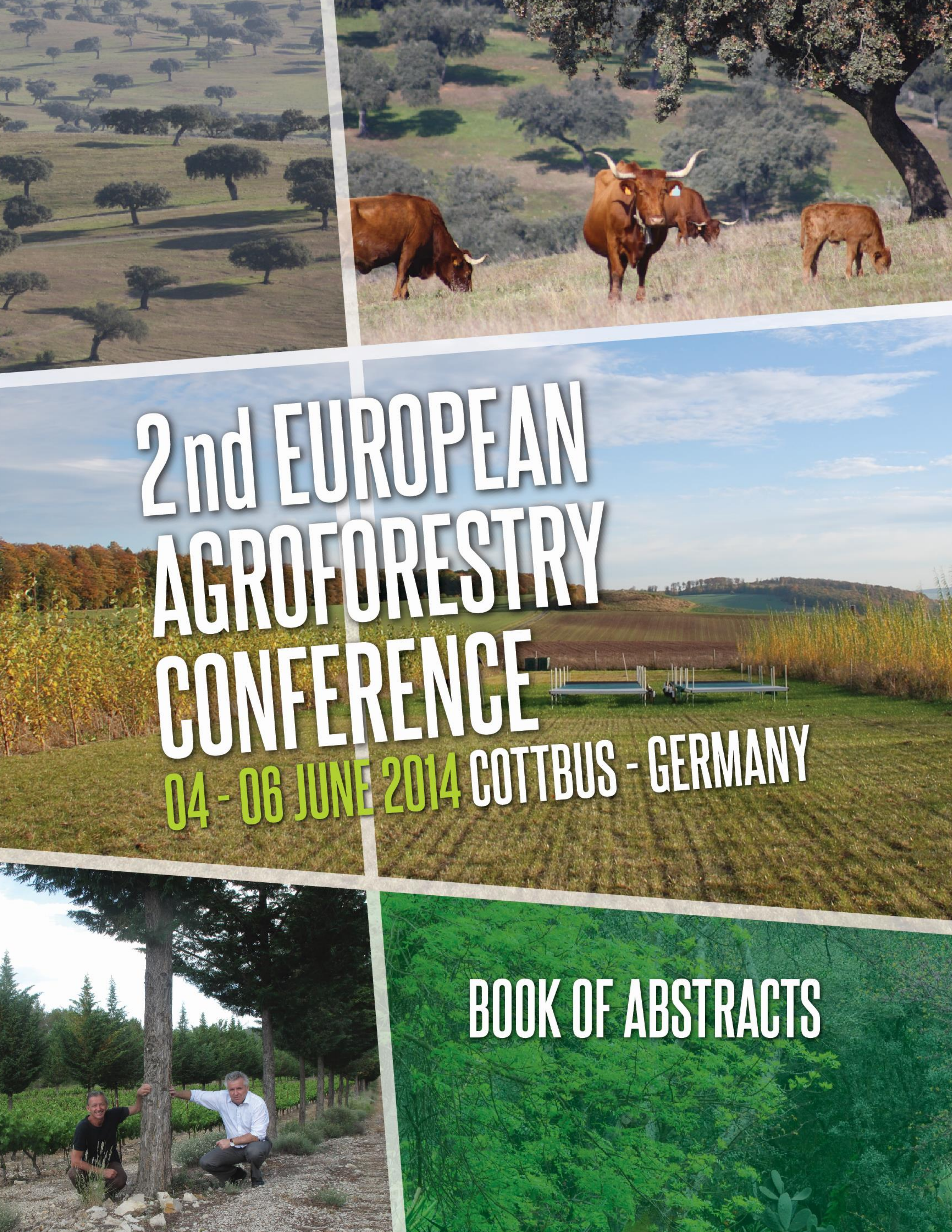

2nd EUROPEAN AGROFORESTRY CONFERENCE

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BOOK OF ABSTRACTS

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EUROPEAN AGROFORESTRY FEDERATION

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The application of treeshelters in forestry

With over 35 years' experience in producing treeshelters, TUBEX is a well-known and trusted brand in Forestry. Focusing its business on making and selling a wide range of products used for 'Advancing Growth' in trees, TUBEX pays particular attention to understanding the silvicultural and agronomical benefits of treeshelters to plants.

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More recently TUBEX has been able to use the expertise of Dr Anton Hammer, Dr Cris Arnold and Prof Sebastian Hein to study the degradation of treeshelters. Dr. Bhukan Parbhoo will be presenting these findings and is available for questions.

For more information on TUBEX please go to www.tubex.com

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Preface

Who is afraid of agroforestry?

The European Agroforestry Federation is proud to bring to you the second European Agroforestry Conference, in Cottbus, Germany.

The first European Agroforestry Conference was held in Brussels in October 2012, and was landmarked by an unprecedented parallel session at the European Parliament. This was the first time European Members of the Parliament discussed this topic and listened to policy proposals formulated by EURAF. Not the last.... In the last two years, they had more opportunities to learn about agroforestry, as EURAF became more and more involved in Agroforestry lobbying, both at the European level and at the national levels in many European countries.

This second European Agroforestry Conference occurs at a special time : the time when the new Common Agricultural Policy (CAP) is being implemented across Europe for the next 6 years. This new CAP is more friendly to trees outside forest than ever. For the first time, a definition of agroforestry is included in an European policy. Thanks to EURAF and to the dedication of its members. The focus of this conference (how to integrate science and policy to promote agroforestry) is therefore crucial. Now that policy has taken agroforestry on board, scientist may feel under pressure. They are. But let’s share the pressure, lets exchange ideas, novels, concepts, results. Let’s document agroforestry failures as well as agroforestry successes.

Agroforestry is not an evidence. Agroforestry is not the solution to all the problems of modern agriculture. But agroforestry can be part of it.

Christian Dupraz,

President of the European Agroforestry Federation

Brandenburg University of Technology Cottbus-Senftenberg

Brandenburg University of Technology Cottbus - Senftenberg

Brandenburg University of Technology is pleased to host the 2nd European Agroforestry Conference between 4th and 6th June 2014 entitled "Integrating Science & Policy to Promote Agroforestry in Practice". Agroforestry had some traditions as an optional land use system in Central Europe, but during the last eighty years these management systems disappeared progressively due to the ongoing industrialization of agriculture and the resulting land consolidation.

The recent rising demand for woody biomass for bioenergy in Germany is expected to lead to an increased cultivation of trees on farmland. As a result, there are numerous research projects that deal with these current issues, e.g. agroforestry systems with short rotation components.

The Chair of Soil Protection and Recultivation at the Brandenburg University of Technology has been intensively engaged in the research field of agroforestry for more than 15 years. The background of this research remains to be in understanding how fast growing tree species planted in agroforestry systems, but also in short rotation coppices, affect abiotic and biotic functions of the environment. Positive effects have been shown for the overall soil quality, the microclimate and the biodiversity.

The interaction between trees on crops and their impact on soil characteristics is the main focus of research including studies of humus accumulation in soil, carbon sequestration and nutrient cycle. Moreover, numerous studies are dealing with the carbon allocation in woody biomass, and hence, address questions concerning site specific yields of woody biomass on agricultural land.

In this context, post-mining areas play a very important role. Furthermore, the development and assessment of suitable reclamation measurements by using fast growing tree species is part of several investigations. The majority of studies are integral parts of national or international collaborative research projects founded by ministries, public institutions as well as industrial partners.

For more information about research projects and publications please visit:

http://www.tu-cottbus.de/projekte/en/multifunctional-land-use.html

New insights into carbon, water and nutrient cycling in agroforestry

Biophysical Interactions in the Alley Cropping System in Saskatchewan

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Introduction

Crop production in alley cropping systems and in other mixed-species systems is dependent on the net effects of facilitative and competitive interactions on availability of growth resources (moisture, nutrients, and light) to the crop and trees components of the system. Controlling these interactions can benefit producers through the increased system productivity associated with optimized yields crops and trees. Previous research in the Canadian Prairies has focused on biophysical interactions in shelterbelts. These studies have demonstrated that trees in the shelterbelt system ameliorate soil moisture and temperature by reducing wind speed and trapping snow; this in turn reduces evaporative and heat stress leading to increased yields of intercrops (Marchand and Masse, 2008; Kort et al. 2009). Unlike Eastern Canada and United States (US), there is inadequate information on the on tree-crop interactions under alley cropping systems in the Canadian Prairies. Studies in these areas indicate that nutrient recycling by trees through nitrogen (N)-fixation and litter and root turnover can enhance soil nutrients, especially N thereby reducing fertilizer inputs in the alleyways (Thevathasan and Gordon, 2004). Because of the reduced N inputs and highly efficient capture of nitrate leaching to sub-soils by tree roots, alley cropping systems also hold high promise to reduce N_2O emissions and groundwater contamination (Doughterty et al. 2009). When plant growth is not limited by water and nutrients, plant biomass production is directly related to the radiant energy up to species-specific saturation points. In the absence of these growth-limiting factors, shading acts as facilitative rather than a competitive effect in agroforestry systems (Jose et al. 2004). Positive ecological interactions discussed here have been demonstrated to increase productivity of food, forage and bioenergy crops in alley cropping systems in Eastern Canada and US, but this has not been done in the Canadian prairies. Thus, it is necessary to assess biophysical interactions in the alley cropping system in this region because impacts of these interactions on plant growth and yield usually depends on many factors including site specific and climatic conditions, age and type of tree species. Thus the objective of this study

was to evaluate the effects of distance from tree row, row orientation, and sampling depth on soil moisture, light and yield and nutrition of oats (*Avena sativa* L.) in the alleyways.

Materials and Methods

The experiment was conducted on a 9-year-old Manitoba maple alley cropping site with oats in the alleys. The site is located in the experimental farm of the Agroforestry Development Centre, Indian Head, Saskatchewan (SK). Tree rows were planted 11 m apart in the East-West orientation in 2004 and the trees were 3 m high at the time of conducting this experiment. The factorial experiment with three factors was laid out in randomized complete block (RCBD) with four replications to test the effects of: 1) orientation (north and south), 2) distance from the maple tree row (i.e. 2 m, 4 m and 6 m), and 3) soil depth (for soil parameters like moisture & nutrients) or time of day (for light parameters) on yields and nutrition of oats. Oats were seeded at 90 kg ha^{-1} in 2012 and sampled for dry matter and nutrient analysis at the tussling stage to coincide with the active growth stage. Oat samples were collected from a 60 cm × 60 cm quadrant at 2 m, 4 m and 6 m from the tree row in each orientation by cutting at 5 cm from the ground. Gravimetric soil moisture samples were collected from the same distance and orientations using a Dutch auger. Photosynthetically active radiation (PAR) was also measured in these locations three times per day (morning, solar noon and evening), on clear sunny days using a Sun Scan Canopy Analysis System. Prior to conducting statistical analysis normal distribution of residuals were confirmed by Shapiro-Wilk test in SAS. Analyses of soil moisture content (SMC) and PAR were done by the repeated measure approach while biomass and nutrient contents were analyzed using ANOVA provided in the PROC MIXED procedure. All analyses were conducted at 5% probability level and significant means were compared using Tukey’s Honestly Significant Difference (HSD).

Results

SMC declined significantly ($p < .0001$) with sampling depth and plot orientation, but no differences were noted due to distance from the tree-row (Fig. 1). SMC was however comparatively higher in the northern compared to the southern orientation and it was lower at 2 m than at 4 m and 6 m from the tree row in the southern orientation. PRA ranged from 400 to 1.000 μmol m^{-2} s^{-1} and was the lowest ($p < .0001$) at 2 m in the north facing plots. At noon, PAR in the southern orientation ($p < .0001$) was higher than in northern orientation (Fig. 2; $p < .0001$).

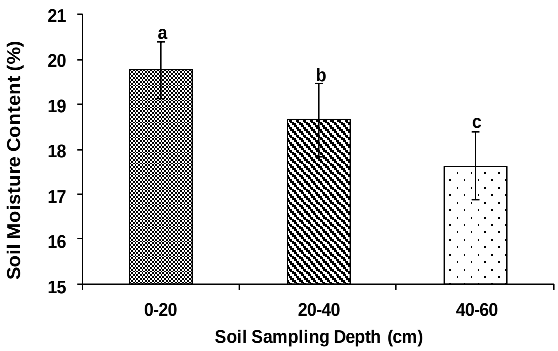

Figure 1: Gravimetric soil moisture content at three sampling depths in the Manitoba Alley cropping system at Indian Head, SK. Means (± SE) followed by same letters are not significantly different at P ≤ 0.05 according to Tukey's HSD

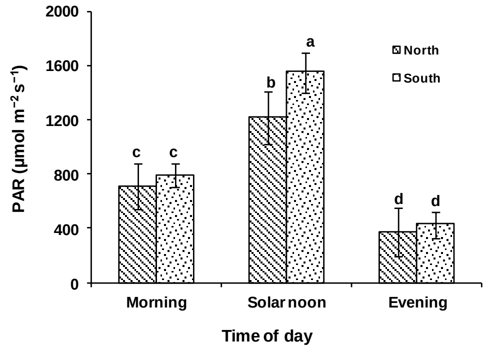

Figure 2: Photosynthetically active radiation in the Manitoba Alley cropping system at Indian Head, SK. Means (± SE) followed by same letters are not significantly different at P ≤ 0.05 according to Tukey's HSD

Total nitrogen (TN) and crude protein (CP) in the northern orientation were 27% higher (p = 0.022 and 0.024) than corresponding values in the southern orientation. These parameters also increased significantly (p = 0.05) with distance from the tree row in both orientations with values at 4 m being the highest (in the north-facing plots) and/or similar to those at 6 m (in the south-facing plots). However, dry matter content (DM), acid detergent fibers (ADF) and neutral detergent fibers (NDF) were not affected by the distance from the tree row, orientation of oats plots and their interactions (data not shown).

Discussion and Conclusions

Generally competitive interactions occur in a zone close to the tree row and depending on the species type, age, and height of a tree; and soil and climatic conditions, this zone may be within at 2-m from the tree row (Thevathasan and Gordon, 2004). Lower SMC and PAR at 2 m from the Manitoba maple row indicate competition for water and light as also noted by Cardinael et al. (2012) in eastern Canada. Slightly higher SMC (27%) in the northern orientation compared to the southern orientation possibly reflect increased evapotranspiration due to higher light (PAR) in the south facing plots at noon (Fig. 2). Despite of high competition within 2 m from a tree row, higher soil nitrogen and organic carbon accumulation has been noted at this zone in a mature tree alley cropping site in Guelph, Ontario (Thevathasan and Gordon, 2004), demonstrating that cumulative ameliorative effects over the years may mitigate such negative interactions due to improved biogeochemical processes. The increase in TN and CP in northern orientation and with distance

from the tree row did not translate into increased DM of oats. This would suggest that other factors, apart from soil nutrients, were driving yield and growth of oats. Thus, comparatively higher SMC and DM in the northern orientation than in the southern orientation imply that yield and nutrition of oats in this semiarid area of the prairies was driven by SMC. Beyond the 2-m zone, there were little effects of trees on tested biophysical parameters and on oats yield and nutrition. This is partly attributed to the age and architecture of the Manitoba maple. When this study was conducted, the tree was 9 years old, 3 m high and had no spreading canopy such that it could compete vigorously with oats for above-and below-ground resources. Moreover, as a C3 plant, oats is not sensitive to shade and has a higher light saturation point (> 1.200 μmol m^{-2} s^{-1}; Nair, 1993) than the range noted in this study (400-1.000 μmol m^{-2} s^{-1}). Thus it can be concluded that producers may integrate Manitoba maple trees on farms to diversify production cycles without comprising forage crop yields and nutrition because no significant adverse effects were noted within 6 m from the tree row during the first decade of tree establishment. However, it is important to monitor tree-crop interactions noted here to note any changes with age and recommend appropriate management for optimizing system productivity.

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Soil carbon sequestration in a Mediterranean agroforestry system

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Introduction

The Earth soils are a large reservoir of carbon (C), containing about 1.500 PgC, which represents two to three times the C contained in the atmosphere. This reservoir is extremely sensitive to land use and can act as a source or as a sink of atmospheric carbon dioxide (CO_2). Agroforestry systems are expected to sequester C into both above and belowground biomass. Such systems could also increase soil organic carbon (SOC) stocks due to higher organic inputs including leaf litter, pruning residues, tree fine root turnover, and root exudates. However, although agroforestry systems have been thoroughly investigated in tropical regions, their potential for C sequestration has rarely been studied in temperate regions, and when studied, has mostly concerned superficial soil layers (Lorenz and Lal 2014). The objectives of this study were (i) to quantify the SOC stocks down to 2 m soil depth in an 18-year-old agroforestry system and in an adjacent agricultural plot, (ii) to study spatial distribution of SOC stocks, especially in relation to the distance from the trees, and (iii) to assess which SOC fractions are responsible for possible differences between treatments.

Material

The experimental field was established in 1995 in Prades-le-Lez (longitude 04°01’ E, latitude 43°43’ N, elevation 54 m a.s.l.), near Montpellier, South of France, on an alluvial carbonated Fluvisol. The climate is sub-humid Mediterranean with an average temperature of 14.5° C and an average annual rainfall of 951 mm (Mulia and Dupraz 2006). In the agroforestry system, hybrid walnut trees (*Juglans regia x nigra cv. NG23*) were planted at a density of 110 trees ha^{-1} (13 m between tree rows), and intercropped with a winter crop, mainly durum wheat (*Triticum turgidum ssp. durum*). In the adjacent agricultural plot, only the annual crop was cultivated. Spontaneous vegetation also grew on the tree rows. A first field sampling was carried out in December 2012, and 24 soil cores were collected down to 2 m depth. Soil texture was analyzed, allowing to delimit two plots of 625 m^2 each in the agroforestry field and in the control field, with the same soil texture. In

May 2013, about 200 soil cores were sampled down to 2 m depth into these two plots. Each soil core was cut into ten layers, and bulk densities were measured for each of them, as well as texture and SOC contents, which were either analyzed conventionally (dry combustion after decarbonatation) or predicted using field visible and near infrared spectroscopy (Gras et al. 2013). Carbon stocks were spatialized at the field scale. To determine which SOC fractions were affected by the agroforestry system, soil particle-size fractionation (Gavinelli et al. 1995) was performed on 64 soil samples, collected at 0-10, 10-30, 70-100 and 160-180 cm soil depth.

Results

Soil carbon stocks were characterized by a high, but organized spatial variability. Spatial analysis showed twice higher SOC topsoil content on the tree rows compared to the inter-rows. Whereas the SOC stock in the reference agriculture plot was 42.29 ± 0.53 MgC ha^{-1} (0-30 cm) and 118.48 ± 0.88 MgC ha^{-1} (0-100 cm), in the inter-row significant additional storage of 2.5 ± 0.80 and 3.5 ± 1.29 MgC ha^{-1} was observed at 0-30 and 0-100 cm, respectively. On the tree row, additional storage was 17.5 ± 1.06 and 20.5 ± 1.50 MgC ha^{-1} respectively, compared to the agricultural plot. Below 1 m depth, SOC stocks did not differ. Knowing that tree rows represent 16% of the agroforestry plot, we calculated the additional SOC storage of the whole field compared to the control plot. Annual additional SOC storage rates were estimated at 272 ± 68 kgC ha^{-1} yr^{-1} (0-30 cm) and 352 ± 98 kgC ha^{-1} yr^{-1} (0-100 cm). This additional storage was mainly due to the particulate organic matter fraction (50-200 and > 200 µm), whereas only 10 to 15% was associated to clay particles (< 2 µm). Total organic carbon storage rate would reach about 1.2 MgC ha^{-1} yr^{-1} when trees biomass was also taken into account.

