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Alley cropping with strawberries: Two case-studies in Romania

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Abstract

The paper focuses on the use of alley cropping, an arable agroforestry system comprising rows of trees planted with a companion crop grown in the alleyways between the rows, in two sub-compartments (81B%: 0.75 ha, elevation 715 m asl; 81E: 3.4 ha, elevation 735 m asl) artificially regenerated at 1.80 m x 1.60 m spacing in the south-east of Transylvania (Romania) in 1997 (81B%) and 2003 (81E). The climate (Dfbx, specific to low and middle mountains) and soil (luvisol, of moderate fertility for pure or mixed *Quercus petraea* stands) are only moderately favourable to strawberry culture. The rows of tree species consists of *Quercus rubra*, *Acer pseudoplatanus, Prunus avium* (81B%), and *Quercus petraea, Fagus sylvatica*, *Acer pseudoplatanus*, and *Larix decidua* (81E). Strawberries (variety Elsanta,) were planted at 60 x 60 cm spacing in two pure rows in-between the tree rows as well as within the rows of planted trees. Both plantations were fenced, with manual topsoil hoeing up to four times a year, lighly fertilized (N, P, K complex) and chemically protected against browsing and pests. Strawberry rotation (six years, of which five years - two to six - with fruit production) was longer than the one (maximum three years) recommended in pure crops. Strawberry production reached the maximum level in years 3 or 4.
Under the local conditions, the alley cropping with strawberries had demonstrated to be a viable alternative to the 'classical' monocropping system in terms of (a) survival rate of plants (over 95 per cent), (b) initial height growth of plants (very quick, resulting from reduced competition with grasses and naturally regenerated forest trees such as pioneer species), (c) establishment of a new forest culture, the full forest cover being achieved immediately after the end of strawberry production, as well as (d) economics (early and relevant revenue from the crop).

Keywords

Agroforestry; Alley cropping; Tree species; Strawberry; Production; Economics

Contents

1 Introduction

The first years of a newly established plantation with ”normally” (not fast) growing tree species are very challenging in economic terms, as they do not generate any income but add only costs with different silvicultural interventions (i.e., weeding, cleaning-respacing). This undesired situation ceases at 15 to 25 years of age, when the first wood volumes can be sold as firewood or other wood products depending on different factors (e.g., forest species - broadleaves vs. conifers -, initial volume growth - slow vs. fast-, local market for small wood, etc.).

One option in order to reduce the burden of early costs, in parallel with generating early incomes and having tended the young plantations, is the use of *agroforestry*, described as ”a land-use involving the deliberate integration of trees with agricultural crops and/or livestock on the same unit of land” (Nair 1993, in Mosquera-Losada et al. 2009). It has been practiced for thousands of years (as early as Neolithic times in France - Thiébault 2005, in Mosquera-Losada et al. 2012) in tropical and temperate regions around the world (Smith 2010).

In Europe, agroforestry systems have been grouped into three categories based on their components: trees, crops, or livestock (Burgess et al. 2015, in den Herder et al. 2016). These systems are *arable agroforestry* (also called *agrisilviculture*), *livestock agroforestry* and *high value tree agroforestry* (Burgess et al. 2015; den Herder et al. 2015a, both in den Herder et al. 2016). According to recent estimates (den Harder et al. 2016), the total area under agroforestry in the EU27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the utilized agricultural area. Livestock agroforestry is the dominant system in EU27 and covers about 15.1 million ha while high value tree agroforestry and arable agroforestry cover 1.0 and 0.3 million ha respectively. The countries with the largest absolute extent of agroforestry are Spain (5.6 million ha), France (1.6 million ha), Greece (1.6 million ha), Italy (1.4 million ha), Portugal (1.2 million ha) and Romania (0.9 million ha) (den Harder et al. 2016).

The arable agroforestry comprises (1) *alley cropping,* i.e. trees planted in single or grouped rows within agricultural or horticultural fields with crops growing in the alleys between the tree rows, (2) *scattered trees* at low density (not in rows) with an annual cropping pattern and (3) *line belts* such as hedgerows, shelterbelts, windbreaks and forest belts (Mosquera-Losada et al. 2009).

In this context, the paper focuses on the use of alley cropping in two forest stands established in the south-east of Transylvania (Romania). Strawberry (*Fragaria* spp.) is the crop species in these stands as in other parts of Europe (e.g., Greece, France - McAdam et al. 2009; Sweden - Tellström 2014; Switzerland - Petrillo and Herzog 2016), Africa (Kenya - Ingram et al. 2017), Asia (Nepal - Schwab et al. 2015), or the U.S.A. (Chamberlin 2016).

