Woodland Trust Research Briefing

Tree: crop interactions in UK alley cropping agroforestry systems: impacts on crop yield and total productivity

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Summary:

- A key concern for farmers contemplating establishing a new agroforestry system is the impact of tree planting on the crops growing underneath or in adjacent alleys. The main limiting resource for plants is usually light and some studies have shown that shading has reduced yields in temperate agroforestry systems. Our research has investigated the impact of trees on crops in the adjacent alleys within an organic silvoarable alley cropping system in the UK.
- In the timber/cereal system, there was a classic 'edge-effect' with lower crop yields adjacent to the trees compared to the centre of the alley; however, the impact on yields differed between crop species, suggesting that some crops such as oats may be better suited to the more competitive environment of growing with trees.
- In the willow short rotation coppice (SRC)/fertility-building grass ley system, this 'edge effect' was also observed when the willow was in its second year of regrowth after coppicing; however there was no difference in ley production in the alley and an adjacent open field in the first year after willow harvest.
- The reduced edge-effect following tree coppicing was also observed in cereals grown in the willow SRC alleys, highlighting the impact of tree management on the adjacent crops. This opens up opportunities to integrate more closely the management of the tree component with the timing of the crop rotation.
- Modelling allows us to predict productivity in agroforestry systems over a whole crop rotation and compare performance with monoculture systems using the Land Equivalent Ratio (LER). The LER for the willow SRC/organic crops system at Wakelyns over a crop rotation (six years) was 1.36 suggesting that there is a 36% yield advantage for the system compared to when the components are grown separately as monocultures.
- Recognising and understanding the interactions between trees and crops allows farmers to design and manage the system with the aim of encouraging complementarity rather than competition in resource use.

Introduction

In this research note we report on studies carried out within an organic silvoarable alley cropping system in the UK, where we have investigated the impact of trees on crops in the adjacent alleys.

In agroforestry systems, interactions between the tree and crop/livestock components can be positive, negative or neutral. Positive interactions can lead to an increased capture of a limiting resource, resulting in greater total production than if the two components had been grown separately. Conversely, negative interactions occur when the two components overlap in their resource use and can result in lower productivity than if the components are grown separately.

These interactions are likely to change over time, so that there may be complementarity between the components

Figure 1. Where crops and trees meet there is likely to be competition for resources including light, nutrients and water.

in the early stages of an agroforestry system, which then shifts into competition for resources as the tree component reaches maturity. Yield impacts can be reduced by designing a system that minimises the interface between trees and crops, and by managing both components to encourage complementarity rather than competition in resource use.

The three main limiting resources are light, water and nutrients. Demand for these resources varies temporally and spatially and depends on physical and phenological characteristics of the species involved. Within northern temperate regions, the main limiting resource for plants is usually light and some studies have shown that shading has reduced yields in temperate agroforestry systems[1,2]. This is a key concern for farmers contemplating establishing agroforestry.

Wakelyns Agroforestry, a diverse organic agroforestry system

Established by the late plant pathologist Prof. Martin Wolfe to put into action his theories of agro-diversity being the answer to achieving sustainable and resilient agriculture, Wakelyns Agroforestry in Suffolk integrates trees for timber, energy and fruit production into an organic crop rotation.

Size: 22.5ha

Location: Suffolk, East Anglia, 52.36°N, 1.35°E

Climate annual averages: Rainfall 606 mm, sunshine 1535 hours, minimum/maximum temperature 6.0 °C / 13.8 °C.

Soils: clay loam over chalk with clay content of 25-30%, pH 8.0, organic matter approximately 3.5%, and low indices for P and K.

Agroforestry: alley cropping design with tree rows running north/south and an organic arable and vegetable crop rotation in the 10-12m wide alleys (Fig. 2a-c). Trees were planted between 1994 and 1998.

The reasons behind establishing such a diverse system were manifold: to reduce pest and disease pressure by increasing the distance between individuals of the same species; to increase biodiversity including beneficial insects such as pollinators and natural enemies; to provide resilience to a changing climate; and to diversify production and reduce the risks associated with farming single commodities.

