Lessons learnt: Maize in silvoarable systems in Galicia, Spain

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Authors	María Rosa Mosquera Losada, Nuria Ferreiro Domínguez, Juan Luis Fernández Lorenzo, Pilar González Hernández, Antonio Rigueiro Rodríguez
Contact	mrosa.mosquera.losada@usc.es
Approved	Michael Kanzler and Paul Burgess (18 January 2018)

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1 Context

The AGFORWARD research project (January 2014 - December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at field-, farm- and landscape scales, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the second objective in that it contains results of the studied innovations from one of the systems being studied within work-package 4 which focuses on agroforestry for arable systems. Together with other reports, this document will contribute to Deliverable 4.11 on lessons learnt from agroforestry for arable farmers. Similar reports exist for agroforestry of high nature and cultural value, agroforestry with high value trees, and agroforestry for livestock systems.

2 Silvoarable systems in Galicia, NW Spain

An initial stakeholder meeting, with 14 participants, was held in 2014 (Mosquera-Losada et al. 2014). In this meeting, the stakeholders identified as the most positive aspects of the silvoarable systems the business opportunities, the originality and interest, the feasibility of the project, the diversity of products, and the general environmental benefits. The negative aspects included the complexity of work, labour and management costs and losses due to wildlife. Integrating trees and crops production such as maize was identified as possible areas for research. For this reason, a research protocol developed by the stakeholder group focused on cultivation of maize between *Prunus avium* L. in Galicia was produced in 2015 (Mosquera-Losada et al. 2015). This research protocol was updated in 2016 (Mosquera-Losada et al. 2016a). In 2017, this report provides guidelines for farmers on how to combine the production of maize with the growth of *Prunus avium* L.

In Europe, silvoarable practices only occupy 360000 hectares representing less than 1% of the European land occupied by agroforestry practices (Mosquera-Losada et al. 2016b). This type of agroforestry practice is also rare in Galicia (NW Spain) and should be promoted due its economic, environmental and social advantages compared with conventional agricultural and forest systems (Rigueiro-Rodríguez et al. 2009). Moreover, in Galicia (NW Spain) the establishment of silvoarable systems could be a solution to the low availability of agricultural area which has decreased in the last years due to the increase of the forest land (IV IFN 2011).

On the other hand, Galicia is a region with high economic dependence on dairy cattle where livestock feeding is mainly based on the production of forage maize. However, Galicia imports maize from Brazil (56 million € per year) which creates a potential opportunity to use maize as a silvoarable crop. Using maize for feeding dairy cows is less costly than grass silage but it does create less flexibility (maize lands cannot be used for grazing in low productive springs) (Ali et al. 2012). Maize could be intercropped with high value trees such as *Prunus avium* L. because this tree species is characterised by a low radiation interception for the understory and a fast growth rate with better financial returns (3000 € m^{-3}) compared with more extended used tree species in the Galicia region (Horgan et al. 2003; Chifflot et al. 2006).

3 Objectives

Two experiments were established to increase our understanding regarding the combined production of maize and high value trees such as *Prunus avium* L. The experimental work included the objectives:

- Experiment 1: to evaluate the production of maize and the tree growth in a silvoarable system under *Prunus avium* L. established at three densities (333, 666 and 1333 trees ha^{-1}) in Galicia (NW Spain) compared with exclusively agronomic and forest systems, respectively.
- Experiment 2: to evaluate the production of maize at different distances to the trees (1.5, 3 and 6 m) in a silvoarable system established with *Prunus avium* L. in Galicia (NW Spain) compared with an exclusively agronomic system.

4 Methodology

The experiments were established in Boimorto (A Coruña, Galicia, NW Spain) on a plot managed by the Bosques Naturales company. The experiments were overseen by the University of Santiago de Compostela. Bosques Naturales is a forestry company focused on the management, maintenance, monitoring and research of high-value hardwood species plantations, mainly walnut and cherry.