Discussion

High SOC contents on the tree rows were mainly due to high inputs from the natural vegetation. No clear pattern of SOC content was observed in relation to the distance to the trees, but the tree row had an important impact on the SOC storage of the agroforestry field due to the spontaneous vegetation. This is an indirect effect of agroforestry systems: the tree row also acts as a permanent pasture, and has a positive impact on SOC sequestration. Additional SOC storage rates are higher than those commonly reported for other techniques used to improve SOC in agriculture, such as no-till farming or conservation agriculture (Pellerin et al. 2013). Up to now, additional storage is mainly limited to topsoil layers and in labile organic fractions, making it an unstable storage.

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Pasture management under hardwood plantations: legume implantation vs. mineral fertilization

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Introduction

Europe has a shortage of quality wood and therefore there is a growing interest in the establishment of hardwood plantations. In Spain, hardwood species are commonly harvested after long rotations of up to 50 or 60 years. But with intensive management, including irrigation, fertilization and chemical weed control, rotation length can be notably reduced by half (to 20-25 years). Fertilization and herbicide application are the most controversial management practices because of the high costs involved and their impact on soil and water pollution. The implantation of forage legumes could reduce the economic costs of these plantations, improve pasture production and quality, and optimize the environmental functions of these plantations, i.e. provide soil cover to control erosion (Gselman and Kramberger, 2008; McCarteney and Fraser, 2010). However, the competition for soil water and nutrients by forage legumes can reduce tree growth. The objective of this project is to study the response of trees and pasture in a silvopastoral system established in an intensively managed hardwood plantation, to the implantation of legumes as nitrogen fertilizer, and its environmental implications.

Materials

The experiment was carried out in Extremadura (Spain) in a 15- year old hybrid walnut (*Juglans major* x *nigra* mj 209xra) plantation, with a density of 333 trees ha^{-1}. Three treatments were applied during three years (2011 -2013): mineral fertilization, that consisted in the application of 40 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}; sowing of legumes (complemented by the same quantities of PK as mineral treatment); and control treatment, combined with three levels of irrigation. In October 2011 and 2013, a mixture of 25 kg ha^{-1} of *Trifolium michelanium* and 10 kg ha^{-1} of *Ornithopus compresus* were sown under trees. Three replicates were used for each combination of fertilization (3) and irrigation (3) treatments that results in nine combinations and 27 plots. Each plot (95 x 15m) comprised two rows of 20 trees. Pasture production, tree normal diameter growth, soil carbon, available soil nutrients (N, P, K and Ca) and nitrate leaching were studied. For determining pasture production, three herbage samples (50x50 cm) were taken from

each plot using hand clippers at a height of 2.5 cm in June 2013. After that, herbage samples were dried in an oven at 80ºC for 48 h. In May 2013, 12 ion exchange resins were installed at 15 cm depth in each plot (six for cations and six for anions). In June 2013 (one month later), they were taken out and analyzed in a laboratory. For determining nitrate leaching, two ceramic cup samplers were installed in each plot at 30, 60 and 90 cm and samples were taken periodically from the beginning of 2013. Tree diameter at breast height (dbh) was measured. Data were analysed as randomized design by ANOVA and LSD test to separate treatment means when ANOVA showed significant effects ($p<0.05$). All statistical analyses were performed using R program.

Results

The results obtained (Table 1) indicate that legumes significantly increased the N available (21.6±3.1 µg N / 50 cm^2 / month). With respect to the other nutrients, levels of nutrient availability (2.3±0.5 µg P / 50 cm^2 / month, 65.3±7.7 µg K / 50 cm^2 / month and 39,1±1.1 µg Ca / 50 cm^2 / month) were similar to those obtained with mineral fertilization (3.6±0.8 µg P / 50 cm^2 / month, 62.1±8.1 µg K / 50 cm^2 / month and 38.1±0.9 µg ca / 50 cm^2 / month) and higher than in the control. However, nitrate leaching was slightly higher under legume sowing (20.6±3.6 mg NO_3^- l), but there were no differences below this depth (data not included).

The application of mineral fertilizer produced the highest increment of tree diameter (4.2±0.1 cm) followed by legume sowing (3.7±0.1) and control (3.3±0.1 cm). In the case of pasture production, mineral fertilization (5.9±0.3 t ha^{-1}) and legumes (6.4±0.3 t ha^{-1}) showed similar values and higher than control (3.5±0.3 t ha^{-1}). In any case, there were significant responses to irrigation treatments.

Treatments	Elements	Control	Mineral	Legumes	sign
Soil	N	7.4±0.8b	9.6±2.2b	21.6±3.1a	***
	P	1.7±0.3b	3.6±0.8a	2.3±0.5ab	*
	K	29.5±2.1b	62.1±8.1a	65.3±7.7a	***
	Ca	37.0±0.8	38.1±0.9	39.1±1.1	ns
Grounwater pollution	NO_3^-	13.9±1.7	14.5±2.1	20.6±3.6	ns(0.16)
Tree growth	Diameter increment	3.3±0.1c	4.2±0.1a	3.7±0.1b	***
Pasture production		3.5±0.3b	5.9±0.3a	6.4±0.3a	***

Table 1. Nutrient (N, P, K, Ca; µg / 50 cm^2 / month) availability in soil, nitrate leaching (mg N-NO_3^- l^{-1}), diameter increment (cm) in trees and pasture production (t ha^{-1}) with different fertilization treatment.

Discussion and conclusions

The use of legumes increased the available nutrients in soil, especially nitrogen, whose value increased by almost 200% compared to control. Gabriel and Quemada (2010) have also observed positive responses in soil nitrogen to the application of legumes as green manure. However, a portion of the nitrogen fixed by legumes could be leached and result in water contamination. In fact, nitrate leaching increased under legumes, although only in the uppermost soil layer (0-30 cm). However there is no difference among treatment below this depth. This could be explained because the contribution of N fixed by legumes occurs gradually (Marinari et al., 2010). Moreover, López-Díaz et al. (2010) have observed that the pasture and tree combination was effective in reducing nitrate pollution in water as a result of the presence of tree roots at greater depths that can use this nitrogen (Moreno et al., 2005), and avoid water contamination (Defauw et al., 2005).

The highest pasture production was obtained with legumes, which additionally increased the quality of forage (Rigueiro-Rodríguez et al., 2007). This can explain the reduction of tree growth that was observed compared with the mineral application treatment. Moreover, the nitrogen supplied by the legume occurs gradually (Marinari et al., 2010), Therefore it is possible that better results can be obtained in the long term.

In conclusion, the sowing of legumes as an alternative to N mineral fertilizers can improve the profitability of silvopastoral systems developed in quality timber tree plantations.

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Carbon Sequestration in a Poplar Agroforestry System in India with Wheat and other Crops at Different Spacing and Row Directions

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Introduction

Owing to its fast growth, deciduous nature, marketing acceptability, and successful intercropping, poplar has become a viable alternative to traditional irrigated rice-wheat rotation in north-western states of India and satisfies the rising requirements of the regional plywood industry. Agroforestry provides multiple ecological and economic benefits including carbon sequestration, soil and water improvement, raising species diversity and stabilizing farmer's incomes by diversification. Experiments were conducted to study the effect of poplar spacing and row direction, suitable crop rotation as well as the carbon sequestration potential of agroforestry as compared to sole agriculture. Furthermore, changes in soil physico-chemical properties were analyzed.

Material and Methods

In Experiment No. 1, the treatments were (A.) Poplar planting spaces: a) 5 x 4 m b) 10 x 2 m c) 18 x 2 x 2 m (paired row) an (B.) crop rotations a) cowpea (*Vigna unguiculata*)-wheat (*Triticum aestivum*) b) sorghum (*Sorghum bicolor*)-berseem (*Trifolium alexandrinum*) c) fallow. The design was split plot in three replications. In Experiment No. 2 poplars were planted along bunds in (a.) North-South, (b.) East-West direction. In the study, the wheat crop was sown during the first week of November and harvested in April. The carbon storage potential of agricultural crops was equated 50 % of the total above ground dry biomass produced by these crops during the six years. The carbon storage potential of poplar at six years age was estimated by felling the trees and recording their dry biomass as well as the leaf and branch fall over the six years.

Results

The height of poplar was not affected significantly at different planting spaces as well as under agroforestry and sole poplar land uses. However, the girth of poplar under agroforestry was significantly more than sole poplar. Paired row planting (18 x 2 x 2 m) of poplar resulted in

significantly less girth than planting of poplar at 5 x 4 m and 10 x 2 m spacing due to increased competition among plants for different growth resources. Leaf fall of poplar decreased with decreasing plant spacing on account of reduced crown size. Except for nitrogen and potassium only little amounts of P were added to the soil through leaf litter fall at all planting spaces of poplar. However leaf litter fall during the six years have helped in maintaining the organic carbon content of soil. The yield of the grain and straw decreased sharply from 15 to 65 % under one to six year duration. Organic carbon content in the top soil increased considerably under agroforestry crops with 0.36 % under the six year plantation and 0.22 % under the control. The carbon stock in different carbon pools under study indicated that the above-ground biomass followed by below-ground biomass accumulated to 39 t/ha at the age of six years under the agroforestry system compared to 4.9 t/ha of the control.

The performance of agricultural crops during the kharif season (summer-autumn) were affected by uneven distribution of rainfall as a result of which crops had to face moisture stress especially under poplar. The green fodder yield of sorghum increased with increasing row spacing and was in the control field was significantly higher than all the spacings of poplar. Cowpea for fodder was found more compatible with poplar than sorghum. The green fodder yield of cowpea at 18 x 2 x 2 m spacing of poplar was significantly higher than 5 x 4 m and 10 x 2 m spacings which were at par with each other.

During the rabi season (winter-spring), the yield of both berseem and wheat increased with increasing row spacing, however, the differences between 5 x 4 m and 10 x 2 m spacings were not significant. The mean decrease in the yield of berseem and wheat under poplar was 20 and 39 % respectively, over control. The poplar contributed the maximum carbon in the poplar-wheat system. The carbon stock in the above-ground biomass followed by below-ground biomass contributed the maximum (37.3 t/ha at the age of six years) towards aggregate carbon pool under agroforestry system. The timber carbon content was estimated to be 28.31 t ha^{-1}, whereas, the contribution of the roots, leaves and bark was 5.67 t ha^{-1}. The branches in total (one to six years) can fix 10.22 t carbon per ha. The carbon sequestrated in soils under agroforestry from biomass turnover was greater than under conventional agricultural operation. The contribution of wheat crop roots was approximately 2.5 % only of the total carbon assimilated in the crop. In the wheat crop, the proportion of straw + grain is substantially higher (97.5 %) than below ground biomass. But the straw and grains are removed from the system and in due course of time, the carbon assimilated by the crop would be released back in the atmosphere. The higher carbon pools within the

intercropping systems compared to those from the sole cropping system were due to the additional carbon pool in the trees and an increased soil carbon pool as a result of carbon from litter fall and root turnover. However, these figures depend upon the assumption that the harvested biomass (timber) goes to durable products, and litter/branches/ roots are not removed from the system but completely added in the soil. Still, the contribution of tree stem and roots play an important role in carbon sequestration in the agroforestry system.

Poplar based sorghum-berseem crop rotation had higher carbon storage potential than the sole crop. The sequestration was 77, 69 and 59 % higher at 5 x 4 m, 10 x 2 m and 18 x 2 x 2 m spacing of poplar than in sole agriculture, respectively. Due to less crop biomass production in cowpea- wheat crop rotation in sole crops, carbon storage under agroforestry was 111, 98 and 88 % higher at 5 x 4 m, 10 x 2 m and 18 x 2 x 2 m spacing than the sole crops, respectively. The mean rate of carbon storage in agroforestry has been found to be 82 % higher than sole agriculture. Moreover, the carbon stored in tree component is locked for a long time whereas the carbon in crops is locked for a short period only.

Effect of row direction on the performance of crops with poplar showed that poplar planted on East-West field bund affected the green fodder yield of sorghum up to 9-12 m and wheat up to 3-6 m distance from the tree line. The green fodder yield of sorghum and grain yield of wheat increased significantly with increasing distance from the tree line up to 12 m and 6 m distance respectively, and after that no significant variation in yield was recorded. The yield of sorghum was found to be significantly higher on southern aspect than the northern aspect due to availability of more sunlight on southern aspect of tree line. However aspect had no significant effect on grain yield of wheat at 12 and 6 m distance, respectively. The poplar planted on North - South field bund also affected the green fodder yield of sorghum up to 9-12 m and wheat 3-6 m distance from the tree line. The green fodder yield of sorghum and grain yield of wheat increased significantly with increasing distance from the tree line up to 12 m and 6 m respectively.

Discussion

Rabi crops like cereals are suited to partner deciduous trees. The crop grows strongly during the initial period from November to mid March, when shading is not a problem. By the time the poplars have developed foliage, the cereal crop is completing its vegetative growth and the ripening of the crop is delayed by two weeks. Kharif crops are affected by shading and competition for water of the fully leaved poplars. Distance to the trees and row direction are therefore of strong

influence on crop productivity. The study strongly reinforces poplar-crops association a better option than the sole agricultural cropping, not for carbon mitigation only but for sustainable productivity as well as profitability.

Main Results

1. After six years of plantation, poplar has been found to attain significantly more girth at 5 x 4 m and 10 x 2 m spacing's than paired row planting (18 x 2 x 2 m).
2. Sorghum and cowpea grown for fodder during the kharif season and wheat and berssem (fodder) grown during the winter season produced significantly higher yield in paired row planting than 5x4 m and 10x2 m spacing's.
3. Poplar based agroforestry system at six years age was found to sequester 82 % more carbon than sole agriculture. The rate of carbon storage was found to be 17.8 t/ha/year in poplar based agroforestry system and 9.8 t/ha/year in sole agriculture.
4. Six years old poplar planted on field bunds has been found to affect the green fodder yield of sorghum up to 12 m distance and wheat grain yield up to 6 m distance from the tree line.

Policy proposals and impacts

A methodological framework for quantification and valuation of ecosystem services of tree-based intercropping systems

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Introduction

Agricultural intensification has raised environmental concerns such as soil erosion, water pollution, and degradation of biological diversity in rural landscapes. In view of these ecological problems related to conventional agriculture, a pressing question is how to simultaneously increase agricultural production while conserving a healthy and well-functioning life support system. Recently, agroforestry has been seen as an option to work at the interface of these global challenges. Studies have shown that this land use system has the potential to maintain productivity and improve ecological functions in agricultural landscapes, while helping to mitigate climate change impacts. Despite the demonstrated contribution of agroforestry systems in producing ecological services (ES), economic analyses on non-market services, as well as on the potential trade-offs between bundles of services, are sparse. Some studies provide a general account of the role of agroforestry systems in providing ES, while others provide frameworks for cost-benefit analysis of agroforestry systems in the tropics. However, a comprehensive analytical framework for quantifying and valuing ES is missing in the context of temperate systems. In view of this research gap, a framework has been developed for the valuation of ES of a tree-based intercropping (TBI) system in southern Québec, Canada, as a case study. The framework also answers several practical questions such as the profitability of TBI systems as a long-term investment when non-market societal benefits are accounted for in benefit-cost analysis.

Methods

Ten ecosystem services were evaluated using a 4-step analytical framework. In the first step, we identified the full suite of ES which are meaningful in the context of the study area as well as in the scope of the study. For doing so, we made an inventory of all potential ES from agroforestry; then, based on consultation with expert colleagues and literature reviews, we short-listed 10

services for analysis. In the second step, we quantified the service providing units and their relationships with the provision of services. In the third step, we attempted economic valuation of each of the ES. The final step involved extrapolation of results and examination of trade-offs. The evaluated ecosystem services were: nutrient mineralization, water quality, soil quality, pollination, biological control, air quality, windbreak, timber provisioning, agriculture provisioning and climate regulation.

Results

This study provides the first estimate of economic values of ES generated by TBI systems. The values ranged from 24 CAN$ ha^{-1} y^{-1} for pollination to 785 CAN$ ha^{-1} y^{-1} for agricultural products. Water quality regulation ranked highest among the non-market services, followed by air quality regulation and carbon sequestration. Although conventional agriculture provides more private benefits than TBI, the value of ES of TBI to society is much higher compared to this private value.

The total annual margin of TBI ecosystem services was estimated to be 2.645 CAN$ ha^{-1} y^{-1}. The economic value of combined non-market services was 1.634 CAN$ ha^{-1} y^{-1}, which was higher than the value of marketable products (i.e. timber and agricultural products) combined. The economic return from agriculture in monoculture was 1.110 CAN$ ha^{-1} y^{-1}, whereas the return from agriculture in TBI was 785 CAN$ ha^{-1} y^{-1}.

We also performed an analysis of the present value of future benefits of ES for a rotation of 40 years. Provision of agricultural products ranked highest (16.287 CAN$ ha^{-1}) among the ES, followed by water quality (11.581 CAN$ ha^{-1}), air quality (9.510 CAN$ ha^{-1}), carbon sequestration (7.346 CAN$ ha^{-1}), and soil quality (3.631 CAN$ ha^{-1}). Total economic value of all the services was 54.782 CAN$ ha^{-1}, only a third of which was contributed by agricultural products. Total non-market benefits were twice as high as the provisioning services combined (i.e. timber and agriculture).

Discussion (and conclusions)

The total potential value of TBI ecosystem services estimated in this study was 5 billion dollars a year in the province of Québec. Many farmers in Canada are adopting agroforestry for farm and societal benefits. The 2006 census data reveals that in Québec alone 5.994 farms out of 30.675 reported to have windbreaks, compared to 1.845 in 2001. Such a trend in the adoption of trees in agricultural landscapes suggests that farmers could positively respond to TBI systems if they found them to be profitable. However, since the private benefits from TBI systems are less than the

societal benefits in terms of provision of ES, government programs to subsidize farmers would be necessary to entice them to adopt TBI systems rapidly. The question, however, is determining what such programs could be? Payment for ecosystem services is regarded as an effective mechanism for managing sustainable provision of these services from landscapes and watersheds. Although most successful payment programs have been implemented in developing countries, there is evidence that such mechanisms can equally work in industrialized nations.

In the current context of agro-environment programs applicable in Québec, agroforestry practices are recognized and supported as are other agricultural beneficial management practices, essentially for specific ecological functions such as stabilizing riverbanks, reducing erosion and improving habitats for biodiversity. However, agroforestry systems differ from the majority of agricultural beneficial management practices in their ability to generate income through the production of various products and services possessing tangible economic value. For this reason, adopting programs focusing on both the private profitability of agroforestry practices and their public benefits is a fundamental issue.

To summarize, despite inherent uncertainties in quantification and valuation of ecosystem services, which are non-market in nature, this study provides a reasonable estimate of the economic contribution of tree-based intercropping systems to society’s welfare. The demonstrated benefits are substantial. However, in the Québec context, the management of TBI systems still needs to be optimized in order to make it more profitable for farmers than is conventional agriculture, as already observed in Europe. The benefits of their ecosystem services are realized at the cost of farmers’ private benefits due to reduced provisioning services and the expected cost of adoption and maintenance of this new technology over a longer time frame. While it is impractical to suggest that all agricultural lands should be converted to agroforestry, a land inventory can determine the areas suitable for TBI based on environmental and technical feasibility and the willingness of the farmers in participating. Therefore, the adoption and expansion of TBI systems in Canada as well as in other parts of the world is certainly worthy of discussion in policy forums.

