A cost-effectiveness analysis of temperate silvoarable systems: what contribution do ecosystem services make?

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Title: A COST-EFFECTIVENESS ANALYSIS OF TEMPERATE SILVOARABLE SYSTEMS: WHAT CONTRIBUTION DO ECOSYSTEM SERVICES MAKE?

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Theme: Biodiversity and added value

Extended Abstract:

Introduction

Silvoarable systems have the potential to be an effective and productive form of sustainable agriculture, in part due to the enhancement of biodiversity and associated ecosystem services. However, currently there is limited understanding of how higher biodiversity in silvoarable systems promotes ecosystem services, such as pest regulation, pollination and nutrient cycling (for example, see Peng *et al* 1993, Thevathasan and Gordon 2004, Varah *et al* 2013), versus ecosystem disservices, such as encouraging certain pests and weeds (Griffiths *et al* 1998, Burgess *et al* 2003), and, furthermore, how this cost-benefit ratio might change with how the system is designed, managed and matures over time (but see Burgess *et al* 2003, Stamps *et al* 2009).

This paper reports on preliminary results of a cost effectiveness analysis based on the Farm-SAFE model (Graves *et al* 2011, 2016), as part of a PhD investigating how management of silvoarable influences biodiversity-derived ecosystem services, and their economic implications. Our study is focussed on silvoarable systems in the UK that combine top-fruit production with arable alley-cropping, which are emerging as a promising design with limited shade effects (Smith *et al* 2016). We compare our findings to a monocropped arable system, with and without purported associated biodiversity benefits (Varah *et al* 2013, 2015).

Methods

The profitability and financial resilience of silvoarable systems, and the potential contribution of ecosystem services, will be evaluated by a cost effectiveness analysis conducted on the Farm-SAFE economic model. First, we are comparing the economics of a silvoarable versus a monocrop arable system, conducting a sensitivity analysis to establish the robustness of our findings in relation to price fluctuations, yield fluctuations, crop rotations, organic vs. conventional management, system design and other farm-specific factors. Our initial findings presented here are based on a conventional winter wheat / winter wheat / oilseed rape rotation, using 24 m wide crop alleys separated by 3 m wide apple tree rows. These figures will be used as the basis to establish the potential contribution of biodiversity derived ecosystem (dis)services based on forthcoming field surveys and assumptions around improved crop yield/quality and reduced input requirements. This analysis will ultimately serve as the basis for exploring the financial resilience of silvoarable to future economic risk scenarios, such as pesticide resistance, pesticide bans and honey bee declines.

Initial Results and Discussion

Silvoarable requires an initial investment in terms of tree establishment costs. Additionally, there is an annual loss of income associated with taking land out of arable production. However, fruit production can deliver higher profits in the long-term. The time taken for establishment costs to be recuperated and for profitability to exceed an equivalent arable system are therefore key factors in encouraging uptake of silvoarable. Based on typical yields and prices for a conventional wheat-based rotation, we predict that silvoarable profitability would exceed an equivalent monocrop arable at six years after establishment. However, this result is sensitive to variation in prices and yields due to site characteristics, weather and stochasticity.

Apple yields fluctuate due to weather conditions and therefore vary to a far greater extent than wheat yields. For example, over the period 1985 to 2016, wheat yield in the UK varied between 6.0 and 9.0 t/ha (+50%) compared to apple yields of 10.9 and 29.1 t/ha (+167%). This could add some element of risk to top-fruit silvoarable systems. Using historic trends to predict upper and lower apple yields based on 95% prediction intervals, the time taken for modelled silvoarable profitability to exceed arable is predicted to range between five and nine years depending on yield (Fig 1a). However, very low yields are historically compensated by higher prices (Fig 2), which could improve the financial resilience of silvoarable to low apple yields.