4.1 Experiment 1

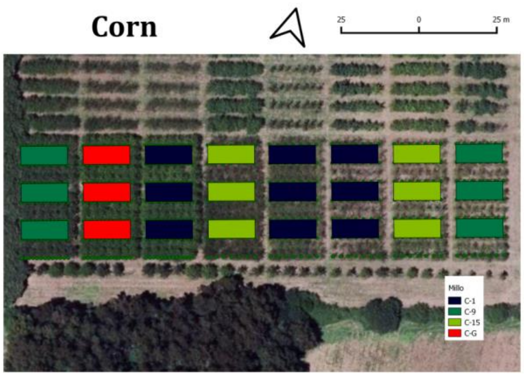
The planting of *Prunus avium* L. was carried out in 2008. Initially, the plantation was a mixed stand which was managed to establish plots of *Prunus avium* L. at the final densities of 6 m x 1.25 m, 6 m x 2.5 m and 6 m x 5 m, equivalent to 333 (LD), 666 (MD) and 1333 (HD) trees ha^{-1}, respectively. Therefore, the treatments consisted of three tree densities. No differences on tree growth between tree densities have been observed before 2015.

In May 2015, after soil preparation, forage maize was sown with conventional farm machinery following a randomized block design with three replicates. The maize variety used was DKC 4608 Ponho. Maize was sown in 3 m alleys, leaving 1.5 m of distance between the alley at the base of the trees (1.5 m both sides of the tree row). The distance between plants rows was 0.75 m and the distance between plants within a row was 0.15 m. Each experimental plot had an area of 36 x 15 m^2 (7 trees separated by 6 m (6 m x 6 m) x 13, 7 or 4 rows of trees (12 m x 1.25 m, 6 m x 2.5 m or 3 m x 5 m)). Sowing was carried out in one of the alleys, whilst the other alley remained uncropped to allow access for machinery for annual pruning and phytosanitary application to the trees. Two control treatments were also established: maize grown in tree-less areas (NT) and trees grown without maize at the three plantation densities.

4.2 Experiment 2

In May 2015, after the soil preparation, the forage maize was sown with conventional farm machinery in an alley between two tree rows of *Prunus avium* L. The trees were planted in 2000 with a distance between tree rows 12 m and the distance between trees within a row 5 m. The maize was sown in a 10.5 m alley, leaving 0.75 m of distance between the alley at the base of the trees (0.75 m both sides of the tree row). The distance between maize plants rows was 0.75 m and the distance between maize plants within a row was 0.15 m. A specific description of the silvoarable system established with maize is provided in Table 1.

Table 1. Description of the silvoarable system established with maize

Specific description of site	
Area	Total area 0.668 ha
Co-ordinates	42°58'30"N, 8°11'24"W
Site contact	University of Santiago de Compostela: María Rosa Mosquera Losada
Site contact email	mrosa.mosquera.losada@usc.es
Example photograph	
Map of system	 Blue, dark green, light green, and red represent the C-1, C-9, C-15 and C-G wild cherry clones, respectively. The control treatment is a conventional agricultural field adjacent to the tree experiment (out of the range of this photo)
Climate characteristics	
Mean monthly temperature	12.6 °C
Mean annual precipitation	1898 mm
Details of weather station (and data)	"Boimorto" weather station (http://www2.meteogalicia.es/galego/observacion/estacions/estacionsHistorico.asp?Nest=19062&prov=A%20Coru%F1a&tiporede=automaticas&red=102&idprov=0#)
Soil type	
Soil type	Humic cambisol
Soil depth	Over 1 m
Soil texture	Loam (42% silt, 31% sand, 27% clay)
Additional soil characteristics	Water soil pH: 5.25
Aspect	East-West in the plots without trees and North-South in the plots with trees