The role of Rural Development Policy in supporting agroforestry systems in EU

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Introduction

Agroforestry systems comprise land use practices in which woody perennials are deliberately grown on the same land management unit with crops and/or animals (Nair, 1993). These systems are traditional practices that formed key elements of European rural landscapes until modern agriculture was introduced, since trees served various purposes in the agrarian economy such as the production of fruits, fodder, wood or timber as well as environmental benefits (Eichhorn, 2006). The introduction of modern management techniques in agriculture such as new crop varieties, fertilisers, and large-scale machinery caused the transformation of traditional agroforestry practices, reducing tree components in rural landscape and producing undesirable social and environmental consequences. Recent research findings have demonstrated that agroforestry systems can play an important role in improving productivity and profitability for farmers (Graves et al., 2007) and providing environmental benefits (Palma et al., 2006). The Common Agricultural Policy (CAP) recognises that the establishment of agroforestry systems should be encouraged due to their “high ecological and social value” (EU Regulation 1698/2005). A financial support was thus introduced in the EU Rural Development Programmes (RDPs) during the 2007-2013 programming period, aiming at promoting the first establishment of new agroforestry systems on arable lands (measure 222). This financial support should be proposed again in the future RDPs, 2014-2020 (Marandola, 2013). The objectives of this paper are to: i) assess the implementation rate of the measure 222 in EU27 during the 2007-2013 programming period; ii) identify the main reasons that influenced the farmers’ interest in the measure 222; iii) highlight the perspectives and opportunities for agroforestry systems in the next RDPs 2014-2020 programming period.

Material

The data on RDPs monitoring were collected and analysed consulting the European Network for Rural Development (http://enrd.ec.europa.eu). The study was carried out comparing the financial resources allocated to implement the measure 222 with: i) the resources allocated to

implement other forestry measures; ii) the effective expenditures invested in establishing new agroforestry systems. The output indicators (number of beneficiaries and hectares under new agroforestry systems) were also analysed in relation to their expected target. Future perspectives of agroforestry systems in the next RDPs (2014-2020) were assessed through an open consultation conducted by the recently constituted European Agroforestry Federation, EURAF (http://www.agroforestry.eu) and carrying out a survey addressed to RDPs Managing Authorities.

Results

The forestry measures of the RDPs are aimed at improving the economic, social and environmental dimensions of forests to promote their sustainable management and their multifunctional role (European Commission, 2009). At EU 27 level, during the 2007-2013 programming period, a total amount of about 7.5 billion of Euro have been allocated to implement the forestry measures, of which almost 4 billion have been effectively spent at the end of 2013, with an average implementation rate of 52.4 %.

Among the forestry measures, almost 90 % of the total resources have been allocated to the measures 221 (First afforestation of agricultural land), 226 (Restoring forestry potential and introducing prevention actions) and 227 (Non-productive investments). Few EU regions and countries (table 1) have allocated resources to implement the measure 222, for a total amount of about 15 million of Euro (0.2 % of the resources allocated to all the forestry measures). More than half of the resources available to implement measures 221 and 226 have been invested. Instead, only 3.4 % of the resources allocated to the measure 222 have been effectively spent. In terms of output indicators, measure 222 reached only 2.3 % of the expected beneficiaries (farmers and land owners) and only 2.1 % of the expected hectares has been realised (table 2).

Discussion (and conclusions)

The analysis of the application of the measure 222 during the RDPs 2007-2013 programming period reveals an extremely weak implementation at EU 27 level. A limited amount of economic resources have been allocated to the measure 222 in comparison to other forestry measures. Moreover, those resources have been underutilised determining a low implementing rate. Several reasons concurred to this failure: i) the lack of knowledge and awareness of farmers, consultants and Managing Authorities concerning agroforestry; ii) the limited range of agroforestry systems that was supported by the measure (only silvoarable systems for timber or biomass production,

excluding, for example, agro-silvopastoral systems that are common in Mediterranean area); iii) the lack of funding to cover management costs of the systems; iv) the conflict between the measure 222 and other CAP instruments such as the Single Farm Payment, according to which the presence of trees reduces the amount of direct farm payments (Pisanelli et al., 2012). The EURAF conducted a lobby activity at European Parliament and through a position paper has remarked the importance to improve the next RDPs, for the period 2014-2020, to allow European farmers to adopt agroforestry systems.

It is thus expected that the above mentioned limits will be removed in the next RDPs. Article 23 of the EU Reg. 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) 2014-2020 asserts that: i) agroforestry systems comprise the combination between forestry plantations and agriculture on the same land; ii) grants should cover both the establishment costs (up to 80 % of the expenses) and the management costs with an annual premium for 5 years; iii) beneficiaries should be not limited to farmers but may include also Municipalities and Associations.

Table 1: resources allocated to the measure 222 and realised expenditures at country level during the RDPs 2007-2013 programming period.

Country	**Regions**	**Allocated resources** ***in 000€***	**Financial execution** ***in 000€***	**Implementation rate** ***In %***
Belgium	Flanders	500	0	0
France	Guadeloupe, Guyane	3.228	39	1.2
Hungary		2.813	380	13.5
Italy	Marche, Lazio, Umbria, Veneto, Sicilia	1.300	10	0.8
Portugal	Mainland, Azores	6.804	93	1.4
Spain	Aragón, Asturias, Canarias, Extremadura, Galicia	411	0	0
Total EU27		**15.056**	**522**	**3.4**

The delegated acts, which are being finalized between the Commission, the Council and the Parliament, will decide the practical details in the implementation of the EU Reg. 1305/2013. However, it seems that the new grant scheme should be more attractive for farmers and, consequently, it is expected that the adoption of agroforestry systems should increase at EU level. This would beneficial to target crucial rural development priorities such as: i) restoring, preserving

and enhancing ecosystem services, ii) promoting efficiency resource use, iii) supporting the shift towards a low carbon and climate resilient economy in agricultural and forestry sectors.

Table 2: output indicators assessing the implementation rate of the measure 222 during the RDPs 2007-2013 programming period.

	Beneficiaries (n)			Area (ha)		
Country	**Target**	**Realised**	**Implementation rate**	**Target**	**Realised**	**Implementation rate**
Belgium	75	0	0	250	0	0
France	610	4	0.7	3.032	34	1.1
Hungary	300	59	19.7	3.000	594	19.8
Italy	1.032	1	0.1	6.729	9	0.1
Portugal	575	0	0	15.025	0	0
Spain	205	0	0	1.600	0	0
Total EU27	**2.797**	**64**	**2.3**	**29.636**	**637**	**2.1**

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Towards a joint strategy for Iberian oak agroforestry systems: acknowledging the value of dehesas and montados

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The Iberian working oak woodlands (*dehesas* in Spain and *montados* in Portugal) are biodiversity-rich, savanna-like extensive grazing systems. They are considered as outstanding High Nature Value (HNV) farming systems and the most extensive agroforestry system in Europe according to CORINE Land Cover. Dehesas extend over 3.5 million hectares in Spain, mainly covered by holm oak (*Quercus ilex*) and devoted to livestock raising, while montados occupy 1 million hectares where cork extracted from cork oak (*Q. suber*) is the main product. Both dehesas and montados are, however, examples of multipurpose systems in which a variety of land uses coexists in a landscape mosaic within farms ranging in size from 100 to 10000 hectares.

Large-scale analysis of Iberian oak agroforestry territories has shown a trend towards intensification in the more productive sites and abandonment in marginal lands. Intensification results in tree regeneration failure and soil erosion, whereas marginalization enhances shrub encroachment. Although reduced landscape heterogeneity in both cases seems to result in lower species richness, shrub encroachment, which is a common trend in protected areas or big game states, is important for a number of endangered species. As an additional threat, oak decline due to root pathogens and water stress is severely reducing tree cover on many farms.

Economic analyses of dehesas and montados show moderate to low profitability of most farms, with a high dependence on public subsidies from the CAP at least in the Spanish case. To date, intensive management practices have been used to increase short-term profitability. Thus, stocking rates have dramatically increased in dehesas at the expense of tree regeneration. Similarly, cork production in most montados requires intensive shrub control, a practice that reduces regeneration and provokes soil erosion. Therefore, profitability is often achieved at the expense of environmental sustainability.

In the last few years increased awareness of the profitability-sustainability dilemma, has led stakeholders and researchers from both countries to develop joint initiatives. Firstly, a comprehensive technical report has been produced in each country. In addition, an Iberian condensed report has been delivered to establish the main challenges shared by both agroforestry systems: (1) to increase the social and political awareness of the economic and environmental importance of dehesas and montados; (2) to create two coordinated national institutes integrating research and development efforts; (3) to ask for national and EU policies focussed on the whole agroforestry system rather than on particular components; and (4) to improve marketing strategies and certification of environmentally friendly products.

Policy measures should consider these priorities in an integrated way. The main decisions are now made at national level, in the Portuguese case, and at the regional level, in the Spanish. There should therefore be room for specific schemes considering the specific land use systems in each country/region. The EU Rural Development Programme regulations give priority to HNV farming systems, especially within the so-called agri-environmental measures, but these measures need to be implemented on a much larger scale in dehesa and montado territories and they will only work if supported by pro-active and expert advisory systems. Current efforts to address these needs in a transnational network through co-operation projects between both countries are presented and discussed.

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Agroforestry in the French Green and Blue Corridors policy: towards promotion of trees?

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Introduction

In order to stop the biodiversity loss, France launched a national strategy in 2004. It was followed by the Grenelle Environment Forum, in October 2007, to determine policy guidelines for sustainable development. The environmental legal measures were completed by the Green and Blue Corridors (GBC) laws.

This conservation and land planning policy tool is a response to landscape fragmentation and loss of biodiversity 1/ by participating in the preservation, management and rehabilitation of the ecological networks, and 2/ by taking into account human activities - including agriculture - in rural areas.

This became a grid of reading for the environmental policy of the State and territorial collectivities. Agroforestry trees can be at the same time markers of the landscapes and essential components of the ecological corridors. But is GBC really a way to promote agroforestry?

Material

This paper focuses on the analyse of a corpus of 163 French official documents regarding the Green and Blue Corridors implementation at different geographical scales, from national to local levels. Using QDA Miner and Wordstat programs a categorization dictionary has been made out of those documents. Then terms related to agroforestry systems were extracted (fig.1) and analyzed.

Fig 1: Cluster of French words showing terms associated with the tree components of the landscapes, issued from a corpus of 163 official documents.

Results

France has different traditional agroforestry systems, such as meadow orchards and wooded meadows, and even trees mixed with vineyards called "hautains". But hedgerows remain the most common traditional landscape structure based on trees outside forests. Modern forms of agroforestry, such as alley cropping are also emerging

and expanding in the last decade. In the case of the Green & Blue Corridor they all create a real network potential associated with the riparian areas.

Nevertheless agroforestry systems and the tree components remain little mentioned in the official documents in spite of their capacity to provide environmental services in the landscapes, as expected by the GBC. For example the word “tree” (*arbre*) appears in 56 % of the total number of documents, “hedgerow” (*haie*) in 68 %, and (*bocage*) in 42 %. But the word “agroforestry” (*agroforesterie*) is very little employed, appearing in only less than 10 % of the corpus documents, and with different meanings.

Discussion and conclusions

The implementation of the French Green & Blue Corridor is a complex and long process which can promote agroforestry systems and practices by valuing their potential in terms of eco-systemic services. But this process can also challenge their development at the local level due to the lack of clarity in the definition of the terms used, possibly introducing confusion for the local stakeholders.

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Environmental benefits provided by agroforestry

Variable-width Buffers to Reduce Sediment Pollution from Potato Production on Steep Slopes: Analysis of Black Brook Watershed using AgBufferBuilder

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Introduction

Intensive agricultural production employs tillage, fertilizers and pesticides to obtain profitable yields. Intensive row crop production leaves soil vulnerable to erosion by water, carrying sediment, nutrients and pesticides into surface waters. Riparian buffer zones mitigate water pollution by trapping sediments, absorbing nutrients, and degrading pesticides. Many provinces in Canada have mandatory setbacks of fixed-width to be maintained between cropped land and waterways. Fixed-width buffers are easy to apply and regulate and are most effective where runoff is uniformly distributed through the entire buffer area. However, runoff flow is often not uniform, diverging from subtle ridges and concentrating into swales, reducing the effectiveness of fixed-width buffers. Effectiveness can be boosted by making the buffer relatively wider where loads are greater, creating variable-width buffer. AgBufferBuilder is a GIS-based tool that evaluates terrain, accounts for non-uniform runoff, and assists decision-making about where to place buffers to provide the greatest environmental mitigation at less cost. New Brunswick's Black Brook Watershed, a 1.450-ha model watershed that has been studied for more than 15 years provided a context to evaluate AgBufferBuilder. The watershed is in New Brunswick's "Potato Belt" and is characterized by rolling topography, with slopes generally 2-9 %, but in some cases greater than 15 %. Potatoes are cultivated on these slopes with no mandatory rotation requirement. Average precipitation is 1.134 mm, with local flash storm events in summer contributing to marked soil sediment erosion.

The objective of the study was to use the **AgBufferBuilder 1.0 extension** (through the ArcGIS 10.0 platform) to evaluate New Brunswick's Black Brook Watershed (BBW) and determine the sediment trapping efficiency of existing vegetative buffers, and the trapping efficiency of model-derived vegetative buffers.

Materials and Methods

The input data for the BBW study area was imported into ArcGIS 10.0 and re-projected in NAD1983 (New Brunswick Double Stereographic) to ensure data integrity during analysis. The AgBufferBuilder 1.0 extension (University of Kentucky, 2014) was loaded into the ArcMap project and using the AgBufferBuilder toolbar, each weir sub-basin was delineated under the Field Margin dataset. Each of the weir sub-basin's existing buffers (including forested zones, diversion waterways, and terraces) was delineated under the Buffer Assessment dataset. A 2011 Land Use Map was selected as a baseline for delineating the current buffers because these records provide a better representation of field boundaries than the 1 m-resolution orthophoto. Four user-defined parameters are used to develop the Model-Derived Buffers: type of pollutant, soil texture of surface soil layer, Universal Soil Loss Equation (USLE) C-Factor and trapping efficiency. Sediment was selected as the parameter for the type of pollutant. The soil texture parameter was set to Class I – Medium textured materials; the soils associated with the BBW range from Sandy Loam to Silty Loam. The USLE C-Factor parameter represented plow tillage after corn or chisel after soybeans (0.50). The trapping efficiency of the model-derived buffers was set to 75 %.

The data analysis results consisted of two raster datasets: a Current Buffers raster and a Model-Derived Buffer raster. The Current Buffers raster includes the buffers that were identified in the Area of Interest (AOI) with the trapping efficiency value, and the Model-Derived Buffers raster identifies buffer locations that provide the user-identified trapping efficiency.

Results

AgBufferBuilder was used to examine crop fields, as well as sub-basins in Black Brook Watershed. The software was used to estimate the sediment trapping efficiency of existing buffers and to propose alternative placements that would trap 75 % (user-defined efficiency threshold) of sediments leaving these fields. Field-by-field analysis revealed examples where existing buffers were ineffective. In one field, buffers were just 9 % effective; AgBufferBuilder suggested a design that used less area to obtain 47 % mitigation. Examination of sub-basins (derived during hydrological modelling in another project) of the Black Brook Watershed showed that in one sub-basin, the existing buffers occupied 12 ha, but delivered just 2 % efficiency, while an AgBufferBuilder scenario with a user-defined efficiency of 75 % suggested preserving a small area of an existing forested buffer zone and planting some small additional buffers for a total buffer area of just 8 ha. Conversely, in another sub-basin, existing buffers were assessed at 21 ha at 26 % efficiency, and the AgBufferBuilder scenario to achieve 75 % efficiency would require 42 ha. In

some cases, overlap between the existing buffers and the proposed buffers was significant, meaning that to achieve the 75 % efficiency only a small amount of planting would be required, and other areas might be removed from buffer and cropped to result in no net cropland loss to growers. In other cases, the existing and proposed buffers had little overlap. Analysing the entire watershed as a whole proved too difficult because the data set proved too large for the computer system to process. Mosaicking the individual sub-basin outputs resulted in AgBufferBuilder scenarios that seemed counter-intuitive at certain locations, and led to a more detailed analysis of the two of the smallest weir sub-basins both separately and together. In both cases a similar area was suggested, but in each case, the suggested placement was different.

Discussion

In the Black Brook Watershed and other parts of New Brunswick's Potato Belt, soil erosion is extreme, reaching 20 tonnes/ha annually (AAFC, 2012). Best Management Practices have been implemented on about 50 % of the watershed's agricultural land, primarily diversion terraces and grassed waterways, which involve re-shaping the land. Additional work is being done to address issues of maintaining sediment in fields for soil health, but preventing sediment and accompanying agrochemicals from reaching surface waters continues to be of grave concern. Vegetative buffer strips appear to be one solution. AgBufferBuilder, developed as a research tool in the US mid-west, may be adaptable to New Brunswick's Potato Belt, and this study was a first look at using the tool there. A 75 % efficiency at preventing sediment from entering surface waters represents a reduction in sediment pollution by as much as 15 tonnes/ha annually.

The US mid-west context differs drastically from the New Brunswick context. In the former, farm sizes are extremely large, and topography is more even. In New Brunswick, farm size is small. Slopes come together in such a way that multiple landowners work potato fields with runoff converging at low points, sometimes at some distance from the land they own. Potato farming is competetive and even now, many farms lack adequate land for rotation, so giving up productive land for buffer plantings is unpopular, particularly since no program exists to assist growers with planning or planting buffers. This work shows that AgBufferBuilder could be used by a skilled land use planner working with growers in a particular region to assess existing buffers, and prepare a landscape plan which could then be used to inform public policy and program support for variable-width buffer implementation. However, significant steps need to be taken before AgBufferBuilder can be reccomended. The model must be field-validated. Recent efforts have begun in the US to

use results from on-going experiments to validate the model. In New Brunswick, it may be possible through a future project to validate the model using data collected in the Black Brook Watershed project. An important additional aspect will be to look for ways to incorporate sediment pollution data that has been collected over the past 15 years in order to priorize plantings. At the moment, AgBufferBuilder can assess the efficiency of existing buffers and aid in the planning of buffers required to reach a theoretical efficiency. From an economic standpoint, it is imperative to know where achieving that theoretical efficiency through buffer planting will result in the greatest reduction in sediment pollution. Applying model efficiency values to estimates of erosion rates can produce estimates of reduction in sediment yield. Decision-making can also include assigning different levels of efficiency within AgBufferBuilder to suit the needs of the users.

Conclusions

The numbers computed in this study point to possible economic advantage for farmers who could plant for greater efficacy at less cost. Analysis of the watershed's sub-basins revealed advantages to using AgBufferBuilder in planning buffers at a local landscape level rather than field by field. Use of the AgBufferBuilder tool can potentially increase the cost-effectiveness of buffer installations and programs for improving water quality in New Brunswick.

