.

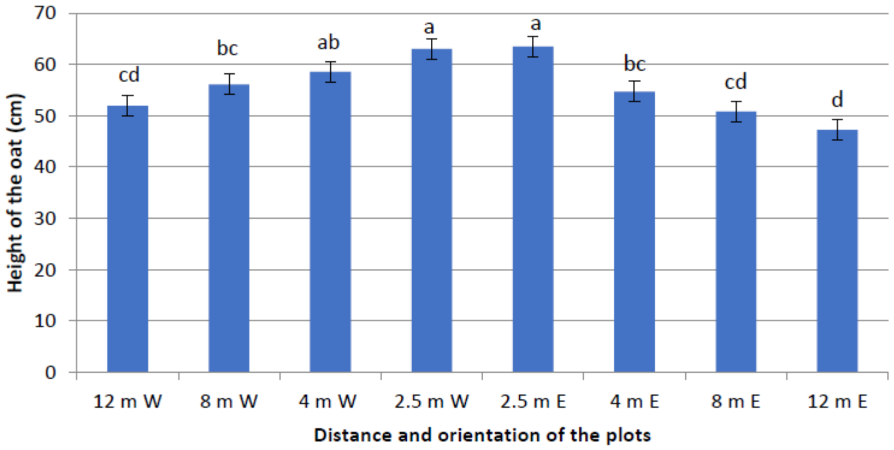

Figure 2. Crop height at 2.5 m, 4 m, 8 m and 12 m east (E) and west (W) from the tree rows (different letters signify significant differences)

Tree: crop: animal interactions

In 2017, the biodiversity of earthworms and ground beetles (Carabidae) were investigated in the tree rows and oat crop. Full details are available in Deremetz (2017). These two taxa support two important ecosystem services; earthworms are important drivers of organic matter decomposition and maintenance of soil structure, while ground beetles contribute to pest control. They showed different patterns of biodiversity in the agroforestry system, reflecting their different habitat and resource requirements. Earthworm abundances were higher in the tree rows (Fig. 3a), which represent an undisturbed stable habitat, buffered from extremes of temperature. The more active ground beetles were in greater abundances in the crop alleys (Fig. 3b); this may reflect higher levels of prey within the crop, or a preferable microclimate in the crop than in the tree rows. However, many species of carabids commonly associated with crops require undisturbed or extensively managed vegetation for overwintering or reproduction sites (Pfiffner and Luka 2000). The role of the tree rows in providing a refuge for ground beetles throughout the winter or during periods of cultivation in the alleys should be investigated further.

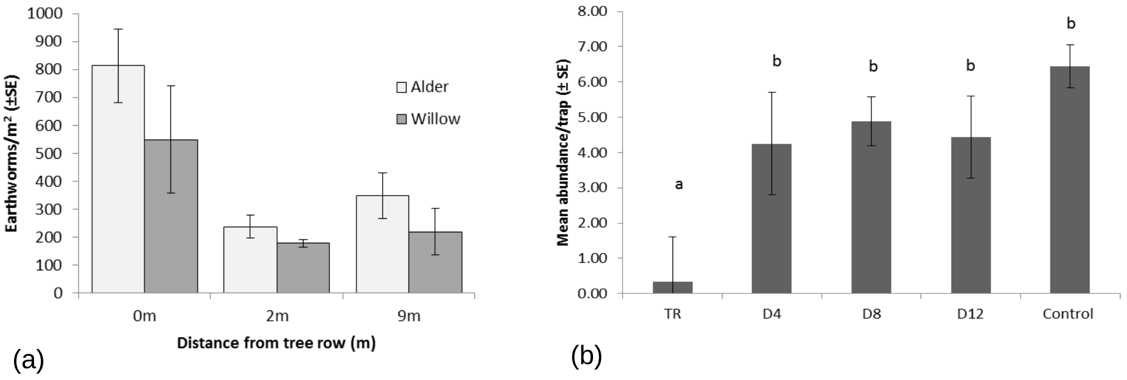

Figure 3a. Earthworm abundance at different distances from the tree row in alder and willow agroforestry plots. 3b. Ground beetle abundance at different distances from the tree row in non-harvested alder agroforestry plots and a control plot. TR = Tree row; D4 = 4 m from tree row; D8 = 8 m from tree row; D12 = 12 m from tree row. Letters indicate significant differences (X^2 = 24.897, $p < 0.001$).

Conclusion

Managing the interactions between trees, crops and animals is an on-going challenge for agroforestry farmers. Our experiences suggest that in the first six years there is no significant impact of trees on the alley crops in this system. As the system will be coppiced on a 3-5 year rotation, it is expected that this will help manage the competition for light by keeping the level of shading lower than in a standard tree system. It may be possible, also, to time the harvesting of the trees to coincide with re-seeding of the pasture in the alleys, to ensure highest levels of establishment of the sward. Protecting the trees from livestock damage is essential in the early years; with cattle, our results show that it this is possible using a single stranded electric fence.

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