Tree characteristics	
Species and variety	Wild cherry (*Prunus avium* L.)
Date of planting	Experiment 1: 2008 Experiment 2: 2000
Intra-row spacing	Experiment 1: Low density: 5 m; Medium density: 2.50 m; High density: 1.25 m Experiment 2: 5 m
Inter-row spacing	Experiment 1: 6 m Experiment 2: 12 m
Tree protection	None
Typical increase in tree biomass	20 m^3 ha^{-1} $year^{-1}$
Crop/understorey characteristics	
Species	Maize (*Zea mays* L.)
Management	Conventional maize management with the usual ploughing
Typical crop yields	According to Moreno-González (1982) and Lloveras (1990) the production of maize in Galicia was approximately 13.4 t ha^{-1} and 14.07 t ha^{-1}, respectively.
Fertiliser, pesticide, machinery and labour management	
Fertiliser	None
Pesticides	Tree–understory competition was reduced with annual application of herbicides following tree rows
Machinery	Machinery for soil preparation, pruning and herbicides application
Manure handling	None
Labour	Four people to establish the experiments, two people to visit the experimental sites all weeks and two people to harvest and process the samples
Fencing	Not required

In Experiment 1 ten plants of maize were collected in each plot and weighed while fresh to determine the production of forage maize (October 2015). In Experiment 2 the production of maize was estimated at three distances of the trees (1.5 m, 3 m and 6 m). In each distance and in three different points, ten plants of maize were collected and weighed (October 2015). In both experiments the production of maize was also estimated in a tree-less area and the maize final density in the rows was taken into account. Moreover, in Experiment 1 the tree height and the tree diameter at breast height were measured with a vertex and calliper, respectively (June 2015).

In the laboratory, the plants were fractionated into the following components: aborted cobs, cobs without grains, stems, leaves and grains. These components were dried and weighed to estimate the dry matter production (60°C x 48 hours). In both agroforestry experiments, the maize production per hectare was calculated subtracting the area occupied by the trees and assuming that the maize was sown in all alleys of the plot. Total maize production was calculated by summing the production of the different components.

Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

5 Results

5.1 Production of maize in Experiment 1

Figure 1 shows that the maize production obtained in the plots without trees (NT) was similar to the production found in different areas of Galicia from 1999 to 2014 (22.9 t ha^{-1}) for the same variety (CMR, 2015). Moreover, the total maize production and its components (aborted cobs, cobs without grain, stems, grains and leaves) were higher in the plots without trees (NT) than in those treatments on which maize was combined with trees established at different densities (LD, MD and HD) ($p<0.001$). This result could be explained by the lower available area of maize in the plots with trees (tree land was discounted) compared with the plots without trees, but also by the shade generated by the trees. This is exacerbated as the maize is a shade intolerant C4 species. If the area occupied by the trees had not been discounted, the maize production obtained in the agroforestry plots would also be lower than in the plots without trees (LD: 14.05 t DM ha^{-1}, MD: 9.35 t DM ha^{-1} and HD: 4.41 t DM ha^{-1}). Similar results were previously observed by Reynolds et al. (2007) and Ding and Su (2010) in poplar-maize systems. Moreover, tree thinning, removing alternate trees in rows, or even removing alternate tree rows, would probably help to reduce the tree shade effect on the crops and the possible competitive effects for soil nutrients and water. However, if timber production is the main objective of the farmer, some shade maize adapted varieties should be developed or another types of agroforestry practices implemented, like, for example, silvopasture (Pardini et al. 2010, Ferreiro-Domínguez et al. 2016a).

