TEMPERATE AGROFORESTRY: YIELD OF FIVE KEY ARABLE CROPS NEAR TREE ROWS OF *POPULUS x CANADENSIS*

Pardon P[1, 2, 3]*, Reubens B[3], Mertens J[1, 4], Verheyen K[1], De Frenne P[1, 2], Van Waes C[3], Reheul D[2]

(1) Department of Environment, Ghent University, Geraardsbergsesteenweg 267, 9090 Gontrode, Belgium (2) Department of Plants and Crops, Ghent University, Coupure Links 653, 9000 Ghent, Belgium (3) Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Burgemeester Van Gansberghelaan 109, 9820 Merelbeke, Belgium (4) Department of Applied Biosciences, Ghent University, Valentin Vaerwyckweg 1, 9000 Ghent, Belgium

*Corresponding author: paul.pardon@ugent.be

Abstract

Agroforestry systems (AFS) are considered to be a sustainable agricultural practice. However, at present, yield and quality data on arable crops in temperate AFS are scarce. Here we assessed the influence of tree rows of contrasting age on the yield and quality of key western European arable crops. Both tree age and crop type were key determinants of yield and quality of the arable crops. Substantial yield reductions were observed near mature trees, in particular for maize and potato. Effects on crop quality were limited, with substantial effects only arising near the oldest tree rows. To optimize the provisioning service of AFS, the cultivation of winter cereals may be advisable over maize and potato towards the end of the rotation of an AFS.

Keywords: alley cropping; maize; potato; winter cereals; poplar; mixed farming

Introduction

In temperate regions, interest in agroforestry has recently been growing (Borremans et al. 2016; Gillespie et al. 2000; Jose et al. 2004; Nair 2007) because it is considered as a sustainable agricultural practice that combines primary production with other ecosystem services (ES) (Torralba et al. 2016). However, in large parts of temperate Europe, implementation of agroforestry remains rather limited (Reisner et al. 2007; Rigueiro-Rodríguez et al. 2009). Besides uncertainties on the legislative and economic level (Borremans et al. 2016), this might result from a lack of actual quantification of the impact of the tree component on the yield and quality of the intercrop. The goal of the present research is to quantify these impacts for the agricultural crops most commonly cultivated in Western Europe, while focusing on arable alley cropping systems with poplar (*Populus x canadensis)* of different age classes.

Materials and methods

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ences in crop performance for varying stages of tree maturity (Figure 1, Table 1). This set comprised six young alley cropping fields (age 2-7 yrs). Since older arable alley cropping systems in Flanders are scarce, a set of 11 common arable fields that are bordered by a tree row was selected as a proxy (age 48 yrs). The latter type of fields are further referred to as "boundary planted fields". Following criteria were used for selection of these fields:

- Orientation of the tree row: (approximately) North-South
- Tree species: *Populus x canadensis*
- Tree rows are of homogenous age at field level but with varying age among the different fields

- Absence of headland next to the tree row
- Part of the field is not bordered by the tree row
- Soil type: loam or sandy loam

The differences in tree-size among the fields allowed to study the effect on crop yield for different stages in the rotation of an agroforestry system. The treeless parts of these fields hereby acts as a reference situation. On each field transects were laid out perpendicularly to both the tree row and the treeless border (# three and two transects respectively). In each transect, five measuring points were marked, located at distances 2 (“A”), 5 (“B”), 10 (“C”), 20 (“D”) and 30 (“E”) m away from the field edge. This allowed to study possible gradients as a function of distance to the tree row. On the alley cropping fields, three transects were laid out between and perpendicular to both selected tree rows (Figure 1). In each transect, six sampling plots were marked, the centre of which was located at distances 2 (“F”), 5 (“G”) and 12 (“H”) m from the closest tree row. In each plot, yield and quality measurements were conducted during three consecutive years (2015-2017). Sampled crops include winter wheat (*Triticum aestivum* L.), winter barley (*Hordeum vulgare* L.), forage maize (*Zea mays* L.), grain maize and potato (*Solanum tuberosum* L.). Linear mixed effects models were used to investigate differences in crop yield and quality.