Figure 2c. Fertility-building ley growing within the willow SRC system. Trees are planted as twin rows with 1.2m between trees and 1.5m between rows. The willow is harvested on a two year rotation with the whole of every other twin row being cut.

Figure 2a. Oats growing within the hardwood and apple tree system in 2009. Species:

- small-leaved lime (*Tilia cordata*)
- hornbeam (*Carpinus betulus*)
- wild cherry (*Prunus avium*)
- Italian alder (*Alnus cordata*)
- ash (*Fraxinus excelsior*)
- oak (*Quercus petraea*)
- sycamore (*Acer pseudoplatanus*)
- apple (*Malus domestica*)

Trees planted in pairs at an average of 1.6m apart, with roughly 10m between pairs. Cereal crops (oats in this example) are harvested in advance of apples enabling access to the fruit trees when alleys are uncropped.

Figure 2b. Potatoes growing in the hazel short rotation coppice system. Trees are planted as twin rows with 1.5m between trees and 1.5m between rows. The coppice is harvested on a 5 year rotation with one of the twin rows cut at a time.

Cereals and timber trees

In 2009 tree:crop interactions were investigated in the hardwood tree system (Fig. 2a). The 15-year-old trees were between 5 and 11 metres high at this point and a spring wheat (mixture of Paragon and Tybalt varieties) crop, a winter wheat (Hereward, Solstice, Spark mixture) crop and oats were growing in the alleys in between. Using a plot-combine, we harvested 1.2m wide strips on the east, centre and west edges of the alleys to compare yields adjacent to the tree rows with those from the centre of the alleys (Fig. 3). Interesting to note is that while the wheat yields at the edges of the alleys were just over 50% of the yields from the centre plots, the oat crop seems more competitive with around a 25% decrease in yields at the edge compared with the centre. This suggests that some crops may be better suited to the more competitive environment of growing with trees.

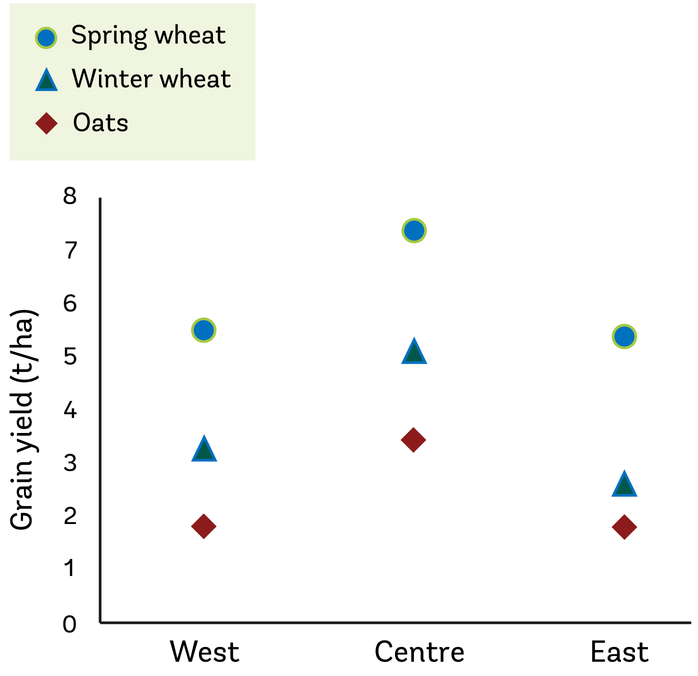

Figure 3. The mean grain yield of a spring oat, spring wheat and winter wheat in three positions across a 10m wide cropping alley between timber tree rows

Fertility-building ley and short rotation coppice willow

In 2012 and 2013 we carried out research to investigate the productivity of a fertility-building legume ley within the willow SRC system (Fig. 2c) and compared it with a neighbouring field which had no trees[3]. The ley had been sown in May 2011 as a diverse mixture of white clover varieties (40%), red clover varieties (40%), Lucerne (7%), yellow trefoil (7%) and chicory (6%) with an overall seed rate of 6 kg/ha. The ley within the agroforestry and no-tree control field was mown regularly to enhance weed control for subsequent cropping.