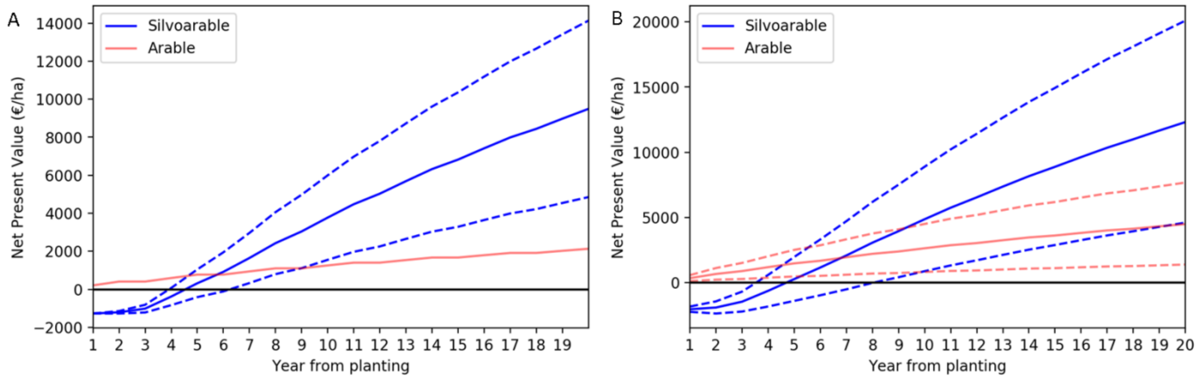

Figure 1. Influence of apple yield variation on silvoarable profitability, based on (a) historic national yield variations, where solid line represents the predicted 2015 yield using a linear model derived from historic yields, and dotted lines represent yields based on the 95% prediction intervals, and (b) high and low productivity farms (dashed lines) versus an ‘average’ level of production (solid lines), using yield values in the John Nix pocketbook (Redman 2017).

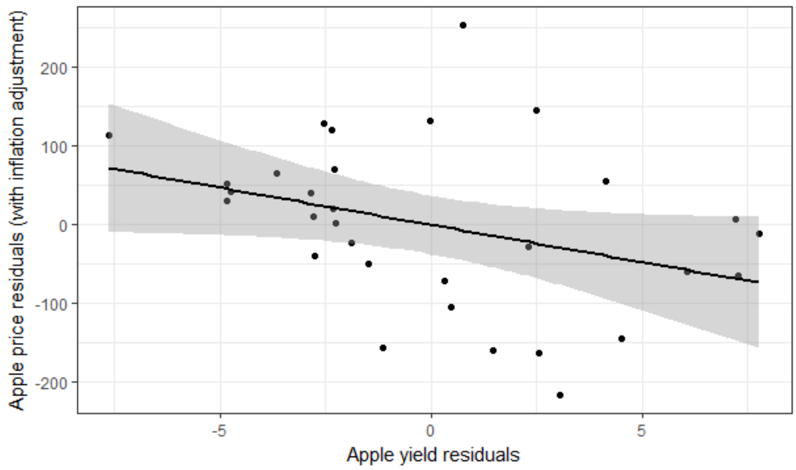

Figure 2. Relationship between apple yield and price residuals, based on linear models of their respective historic UK trends with time using FAOSTAT data.

Farm characteristics such as soil productivity and location can also strongly influence yields of both the arable and top-fruit components. A simulation using low, average and high yields for both apple and arable components as specified in the John Nix Pocketbook (Redman 2017), which reflect variation in productivity due to farm-specific factors, shows that the profitability of silvoarable relative to an equivalent monocropped arable is strongly influenced by the achievable yield (Fig 1b). For farms with high production levels, silvoarable profitability is predicted to exceed arable at six years, but this increases to 10 years for low productivity situations. Enhanced ecosystem services in silvoarable could help to increase production levels and profitability, for example by reducing pollination deficits.

Ecosystem services derived from biodiversity could also contribute to silvoarable profitability and financial resilience by reducing pesticide input requirements. Although empirical data is lacking as to whether enhanced conservation biological control (CBC) could allow inputs to be reduced in temperate silvoarable systems without incurring a net cost, enhanced CBC arising from hedgerow restoration in California was predicted to reduce insecticide input requirements by 75% (Morandin *et al* 2016). If pesticide costs were reduced by 75% in silvoarable, the time taken for profitability to exceed arable is reduced by one year, and net present value at 20 years increases by 22% compared to typical pesticide use (Fig 3). More empirical data is required to inform our understanding as to the contribution of ecosystem services to silvoarable profitability and resilience.