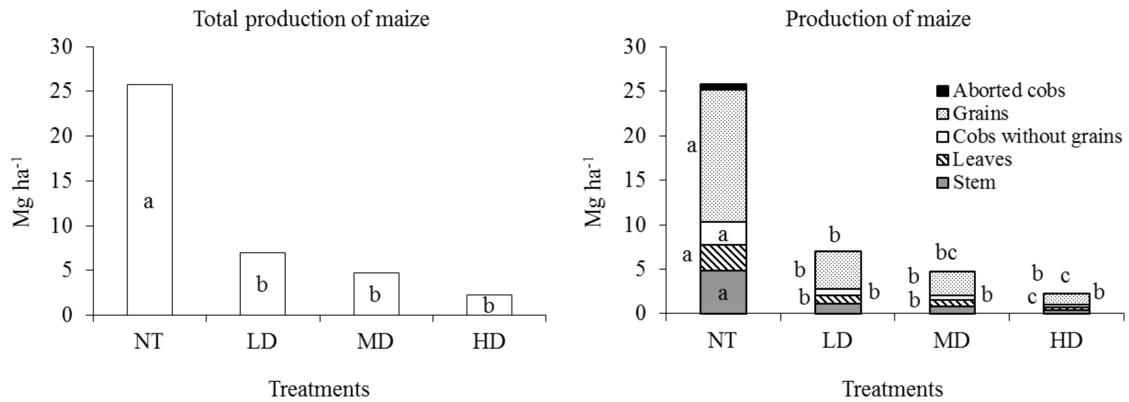


Figure 1. Total production of maize (Mg DM ha^{-1}) and production of the different components of maize (aborted cobs, cobs without grain, stems, grains and leaves) (Mg DM ha^{-1}) under the different treatments in 2015. NT: 0 trees ha^{-1}, LD: 333 trees ha^{-1}, MD: 666 trees ha^{-1} and HD: 1333 trees ha^{-1}. Different letters indicate significant differences between treatments. In the agroforestry plots, the maize production was calculated subtracting the area occupied by the trees.

The results are described in more detail in: Ferreiro-Domíngez N, Rigueiro-Rodríguez A, Mosquera-Losada MR (2016b). Productivity of silvoarable systems established with *Prunus avium* L. in Galicia (NW Spain). 3rd European Agroforestry Conference, Montpellier, France.

5.2 Production of maize in Experiment 2

Figure 2 shows that the total maize production increased with the distance to the trees ($p < 0.001$). As it was previously indicated this result could be explained because the maize variety established in this study was selected for open sites and the negative effect of shade generate by the trees on the maize production probably decreases as we move away from trees. Moreover, competitive effects for soil nutrients and water probably were also higher close to the trees. On the other hand, the total maize production and the production of its components (aborted cobs, cobs without grain, stems, grains and leaves) was generally lower when the maize was combined with trees compared with the plots without trees ($p < 0.001$). In any case, the maize production found in the plots without trees was similar to the production described for the same variety in different areas of Galicia (22.9 t ha^{-1}) (CMR, 2015). As it was previously described in Experiment 1, the lower production in the agroforestry plots as compared to the plots without trees could be due to the shade generated by the trees and the competition for water and nutrients between trees and maize, but also due to the lower available area of maize in the plots with trees.

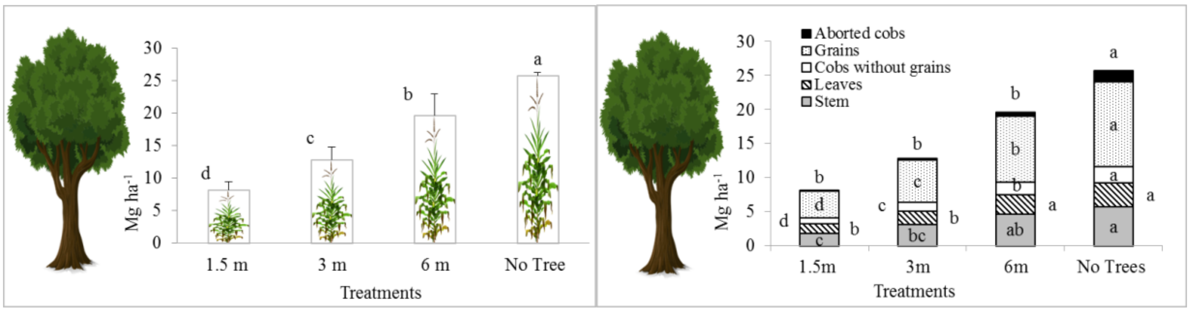


Figure 2. Total production of maize (Mg DM ha^{-1}) and production of the different components of maize (aborted cobs, cobs without grain, stems, grains and leaves) (Mg DM ha^{-1}) under the different treatments in 2015. 1.5 m, 3 m and 6 m are the distances between the trees and the maize. Different letters indicate significant differences between treatments. Vertical lines indicate mean standard error.