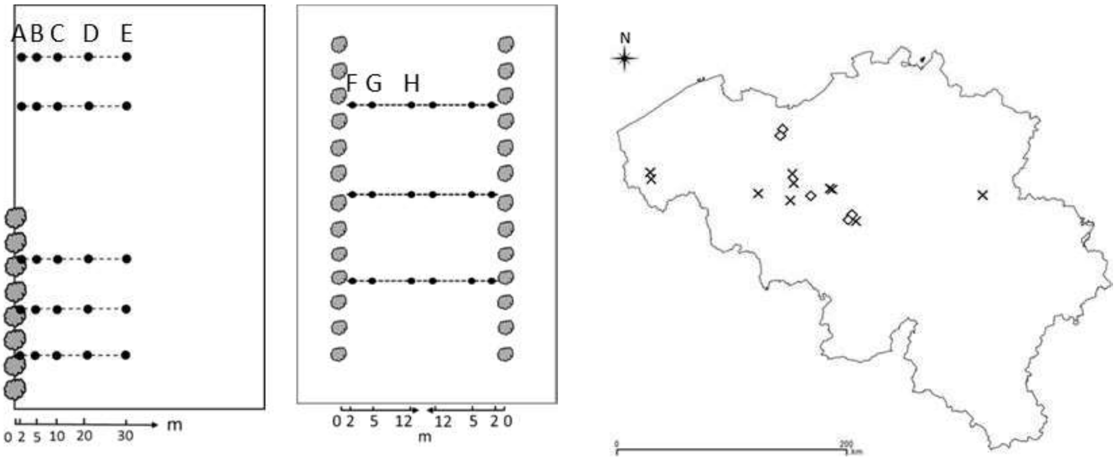

Figure 1: Experimental design. Left: boundary planted fields, middle: alley cropping fields, dots represent measuring locations. Right: Location of experimental fields in Belgium (x boundary planting, ◊ alley cropping).

Table 1: Characteristics of experimental fields. Year of plantation was estimated based on pers. comm. with farmer and/or tree coring. “Orientation”: orientation of tree alleys (EW: East-West, NS: North-South). “Exposition”: location of sampling field with regard to tree row. “NA”: no samples collected in this field.

ALLEY CROPPING					
Location	Year of plantation	Orientation	Crop 2015	Crop 2016	Crop 2017
Lochristi 1	2011	EW	Forage maize	Winter wheat	Forage maize
Lochristi 2	2011	EW	Forage maize	Forage maize	Potato
Lochristi 3	2012	EW	Winter wheat	Forage maize	Maize
Vollezele	2010	NS	Winter barley	Potato	Winter wheat
Haut-Ittre 1	2011	NS	Winter wheat	Winter wheat	Potato
Haut-Ittre 2	2011	NS	Grain maize	Winter wheat	Winter wheat
BOUNDARY PLANTING					
Location	Estimated year of plantation	Exposition	Crop 2015	Crop 2016	Crop 2017
St P. Leeuw 1	2001	West	Maize	NA	NA
St P. Leeuw 2	2001	West	Winter wheat	Forage maize	Winter wheat
Haut-Ittre 1	2000	East	Winter wheat	Cichory	Winter wheat
Haut-Ittre 2	2000	East	NA	Cichory	NA
Maarkedal	1998	West	Maize	Maize	Potato
Tongeren	1998	East	Winter wheat	Forage maize	Winter wheat
Ieper 1	1985	West	Maize	Maize	Pea
Geraardsbergen	1988	West	Winter barley	NA	NA
Herzele	1977	East	Forage maize	Winter wheat	Forage maize
Steenhuize	1985	East	Forage maize	Winter wheat	Forage maize
Ieper 2	1969	East	Winter barley	Maize	Potato

Results

Clear effects of tree row presence on yield of intercrops were observed as function of distance to the tree rows. The magnitude of these effects was however strongly dependent on both the size of the trees and the specific intercrop (Figure 2). The effects appeared to be most pronounced if (forage) maize was grown, in particular on fields with mature tree rows, whereas only limited effects were observed in case of winter barley. On the old boundary planted fields, the impact on crop yield appears to extent to ca. 30m into the field where yield-levels equal values observed in the control part of the fields.

