Effects on Crop Production of Agroforestry in Western Australia and Central-Western Spain

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Abstract

Intercropped agroforestry systems have been found to have both positive and negative effects on crop productivity. These effects are due to the complex interactions between trees, soils, and agricultural crops, including tree-crop competition and tree-mediated improvements to soil fertility.

The two papers considered in this analysis both address the impacts on crop production of intercropped agroforestry systems. Each paper looks at a different combination of tree species and crop plants, and a different agroforestry management system and layout. The studies were carried out respectively in Western Australia and in central-western Spain, but the findings of both are relevant to agroforestry in a Western Australian context.

Introduction

Over the last decade there has been increasing interest in the inclusion of trees into pastures and croplands due to multiple environmental benefits attributed to agroforestry systems (Palma et al., 2007; Howlett et al., 2011). In Western Australia this is particularly relevant due to our fragile soils and high water table, leading to widespread problems with soil erosion and salinity (Taylor and Hoxley, 2003; Mollison, 1988). The potential of agroforestry systems to increase farm productivity via additional products and services, including biofuel, fuelwood products, timber, fodder, and shelter for livestock has not been adequately explored in a Western Australian context.

This analysis compares two papers addressing the effects on crop production of agroforestry systems, one in Western Australia, and one in central-western Spain. *The impact of evergreen oaks on soil fertility and crop production in intercropped dehesas* paper (Moreno et al., 2007) considers the effects of evergreen holm oaks in dehesa woodland systems in central-western Spain. *The extent and cost of mallee–crop competition in unharvested carbon sequestration and harvested mallee biomass agroforestry systems* (Sudmeyer et al., 2012) considers three mallee species in alley systems in the Western Australian wheatbelt.

Due to the similarities between the two locations, the findings from both papers are relevant to the design and initiation of agroforestry systems in Western Australia. Although the two papers focus on different aspects of the question, both address the effects on crop productivity of an intercropped agroforestry system on standard cereal, grain legume, and pasture crops. It is expected that these two papers will provide, in synthesis, a window into the impacts of tree-crop interactions in an arid-tending Mediterranean climate zone.

Analysis

Mallee-Crop Competition in Alley Systems: Western Australian Wheatbelt

Sudmeyer et al. (2012) investigated the effects of competition between agricultural crops, including pastures, and mallee species in agroforestry systems in Western Australia. A lack of reliable information around agricultural production in mallee agroforestry systems limits their development, constraining decision making by landowners, investors, and policymakers (Sudmeyer et al., 2012). The study documented in this paper investigated several hypotheses in order to advance the state of current knowledge regarding mallee agroforestry systems and crop interactions:

(i) *reducing mallee water use by harvesting the mallee belts* [in alley systems] *will reduce the extent and magnitude of competition with adjacent crop and pasture;*

(ii) *season of mallee harvest and time between harvests will influence how water is partitioned in the competition zone and subsequent crop and pasture growth;*

(iii) *root-pruning of coppicing mallees will further reduce mallee water use and competition extent and magnitude;*

(iv) *site edaphic characteristics influence competition, allowing site selection to be used to manipulate competition magnitude and extent;*

(v) *economic impacts of competition can be reduced by manipulating agricultural inputs in the competition zone.* (Sudmeyer et al., 2012)

The paper is structured in the standard format, with an economic analysis included in the results. It provides a broad overview of mallee agroforestry in Western Australia and describes the need for more robust and detailed information moving forward, based on likely regulatory changes and the potential impacts to farmers. Specifically, federally mandated renewable energy targets and cap-and-trade carbon legislation may provide an incentive for biomass based carbon sequestration crops such as mallee. However, the competition for resources, primarily water, by mallees can present a significant cost to farmers through lost crop or pasture productivity if the system is not designed and managed effectively.

Both the methods used and the documented results were complex due to the number of variables involved in the study. Overall, sufficient detail was included to repeat the study effectively, but some details were not clear. For instance, three species of mallee were used in the study, *Eucalyptus polybractea*, *E. loxophleba ssp. lissophloia*, and *E. kochii ssp. plenissima*. The reasoning behind the use of these three species was not apparent. Fifteen sites were included in the study. Soil cores were taken over three years, with sites sampled in one of the three years. The treatment of the cores taken in 2010 was different to the treatment of soil cores from the previous two years; the reasons and potential consequences of this to the results were not explored. In addition, the authors point out that their method for measuring water table depth may have produced overestimates in some instances. As the water table depth was used to estimate mallee rooting depth, this may have led to inaccuracies in the results.

The study found that the extent and magnitude of competition effects on the various crops varied widely between sites and years. Tree-crop competition was shown to be affected by the season of mallee harvest and the time between harvests, although this was not definitely shown to be due to changes in water partitioning. Hypothesis (iii) was rejected, as root pruning of coppicing mallees was not shown to significantly reduce competition or water usage. Not all hypotheses were given equal consideration, although all were explored to some extent. The main conclusion of the study was that the economic impacts of tree-crop competition on farmers with mallee agroforestry systems require specific consideration when designing such a system.