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SCA0PEST, a pesticide-free agroforestry cropping system: ex-ante performance evaluation

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Introduction

From mid 2000, in order to address global challenges, European member states' strategies for agriculture have progressively identified and given priority to the set up of a multi-functional farm model. In France, first reflection officially started in 2007 through the Grenelle de l'Environnement initiative from which several priority themes were identified, and dedicated measures approved. Concerning agriculture, four different objectives were selected: (a) the deployment of organic farming up to 20 % of the utilized agricultural area by 2020, (b) the Ecophyto plan for a 50 % reduction of the pesticides use, (c) the enforcement of the High Nature Value (HNV) certification scheme and the certification of at least 50 % of the French farms by 2012, and (d) the energetic diagnosis of at least 100.000 farms every 5 years within the farms' energetic performances (PPE) plan.

If most of the quantified objectives have not been reached by 2014, coming into force of these measures actually goes on and represents a real opportunity for research organisms to participate to both food security and socio-environmental sustainability by the design, test and deployment of new Productive and Efficient Cropping Systems (PECS). Conversely to the majority of the PECS tested within the EXPE Dephy Ecophyto program, some have been imagined to go further the sole re-conquest of water quality by reducing drastically, or even renouncing chemical pesticides. They actually target (i) the reduction of the farm carbon footprint by reducing and/or mitigating GHG emission, (ii) the improvement of local ecological connectivity by contributing to the establishment of new biocorridors and (iii) the financial sustainability of the experimental farms.

Among the forty-one EXPE projects funded in 2012 and 2013, only one is testing and monitoring a pesticide-free agroforestry cropping system: SCA0PEST. It aims to: run an experts' panel conceptualization of the SCA0PEST cropping system by considering locally the actual and future market outlets, the hosting parcel and farmhouse agrotechnical potential, and local epidemiologic pressures; to deploy and conduce in farm conditions the cropping system; assess

global and thematic performances of it; and favour the disclosure of the obtained knowledge and references towards farmers, advisers and agricultural students.

Material

Following the STEPHY methodology (Attoumani-Ronceux, et al., 2011), an experts' panel (n=12) grouping innovative farmers, agricultural advisers, agronomists and researchers worked iteratively during 6 months to the experts' opinion-based design of the SCA0PEST PECS by respecting principles of integrated pest & weed management (Agro-PEPS, 2011). The result was a new and innovative agroforestry PECS for which every single agricultural practice and decision rule are detailed for each one of the 8 crops of the rotation [Alfalfa – alfalfa - winter wheat – oil seed rape – spring barley – field bean – winter wheat – (alfalfa + sunflower)] and related intermediate crops.

By September 2013, the SCA0PEST PECS was then set up within a 34 ha and 5-years old alley cropping agroforestry matrix (N49°28'21'', E2°03'55''). Each year, 6 over the 8 components of the crop rotation are present on a 0.5ha acreage each and are separated by standard trees lines distant of 28 m each other, presenting a mean stand density of 60 trees ha^{-1}.

Basic experimental and agronomic follow up are then organized yearly according to the Rés0pest project experimental standards (Cellier et al., 2014). They are mainly dedicated to the measurement of the crops health status, the spatiotemporal assessment of weeds and pests pressures, and their consequences on yields and harvested supplies quality. In parallel, supplementary protocols are annually conducted in order to estimate the carbon sequestration potential of the agroforestry matrix (Yield-sAFe, Talbot et al., 2014) and to demonstrate the biological control potential of agroforestery by scrutinizing weeds' communities influence on aphids-aphids parasitoids relationships (Brewer and Elliott, 2004). Finally, ex-ante and continuous economic, environmental and social assessments of its performances are performed against a conventional cropping system as reference [Oilseed rape – winter wheat – winter barley].

Results

These results presented concern the sole ex-ante assessment of the performances of both the reference conventional and the SCA0PEST systems.

Depending on raw products sale prices, energy and fertilizers costs, SCA0PEST ex-ante assessment provided limited economic prevision, as direct margin would decrease from 140 up to 250 €/ha (Fig. 1a) when compared to the reference cropping system. This financial loss is mainly due to yield losses, less frequent cash crop revenues and additional costs for seeds. Conversely, environmental performance would be improved as annual GHG emissions from the arable compartment fall down to 1.140 kg eq.CO_2/ha/year (Fig. 1b) meaning 48 % of the reference system with pesticides.

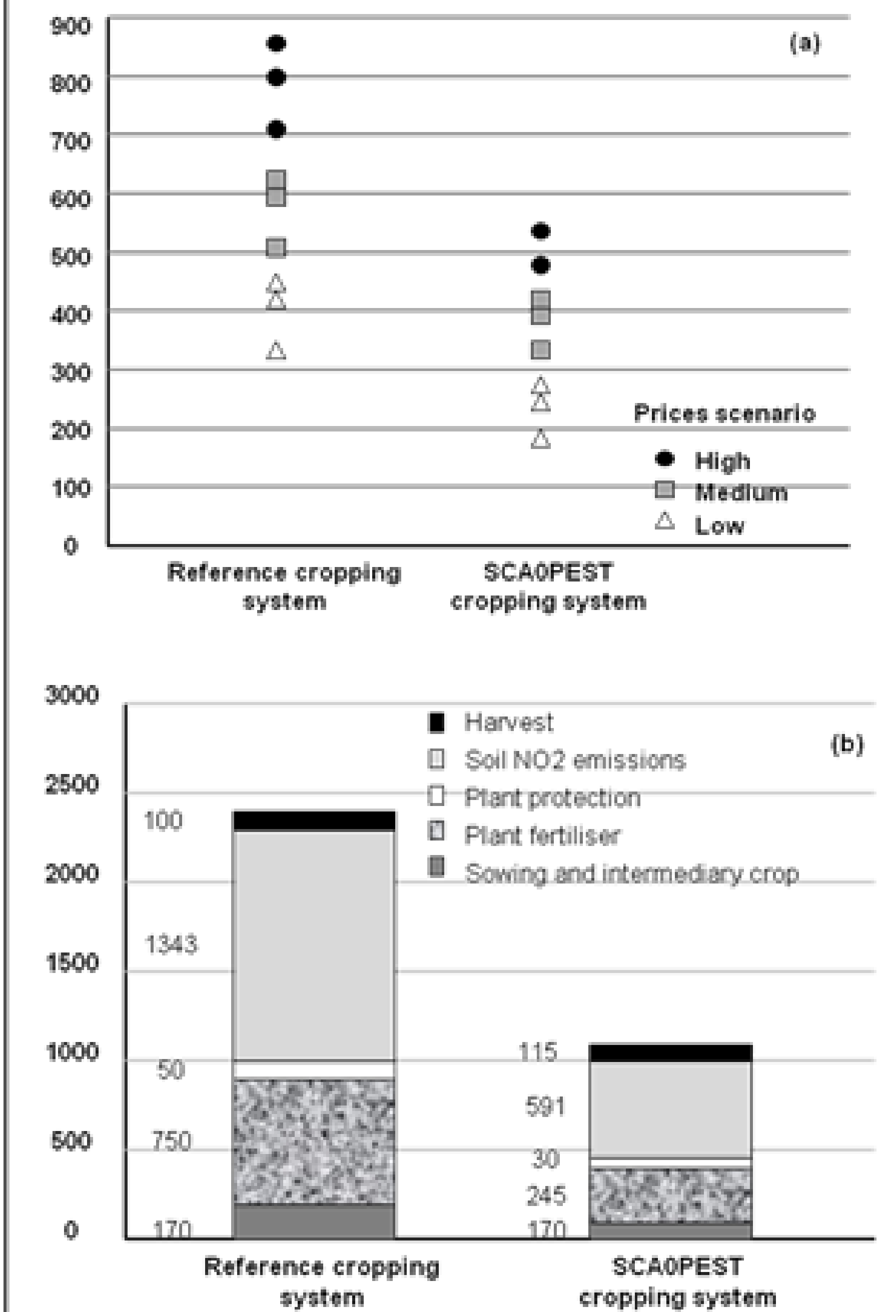

Fig 1 : (a) Financial balance as direct margin (€/ha/year) using the Stephy tools and (b) GHG emissions quantification (eq. kg CO_2/ha/year) using the eGES tools for both the reference conventional and the SCA0PEST cropping.

Discussion and conclusions

If considered as a whole, previous financial and environmental results tend to disadvantage the SCA0PEST system. Fortunately, inclusion of a 2-years alfalfa production (9t/ha/year) within the rotation could provide a supplementary 150-230€/ha indirect gain when incorporated at 25% within the dairy cows ration of the hosting farm (IDELE,

2011), offsetting part of the predicted financial losses. Moreover, despite the fact that farmers cannot expect environmental payements for CO_2 emission reduction yet, a mean estimation of 650 eq. $KgCO_2$/ha/year (Yield-sAFe model, results not shown) for the annual carbon sequestration by the standard trees lines suggest that the SCA0PEST PECS should at least perform financially as well as the conventional reference system and demonstrate of a quasi-null carbon footprint of the system.

Additionally, other agriecological benefits such as enhanced biologiocal control of pests or yield increase due to microclimate improvement (e.g. through water availability increase) would be later expected and could enhance SCA0PEST performances. On the other hand, weeds and pests could be out of control in the next future or local climate change could result in drier springs; then, these local modifications could endanger the expected yeilds and related financial and environmental performances of the system.

Today, after the first year of the trial, uncertainty is too important to precisely figure out the potential of such a system. And even if SCA0PEST is promising, further diagnosis and future assessments would have to confirm the performances of this innovative free-pesticide agroforestry cropping system.

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Do agroforestry systems promote a thriving nightlife? Assessing bat activity with an easy to use standardized protocol

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Introduction

Increasing competition for land by different users is a great challenge. Agroforestry (AF) is said to satisfy both agricultural and conservation demands, and can benefit many species. However bats, although highly relevant for conservation and as bioindicators (Jones et. al. 2009), are rarely assessed. This may be due their nocturnal activity and the large effort and knowledge required. Nevertheless, agroforestry systems could have a twofold positive effect on bat populations. Firstly bats use these habitats for preying upon nocturnal insects. Secondly bats need linear landscape structures for orientation during their movement at night. Knowledge about the use of agroforestry systems by bats is thus crucial to design efficient conservation measures targeted at this species group. Here we present a new method for rapid assessment of bat activity. Results are used to evaluate whether and how agroforestry systems can be used as conservation measures.

Material

Bat activity was analyzed at Scheyern Research Station located in the Bavarian tertiary hills in southern Germany. Two organically managed fields with seven crops in rotation (winter wheat and winter barley in 2013) and two integrated managed fields with four crops in rotation (winter wheat and maize in 2013) were transformed to agroforestry systems in 2009. Thus four short-rotation coppice systems, each comprising of three 8.25 m wide tree strips, were planted. Each strip consists of three double rows of different trees. The first harvest was in winter 2013. We used simple heterodyne detectors (CSE bat detector) and a standardized protocol to record bat activity on presence/absence basis within 15 second intervals for a total of 20 minutes per plot. On ten dates during summer 2013 activity was recorded after sunset in eight randomly ordered plots. Four habitat types (AF-organic, AF-integrated, grass strip and hedgerow) were sampled with two plots each. To validate the simplified method bat calls were recorded and analyzed in more detail using a batcorder 3.0 system (ecoObs GmbH). Data were analyzed using a generalized linear mixed modeling (GLMM) approach.

Results

Bat activity was low in agricultural habitats but increased with age and height of semi-natural structures present (Fig. 2). Landscape diversity had a positive effect on bat activity. Activity was lowest in a plot on a grass strip between two large arable fields and highest in a plot with trees and a small waterway beneath. Plots on agroforestry fields showed an intermediate level of bat activity. There was no visable difference bewteen organic and conventional managed fields. Although agroforestry strips were harvested in winter they were used by the bats for commuting and hunting. The detailed analysis detected species from the Myotini, Nyctaloid and Pipistrelloid group. Bat activity patterns were similar with both methods (Fig. 1).

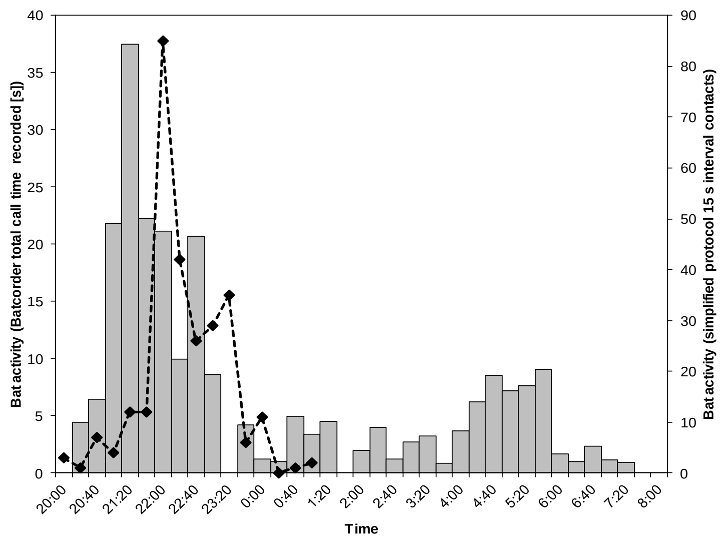

Fig 1: Course of nightly bat activity recorded with a batcorder (grey bars) in comparison with results obtained with the simplified protocol (dotted line). Assessments with simplified protocols were only conducted during the first half of the night.

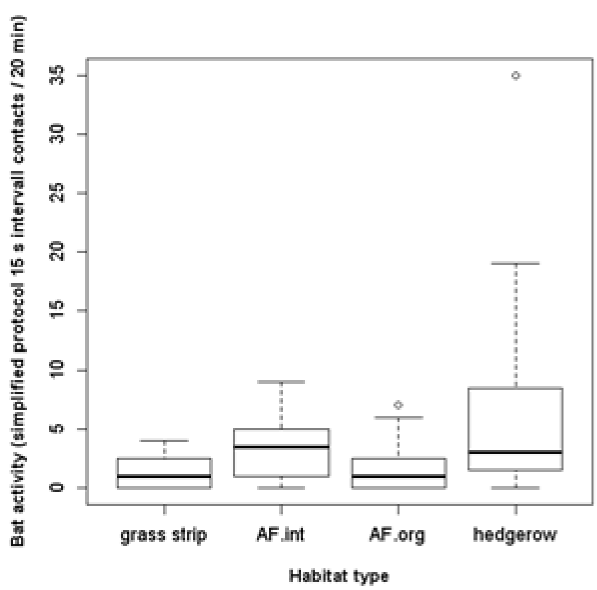

Fig 2: Boxplots for bat activity in different habitat types assessed with the simplified protocol.

Discussion and conclusions

Intensive agriculture poses a considerable threat to bat populations and therefore new farming approaches such as organic agriculture are needed to mitigate adverse effects (Wickramasinghe et. al. 2003). If used by bats as foraging and commuting structure, agroforestry systems could be an important component in conservation strategies for bats in agricultural dominated landscapes. This study shows that bats are active in agroforestry systems and do fly along the tree strips, even shortly after harvest.

Our results are thus in line with previous findings on bats and woody linear landscape elements by other authors (Boughey et al. 2011, Downs et al. 2006, Frey-Ehrenbold et al. 2013, Fuentes-Montemayor et al. 2013). Linear landscape elements with shrubs and trees are important habitats for bats in agricultural dominated areas. Agroforestry systems offer such structures and can provide biomass for bio-energy. They are therefore appropriate as a conservation measure on both arable and grassland. However, requirements of other species important for nature conservation need to be considered.

We conclude that the new simplified protocol is suitable for rapid and cost efficient assessment of bat activity. Furthermore, results suggest that agroforestry can be recommended as conservation measure to improve agricultural habitats for bats. To optimize agroforestry systems from a bat's perspective it should be considered to leave some of the tree strips for later harvest to ensure continuous connectivity.

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The Spatial Distribution and Functioning of invertebrates in Organic Agroforestry Systems

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The inability to use inorganic fertilizer and crop protection products in organic systems increases the requirement to optimize sustainable approaches to crop production and pest control through ecosystem services provided by crop-associated biodiversity (Eyre and Leifert, 2011). Maximizing beneficial invertebrate predator and parasite activity is a priority in a farming system using no artificial pesticides (Gurr et al., 2003). Some groups are predators whose feeding activity may be important for regulation of the abundance of other groups, including plant feeders and potential crop pests. Ground beetles (*Carabidae spp.*) and spiders (*Araneae spp.*) are two major groups of predatory natural enemies.

Semi-natural habitats surrounding agriculture fields may be manipulated in ways that benefit predatory invertebrates by providing alternative food sources, overwintering sites, and refuge from farming activities. Ecological theory predicts that complex plant communities should support a richer community of natural enemies of pest insects than a simple plant community (Varchola and Dunn, 2000). For example, silvoarable agroforestry consists of alleys of arable crops separated by rows of trees.

In this study, we investigate the spatial and temporal variation in species richness, activity-density and distribution of generalist predators and their pests, including ground beetles (*Coleoptera: Carabidae spp.*), Spiders (*Arachnida: Araneae spp.*) and hoverflies (*Diptera*: *Syrphidae spp.*) in organic silvoarable agroforestry in two sites; Sheepdrove and Whitehall Farms, UK. The samples were taken twice a month from May to August. Coloured pan traps and pitfall traps are used to attract and catch insects distributed across spring barley crop growing in the alleys.

The results showed that predator diversity and abundance were higher in and near the tree strips and declined towards the centre of the crop alley. In addition higher abundance and diversity of natural enemies is predicted in the agroforestry alley crops than in pure barley monoculture.

Agroforestry for land reclamation

Modeling of agroforestry in Natura 2000 habitat site in Hungary

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Introduction

The regional growth of arable land has had a significant effect on European landuse in the last decades, and this has radically reduced the coverage of natural forest. However, this caused conflicts of interest between the agricultural and forestry sectors. The agroforestry landuse could be a solution to the conflict, resulting in a compromise of ecologically mixed landuse. The European policy makers have discussed the planning steps of agroforestry, and similarly Hungary also aims to involve 4-600.000 hectares of agroforestry systems, partly converted from arable land, partly as new afforestation. The Hungarian national stock of forest area is 1,9 million hectares, of which 12 % is located in agricultural lowland areas. The Great Hungarian Plain has got less favourable soil conditions (salinization, extreme water management, soil structural degradation) which means there are limited opportunities for conventional agricultural production. Therefore these areas have been typically utilized for grazing and forests for hundreds of years. Real problems are that network function is partly missing without connecting ecological green corridors. In the introduction of an agroforestry landuse system, this is a key consideration.

In this Hortobágyi National Park case study we made a Spatial Decision Support System (SDSS) to construct an agroforestry model. The aim of model building was to ensure the continuity of ecological green corridors and to maintain the appropriate landuse of regional importance. The investigation tool was the more widely used airborne LiDAR (Light Detection And Ranging) remote sensing technology which can provide appropriate data acquisition and data processing tools to build a decision support system.

We concluded that in the case of appropriate decision criteria our model proved to be a success to determining suitable areas for forestation and to ensure the continuity of ecological green corridors. Furthermore we concluded that the opportunities provided by remote sensing technology can be used to help verify the agroforestry payment system.

Material

The study area of the model was carried out in part of Hortobágy (site code: HUHN10002) NATURA 2000 site. It covers about 830 hectares and is located near Püspökladány in the North Great Hungarian Plain. The main landuse classifications are saline grassland, wetlands and forest (Tóth, 2001).