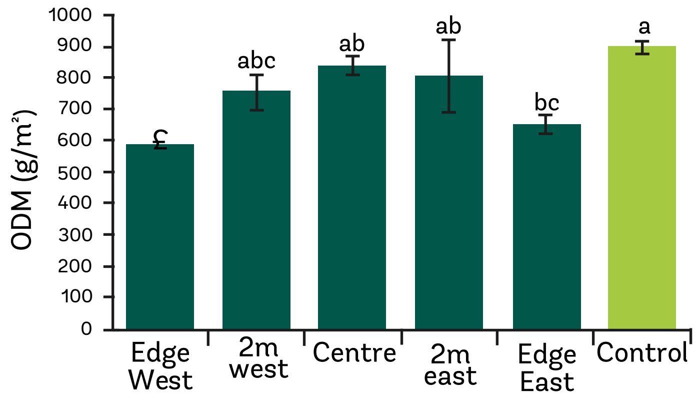

Figure 4. Total biomass production (oven dried mass; ODM) of the ley in the agroforestry and no-tree control plots 2012 (average per plot +/- se). Different letters denote significant differences.

There was a significant difference in total biomass production (ODM) from different locations in 2012, with plots at the edge of the agroforestry alleys yielding less than plots in the control and centre of the alleys (Fig. 4). This suggests that there is competition for resources between the willow and ley at the edge of the alleys, but this competition decreased as distance from the alley edge increased. However, in 2013 after willow harvest in January, analysis of total biomass showed no significant differences between plots; this may be due to reduced shading effects on the alleys following harvest, and potentially reduced other competitive interactions e.g. for water and nutrients.

Cereals and short rotation coppice willow

In 2014, cereal production was investigated in the willow SRC alleys4. The trial plots were drilled at a seed rate of 425 seeds m^2 in March 2014 with oats (Canyen variety), a spring milling wheat (Paragon), and a spring wheat Composite Cross Population (YQCCP). The tree row on the west side of the alley was coppiced in January 2014 while the tree row on the east side of the alley was left standing throughout the season. Each plot was harvested with a plot combine to measure grain yield.

Oat yields were highest adjacent to the coppiced hedge, perhaps reflecting some benefits provided by proximity to the tree row such as better soil conditions (nutrients or structure) (Fig. 5). Yields of all crops dropped considerably across the alley towards the standing hedge. These results highlight the impact of tree management on the adjacent crops; coppicing the SRC reduced yield loss at the edge of the alley. It opens up opportunities to integrate more closely management of the tree component with the timing of the crop rotation by, for example, growing less competitive cereals immediately after the trees are coppiced.

Total Productivity: The Land Equivalent Ratio

One of the key attractions of agroforestry is that while productivity of the individual components of an agroforestry system may be lower than in farming systems without trees, overall productivity can be higher due to complementarity of resource use. This is based on the ecological theory of niche differentiation; different species obtain resources from different parts of the environment and/or at different times of the year. For example, tree roots generally extend deeper than crop roots and so access soil nutrients and water unavailable to crops, as well as absorbing nutrients leached from the crop rhizosphere. These nutrients are then recycled via leaf fall onto the soil surface or fine root turnover. This should lead to greater nutrient capture and higher yields by the integrated tree-crop system compared to tree or crop monocultures[5].

Modelling allows us to look at the productivity of an agroforestry system over time, by predicting daily growth of the trees and crops in a particular system using local weather, soils and management data. Using a special agroforestry model called Yield-SAFE[6], it was possible to model and thus compare the yields that might be expected at Wakelyns as a pure arable system, a pure willow SRC system and a willow-arable agroforestry system for a 10-year period4. The modelled rotation for the crops was spring wheat/ley/potato/ley/winter squash/ley (repeated). Figure 6 below shows the comparison between the biomass production in the three scenarios: 100% crops, 100% willow coppice and agroforestry system (20:80 willow coppice: crops).