<u>Impact of Holm Oaks on Soil Fertility in Dehesa Woodland: Central-Western Spain</u>

By contrast, Moreno et al. (2007) investigated the impact on soil fertility and crop production of oak woodland (dehesa) agroforestry systems in central-western Spain. Specifically, they looked at the effect of holm oak (*Quercus ilex L.*) on soil nutrient concentration and therefore on the production of oats (*Avena sativa L.*) as an understorey crop. The authors state early on in the paper that others studies have found both increases and decreases in crop yield as a result of the presence of trees. No overt hypotheses were documented, but the aims of the study were stated as:

(1) *To describe the soil nutrient distribution around scattered Holm-oak trees by studying soil nutrient content at different distances around trees in dehesas with different fertility and fertiliser applications.*

(2) *To determine the effect of trees on crop plant characteristics and crop production.*

(3) *To ascertain the relative importance of the different effects of trees on crop production: soil fertility improvement (positive interaction), below-ground com- petition and light reduction (negative interaction) and management practices.* (Moreno et al., 2007)

Like the mallee agroforestry paper considered above, this paper was presented in the standard format. There was no economic analysis included, although this would have been quite interesting, given the results of the study. Soil organic matter, total nitrogen, exchangeable potassium ions and exchangeable base cations were all shown to be higher under the tree canopy than beyond it. Soil organic matter under the oak trees was approximately twice that outside the canopy. These findings match the implied hypothesis of the study, that the traditional belief that holm oaks improve chemical soil fertility and crop or pasture production (Moreno et al., 2007). Crop biomass and grain yield increased, overall, with distance from the tree, but the nutritional qualities of the crops decreased with distance from the tree.

The traditional belief that oaks improve soil fertility and crop productivity is derived from the history of dehesa oak woodland management and cultivation on the Iberian peninsula since 500 BC (Joffre et al., 1999). The dehesa woodland system is unlike the alley-cropping system studied by Sudmeyer et al. (2012). A dehesa woodland consists of widely spaced trees, usually maintained at a tree density of between 20 and 60 trees per ha, either intercropped with cereals and sometimes legumes or stocked with livestock or game (Moreno et al., 2007). This system is widely regarded as being environmentally friendly as well as enhancing productivity in an increasingly arid Mediterranean area (Howlett et al., 2011; Joffre et al., 1999). Empirical evidence of improvements to productivity, or at least equivalent productivity, in dehesa woodland agroforestry systems as opposed to cleared cropland would support the conservation of these systems. These findings may also have value for other parts of the world where similar climatic and geophysical conditions apply, such as Western Australia.

In this study measurements were taken at sixteen plots, all with very similar climatic and soil conditions, and similar terrain. Although slightly different procedures were followed at the various sites, this was clearly stated, and was due to the nature of the study being carried out. Compared to the single soil sample per site taken in the mallee tree-crop competition study mentioned previously (Sudmeyer et al., 2012), Moreno et al. (2007) took 480 soil samples across their sixteen plots, although their soil samples were much shallower than those taken by Sudmeyer et al. (2012). They also considered and factored in the effects of light penetration on crop productivity.

This study found that the presence of holm oak trees increased soil fertility, but that other interactions between the trees and crop plants, as well as poorly adapted seeding and fertilisation machines, resulted in variable effects on crop productivity. On unfertilised plots, crop productivity was increased; however, this effect was masked or absent in fertilised plots. Overall, the authors state that further studies are required, as this study was not sufficient to separate the effects of crop management, shade, and tree-crop competition for water and nutrients.

The authors specifically suggest a study to determine the effect of light on crop production in an agroforestry system. They similarly suggest looking into the effects of climate mitigation, and a further study into the effects of soil nutrition with a similar range of plant densities under and outside of the tree canopy.

It would also be interesting, given the negative tree-crop competition effects in the mallee study by Sudmeyer et al. (2012), to look at the difference between agroforestry systems using different species. Mallee are Eucalypts, adapted to the minimally managed and fire prone landscapes of Western Australia, while holm oaks and cork oaks, which are also often used in dehesa woodland systems (Howlett et al., 2011; Joffre et al., 1999), are adapted to management by livestock and intercropped cereal or pasture cultivation (Joffre et al., 1999).

Synthesis & Critique

Both papers are comprehensively written, and fully describe the experiments discussed in them. The results presented by Moreno et al. (2007) are perhaps easier to absorb, due to the use of graphs, and clearer textual descriptions of findings. For example, figures 3 and 4 of *The impact of evergreen oaks on soil fertility and crop production in intercropped dehesas* paper (Moreno et al., 2007) clearly show the effects of increasing distance form the tree trunk on crop productivity. In contrast, Sudmeyer et al. (2012) use tables to present their findings regarding the extent of competition between mallees and crop plants as illustrated by crop productivity at various distances from the trees. While the data is there, it is not immediately clear what conclusions one should draw from it.