The applied Spatial Decision Supporting System used two types of criteria: constraints and factors. Constraints are those logical criteria that limit our analysis, so 1 or 0 Boolean logical value is added to each investigated decision factors. In our case, this logical value was ideal to distinguish landuse areas, that could be suitable or unsuitable for forestation under any condition. Factors are criteria that define some degree of suitability for all geographic regions. In our case we could define the effectively forested areas depending on certain boundary conditions for forestation. Furthermore, the opportunity of efficiency of forestation was determined by a semi-automatic cost-distance software built-in algorithm. The current landuse classes were segmented based on air and satellite photos. The most important factors were digital elevation and related hydrological process. Till now the water accumulation process on flat Hortobágy lowland, cannot be characterised.

The airborne laser scanning (LiDAR) of this area was carried out within the framework of the ChangeHabitats2 project to eliminate this problem. An important aim was to evaluate the advantages the novel Airborne laser scanning (LiDAR) technology provided for habitat mapping, biodiversity monitoring, environmental and nature conservation in NATURA 2000 habitat sites. LIDAR is an optical surveying technology for obtaining detailed information about the land surface. Results of the survey generate a point cloud consisting of millions of points (Wagner, 2007). Our airborne survey contains more than 700 million laser points in 14 flight range distributions 12.86 point/m2 point density.

DEM (Digital Elevation Model) and runoff models of study areas were created from the LIDAR point cloud by Tarboton algorithm. To derive the topographic features a hydrologically correct DEM is created by filling sinks, using the D-infinity (D∞) flow model. The D∞ flow model (Tarboton, 1997) a flow formalism that calculates the contributing area to derive a wide range of flow related quantities useful for hydrological and environmental modelling.

Results

The first step was set up conceptual model. The unsuitable areas such as existing forested areas, water courses and lakes, roads/dirt roads, canals, built up areas etc were selected. The fine scale DEM was made to exclude salt impacted areas where extreme soil conditions occurred. The runoff model was created by micro-morphological analysis. The D∞ algorithm used the filling sinks operation which resulted in a continuous stream line flow model (Fig 1).

Fig 1: Runoff model of the study area

Between the investigated parameters of micro relief and hydrological conditions, strong correlations were found. We concluded that the potential forested areas can be located between from 123 to 137 mBf vertical ranges with good water supply conditions. It means that unsuitable areas for forestation could be found in saline grasslands, wetlands, but could be as the continuity of existing forest.

Our results were completed by the evaluation of the cost-distance algorithm. Based on the algorithm, it was established that the potential forestation areas linked with the existing forests, provide the most cost-effective manner of plantation.

Discussion and conclusions

The development of agroforestry systems can cause conflicts of interest between the agricultural and forestry sectors. Agroforestry could be a solution to the conflict management which means a compromise with ecologically mixed landuse resulting.

The development of such systems requires a multi-factorial planning task. Depending on the type of agroforestry, we need to take into consideration all interests e.g. agriculture, ecology, environmental and nature conservation, forestry policy and proximity to regional and geographical features of national importance. Harmonization of these factors can be solved with a spatial decision support system (SDSS).

In our study we tried to create the basics of an agroforestry site selection model which can be used generally. The aim was to raise the extension of forest, as a part of a potential agroforestry system. Our study area was selected in the North Great Hungarian Plain near Püspökladány, in part of Hortobágy (site code: HUHN10002) NATURA 2000 site. In the SDSS the decision criteria (constrains and factors) were defined and as a result we obtained the potential areas suitable for forestation. Near the geographical features of the area we had to consider the directives of Natura2000 and Green corridors as ecological networks. Accordingly, we searched those areas, where the forestation allows the continuity of green corridors, and does not appear as ecological stepping stones.

The accuracy and speed of field measurement was increasingly helped by the airborne LiDAR data sources, which is a more widely used remote sensing technology inter alia in habitat mapping, environmental and nature conservation. However, during the evaluation, we thought that the remote sensing technology can be used to support verification of agroforestry payment systems. The control of the payment system is generally a problem both at national and international levels.

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Small ruminants as a fire management tool in a Mediterranean mountain region

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Introduction

Forests represent a key-resource for the Mediterranean region and have supplied wood and non-wood products for centuries. Socioeconomic transformations that have been taking place for the last one hundred years convert forestlands into time bomb able of blowing up every summer. Actually, Southern Europe has in last years experienced dramatic changes in the fire regime because of changes of land use. Further alterations toward more severe fire events are expected with the prospect of a warmer and drier future. Portugal has adopted some policy regulations to protect the forest, including a national strategy for forests and a national defense plan against forest fires. Despite improvements in fire statistics, Portugal failed to achieve the goals it had set itself. Political options privilege fire suppression, even though land and forest management issues are at the core of the wildfire problem. Agroforestry systems can be used as a forest fire prevention technique, since they implement a fuel management network at different scales of landscape. Particularly, silvopastoral systems (SSP) are especially interesting as a fuel management tool and reducing fire risks. The objective of this study was to compare the diet of goats and sheep in a SSP namely *mosaic of different land uses within one management unit* (Etienne, 1996).

Material

The experiment was carried out in Morais region, NE of Portugal (Nature network, 2000). It is one of the most representative serpentine areas of Portugal. Extensive livestock production is a key activity in this region. Forestland use occupies about 68 % of the territory (ICN, 2006) and it is comprised by semi-natural grasslands and scrublands (about 43 % of the surface), and woodlands (about 25 % of the forest land use). The herds of goats and sheep, guided by a shepherd, set out for pasture every day. For the purpose of the present study three herds of goats (*Serrana* breed), and three herds of sheep (*Churra Terra Quente* breed) were followed. To evaluate diet composition and goats and sheep selectivity (herbaceous, shrub and tree), a method of visual observation was used (Altmann, 1974). Animal activity and grazed species were checked each 15 minutes (instantly recorded). Field observations were made in September (autumn) 2010, January (winter), April (spring), and July (summer) 2011. During summer, when temperatures were very high, herds of

sheep were monitored at night. Grazing itineraries of each herd were recorded by GPS (one day per season). Data GPS comprise time, geographical position and land cover of 24 herd itineraries (4 by herds). Diet composition was estimated by the ratio between the number of animals in each vegetal plant and the total of animals in feed activity. Diet selection was estimated by the preference index of Krueger (Krueger, 1972). It is described as the ratio of the percent of a species in the diet to the percent on the study area: $RP_i = \Sigma_{k=1,n} (D_{ik}/RA_{ik})/n$, where P_i is the mean preference ratio over *n* areas; D_i is the percent of species *i* in the diet, and RA_i is the percent of species *i* in the area. This model is easy to interpret in terms of whether an animal is for or against a species. Values greater than 1 indicate preference, while values less than 1 indicate avoidance. Preference index was calculated in goats and sheep in each sampling season (spring, summer, autumn and winter). With ANOVA analysis we tested the effect of herds (sheep or goats) and season (autumn, winter, spring or summer) on diet diversity. Logarithmic transformations and the Bonferroni test were used to detect any significant differences ($P<0.05$). The statistical software package SYSTAT 12 was used for all analyses.

Results

Herbaceous ingestion in goats and sheep tended to increase in spring, although not significantly, compared to the other grazing seasons (Table 1). The presence of tree species in the diet of goats and sheep increased significantly in autumn compared to the other seasons ($P < 0.05$). Shrubs ingestion tended to increase during summer and winter compared to autumn, in goats; and decreased in autumn compared to winter, in sheep.

	Goats			Sheep		
	Herbaceous	Shrub	Tree	Herbaceous	Shrub	Tree
Autumn	49	16	35a	80	1	19a
Winter	42	37	21bc	78	11	11b
Spring	69	21	10c	94	6	0.2c
Summer	38	33	30b	83	6	11b

Table 1. Percentage of herbaceous, shrubs and tree in the diet of goats and sheep in autumn, winter, spring and summer. Different letters indicate significant differences between seasons in the same vegetation type.

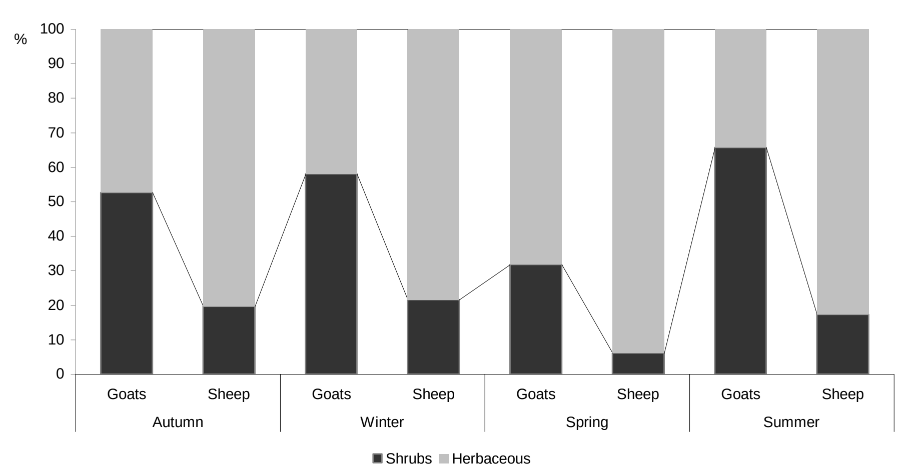

Fig. 1 Percentage of herbaceous species and shrubs in goats and sheep diet in each season

Goats' diet composition had higher content of shrubs species than that of sheep along the year while; sheep had a higher content of herbaceous species in their diet (Fig. 1). The presence of shrubs decreased in the diet of both animals during the spring. Finally, the individual preference of the animals being studied by some shrubs species presents in the area can be seen in Fig. 2. *Erica spp.* (Er) in sheep and *Rubus* sp. (Ru) in goats were the shrubs with the highest preference index (both species in summer). Goats showed a higher preference for *Genista hystrix* (Gh), *Erica* spp (Er) and *Cistus ladanifer* (Ci) except in spring. On the other hand, some species such as *Cytisus multiflorus (Cm)*, *Lavandula pendulata* (Lv) (autumn), and *Cistus ladanifer* (Ci) (summer) were avoided by both animals.

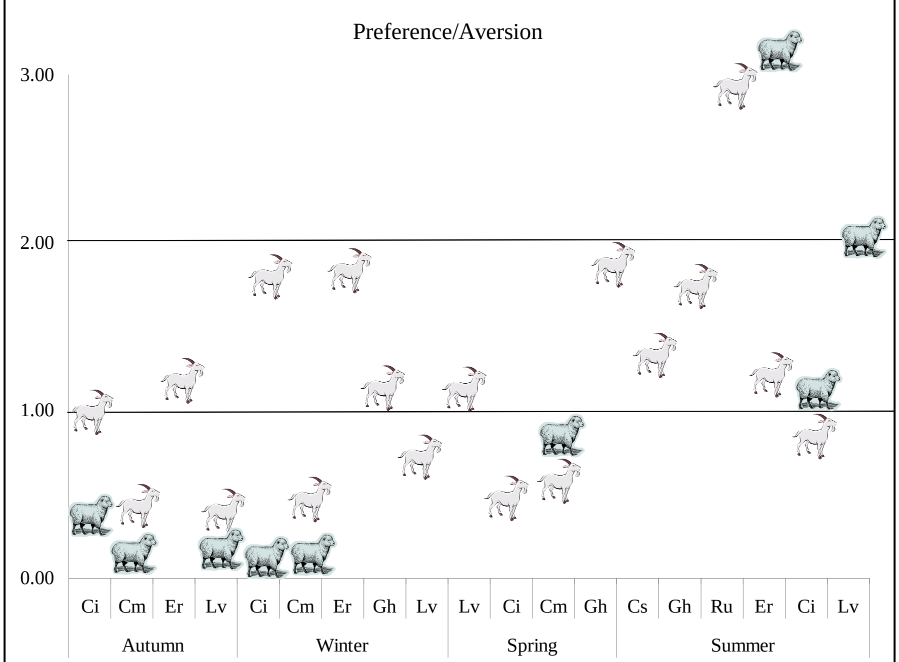

Fig 2. Preference / aversion by goats and sheep for shrubs species in each season. Ci: *Cistus ladanifer*, Cm: *Cytisus multiflorus*, Er: *Erica* sp., Lv: *Lavandula pendulata*, Gh: *Genista hystrix*, Cs: *Cytisus scoparius*, Ru: *Rubus* sp.

Discussion

Goats and sheep showed a different pattern of consumption between themselves and also between seasons. Goats have the highest consumption of trees and shrubs (ligneous) resources while sheep showed the highest value for herbaceous resources. The higher preference for trees and shrubs shown by goats compared to sheep has also been observed in many studies (Celaya et al., 2007). In contrast, herbaceous species are utilized more intensively by sheep than by goats. In the present study, the differences between them may increase during summer where the percentage of herbaceous species in sheep diets was 55 % higher than in goats. In addition, goats showed a typical behaviour of opportunistic feeder, since in winter and summer they consume a greater quantity of ligneous species than herbaceous while; in spring they select more herbaceous species due to their high quality. Nevertheless, sheep showed a preferential consumption to select

herbaceous species along seasons (more than of 75 % of its diet were herbaceous species) and mainly in spring as happened with goats. Then, results obtained in this study confirmed a behaviour *mixed feeder type* for goats and a *grazer type* for sheep in this kind of grazing system.

As is known, sheep and goats vary in the preference, tolerance, and ability to graze lands with different features (Animut and Goetsch, 2008). In the SSP studied, sheep are mainly important to maintain landscape mosaic, by trampling over there. Goats have a decisive function in a shrubby consumption of scrublands and forests. In mountain areas of North Portugal, sheep graze in lands near the urban core, where the meadows and forage cultures are more abundant, while goats use preferentially the most remote areas of the village where the woodlands are most abundant (Castro et al., 2004). Also, the results obtained in this work suggest a seasonal effect on the utilisation ability of ligneous vegetation by goats as a consequence of modifications in its nutritive value according to the time of the year. This variation on preference for some plant species with grazing season should be taken into account when designing management practices in forestry areas.

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Celtic Pig production in Chestnut extensive systems in Galicia

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Introduction

Celtic pig or "Porco celta" is an autochthonous pig breed of Galicia (ASOPORCEL, 2014). The high quality of its meat makes it of interest for farming in chestnut stands. Grazing by this breed on the understory vegetation increases bare soil and reduces the proportion of ferns when stocking rate is high (Santiago-Freijanes et al. 2011). Pigs also caused more damage to oak than to chestnut when old and young trees are analyzed (Santiago-Freijanes et al 2011). The objective of this experiment was to study the effect of Celtic pig breeds on soil parameters under different types of understory vegetation after one year of grazing with a high stocking rate.

Material

The experiment was established in Goo (Lugo, Galicia, Northwestern Spain) in 2010 in a mature stand of *Castanea sativa* L. used in the past to obtain firewood and later abandoned. Pigs from the Galician celtic authocthonous breed were allowed to graze the understory in 2010. Understory included *Rubus* spp., erica and ferns compared with open adjacent areas dominated by gorse (*Ulex europaeus* and *Ulex galli)*. Before and after the animal left the plot, randomized soil samples were taken at 25 cm intervals to a depth of 1 m in each type of vegetation cover. Soils were sieved and the main cations (Na, K, Ca, Mg and Al) extracted in Cl_2Ba (Mosquera and Mombiela, 1986) (Monterroso et al. 1999) were determined, with the exception of Na in Mehlich 3. Cation exchange capacity (CEC) was estimated by summing up Na, K, Ca, Mg and Al extracted in Cl_2Ba. Mehlich 3 extraction was also used to determine the level of Cr, Cu, Ni, Zn, Mn and Fe. Principal component analysis (PCA) was carried out for a multivariant analysis using SAS (2001).

Results

The proportion of the accumulated variance explained by the PCA with two factors was over 80% (Figure 1). The first factor was positively correlated with the saturation percentage of Mg (0.94), K (0.94), and also with the levels of Mg (0.8) extracted with $BaCl_2$ and the levels of K (0.73), Cu (0.74), Zn (0.9) and Ni (0.81) extracted in Mehlich 3, but negatively related with the percentage of saturation of Ca (-0.7). The second component was positively related with the percentage of Al (0.69) and Ca (0.79) extracted in $BaCl_2$ and the levels of Ca (0.9) and Mg (0.86) extracted in Mehlich 3 as well as with the cation exchange capacity (0.95), but, negatively with the levels of K (-

0.76) and Na (-0.89). Scores from these two factors clearly separate both years of study (Figure 1), having the second lower levels of Factor 1 and higher levels of Factor 2 compared with the first year. This fact is indicative of soil changes caused by grazing and makes advisable to perform a separate CPA analysis.

While in the first year of the experiment soil Rubus understory have higher scores of Factor 1 and lower of Factor 2 than the rest of the understory covers, no clear effects were shown after grazing. Rubus soils have high levels of Ca but low of Al, Na and K in the first year, but differences dissapiared in the second.

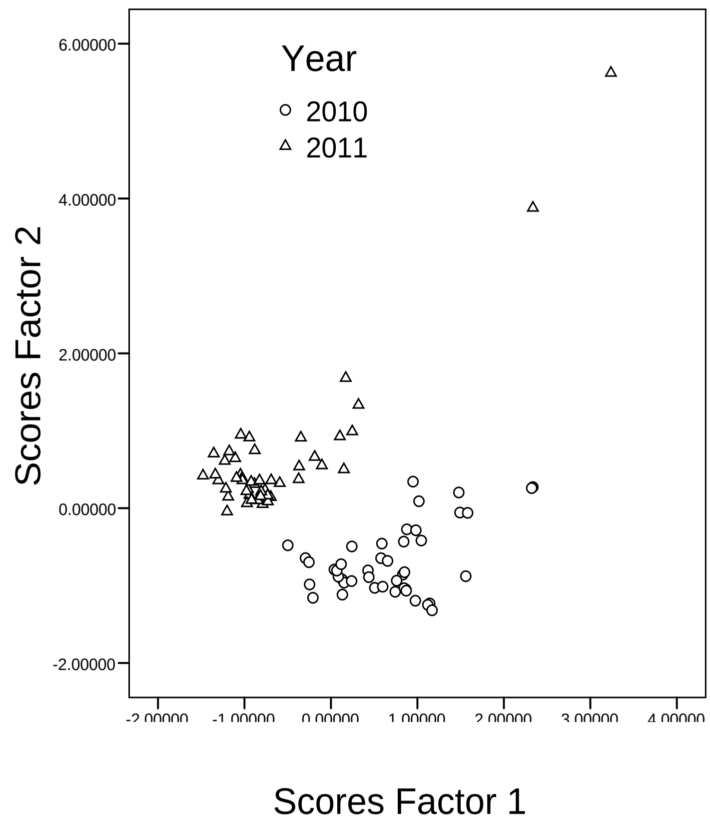

Figure 1. Scores of factors for both years of study.

Discussion

Tree understory and open vegetation cover affect soil cation composition. Low soil Ca has been already associated with high levels of erica, like that found in this study as understory in tree areas (Zas and Alonso, 2002). The high stocking rate used in this experiment, as animals are fed with chestnut fruits and understory vegetation, caused an increase in the proportion of bare soil (Santiago-Freijanes et al., 2011) and reduced differences between the cation concentrations in soils occupied by different types of vegetation. Experiments comparing different stocking rates with pigs in oaklands shown that the levels of Ca are reduced as consequence of high stocking rate and bare soil (caused by clearing before grazing) (Rigueiro-Rodríguez et al., 2011). High stocking rates reduced vegetation proportion in chesnut forest affecting soil chemical parameters by increasing mineralization rate in soil, probably due to the increase of bare soil and faeces depostion.