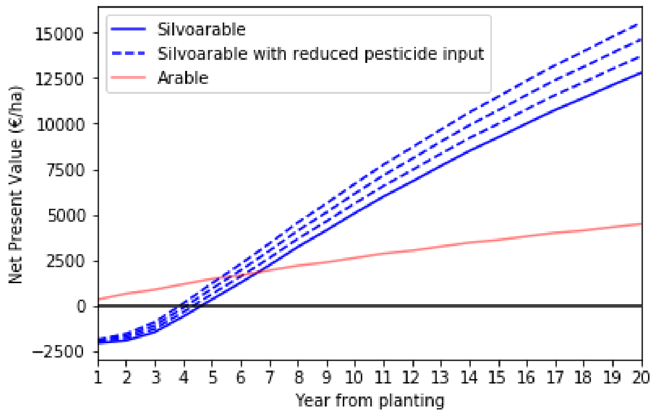

Figure 3. Effect of reducing pesticide costs by 25%, 50% and 75% in silvoarable.

Conclusions and Future Research

Silvoarable systems based on top-fruit production have potential to provide a relatively rapid return on investment, albeit this is strongly influenced by variables such as apple yield and farm productivity. Ecosystem services derived from biodiversity could improve profitability, for example conservation biological control could reduce input requirements in conventional systems and improve yields in organic systems, whilst pollination services could enhance apple yield and quality. Financial resilience against future risks such as pesticide regulations, resistance and pollinator declines could also be enhanced. However, the quantification of any such benefits is constrained by a paucity of empirical data.

Therefore, the next steps of the project are to carry out biodiversity field surveys at three silvoarable sites in the UK over a three-year period from 2018, to establish the link between biodiversity and ecosystem services and how these are influenced by system design and management. Specifically, we will investigate the associations between natural enemies and pests, and pollinators and pollination, in relation to tree alley width and tree row understorey management, from naturally colonised vegetation to the active maintenance of bare ground, seeding of wildflower mixes and horticultural production.

We plan to incorporate the empirical data collected over the course of the project to inform the economic modelling, with the objective of predicting the economic value of ecosystem services derived from biodiversity in silvoarable systems, and the influence of management options. This will help to inform policy makers and farmers as to the most effective system designs and the potential financial risks and rewards of silvoarable systems as an alternative to monocropped arable.

References

Burgess PJ, Incoll LD, Hart BJ, Beaton A, Piper RW, Seymour I, Reynolds FH, Wright C, Pilbeam DJ, Graves AR (2003) The impact of silvoarable agroforestry with poplar on farm profitability and biological diversity. Final Report to Defra.

Graves AR, Burgess PJ, Liagre F, Terreaux J-P, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: the process of developing a plot- and farm-scale model of arable, forestry and silvoarable economics. Agroforestry Systems 81: 93-108

Graves A, Palma J, de Jalon SG, Crous-Duran J, Liagre F, Burgess P (2016) Farm-SAFE: financial and resource-use model for simulating agroforestry in Europe. AGFORWARD, https://www.agforward.eu

Griffiths J, Phillips DS, Compton SG, Wright C, Incoll LD (1998) Responses of slug numbers and slug damage to crops in a silvoarable agroforestry landscape. Journal of Applied Ecology 35: 252-260

Morandin LA, Long RF, Kremen C (2016) Pest control and pollination cost-benefit analysis of hedgerow restoration in a simplified agricultural landscape. Journal of Economic Entomology 109(3): 1020-1027

Peng RK, Incoll LD, Sutton SL, Wright C, Chadwick A (1993) Diversity of airborne arthropods in a silvoarable agroforestry system. Journal of Applied Ecology 30(3): 551-62

Redman G (2017) John Nix Pocketbook for Farm Management. 48th edition. Agro Business Consultants Ltd.

Smith J, Wolfe M, Crossland M (2016) Silvoarable agroforestry: an alternative approach to apple production? 12th European International Farming Systems Association Symposium.

Stamps WT, McGraw RL, Godsey L, Woods TL (2009) The ecology and economics of insect pest management in nut tree alley cropping systems in the Midwestern United States. Agriculture, Ecosystems and Environment 131: 4-8

Thevathasan NV, Gordon AM (2004) Ecology of tree intercropping systems in the north temperate region: experiences from Southern Ontario, Canada. Agroforestry Systems 61: 257-68

Varah A, Jones H, Smith J, Potts SG (2013) Enhanced biodiversity and pollination in UK agroforestry systems. Journal of the Science of Food and Agriculture 93(9): 2073-75

Varah A (2015) Can agroforestry reconcile conflicting demands for productivity, biodiversity conservation and delivery of ecosystem services? PhD thesis, University of Reading