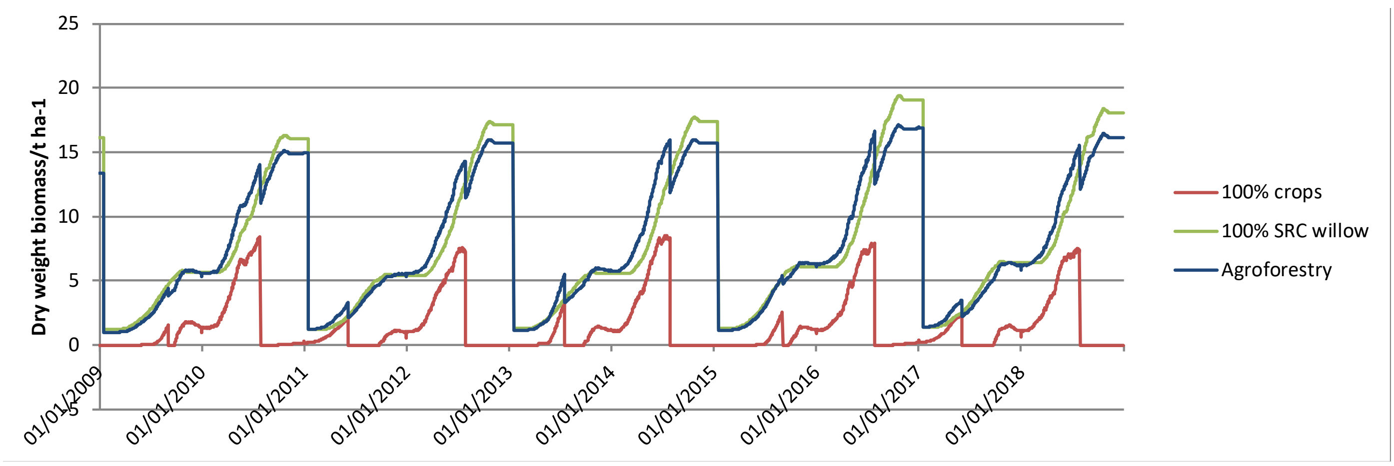

Figure 6. Modelled total biomass production at Wakelyns Agroforestry for the period 1 January 2009 to 31 December 2018 for 100% crops, 100% SRC willow and an agroforestry scenario. Pure SRC is modelled as 15 000 trees/ha.

Over the course of one full crop rotation (three coppice cycles), total biomass was modelled at 57 t/ha under the agroforestry system (i.e. combining trees and crop biomass), compared to 47 t/ha under pure SRC (i.e. just tree biomass) and 32 t/ha under pure arable (just crop biomass). The model can be used to calculate a Land Equivalent Ratio (LER) i.e. the ratio of productivity under agroforestry versus that in monoculture systems. A ratio > 1 indicates that greater production is achieved under agroforestry than by an identical area of monoculture production. In other words, a greater area of land is needed to produce equivalent yields if arable and coppice are spatially separated than when they are combined in an agroforestry system. The LER is calculated as:

$$\frac{\text{harvested crop biomass (AF)}}{\text{harvested crop biomass (100\% arable)}}$$

$$\frac{\text{harvested tree biomass (AF)}}{\text{harvested tree biomass (pure SRC)}}$$

where AF represents modelled yield per ha from the agroforestry system. The LER was calculated across one full arable rotation (i.e. six years):

$$LER = \frac{14.34}{32.07} + \frac{42.81}{46.79} = 0.45 + 0.91 = \mathbf{1.36}$$

A LER of 1.36 suggests that there is a 36% yield advantage for agroforestry compared to when the components are grown separately as monocultures. This sort of modelling provides the basis for development to compare systems in terms of harvested yields, total profits, optimal coppice:arable ratios etc. One could even set targets (based, for example, on the amount of woodchip required to meet the farm's own energy needs) and calculate the system design required to meet them.

Recommended citation:

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