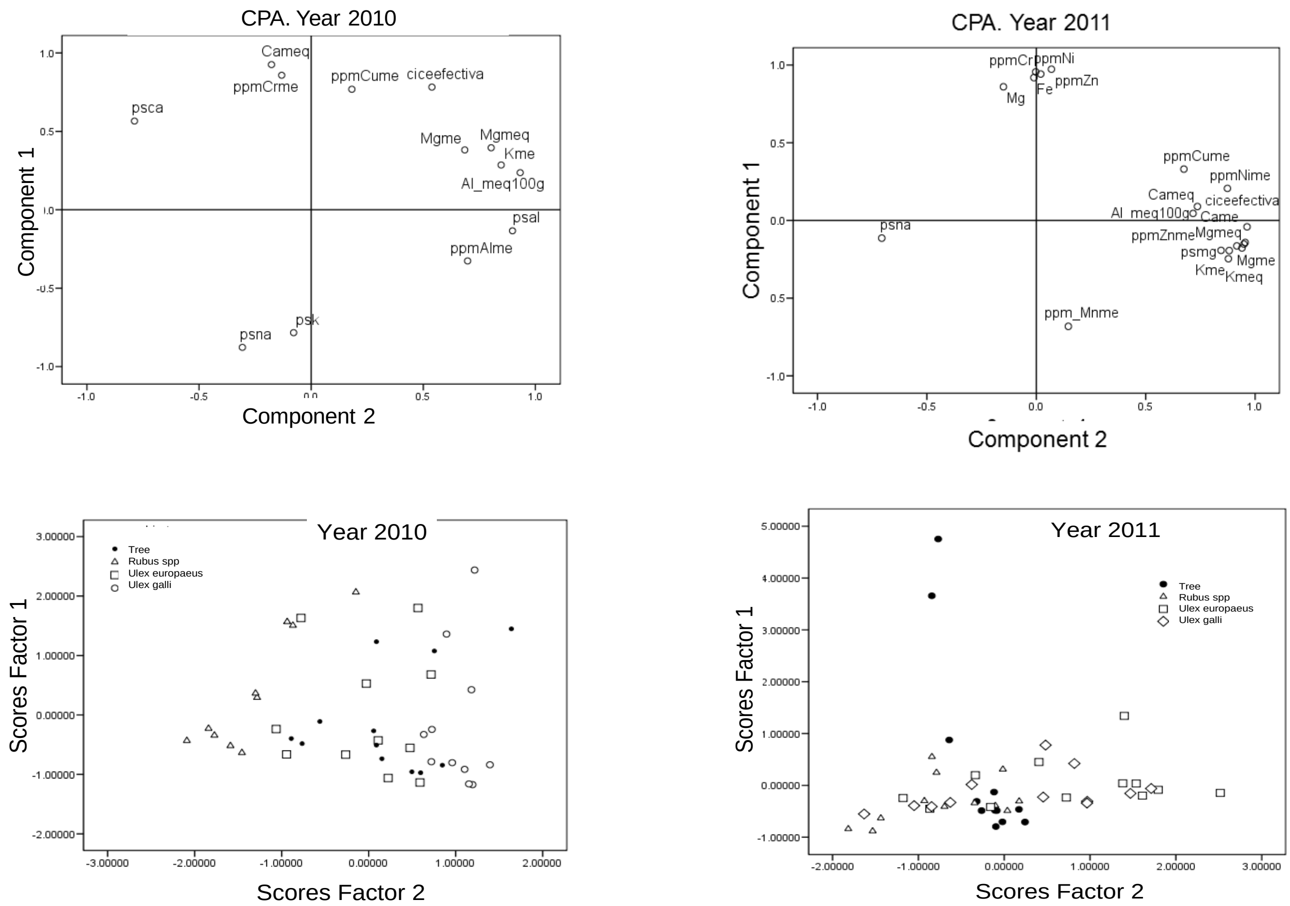

Figure 2. Principal Component Analysis (CPA) of soil analysis before (2010) and after grazing (2011) and score punctuations based on CPA. Ps: percentage of saturiation; ppm: mg per kg; cicefectiva: CEC; me: Melich3; meq 100grs: concentrations of cations in soils extracted with Ba_2Cl.

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Alley Cropping – A promising multifunctional form of land use for reclaimed lignite mining sites in Germany

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Introduction

Since the 1920s, more than 80.000 ha of land have been affected by lignite opencast mining activities in the Lusatia region (Eastern Germany), resulting in the evolution of large post-mining landscapes with substrates poor in humus and nutrients. As a consequence, the current conventional crop production on these post-mining areas is restricted. Against this background, the increasing demand for woody biomass for bioenergy, and thus the cultivation of fast growing trees for woody biomass production, could represent a promising option to enhance the productivity of land reclaimed from mining. Accordingly, considerable research has been carried out over the last two decades on reclamation technology, in addition to attempts to improve the soil quality through the use of different fast growing tree species in the Lusatia lignite region. Through such studies, it has been shown that it is possible to cultivate a sustainable supply of bioenergy wood through the use of black locust (*Robinia pseudoacacia* L.) trees, even under the unfavourable growth conditions of the marginal post mining areas. Since this knowledge is mainly based on studies of monocultural plantations (SRC), in 2007 a short rotation alley cropping system (SRACS) was established in the reclaimed lignite mining site “Welzow-Süd” with the purpose of obtaining fresh insight. The present paper evaluates the positive impacts of agroforestry land-use in terms of soil fertility, agricultural crop production, and soil protection against wind erosion based on the results of several years of examination made in this degraded area.

Material

Investigations were carried out at a reclaimed site of the lignite opencast mine Welzow-Süd (51.621161°N, 14.326766°E), in Germany, about 150 km southeast of Berlin. The study area is characterised by an average annual precipitation sum of 560 mm and a mean annual temperature of 9.3 °C (1951-2003, meteorological station Cottbus). Generally, the whole research area is typified by deep groundwater, with the nearest source being at a depth of approximately 40m, and dominated by humus- and nutrient-poor, sand-dominated dump substrates. The establishment of

the alley cropping system in Welzow-Süd occurred in spring 2007 using one-year-old, bare-rooted seedlings of black locust planted in north-south directed hedgerows with a width of 11 m among 24 m width arable stripes. Alfalfa (*Medicago sativa* L.) was cultivated on these crop alleys during the first four years. Crop rotation was continued with spring barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.) and winter rye (*Secale cereal* L.). Wind velocity data was collected by means of four anemometers (A100R, Vector Instruments), which were installed on a 24 m width crop alley with varying distances to the tree stripes and on an nearby open field. The aboveground biomass yields within the hedgerows and on the crop alleys were sampled completely on three times eight plots of 1 m x 1 m each summer, beginning in 2008. All of these sampling plots were arranged at different distances from the hedgerow on the west, east and the centre side of the 24 m width arable stripe. Additionally, soil samples were taken each year in spring on plots located in the centre, east and west side of crop alleys as well as within the hedgerows from a depth of 0 - 30 cm. These soil samples were analysed for different chemical soil parameters such as hot water extractable carbon (HWC) and nitrogen (HWN), which are defined as the labile fractions of the organic carbon or nitrogen in soil.

Results

Black locust hedgerows were able to reduce the wind speed on crop alleys significantly and thereby provide enhanced protection against soil erosion on frequently exposed soil in the state of Brandenburg. As a result, average wind velocity at the centre of the 24 m width crop alley was reduced by up to 30 % in relation to the nearby open field, while tree height was not more than a few metres. In addition, the cultivation of woody crops led to higher C and N accumulation rates in soil under short rotation trees when compared to the centre of the field alleys. In fact, despite comparable starting conditions, the hot water extractable carbon (HWC) content rose by almost 50 % under black locust trees (including litter layer) within the first four years of the investigation period, while the increase was approximately 8 % (west), 23 % (centre) or 17 % (east) within the arable stripes, respectively. Meanwhile, hot water extractable nitrogen (HWN) content increased strongly under tree hedgerows (including litter layer) by almost 470 %, whereas increases of approximately 365 % (west), 368 % (centre) and 162 % (east), respectively, were also determined. This suggests that black locust trees were able to accelerate the increase of the labile humus fraction rapidly. Finally, those crops growing in the peripheral areas of the arable stripes benefited

from the hedgerows within the investigation period, as biomass yield were up to 39 % higher than those in the centre of the crop alleys.

Discussion and Conclusions

These findings suggest that SRACS can contribute significantly to environmental benefits such as wind velocity reduction, enhanced soil fertility and intercrop productivity. In addition, the combination of crop and woody biomass production provides a reliable opportunity for local farmers to improve the ecology of the site whilst providing a possibility to meet the growing demand for wood. Thus SRACS is a meaningful multifunctional form of land use that can contribute to the successful rehabilitation and agricultural reuse of marginal sites in post-mining areas.

Acknowledgements

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Innovative solutions for sustainable agriculture with agroforestry

Alley coppice: an innovative land use system - options of system design with experimental evidence

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Introduction

Population growth, the intensification of land use, and the concurrent destruction of natural resources has led to a predominantly scientific recognition that the earth's natural systems supporting life have their limits (Brundtland, 1987). This has led to the identification and establishment of new socially and environmentally acceptable alternative land use systems. Agroforestry and short rotation coppice (SRC), for timber and bioenergy wood production, are two such systems. Both are recognized as economically viable as separate cropping systems under ideal growing conditions. Little is known about agricultural and ecological interactions which might occur combining them in a tree-based intercropping system. This mixed approach, called alley coppice (AC) (Morhart et al., 2014), is currently investigated in a European research Project (www.agrocop.com), and has important potential advantages including: i) a regular income guaranteed from the SRC component; ii) a land equivalent ratio (LER) potentially greater than 1; iii) improved stem form of timber trees due to light competition between the species; vi) reduced costs because timber trees can be planted at final spacing, avoiding expensive thinning; v) reduced wind/storm damage to young timber trees because the SRC component protects young timber trees; vi) positive impacts on biodiversity, and reduced soil erosion. The aim of this paper is to present the preliminary results obtained in experimental plots that have been established to study the interactions between timber and poplar SRC trees in two sites, one in Italy with simultaneous planting (SP) of both tree components; and one in France, with lagged planting (LP) of SRC under adult timber trees.

Materials and method

The SP experimental field, with a total area of 1.5 ha, was established by CRA-PLF in 2007 near Casale M. (45°08'11" N; 8° 30" 50" E, 102 m a.s.l.), northern Italy, on a flat agricultural field with alluvial soil. The climate of the area, according to Köppen-Greiger world climate classification, is warm, temperate, fully humid, with hot/warm summers. The soil texture is sandy and sandy loam. Experimental plots were established for comparing pure plantations of *Sorbus domestica L.* and

Pyrus spp. (3 clones) with a mixture of the same trees and poplar clones under biennial SRC management in an AC system, using a randomized block design with two replications. The distance between the noble hardwood trees and the poplar SRC is 3 m. Since the establishment year, tree growth and yield have been recorded. In 2013, during the 7th year of growth, light competition effects of SRC on the timber trees was studied using hemispherical photos, and stem form of timber trees was assessed using a non-destructive method of evaluating wood quality (index Q) (see Paris et al., 2014).The LP site is situated in Southern France (43° 43' 07' 'N; 3° 54'29'' E). It has a total area of 1.5 ha. The climate of the area is temperate, Mediterranean with dry and hot summers (Köppen-G.). The soil is alluvial; its texture is loamy clay sand. Hybrid walnut (*Juglans regia x nigra L.*) timber trees were planted in 1995, in an alley cropping system design at a 13 m x 4 m spacing. Since then optimized intercrops were studied *i.e* winter cereals to optimize resources use complementarity. Then in 2012, poplar *Monviso* cuttings were planted in double rows between the 18 year old timber tree lines at 2 m from them. A SRC control without timber was also planted. A randomized block design with three replicates was used. Tree growth, yields, understory illumination, and poplar water status (via mid-day and pre-dawn leaf water potential, Ψ_{md} and Ψ_{pd}, respectively) conditions were studied during the year 2013. Here we present results from the first coppice cycle. An analysis of variance (ANOVA) was made using biennial poplar yield as the independent variable. Treatments tested were: the AC system with LP (pure SRC *vs.* SRC between old timbers), the sun exposure of SRC rows from the timber tree line (North, South), and the distance from timber tree line.

Results

In Figure 1, the growth rates in total stem height (H) for the tree species during the first seven years since plantation establishment are reported. Poplar SRC was managed with a biennial coppicing rotation, therefore its H values reflect the cyclical re-growth after coppicing in years 3, 5 and 7. The timber tree species had a continuous growth pattern, reaching a total H at the end of the seventh growing season of 4.1 and 3.8 m for pure *Sorbus* and *Pyrus* respectively, while the same species reached an H of 3.4 and 3.6 m, respectively, in the AC mixture. The analysis of variance (ANOVA) did not show significant difference between the treatments on timber tree H within the seven year. Hemispherical photos taken along timber tree rows, at the end of April of the seventh growing season, showed a ca. 35 % reduction in the total light transmittance for timber trees in the AC treatment early in the growing season, before full leaf expansion of the poplars. The

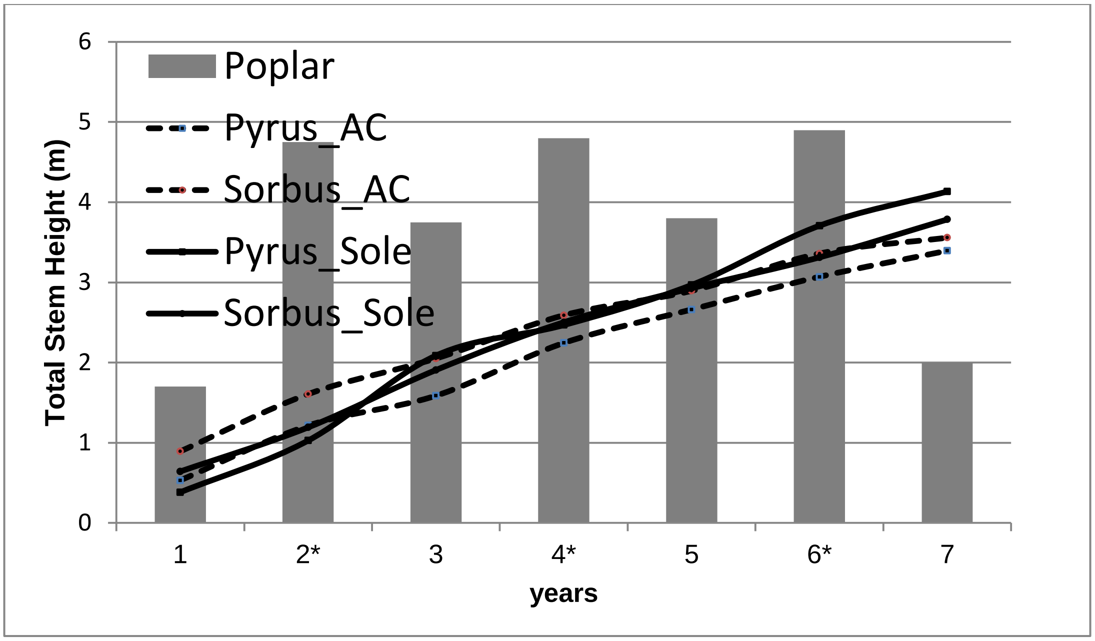

Fig 1: Total height of timber trees and poplar SRC for the first 7 years since establishment, in Casale M, Italy. SRC harvestings were conducted at the end of 2nd, 4th, 6th years. AlleyCop= mixture of timber trees with poplar SRC; Sole= pure timber tree.

light competition of SRC poplar shoots positively affected the wood quality of the timber trees in the AC treatment as these had a higher Q (3.7; $p>0.05$, Friedman's Test) in comparison to pure system timber trees (Q=2). For the LP site in France, the first coppicing rotation gave a very low yield both in the pure system and in AC, 1 and 0.3 Mg dry matter/ha/year, respectively. In AC, SRC yield loss was more than 40 % when compared to pure SRC (Fig. 2). The SRC yield was significantly affected by timber competition on the south side of the timber tree line when compared to the north side of the timber tree line. There was also a strong competition gradient from the timber tree line to the center of the intercrop alley. Yield difference was significant between 2 and 6 m. A significantly higher water stress on poplar was measured in the presence of timber trees, with water stress on poplar shoots increasing the closer they were to the walnut row. However this competition for water was mitigated by the microclimatic effect of timber trees. Indeed we observed a protection effect by walnut shade on SRC, by measuring differences between Ψ_{md} and Ψ_{pd} in control and AC. This may explain the yield difference between north and south SRC exposure.

Discussion and conclusions

The preliminary results presented in this paper for the SP site in Italy show that the hypothesized beneficial effects of AC can be achieved through a balanced mixture of slow growing timber trees and fast growing poplar trees under SRC. After seven growing seasons, the timber

trees in the AC treatment reached satisfactory stem dimensions, in association with improved stem form and wood quality in comparison to pure timber system. We used a distance of 3 m between the timber trees and poplar rows. This distance seems to leave enough room for the timber trees to grow without strong, detrimental competition effects from the adjacent poplar trees. We detected light competition effects of poplar shoots on the timber trees, but so far this has not been so intensive as to inhibit the growth of *Sorbus* and *Pyrus* trees. For the LP in France, the first coppicing cycle resulted in very low yields. However the SRC is not yet well established (2 years from planting), and faced a severe drought during the first growing season. Our data show that in LP, the competition for light and water from the 18 year old walnut trees had strong negative effects on the SRC. This result will be compared to the Irish experimental site which has the same conditions for LP, but without drought. Unlike results for SP, LP presents strong competition drawbacks for SRC yield. Co-planting seems to enhance complementarity for resources acquisition and use. It may be due partly to under-ground optimized co-development. In AC, preliminary benefits on timber wood quality and on SRC micro-climate have been observed. These benefits have to be further explored for system optimization.

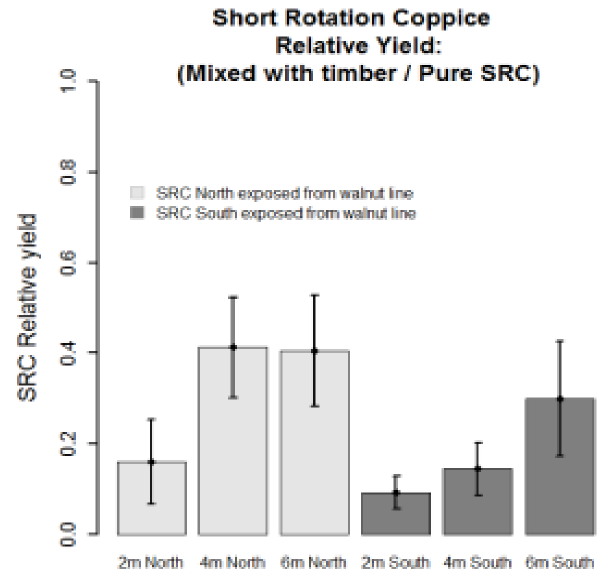

Fig 2: Relative SRC yields (AC / pure SRC) depending on sun exposure and distance from timber tree line

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Holistic agroforestry system in practice. Just an idea or is there a living model?