The language and structure used by Moreno et al. (2007) was also more accessible to a lay audience than the language and paper structure used by Sudmeyer et al. (2012). The differences in structure and language can not be attributed to a difference in intended audience, and the audience for the two papers appears to have been similar given their respective publishers (*Agriculture, Ecosystems and Environment* versus *Crop and Pasture Science* journals). However, in spite of differences in presentation and accessibility, the information in both papers would be of use to farmers and policy makers. The information presented would perhaps be most useful if read together, or if similar studies were carried out to consider both the economic and environmental impacts of intercropped agroforestry systems.

While the broad topic of the two papers is very similar, being an exploration of the effects on crop productivity in intercropped agroforestry systems, the objectives of the two are not aligned. Both papers aim to improve the state of current knowledge regarding intercropped agroforestry systems, but *The extent and cost of mallee-crop competition in unharvested carbon sequestration and harvested mallee biomass agroforestry systems* (Sudmeyer et al., 2012) is focused on potential economic benefits or impacts to farmers of intercropping with mallee, while *The impact of evergreen oaks on soil fertility and crop production in intercropped dehesas* paper (Moreno et al., 2007) is focused on the sustainability and environmental benefits of intercropped oak agroforestry. These are both areas of interest to farmers, investors, and policy makers.

Although useful, both papers are limited in the factors they consider. Further studies might consider:

- the effects of shade and tree-crop competition for light,
- specific competition for nutrients and the potential soil fertility improvements from trees, especially under conditions where no fertilizer or low levels of fertilizer were applied,
- tree-crop competition for water, and the effects of root pruning on this competitive impact as well as on the trees,
- the impact of tree-mediated climate mitigation on crop productivity as compared to the effect of tree-crop competition,
- the differences between tree species in similar agroforestry systems, indicating which tree species are best suited to intercropped systems and will have the least negative impact on crop productivity through competition.

RELEVANCE TO WESTERN AUSTRALIAN AGRICULTURE

It may not at first be obvious why a study into the dehesa woodlands of central-western Spain is relevant to Western Australia. The two locations are similar, both climatically and in terms of terrain, with the Iberian peninsula exhibiting the same poor soils, flat or gently hilly terrain, and arid-tending Mediterranean climate of Western Australia (Joffre et al., 1999), and in addition the predicted climate outlook for the two is also similar (IPCC Core Writing Team et al., 2007; Steffen and Hughes, 2013). As such, information derived from Spanish studies is extremely relevant to Western Australian farming.

The use of trees, either in productive agroforestry systems or as simple animals shelters and windbreaks, is recommended for most areas of Western Australia to mitigate potential salinity problems and restore cropland damaged by salinity (Taylor and Hoxley, 2003). Tree cover is also of use to mitigate soil erosion (Palma et al., 2007; Mollison, 1988) and to maintain the hydrological cycle, leading to an increase in rainfall as compared to recent trends (Mollison, 1988). As such, it is of great interest to the Western Australian farmer to know which tree species and which agroforestry systems will provide the most benefit and the least detriment to productivity.

Due to the maturation times for tree species as compared to pastures, cereals and grain legumes, there is a significant investment required to set up agroforestry systems (Abadi et al., 2006; Palma et al., 2007; Sudmeyer et al., 2012). Studies such as the two considered here are vital in order to provide information to farmers and investors before investing in agroforestry systems. For example, mallee agroforestry has been put forward as providing a potential income for famers through carbon sequestration and biomass for the production of biofuels (Abadi et al., 2006). Knowing that this potential is offset by the costs incurred in terms of crop productivity may deter farmers from investing in mallee agroforestry unless given assurances of governmental assistance and regulatory support.

Alternatively, given more information on the subject of intercropped agroforestry and the impacts of various tree species on crop productivity, farmers may move away from mallee and use an alternative tree species for carbon sequestration and biomass production. As a number of tree species exist which are able to provide fodder for livestock (Lefroy, 2002), or alternative crops such as olives and olive oil, sandalwood, or timber and timber products, this presents a useful pathway for further research into intercropped agroforestry systems for Western Australia. Studies such as the one presented by Moreno et al. (2007) could provide a not insignificant benefit to Western Australian farmers in selecting tree species and agroforestry management systems and layout, providing an alternative viewpoint and options rooted in the same environmental and climatic context.

Conclusion

There is a great deal of further research that could be carried out regarding agroforestry systems and their application in Western Australia. Cues for this research should be taken not only from existing knowledge and studies done in Western Australia, but also in similar areas around the world, and specifically the Iberian Peninsula. It is likely that Western Australian farmers could benefit from studies into the dehesa woodlands of Spain and Portugal, and the potential to create similarly stable, resilient, productive systems in Western Australia.

Tree-crop competition and its economic impact on agricultural productivity is a significant factor for farmers and policy makers. This aspect will have to be managed carefully, through agroforestry system design and potentially through governmental support. The environmental benefits of agroforestry systems are well documented, however, and this is likely to become a more significant factor as the effects of climate change are felt in Western Australia, and in similar climatic zones.

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