Discussion

The substantial differences in crop response are assumed to be primarily related to the differences in growing season between the different types of crops and the consecutive differences in overlap with the growing season of the trees (Artru et al. 2017). Our results demonstrate that tree-impact on yield of winter cereals, maize and potato remains limited during the first six to seven years after tree establishment. However, if possible, a modified crop rotation may be recommended as trees mature to limit yield losses due to tree-crop competition. In practice, this implies a shift to a rotation dominated by winter cereals.

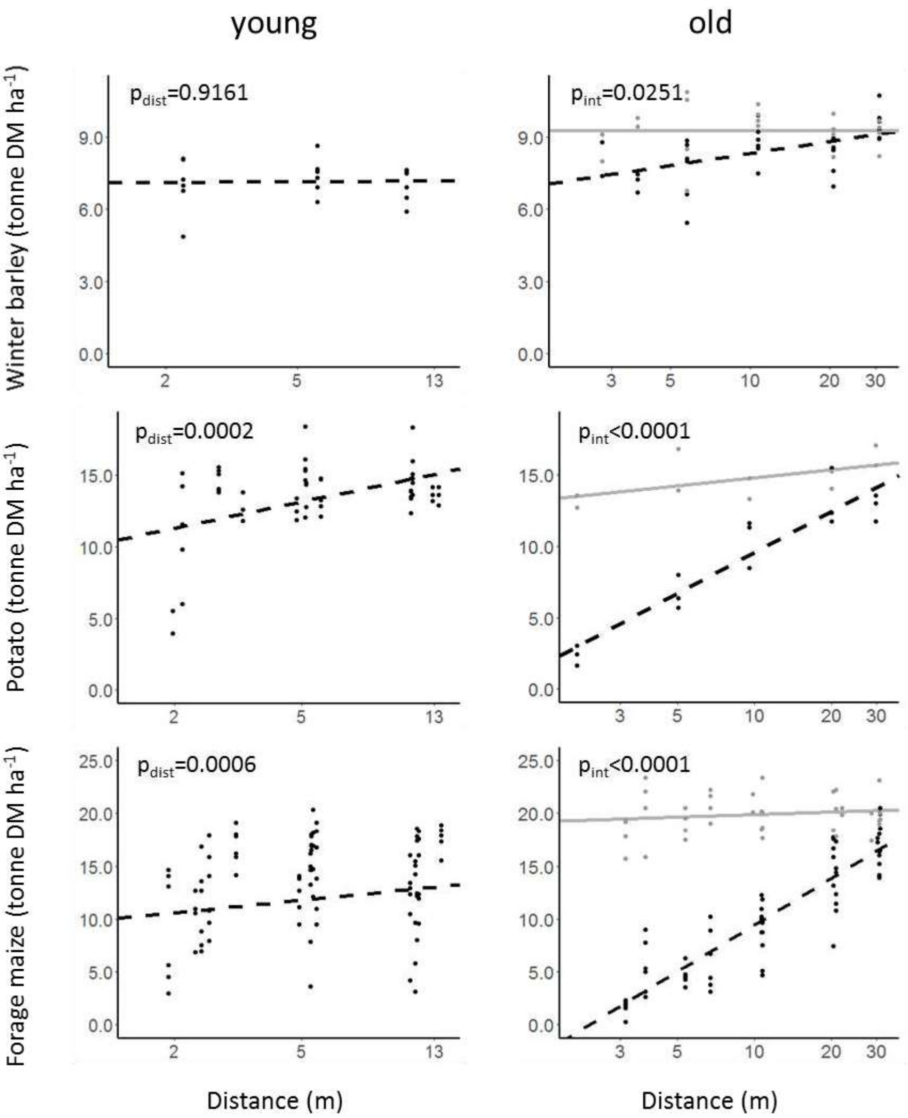

Figure 2: Effect of crop type and tree age on intercrop (tonne DM ha^{-1}) yield of winter barley, potato and forage maize. "$p_{dist.}$" indicates significance of distance to the tree row on young alley cropping fields (2-7 yrs). "$p_{int.}$" indicates significance of interaction between distance to the tree row and tree row presence on old boundary planted fields (27-48 yrs). Black (dashed): tree row, grey: treeless field edge.

Outlook

Future analysis will focus on further elaboration of crop yield results and associated quality parameters.

Acknowledgments

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