One should mention that in Romania, even used in forestry on a quite large scale during the Communist times, alley cropping (mostly with maize or melon as agricultural crops) is used nowadays on a very small scale. It is considered that the main factors restricting its application are (i) the lack of information on this agroforestry system, (ii) the lack of projects in the field and (iii) the lack of funding for agroforestry activities (Mihăilă et al. 2012).

2 Material and methods

The fieldwork was performed in two sub-compartments, 81B% (0.75 ha - Lat. 45.9134, Long. 25.895) and 81E (3.4 ha - Lat. 45.9129, Long. 25.903) (Figure 1), part of former Management Unit VI Bodoc, Șugaș Forest District, Romanian Forest Administration-ROMSILVA.

Figure 1. Location of sub-compartments 81B% and 81E in the south-east of Transylvania-Romania.

Currently, the area is privately owned, due to the restitution process to the pre-WWII forest owners, performed after the fall of Communism in Romania.

The most important site conditions in the area are as follows:

Orography: elevation 715 m asl (sub-compartment 81B%) and 735 m asl (81E), mean slope 8^g (5-15^g) in both stands, aspect W (81B%) and SE (81E).

Climate (Sfântu Gheorghe Weather Station, Lat 45.52, Long. 25.36, altitude 561 m): mean annual temperature 7.6°C, mean monthly temperatures in the growing season between 8.4°C (April) and 18°C (July), mean annual rainfall 584.1 mm, growing season 166 days, mean aridity (de Martonne) index 33.2. Climate type: Dfbx (D - boreal climate, with cold winters and with a stable snow layer; f - sufficient rainfall all year long; b - the average temperature of the warmest month below 22°C, but at least 4 months over 10°C; x - maximum rainfall at the beginning of summer, minimum rainfall towards the end of winter) (Köppen' classification), or *climate of low and middle mountains* (Anonymous, 1960).

Soil: luvisol, moderately acid (pH 5.2-5.6) and of moderate fertility for pure or mixed sessile oak (*Quercus petraea*)-dominated stands, with European beech (*Fagus sylvatica* L.), linden (*Tilia* spp.), field maple (*Acer campestris* L.), hornbeam (*Carpinus betulus* L.), wild cherry (*Prunus avium* L.).

Natural forest vegetation consists of the above broadleaved tree species showing a medium (III) yield class. The same productivity potential for the natural forest vegetation (sessile oak pure and mixed stands) is confirmed by the grass vegetation type (*Luzula luzuloides*).

The two stands were managed before planting and during planting as follows:

a. *Sub-compartment 81B%*: clear-felling for substitution of a degraded stand, with a high proportion of pioneer species such as silver birch *Betula pendula* Roth. and trembling aspen *Populus tremula* L., in autumn 1996-spring 1997; clearing of logging debris and fencing of logging area using the debris; spring 1997: planting 67% northern red oak (*Quercus rubra* L.), 22% sycamore (*Acer pseudoplatanus* L.) and 11% wild cherry, 1.80 m x 1.60 m spacing. Planting of strawberries (variety Elsanta, one of the

most used worldwide, resistant to mildew, with high fruit production) in May-June 1997, 60 cm x 60 cm (two pure rows of strawberries in-between the tree rows and in-between the planted trees, within their rows).

b. *Sub-compartment 81E*: substitution clear-felling in autumn 2001-spring 2002; the area had logging debris cleared, was fenced then left barren all year 2002. In spring 2003, planting (1.8 m x 1.6 m spacing) of all area, using plants of sessile oak, European beech, sycamore and European larch (*Larix decidua* Mill.). Summer of 2003: planting of strawberries (variety Elsanta), exactly as above.

The following interventions have been carried out in the two stands in the first years after establishing both plants and strawberries:

- manual topsoil hoeing 3-4 times a year over both trees and strawberries: the first intervention in spring, before the soils drying, the second before the fruit harvest, and 1-2 afterwards. The cost of individual intervention per ha about 650 euro so the total cost of hoeing reached between 1,950 and 2,600 euro ha^{-1} yr^{-1}.
- N, P, K complex fertilization in summer (July), using 300 kg of substance ha^{-1} at a total cost per ha of about 110 euro. Two fertilizations covering the whole area of the two stands were carried out in 81 E (years 2004 and 2007), and only one in 81B% (1999).
- local protection using repellents of some individual plants (especially northern red oak) against rabbit browsing (1998) as well as local spraying against blight and mildew (2001, only in 81B%). No cost incurred as these two minor interventions were carried at a very low scale by the forest owner.