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Introduction

In the last decades there has been a tendency to classify agroforestry systems to help focus on particular aspects of different practices with specific objectives. However, in practice, the management of land use at farm scale can have a wide range of options and decisions to be made at operational level following a certain strategy.

Farmers can adopt certain agroforestry practices to suit and enhance their business as usual. What if agroforestry is considered the central key for the farming system and the business as usual is built under the "agroforestry concept umbrella" to produce different farming activities?

Within the EU project "Agroforestry that will advance rural development" (AGFORWARD 2014-2017) a participatory approach is engaging land managers to share experiences and innovations while raising bottom-up questions that could envision focused scientific research to users' needs.

In this context we introduce a holistic agroforestry business model that runs in practice in Herdade do Freixo do Meio (HFM).

Results

The farm is about 100 km east of Lisbon, having 423 ha running a business which strategy is based on sustainability concepts. There are three pillars in the current sustainable management model: Deepening, Widening and Repositioning. The first one focus on a) diversification of income, b) organic agriculture, c) extensive production practices, d) autochthonous species and their certification, e) on-farm added value to products. The Widening strategy focus on f) recreational and environmental education, g) participation in research h) enabling visiting activities, i) organizing thematic pathways, j) eco-camping, k) catering and l) environmental services. The Repositioning strategy focus on m) energy production, n) organizing on-farm events and m) host "your nursery" projects (Auriault 2012). The farm has the social responsibility of employing about 20 local people.

The cornerstone in the management strategy is the improvement of the soil quality as this is considered vital to surrounding around 300 satellite products and services coming from the farm.

Trees under the Montado agroforestry system are vital in the management as they provide services such as improvement of soil organic matter, soil water management, fungus and bacteria hosting, erosion regulator, animal shelter, fodder, ecological niches, direct non wood forest products (e.g. cork, acorns) and indirect (e.g. mushrooms, honey), hunting services, aesthetic value and cultural heritage.

The results of the implemented strategy for more than twenty years are now visible and the farm is being recognized as a hotspot for a multitude of disciplines becoming a live example of what a farm could be in its sustainability plenitude, a concept usually seen only in theoretical literature.

Discussion

According to the recent established EU project AGFORWARD, agroforestry systems can be roughly focused in four types: 1) High Natural and Conservation Value, 2) High value tree systems, 3) Silvoarable systems and 4) Silvopastoral systems. Throughout the above brief description of HFM farm, it is not possible to frame HFM in a singular type due to its holistic management embracing all “types of agroforestry”.

The AGFORWARD project is embracing the farm to be studied under a High Natural and Conservation Value system, but the farm is also a unique opportunity to improve existing farm-scale agroforestry models (e.g. Graves et al 2011) as it helps to understand the interactions between products and services of agroforestry systems in a multifunctional concept, a goal envisaged in the project under field and farm evaluation.

The complexity of interactions between the market and non-market values often leads to study limited specific relationships due to the difficulty of trying to “understand everything”. However such stratification into simple relationships hampers the vision of the “big picture” that provides externalities still undervalued in terms of farming land use. Two examples:

1) Currently the farm employs 20 local people. If these people were unemployed (high probability given the region characteristics), all tax payers would have to support unemployment costs. Would this social responsibility be accounted when designing EU payments to farmers?

2) Discussions about low pricing of food are common. The discussion frequently ends in intensification and optimization of monocultures to provide more products and low price under the “closed box” of micro-economy models. But is the price we pay being calculated correctly under current market rules? Far from frequent are conclusive discussions of the medium-long term costs

of negative externalities of farming practices. The environmental costs are becoming more evident up to a certain scale in certain specific studies, but the “bubble” of indirect costs is far from being clearly understood. Some studies already provide consistent relationships between more frequent diseases to the ingestion of pesticides and antibiotics in the food chain. The costs of such relationships in the health system, and consequently in the social system, seem to “fly by” the discussion of intensive “low price” food. We may be actually paying more than the “unreal price” we see in the supermarkets.

Mixing trees in cropland opens a whole range of benefits reported in numerous scientific literature. One of the main concerns of the farmer is the reduction of yield of the crop component, which was found in some cases that either this effect has low impact or is economically compensated with the tree products income at later stages (Graves et al, 2007). But research still needs to test and evaluate the impact of trees on the reduction of external inputs compared to an intensive system. Trees have a multitude of functions that could reduce the need of artificial fertilizer, pesticide application, or animal pest control by acting as a regulator with natural predators, or simply strengthening animal welfare becoming more resistant to diseases. Although still at micro scale, such relationships are important to provide confidence to the farmer to implement an agroforestry system.

Not every farmer might have the opportunity to develop such complexity as we find in HFM. In one hand, the farmer own will has to prevail to his concept of sustainability while constantly being “invited” to easier and more profitable intensive farming activities under common agricultural policy. In the other hand, the farmer has to resist to large initial investments which, in this case, was partially supported by other holdings of the same farmer. Nowadays, the farm is economically self-sustained but still undervalued comparing to what could be an intensive and monospecific agricultural practices. In the case of HFM, the concept prevailed at the cost of the farmer. An analysis to the development process of the farm could be a basis to estimate the financial support to establish agroforestry systems when promoting these kind of sustainable farming practices, while a comparison to an hypothetical monocropping system could establish a relationship towards a fairer equity when payments are to be considered.

According to the farmer, “*if I would do conventional farming practices, I would increase my income by almost double. This is due to the current payment scheme biased towards intensive agriculture*”. This was partially studied in Palma et al (2007), and a more comprehensive evaluation

is being strengthened through the improvement and validation of models, where innovative farms, such as HFM, are of high importance.

Acknowledgements

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The Economics of Woodland Eggs in the UK

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Introduction

Annually around 11.5 billion eggs are consumed in the United Kingdom with a retail value of about £990 million. In 2013, the UK market was dominated by colony or “enriched” eggs (51 %) and free-range eggs (44 %). European Commission Regulation 589/2008 Annex II specifies minimum conditions for “free-range” egg production such as providing the hens with access to open space and a maximum density of 2.500 hens per hectare.

The study focuses on the economics of woodland eggs. At a minimum, woodland egg systems follow the standards for free-range production. The UK Woodland Trust, which adds its logo to the woodland eggs sold by Sainsbury’s plc (a major UK retailer), specifies 20 % cover in the free range area with some trees within a 20 m distance from the shed. In 2013, the Woodland Trust reported the sale of about 400 million woodland eggs through Sainsbury’s, equivalent to about 3.4 % of the UK market. Other retailers also sell woodland eggs.

Method

The benefits and costs of woodland eggs were determined from the perspective of a farmer who manages a grassland free-range system with a flock of 2000 hens over one hectare, and who sells eggs to a packer. It was assumed that each hen produces 280 eggs per year. A cost-benefit model was developed using a Microsoft Excel spreadsheet, and we assumed a discount rate of 8 % (Yates et al, 2006). The spreadsheet model included the costs and benefits of i) the poultry component, ii) the tree component, and iii) grazing cattle. The results for including grazing cattle are not presented in this paper. The key changes considered in the poultry component include a price premium from packers, the effect of the trees on mortality and feather pecking, the level of “seconds”, and egg loss. These are covered in turn.

Price premium: during April 2014, three retailers in the UK (Sainsbury’s, Morrisons and Aldi) were selling eggs that specifically indicated that the hens had access to woodland. The retail price of six medium Class A “woodland eggs” varied from £1.19 to £1.59, with a price premium over “non-woodland” free-range eggs of about 15-20 pence (£0.15-0.20) per six eggs. Based on a existing UK survey (Defra, 2011), 75 % of respondents identified animal welfare as a reason for buying free-range eggs, and we assumed that this is likely to be the principal reason for consumers

paying a premium for woodland eggs. For the model we assumed that egg packers could give a price premium to the producer of one pence per six eggs (IGD, 2008).

Mortality and injurious feather pecking: woodlands are the natural habitat of poultry and Bright and Joret (2012) observed that the mortality rate of woodland hens was 1% lower than for free-range chicken in an open field. However this effect was not statistically significant and hence we did not include it in the model. Bright and Joret (2012) also report reduced injurious feather pecking by laying hens in a woodland environment, but because it is difficult to relate to a production gain, this was also not included in the analysis.

Seconds: eggs with poor quality shells can be classified as seconds rather than class A. Bright and Joret (2012) report that the proportion of seconds at a farm level fell by 1 % when hens were given access to a woodland. In 2013, class A eggs were typically sold by farmers to packers at 52.6 pence per six eggs (Defra, 2014), and the price received for seconds is usually only a third of that for class A eggs (Bright and Joret, 2012). For 2.000 hens, the annual benefit would be £327 (Table 1).

Egg loss: our discussions with producers suggests that the presence of trees could mean that some hens will lay their eggs in the field rather than the sheds provided. In teh absence of other data, we assumed the loss of one egg per hen per year.

Table 1: Annual change in the revenue for poultry component (assuming 2000 birds per hectare each laying 280 eggs per year) with a £0.01 premium per six eggs, a 1 % decrease in seconds (worth £0.058 per egg), and a loss of 1 egg per bird per year (worth £0.087).

	(£ ha^{-1})
Premium on egg price	933
Revenue from seconds being class A	327
Increased loss of eggs	-174
Change in revenue	1086

The revenue and costs associated with the woodland component included the costs of establishing a mixture of hazel, Scots pine, and oak on 20 % of one hectare (173 trees ha^{-1}). Estimates of timber yields were based on Burgess et al (2000), planting costs were estimated to be £380 ha^{-1} (assuming some external support for tree costs), and the annual maintenance cost was

assumed to be £60 ha^{-1}. We also assumed a once-off immediate loss in the land value from tree planting equivalent to £1.700 ha^{-1}.

Results

On the basis of the above assumptions including a price premium of 1.0 pence per six eggs, the woodland egg system was profitable for the farmer, indicated by a positive equivalent annual value of about £700 ha^{-1} over the first 15 years. Using the assumptions stated, the price premium required for the system to break even was 0.25 pence per six eggs. If there was no reduction in seconds, then the price premium required was 0.60 pence per six eggs. If the loss of eggs amounted to six eggs per hen per year, then a premium of 1.19 pence per six eggs was needed to break even. During the first 15 years, the profitability of the system was not sensitive to changes in revenue from the trees (although this could change over a longer time period). Lastly taking the scenario of no reduction in seconds and a loss of six eggs per hen per year, the farmer would requre a premium of 1.54 pence per six eggs. As the average difference between the retail value of free-range and woodland eggs is 15 to 20 pence per six eggs, it would appear that retailers and packers have capacity to pay such a premium.

Table 2: Price premium (pence per six eggs) required by the farmer to break even with a woodland egg system over the first 15 years assuming a discount rate of 8 % (with a mixed species woodland and no cattle grazing)

Baseline	Baseline but no reduced seconds	Baseline but 6 eggs lost per hen per year	Baseline but no tree revenues	No reduction in seconds, loss of 6 eggs, and no tree revenue
0.25	0.60	1.19	0.25	1.54

Discussion and conclusions

This is a first attempt to look at the financial aspects of woodland egg production, and it is possible for users to modify the parameters in the model. The model could also be developed further. For example, in this analysis, the benefits of woodland planting on egg production were assumed to be instantaneous; in practice the reduction of seconds is expected to be sensitive to the level of canopy cover. The analysis also assumed no increase in the labour cost of ensuring the hens returned to the barn at night, and no change in feed-egg conversion ratios.

Although not reported here, we also extended our analysis to consider some of the wider environmental impacts of woodland egg production. Our initial analysis suggests that the societal benefits of improving the aesthetics of the system, the carbon storage of the trees, and to a lesser effect the capture of ammonia. Depending on the assumptions made, over the first 15 years such benefits could be equivalent to 0.37 pence per six eggs. Other than the price premium, the analysis does not account for the societal benefits from improved hen welfare. The societal benefit of this can be assessed using contigent valuation methods (Bennett and Blaney, 2003).

This initial analysis suggests that there is a market for eggs obtained from hens who have access to a woodland environment, and there is a sufficient retail premium to compensate farmers. Further research to quantify the production and welfare benefits will help ensure clear communication to producers and consumers of what such systems can deliver.

Acknowledgements

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Combining Hens for Egg Production and Trees for Wood Chips in an Agroforestry System

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Introduction

A 7.1 ha agroforestry field experiment located in south-western Germany demonstrates how to combine short rotation coppicing for fuel wood production with poultry keeping for the production of eggs. This combined system offers additional ecosystem services and gives multiple benefits. The agroforestry system has been established since 2009 by an organic farmer (certified) in close cooperation with the University of Applied Forest Sciences Rottenburg.

Objectives and main idea

Some years ago the standards of organic farming changed from indoor to outdoor housing (BMELV, 2014). However in addition to these standards, the project aimed at additional objectives:

- Raising and keeping hens in a close-to-nature environment,
- Finding a way, that hens exploit all the terrain available and not only those areas close to the chicken-coop (cf. Elbe, 2006),
- Improving the conditions of the vegetation, soil and hygiene of the hens.

In order to meet these requirements the agroforestry system is based on two components: Firstly it consists of the construction of mobile chicken-coops (patented). The mobile coops can be moved in their position over the experimental plots several times per year without much effort. The second component consists of strips of willows and poplars, which are managed by short rotation coppicing. Trees are harvested every 4 to 7 years and will be marketed as woodchips for energy production. The rootstocks will sprout again after harvesting. The trees offer several additional services in the agroforestry system:

- Protection of the hens against hawks, sun and wind (animal health and survival)
- Production of renewable resources (renewable energy)
- Absorption of nitrogen from the excrements (nutrient cycling in the ecosystem)
- Field integration into the country side (aesthetics and landscape planning)

Concept

The whole experimental field was subdivided into 18 tracts of 0.4 ha. Rows of willow and poplar trees have been established along the borders of these tracts. Between the rows there is space enough for moving the mobile chicken-coops over the area (Fig. 1). Every chicken-coop offers space for 1.000 to 1.200 hens. In total six coops are installed on the experimental field.

The main reasons for the choice of willows and poplars for the tree strips have been:

- Fast growth even during the first years following tree planting.
- Especially willows don´t provide possibilities for a raised stand for a raptor (e.g. hawk).
- The establishment of willows and poplars ist possible with comparatively well-priced cuttings.
- From the legal view it is possible to reconvert the whole field later into arable land (Marx, 2010).

The establishment of the trees and the selection of appropriate tree species and provenances have been difficult due to challenging site conditions and high standards of organic farming: shallow soil, a high clay content and the prohibition of herbicides. Different techniques of non-herbicide-establishment of the short rotation coppicing system have been tested during the last years (Spangenberg and Hein, 2011). For instance the use of mulch foil has emerged as the essential factor for a successful establishment and reduced mortality of trees under such difficult soil conditions.

Fig. 1: Aerial picture of the agroforestry system from 2012 (photo: P. Martin-Jacob)

Conclusion

Willows and poplars helped to create a structured field already two years after setting up the agroforestry experiment. In addition the hens indeed use the whole area for grazing and pawing in contrast to only close neighbourhood of their coops. However the main goal of adding trees to poultry keeping for egg production is not to raise the financial yield with the fuel wood production but to keep the hens in a close-to-nature environment.

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Variation of understory biomass in a valonia oak silvopastoral system according to distance from sheep and goat sheds

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Introduction

Valonia oak silvopastoral systems cover relatively large areas in Greece (about 30.000 ha) and constitute an important vegetation type with great economic and environmental interest. They are mixed systems composed of valonia oak trees with a crown density of no more than 40 % and understory vegetation consisting of herbaceous and woody species (shrubs). The overstory species are used for the production of acorns and foliage to be fed to livestock while the understory vegetation is directly used by sheep and goats for grazing, making them invaluable areas for livestock production (Papanastasis, 2002). On the other hand, valonia oak systems play a significant environmental role because they protect the soil from erosion, ensure increased biodiversity, regulate carbon sequestration, and control mountain hydrology (Pantera et al., 2008). In a typical valonia oak silvopastoral system in the Aetoloakarnania prefecture, western-central Greece, grazed by sheep and goats, the variation of biomass production is described and analyzed according to various distances from the sheds.

Materials

In a valonia oak silvopastoral system located in western-central Greece, three sheep sheds and three goat sheds, housing more than 300 heads each, were selected. Livestock were grazing, in all cases, around their sheds during the day and housed indoors at night. All samplings were conducted in May of 2013, at the peak of plant growth, and in each shed. Specifically, five square (5.0 x 5.0 m) plots were established at distances of 0, 100, 200, 400 and 800 m away from each shed, along two randomly selected transects. Five quadrates (0.5 x 0.5 m) were randomly chosen within each plot, and the aboveground understory biomass (herbaceous and woody) was harvested and subsequently oven dried in the laboratory for the determination of biomass production. Additionally and in order to understand the understory biomass variation, a visual estimation of tree canopy cover and understory cover took place at the same quadrates.

Results

No statistical differences in biomass production were found between sheep (0.91 t/ha) and goat (0.79 t/ha) areas. On the contrary, differences were found between the distances from the animal shed (Table 1). As expected, the closest distance (0 m) had the lower production. The higher production was found in the second and third distances (100 and 200 m) but not at the fourth and fifth as was expected.

Table 1: Above ground biomass production in various distances from the shed (t/ha)

Distance from the shed	0 m	100 m	200 m	400 m	800 m
Biomass production	0.45 c[1]	1.14 a	1.04 ab	0.84 b	0.78 b

[1] Same letters in the row means no significant difference at the statistical level of 95%.

Regarding the oak understory cover, the herbaceous vegetation was close to 50 % of the area in most distances except the first one where bare ground and rocks had higher percentages related to other distances (Table 2). The tree canopy cover was lower at the distances of 0 and 200 m while at the other distances were similar and about 30 %.

Table 2. Oak tree understory and canopy cover (%)

Cover type	**Distance from the shed (m)**				
	0	**100**	**200**	**400**	**800**
Herbaceous vegetation	35,0	57,4	52,2	46,0	49,7
Shrubs	0,0	1,8	0,8	3,6	2,0
Dry matter	17,2	18,7	17,9	23,7	24,8
Rocks	13,0	8,8	9,2	5,0	9,3
Bare ground	34,8	13,3	19,9	21,7	14,2
Total	**100**	**100**	**100**	**100**	**100**
Canopy cover	9,0	33,0	5,1	31,2	32,2

Discussion and conclusions

Based on Papanastasis et al. (2009), the grazing pressure was high around the sheds reducing, however, by distance and subsequently resulting in lower biomass production close to the sheds. The higher production of the second and third distances can be explained by the time of grazing. Livestock spends more time grazing away from the sheds at this specific time of the year. Another possible explanation is food availability. Herbaceous vegetation cover was higher at the specified distances compared to the others. In addition, canopy cover had the lower value at the third distance contributing to higher herbaceous vegetation cover and biomass production. Regarding the animal species, sheep and goats had the same effect on understory biomass production since, in the absence of the more preferable shrubs for the goats, both species consumed the same feed type.

Conclusively, the animal behavior and variation of biomass production is determined by feed availability rather than the distance from the shed.