The results are described in more detail in: Ferreiro-Domíngez N, Rigueiro-Rodríguez A, González-Hernández MP, Palma JHN, Mosquera-Losada MR (2017). Maize yield in silvoarable systems established under *Prunus avium* L. in Galicia (NW Spain). 19th Symposium of European Grassland Federation, Sardinia, Italy.

5.3 Tree growth in Experiment 1

The results presented in Figure 3 suggest a negative effect of the maize sowing on the height and the diameter of the trees planted at a medium density (MD) ($p < 0.001$) and at a high density (HD) ($p < 0.05$). The initial negative effect of maize sowing on tree growth could be explained by the cultivation carried out in the plots sown with maize. The soil aggregate structure was probably degraded by cultivation (Dexter 1988) which could also have damaged the most superficial roots of trees thus decreasing the tree growth. However, other authors, such as Chifflot et al. (2006) found a beneficial effect of intercropping on the tree growth due to the improvement in tree nitrogen nutrition when silvoarable practices were established with *Prunus avium* L. and maize in France. Therefore, these results indicate that a continuation of our study is necessary to properly evaluate the tree growth combined with the production of maize.

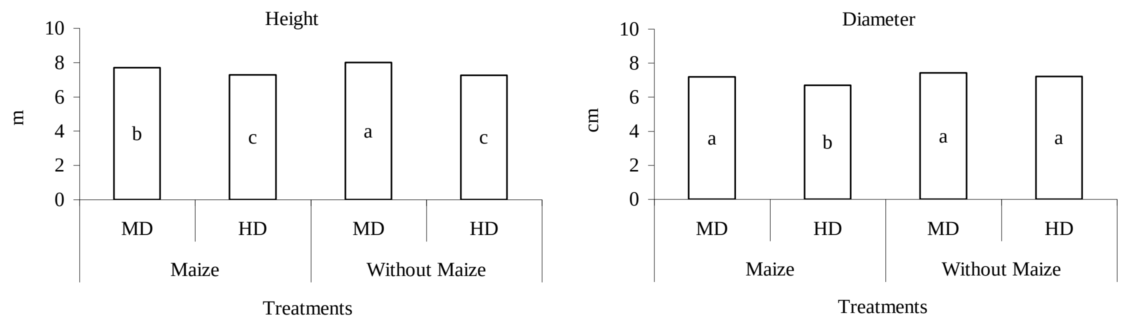


Figure 3. Tree height (m) and tree diameter at breast height (cm) under the different treatments in 2015. MD: 666 trees ha^{-1} and HD: 1333 trees ha^{-1}. Different letters indicate significant differences between treatments.

The results are described in more detail in: Ferreiro-Domíngez N, Rigueiro-Rodríguez A, Mosquera-Losada MR (2016b). Productivity of silvoarable systems established with *Prunus avium* L. in Galicia (NW Spain). 3rd European Agroforestry Conference, Montpellier, France.

6 Conclusions

The principal lessons learnt from the measurements and observations in the silvoarable system established with maize under *Prunus avium* L. include:

- Maize production was lower in the agroforestry plots compared with tree-less agronomic plots probably due to the shade and the surface occupied by cherry trees and because maize varieties are currently selected for open conditions. Therefore, other maize varieties have to be tested in order to find the most appropriate variety for agroforestry. In any case, the economic and environmental benefits from trees can compensate the lower maize production in the agroforestry compared to the tree-less plots.

- Tree growth was reduced in maize plots which could be explained by the tilling process carried out before maize sowing that probably destroyed tree roots that should be further tested to evaluate if tree recovery is produced.

7 Acknowledgements

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