3 Results and discussion

The use of alley cropping with strawberries, including various interventions and outputs, has shown some interesting results:

1. The use of manual topsoil hoeing, even a quite expensive operation, on all sub-compartment areas, has shown a very positive effect on survival rate of plants, reaching over 95 per cent in both stands. By tending cautiously both plants and strawberries, and removing grasses there have been almost no losses of plants.
2. The young plants have shown a quick initial height growth, resulting from reduced competition with grasses and naturally regenerated forest trees such as pioneer species (e.g., goat willow *Salix caprea*, silver birch and trembling aspen in the local conditions). Consequently, fast growing tree species like sycamore have started to shade the crop very quickly after the establishment of plantation so they have been cut (after three growing seasons, in December 2005 - 81E) at ground level in order to eliminate competition with strawberries; consequently those sycamore plants were converted to coppice.
3. The quick initial height growth of tree species such as northern red oak, sycamore, wild cherry, European larch etc. has allowed for the quick establishment of a new forest culture, its new forest environment (full forest cover) being achieved immediately after the end of strawberry production.

4. In terms of crop, strawberries have been managed under a six-year rotation, of which five years (2 to 6) with fruit production. This rotation is longer than the one (maximum three years) recommended in pure multiannual strawberry crops in Romania (Chira 2000). Strawberry production has grown from year 2 of culture on and reached the maximum level in the two plantations in years 3 or 4, as shown in figure 2.

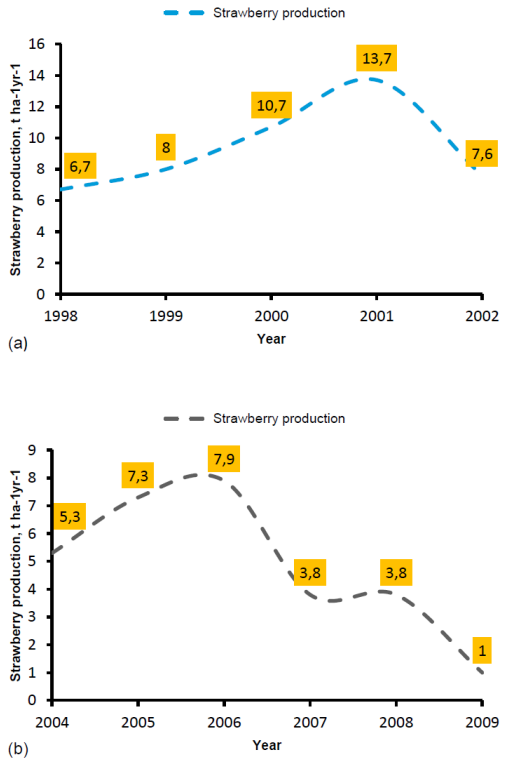

Figure 2. Strawberry production in sub-compartments 81B% (a) and 81E (b).

However, the maximum production is very different in the two situations: 13.7 t/ha in 81B% and only 7.9 t/ha in 81E. This quite big difference between the two cultures could be explained by the drier period occurring since 2004, which affected the strawberries. This crop shows a low resistance to dry periods and requires between 500 and 900 mm rainfall per year, with a good distribution along the growing season, for high fruit productions (Chira 2000). As the culture in 81E has not been irrigated because of both lack of sources of water in the area as well as high cost of irrigation, their production was strongly affected by the dry period after 2004.

However, the maximum fruit production is higher than the one specific to multiannual strawberry crops (5-8 t ha^{-1}) but lower than the one produced in annual strawberry crops (15-25 t ha^{-1}) in Romania (Chira 2000).

In terms of revenue per ha, there is one important issue to mention: as agreed with the workers (strawberry pickers), they have been paid either in fruits or in money. The cost of labor was 20% of the overall gross value of strawberries After subtracting this expenditure, the net revenue per ha and year ranged between 2,270 and 4,450 euro (81B%) and 1,710 and 3,550 euro (81E), (Figure 3).

