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Greening and producing: An economic assessment framework for integrating trees in cropping systems

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ABSTRACT

Environmental measures in an agricultural context often lead to extra constraints in current farming. This suggests trade-offs between the environmental objectives and profitability. Whether trade-offs exist, or may be turned into win-win, depends on creative farm options to comply new constraints. This paper concentrates on Ecological Focus Areas as a new EU Common Agricultural Policy greening requirement, and investigates profitability changes of two greening options with permanent woody elements, hedgerows and alley cropping. We predicted discounted gross margins for a hedgerow and alley cropping greening option and four market scenarios on a representative arable farm in Flanders (Belgium). Starting from the tree row, over a distance of 1.64 times the tree height, relative crop yield is 70% as compared to a treeless situation. Between 1.64 and 9.52 times the tree height, relative yield is 107%. Beyond that point, the effect is considered negligible. Discounted gross margins are calculated to account for the time horizon. Relative discounted gross margins at farm level, compared to the business as usual option, vary between 91% and 108%, depending on market conditions and policy support. The calculations show that fulfilment of the 5% ecological focus area greening requirement on arable farms with hedgerows and alley cropping only becomes economically competitive to the traditional cropping systems with extra financial stimuli (e.g. greening payments). We also show and discuss how the calculations can be fine-tuned and used in policy making, e.g. by i) getting better insights in the tree-crop interactions, ii) including the effect of e.g. crop type, tree species, tree line space and tree line orientation in the meta-information, iii) evaluating this conditional competitiveness and suggesting a better linking between subsidy level and ecological value and ecosystem services and iv) exploring novel valorization channels for wood products.

1. Introduction

A major part of the European countryside is shaped by agricultural land use. Farming creates habitats for wildlife and enjoyable landscapes and contributes to indirect benefits such as resilience to flooding. However, intensification of agriculture also has a negative impact on soil, water and air quality, as well as on biodiversity. Various measures to mitigate the negative impact of agriculture on the environment and to restore positive links between the environment and production are undertaken, including the recent greening measures in the Common Agricultural Policy (CAP). Since the 2013 reform, CAP direct payments consist of, among others, basic payments and greening payments. Thirty percent of the direct payments to farmers is linked to greening requirements: the implementation of Ecological Focus Areas (EFA) on 5% of the arable land, crop diversification and the maintenance of permanent pasture at farm level (Matthews, 2013). Within the constraints of a member state's specific list of options, farmers are free to choose how they fill in the EFAs, e.g. with hedgerows, buffer strips, alley cropping agroforestry, fallow

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land, nitrogen fixing crops, catch and cover crops. According to the ecological value of the chosen option, a conversion and weighting factor is used to convert the lengths/areas of the elements into equivalent focus areas: elements with a lower ecological value, will have a lower weighting factor (EU Commission, 2013) compared to elements with a higher ecological value (e.g. hedgerows have a weighting factor of two). In 2015, 85% of the Flemish EFA was composed of cover crops (data retrieved from the Flemish Department of Agriculture and Fisheries). However, it is known that this land use type contributes little to biodiversity (Pe'er et al., 2014). This suggests that the current EFA requirements and the weighting factors are not effective in reaching their primary target of biodiversity conservation. On the other hand, EFAs with permanent elements such as hedgerows and alley cropping, may have a positive impact on biodiversity (Westhoek et al., 2012).

Greening requirements will have an impact on farm economics: average decrease in overall farm income per worker is estimated between 1.4% and 3.2% (Matthews, 2013). Farmers that do not comply with the greening requirements may lose up to 125% of the greening payment (European Commission Memo, 2013). Farmers' decisions are mainly based on economic considerations but these are hard to predict, in particular in the hedgerow and alley cropping case. Despite the crop yield loss due to cropland reduction and potential crop-tree competition for light, water and/or nutrients, alley cropping has the potential to deliver economic advantages such as wood production and diversification of farm income. However, profitability depends on many factors. A higher yield does not always result in more income (Dupraz and Liagre, 2008) and both are influenced by tree and crop type, tree density, orientation of the trees, interactions between crop and trees, and costs and prices of crops and wood. Moreover, as alley cropping is a multiannual system, we face uncertainty in the changes in crop yields, costs and crop and wood prices. Besides data uncertainty, there is a considerable time lag between expected revenues and the decision to start-up alley cropping. Profit assessment then needs discounting the revenues and costs into a net present value.