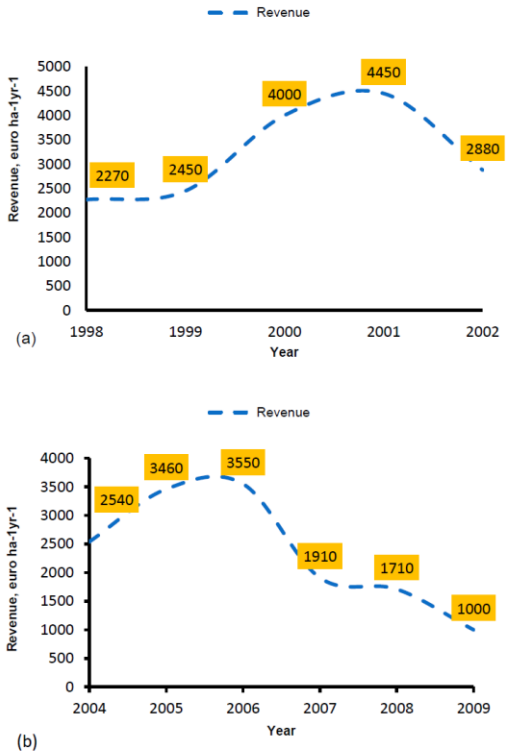

Figure 3. Revenues in sub-compartments 81B% (a) and 81E (b).

These values are higher than or similar to all costs with different interventions (manual topsoil hoeing, fertilization = maximum 2,700 euro $ha^{-1}yr^{-1}$) carried out in the two plantations. In this way, the marketing of crop (strawberries) was able to offset the costs of tending interventions and, in good crop years, even provide a certain revenue to the owner (Table 1).

Table 1. Comparison between the costs of interventions and revenues from selling the strawberries in the two plantations.

Sub-compartment	Year	Cost of interventions, euro $ha^{-1}yr^{-1}$	Revenue from selling the strawberries, euro $ha^{-1}yr^{-1}$	Profit, euro $ha^{-1}yr^{-1}$
81B%	1998	1950	2270	320
	1999	2050	2450	400
	2000	1950	4000	2050
	2001	1950	4450	2500
	2002	0	2880	2880
81E	2004	2050	2540	490
	2005	2600	3460	860
	2006	2600	3550	950
	2007	1950	1910	*- 40*
	2008	1950	1710	*-240*
	2009	0	1000	1000

The evolution of the two stands since the first years of their life until the present days is depicted in the images 4-10. The ways they look like are the results of the application of a mixture of stand silviculture and single-tree silviculture (81B%), with potential final crop trees selected based on the vitality-quality-distribution

criteria before reaching the pole stage of development (Figure 4-6), and stand silviculture (81E), (Figure 7-9). Some of these crop trees, mostly of northern red oak and wild cherry, have been kept in a free-growth state, growing quickly in diameters and crown size; consequently they show current diameters up to 22 cm (Figure 6a and 6b).

a b

Figure 4. Sub-compartment 81B% in year 2000 (age 3 years), after second manual hoeing.

Figure 5. Sub-compartment 81B% in summer 2007 (age 10 years).

Figure 6. Sub-compartment 81B% in winter 2017-2018 (age 20 years); a = free-grown wild cherry final crop tree; b = free-grown northern red oak final crop tree; northern red oak final crop tree.

Figure 7. Sub-compartment 81E in spring 2007 (age 4 years), after the first hoeing.

Figure 8. Sub-compartment 81E in summer 2007 (age 4 years), during strawberry picking.

Figure 9. Sub-compartment 81E in winter 2017-2018 (age 15 years); a = area of sycamore trees treated as coppice.

4 Conclusions

Under the local conditions, with cheap and available labor, and quite fast growing tree species, *the alley cropping with strawberries had demonstrated to be a viable alternative to the 'classical' mono-cropping system* resulting in a (a) high survival rate (over 95%) of young plants, (b) quick initial height growth of plants, allowing for a (c) quick establishment (achievement of full canopy cover) of a new forest culture as well as (d) economic results (early and relevant revenue from the crop, able to offset the costs of tending both trees and crop and even generate a certain income to the owner in good crop years).

However, the application of alley cropping with strawberries is possible only when some prerequisites are fulfilled:

- there is a good local market for the crop species (strawberries) and the distance to the buyers/beneficiaries is short in order to reduce the transport costs;
- there is a cheap and available local labor that can be used for all interventions - from manual hoeing to fertilizing - carried out during the growing season.

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