In this paper, we design an assessment framework to combine crop yield information on tree-crop interactions with farm data in order to assess farm economic outcomes of greening measures. To this end, we i) quantify the effect of trees on crop yield in temperate regions and ii) assess the economic consequences of two farm level EFA choice options, a hedgerow and an alley cropping option, through comparison of discounted gross margins with the business-as-usual (BAU) option. A hedgerow can take many forms and dimensions; in this paper a hedgerow is defined as linear structure of unpruned trees and shrubs on the field boundary (Kuemmel, 2003). This option is seen as intermediate towards alley cropping because it is less far-reaching in terms of crop-tree mixing (Borremans et al., 2015, Vandermeulen et al., 2012). In a tree row in the alley cropping system, we assume the trees to be pruned and the wood to be harvested.

2. Materials and methods

2.1. Effect of trees on crop yield

To investigate the effect of hedgerows and trees on crop yield, a double research question was defined: i) what is the spatial extent of the influence of the trees on crop yield and ii) what is the impact of tree-crop interaction on crop yield? Potentially relevant papers were searched on the ISI Web of Knowledge and Sciencedirect. Search terms were: trees, tree row, agroforestry, hedgerow, alley cropping, intercropping, woody edge, woody field margin, crop yield and productivity. Several combinations of these terms were searched. First, candidate papers were selected on title and abstract, meeting following conditions: i) data from areas with temperate climate, ii) actual field data are used (modelling studies are excluded), iii) true controls are present allowing yield comparison with and without tree-influence, iv) yield data are linked to the distance from the trees and v) interaction with arable crops, not with pasture. We focused on arable crops because we expect the effect of trees to be better measurable in crops compared to pasture. When necessary, the authors were contacted and asked to provide more information on the experimental setup or data statistics. The reference lists of the retained papers were used to search for additional papers. Twelve articles (Appendix I) were retained. Own measurements from 2014 and 2015 on the effect of hedgerows and alley cropping on crops were added to this dataset. The experimental setup is described in Appendix VI.

Considering measurements conducted in different years or on different locations as individual (but not independent) experiments, a set of 80 different experiments was used in the analysis.

Relative yields (R) are used to express the effect of trees on crop yield and are calculated as the ratio of yield in the experiment group (plot with tree-influence) to the yield in the control group (plot without tree-influence). When $R < 1$, yield is negatively influenced by the trees and when $R > 1$, more is produced in the experimental plots than in control plots. R is related to the distance from the tree row. To allow comparison between different experiments, distance is related to height of the tree row. We therefore use H, which is the ratio of the distance from the tree row to the height of this tree row. This means that for a tree height of 20 m and experimental plots on a distance of 10 m from these trees, $H = 0.5$. The natural logarithm of R, ln(R), linearizes the response ratios and thus ln(R) will be affected equally by changing the numerator or denominator. Furthermore, ln(R) is more likely to be normally distributed, especially in small samples (Hedges et al., 1999).

A traditional meta-regression was performed with the metaphor-package (Viechtbauer, 2010), using the rma.mv-function. This was done in R, version 3.1.2 (R Development Core Team 2014). Each ln(R) was weighted by the inverse of the corresponding standard deviation, giving a greater weight to studies with a lower standard deviation. However, standard deviations were only reported in 37 experiments. Only this subset was used in the meta-regression. A mixed-effects meta-regression model was applied, with H being the fixed effect. Due to the multi-level structure in the data, 'study' was included as a random variable, to account for non-independence between data from the same study. To include all experiments, a non-linear mixed model was applied on the dataset. Similarly, 'study' was included as a random variable. In the non-linear mixed model, data are not weighted and this could have a negative impact on the preciseness of the result (Koricheva and Gurevitch, 2014). Therefore, results of both models are compared in Appendix II.

2.2. Economic consequences of greening

The economic consequences of three choice options in the greening context are investigated. The first option is business-as-usual (BAU) without EFAs. The farmer does not benefit from greening payments and loses a part of the basic payments. This option is selected because it entails no additional costs or arable land loss. The second option is the hedgerow option: the EFA is entirely implemented with trees and shrubs on field boundaries. To meet the EFA requirements, the minimal hedgerow surface is 0.1 ha and maximum width is 10 m. In the EFA requirements, hedgerows are given a weighting factor of two. Therefore, only 2.5% of the arable surface (instead of 5%) should be filled in with hedgerows, because the hedgerow surface is doubled in the EFA calculations. The third option is the alley cropping option where trees are planted in lines on the field. The weighting factor of alley cropping is one. To meet the EFA requirements, the alley cropping parcel(s) should have an area of 5% of the arable farm land.