Acknowledgment

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Posters

Results for net primary production from poplars and willows irrigated with biologically treated wastewater in short rotation coppices

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Introduction

In the lowland of Thuringia, one of the driest regions in Germany, short rotation coppices (SRC) stocked with poplar and willow clones were watered with biologically clarified wastewater. From May to September during the reference period 1961- 90 only 270 mm of water precipitation occurred on average (DWD- station Erfurt- Weimar). Due to the predicted climate change, the drought in the Thuringian lowland will increase. The experimental plots are located 20 km north-east of Erfurt. The soils are classified as Cambisol.

The focus of the study was the determination of net primary production and growth of watered and non-watered residuals, respectively. The study aims to provide evidence that, for the production of energy wood, the use of wastewater in dry areas represents a valuable water-and nutrient source. This enables regional water storage, avoiding drainage via the rivers. The aim of the SRC-cultivation is the maximum production of energy wood for further thermal and material utilization. Thus this research is an example for the use of water resources for the production of woody biomass in regions with water shortages such as the "Region of Bioenergy of Thuringian Farmland Area".

Material

Detailed information about utilized instruments and methods can be found in Lorenz and Müller (2013).The effect of the additional watering on tree growth is determined on the experimental plots continuously through measurements of radial and height increments, as well as stock and biomass estimates. The yield increase with wastewater irrigation is assessed by the differences between the irrigated and non-irrigated stocks. The watering demand of stocks is determined by the water balance model ("Zephyr"). For the parametrisation of the water balance model self- measured precipitation, soil and vegetation data are used. Soil and plant development, date and amount of additional water transfer are calculated depending on weather conditions. The waste water supply is carried out as furrow irrigation.

Results

The Cumulative Climatic Water Balance is negative without additional watering during the vegetation period (April- October) during 2011 to 2013. In 2011 watering was not sufficient because of technological difficulties at the beginning. These difficulties were remedied in 2012. Thus, in 2012 and 2013 no shortage of water for the plants occurred.

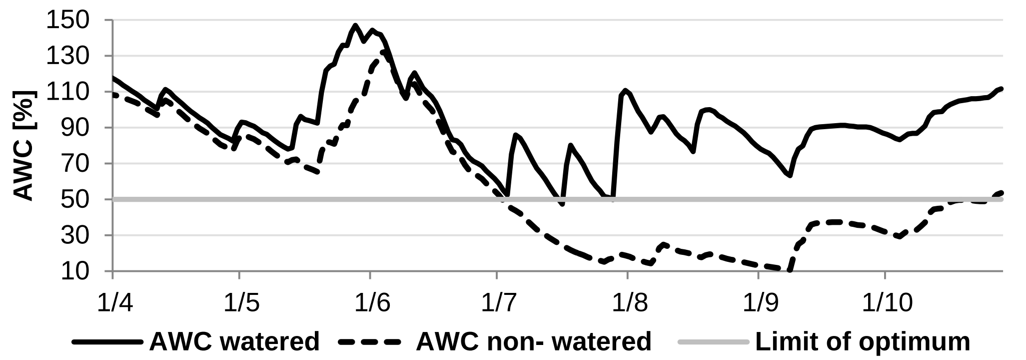

Fig 1: Development of available water capacity (AWC) in soil depth of 10- 130 cm on poplar “BERTA II” 2013

In 2012- 2013 the available water capacity (AWC) was maintained above the optimum limit of 50 % at all experimental plots (Fig 1).

The younger trees (planted 2011) react by producing a higher (relative) leafy biomass, much more sensitive to watering than the older trees (planted 2008).

A clear differentiation of the development of the radial diameter is determined between the older stands of poplars and willows. Within the vegetation period in 2012 and 2013, the poplars showed a greater radial growth than the willows (Fig 2) and the watered trees had a greater increment of radial diameter than the non-watered.

The watered poplars and willows had greater height growth than the non- watered (Fig 3). In 2012 and 2013 intensive frost damage occurred in the young willow stands. Despite the withering away of the main trunk in 2012 only very small differences in the height growth between the tree species can be found. This suggests dependence between the height development and a watering effect and a similar sensitivity to watering in 2012 and 2013.

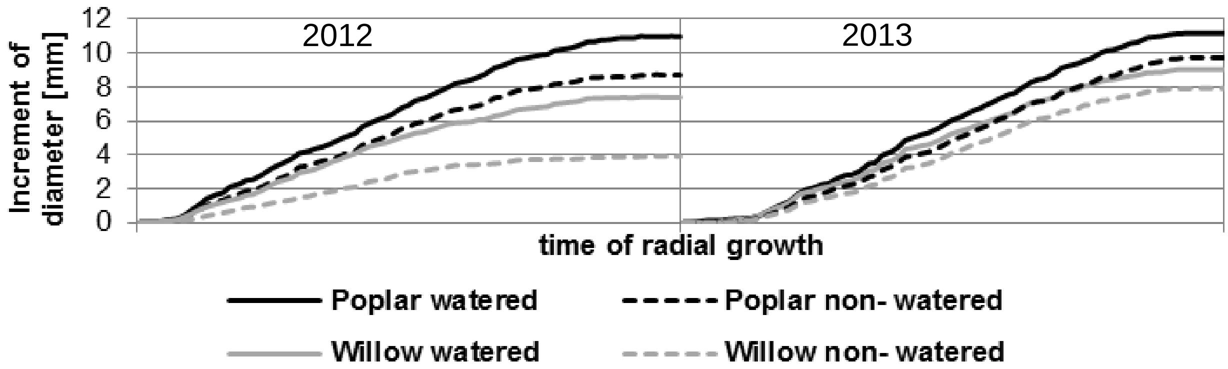

Fig 3: Cumulated increment of radial stem diameter on representative trees of "BERTA I" 2012 (14.04.- 24.09.) and 2013 (15.04.- 25.09.)

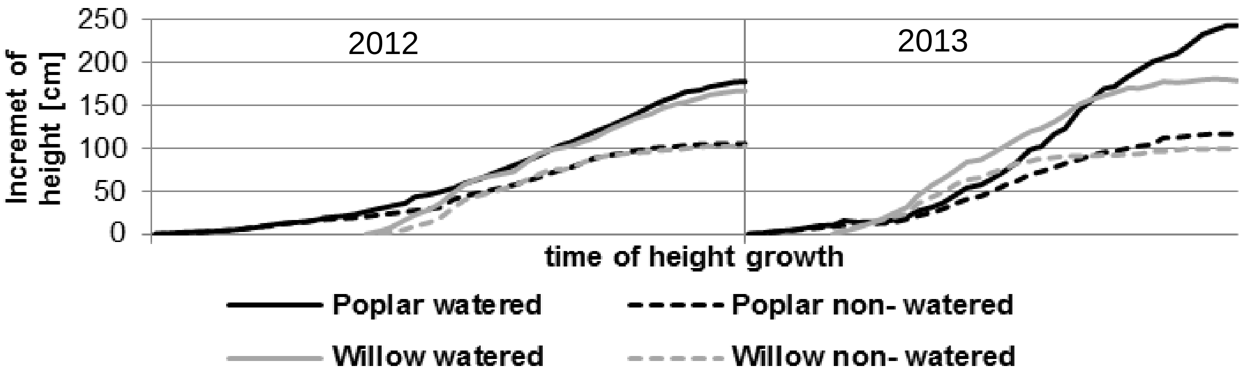

Fig 2: Increment of tree height on representative trees of "BERTA II" 2012 (05.04.- 20.09.) and 2013 (23.04.- 09.09.)

The difference of the stock at the older watered and non- watered poplar is very low. At the older willows stands the groundwater level in all years was less than 1.35 m below ground level, so that a possible capillary rise cannot be excluded. Throughout the experimental period the differencesin the three-year stands between the watered and non-watered trees increased strongly. The watering effect is more evident in the younger plots, due to the absence of groundwater close to the surface.

Discussion and conclusions

The older stocks have a large root depth (up to 2.40 m). It is possible that the roots reached the groundwater thus interacting with irrigation. LIEBHARD (2007) confirmed this assumption. Accordingly, SRC-sites are influenced by groundwaterat soil depths between 0,60 and 1,50 m, regardless of rainfall. Watering is not recommended on groundwater-influenced locations as in our older poplars plot. However a watering effect can be detected despite a possible capillary rise. This

leads to the conclusion that watering is recommended on elderly willow- plantations even in groundwater-infuenced locations, depending on the business requirements.

The young irrigated stands produced more stock than the non-irrigated. Therefore a watering on dry stands with deep groundwater in the establishment phase is to be recommended at the Thuringian flat farmland to increase income. The poplar need an additional irrigation more than the willow, due to the relatively large stock and the higher leaf biomass on the sites.

The technique of carrying out additional water with the waste water transport of a tank wagon is not an economically optimal solution in its current form. Due to the higher water consumption of SRC an increased additional amount of water is required in comparison of conventional arable crops. For a large- scale watering it would be more economical to use storage facilities near the watering place. Reconstructed fire extinguishing ponds or newly created liner pools can be used as water storage.

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Agricultural, forest and rural policy sectors' receptiveness to agroforestry intercropping systems in Quebec (Canada)

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Introduction

In Quebec (Canada), intercropping trees and crops is a new practice in the agricultural landscape dominated by conventional monocropping systems. As research goes on and slowly reveals the potential of agroforestry intercropping systems (AIS) to address some key issues in agriculture, forestry and rural development, there is a pressing need to find public support for these systems (Tartera et al., 2012). However, finding the right policy tracks and schemes to support AIS remains a challenge in the current policy context. As a matter of fact, AIS implementation raises various issues which are tackled by different policy sectors. Thus, we conducted a comparative study of the receptiveness of the agricultural, forest and rural policy sectors to AIS in order to shed light on the opportunities lying within these sectors for the support of agroforestry intercropping systems.

Material

The literature on public policy processes has stressed for years the importance of stakeholders' ideas for drawing and implementing new policies (Fouilleux, 2000). Following this trend, this study compares the ideas currently driving the agricultural, forestry and rural policy sectors to the ideas supporting the implementation of AIS using a conceptual framework based on cognitive frames (Jobert and Muller, 1987). This framework divides the cognitive frames of policy stakeholders in four different types of ideas: 1) the values they share, 2) the ideal representation of their sector (called the "image"), 3) the norms they have to meet to reach this ideal, and 4) their main algorithms, i.e. the actions that have to be taken to reach these norms. In a second phase, the study looked at the number and consequences of current policy schemes on AIS implementation. The receptiveness of each policy sector to these systems was therefore evaluated by comparing the ideas composing each policy sector's cognitive frame with the ideas composing the agroforestry intercropping systems' cognitive frame and by identifying, within each policy sector, opportunities and barriers to the implementation of these systems.

Data on agroforestry, agricultural, forest and rural stakeholders' cognitive frames was collected in two different ways. First, 57 formal publications on policies, agroforestry and intercropping systems were selected based on their sources, their financial implications and their relevance in each specific sector. Then, 22 semi-structured interviews conducted with 19 different policy stakeholders and 3 agroforestry specialists were undertaken in order to get an in-depth understanding of the ideas embedded in their specific cognitive frames. Data analysis on publications and interviews was performed using formal content analysis (Paille and Mucchielli 2012), where each policy sectors' discourse was separated in categories corresponding to the four main types of ideas described in our framework.

Results

Our preliminary results underline that the AIS stakeholders' cognitive frame is dominated by values, image, norms and algorithms integrating environmental sustainability and landscape multifunctionality. Forestry and agricultural cognitive frames mostly rely on ideas related to economic sustainability, and to a lesser extent to environmental sustainability. The cognitive frame of rural policy stakeholders is composed by ideas of community well-being and environmental sustainability (Table 1).

The current rural policy scheme, notably with its broad-ranged programs for community resilience, appears to be the most supportive and receptive to AIS, although these programs aren't specifically devoted to support agroforestry initiatives. Some minor agricultural policy schemes aiming at diversifying agricultural activities in devitalized areas and enhancing adaptation to climate change are also found to be supportive of agroforestry intercropping systems, although these remain marginal compared to the main programs offering support to agricultural activities. Only one small policy tool was found to support agroforestry intercropping systems in the current forestry policy.

Table 1: Policy sectors' cognitive frames and receptiveness to agroforestry intercropping systems.

	Forestry	**Agriculture**	**Rural**	**Intercropping systems**
Values	Economic sustainability	Economic sustainability	Community resilience Multifunctionality	Sustainable systems
Image	Productive forestry system	Productive family farms	Multifunctional and sustainable communities	Multifunctional and modern systems
Norms	Efficiency Environmental standards	Profitability Environmental standards	Economic diversification	Intercropping trees and crops
Algorithms	Planning Marketing	Access to subsidies Grouped marketing	Regional concertation Small innovations	Management Ecological services
Incentives	1 program ($)	3 specific programs ($$)	3 programs ($$$)	
Barriers	Subsidy programs' rules	Subsidy programs' rules	None found	
Receptivity	**+**	**++**	**++++**	

Discussion and conclusion

The analysis highlights that the rural policy sector, which puts multifunctionality at the core of its cognitive frame and materializes its ideas in rural programs, is the most receptive to AIS. The openness of the rural policy sector to agroforestry initiatives has been noticed in many other countries before (Place *et al.* 2012). This might show that rural policy tools, by essence, are often drawn and implemented to support initiatives that have broader and more complex impacts than the tools developed in specialized sectors such as agriculture and forestry. On the opposite, the forestry sector, both with its cognitive scheme and the absence of clear incentives, is found to be the less receptive sector to AIS. This might be due to the fact that in Quebec, these systems aren't

proposed as a possible solution to forestry problems, but mostly as tools to tackle agricultural and environmental issues. The agricultural policy was found somehow receptive to the studied systems, although its cognitive frame focus on ideas that are different from agroforestry promoters' ideas. In Quebec's context, it seems that agroforestry intercropping systems have benefited from the intrusion of the ideas of multifunctionality and climate change adaptation in minor agricultural schemes to get public support. However, in order to tear down major policy barriers and increase public support from both the agricultural and forestry sectors, featuring agroforestry intercropping systems as economically viable and productive systems might be a necessary argument shift.

Globally, our preliminary findings show that: **1)** in Quebec, the receptivity to agroforestry intercropping systems (AIS) is the highest in the rural sector, followed by the agricultural and the forestry sectors; **2)** policy tools implemented to support agroforestry intercropping systems are coherent with the core ideas of the agroforestry promoters' cognitive scheme; **3)** a cognitive scheme might integrate, even poorly, new and challenging ideas that can represent opportunities to support intercropping agroforestry systems, and **4)** the conceptual framework based on cognitive schemes appears well-suited to get a broader and deeper understanding of the policy context surrounding the implementation of innovative agroforestry practices.

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Could tree leaves serve as a mineral supplement for dairy cows and goats?

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Introduction

The reform of the EU's Common Agricultural Policy (CAP), has created renewed interest in agroforestry and silvopastoral systems. The CAP includes several "greening measures" aimed to enhance biodiversity on farmland, such as creating Ecological Focus Areas (EFA) and requiring farmers to grow at least three crops on their farms. The multifunctional use of trees for energy and wood production, nutrient cycling, carbon storage, biodiversity and -last but not least- fodder, makes trees an interesting candidate to grow as a third crop on Dutch dairy farms, next to grass and maize. The introduction of fodder trees on dairy farms requires insight into the cultivation, harvest, production and feeding value of different species. The objective of this research was to investigate the feeding values (protein and mineral levels) of a number of common tree species and to investigate the relation between feeding value of tree leaves and harvest date, soil type and soil conditions.

Material

Based on a literature review, records about the feeding value of leaves and twigs from temperate tree species were collected in a database. A follow-up field study was conducted on small selection of tree species which often occur in similar locations in rural areas of The Netherlands: alder (*Alnus glutinosa* L. Gaertn.), ash (*Fraxinus excelsior* L.), and white willow (*Salix alba* L.). Tree leaf samples were taken from specific trees at two different soil types (sand and clay) at three moments during the growing season of 2013 (with a six week time interval, starting in mid June). Grass samples were taken as a reference from grass growing at the same locations (grass species was not defined). Soil samples were taken around the tree locations during the first sampling date with a 25 cm auger. Both tree leaves and soil samples were oven dried and analysed in the lab to determine the nutrient levels. The data was statistically analysed (ANOVA with a split-split plot design) for the factors 'soil type', 'tree species' and 'sampling date'.

Results

The online database shows that there are ample data available on feeding values of temperate fodder trees (www.voederbomen.nl/nutritionalvalues/). High crude protein levels are recorded for *Robinia pseudoacacia*, (>20%) and our leaf samples in June of alder and willow contained on average 21% crude protein. Protein levels of tree leaves declined during the growing season significantly ($p<0.01$). Most tree leaves contained high levels of calcium compared to perennial ryegrass. The calcium content of ash leaves increased from 14 g kg DM^{-1} up to 30 g kg DM^{-1} during the growing season. Looking at the levels of other minerals and trace elements in tree leaves, both literature records and our measurements show a wide variation for the different species. Table 1 summarizes a selection of tree species which mineral levels in tree leaves are higher than in perennial rye grass. Remarkable differences in selenium levels were measured for willow on sand and clay over time (Fig 1).

Table 1: Tree leave species that contain higher levels of protein, minerals and trace elements than perennial ryegrass (* based on our field samples **based on data from literature)

Species	**Potential supplementary source of:**
Acer campestre**	Ca, Mn, Cu
Aesculus	Ca, Cu, Co
Alnus glutinosa*	Protein, Ca, Mg, Cu, Zn,
Corylus avellana**	Ca, Mn, Cu, Co, Se
Fagus sylvatica**	Ca, Fe, Mn, Cu, Zn, Se
Fraxinus excelsior*	Ca, Mg, Cu, Se
Quercus robur**	Ca, Fe, Mn
Rhamnus	Ca, Mn, Co, Se
Robinia	Protein, Ca, Zn, Co, Se
Salix alba*	Protein, Ca, Mg, S, Mn, Zn,
Sambucus nigra**	Ca, Mn, Cu, Zn, Co, Se
Tilia platyphyllos**	Ca, Mn

<u>Discussion and conclusions</u>

As trees have a much deeper and wider rooting system than grass, it is not surprising that the uptake of nutrients by trees is greater, resulting in relatively high mineral levels in tree leaves. Trees have a species-specific root morphology and growth characteristics. Species like robinia and alder for example, live in symbiosis with nitrogen binding bacteria, and have a higher average crude protein content than perennial rye grass in the Netherlands.

The literature database shows a considerable range in feeding values for the same tree species. This range is probably due to seasonal differences (Smith et al., 2012), local soil conditions (Saramäki and Hytönen,, 2004; Wroblewska et al. 2009) and the ability of tree species to adapt to local conditions. Unfortunately, most literature studies did not record soil conditions. Our field study shows that the different fodder tree species have very different feeding values and

responses to local soil conditions and time. Willow for example accumulates trace elements (Robinson. 2005) like Se in the leaves on clay, whereas ash leaves have a high Ca level on both soil types, which increases over time.

In the Netherlands, Se, Cu and Zn deficiencies are often reported for dairy cattle and goats, especially for free ranging animals on sandy soils. But a surplus of for instance Se could also be toxic for animals. Our study shows that various common tree species are very interesting in terms of protein, mineral and trace element levels. Therefore we conclude that tree leaves could serve as supplementary source of proteins, minerals and trace elements. However, 'tree species', 'soil type' and 'harvest date' are factors that significantly influence leaf composition and therefore should be taken into account if tree leaves are used as a feed supplement.

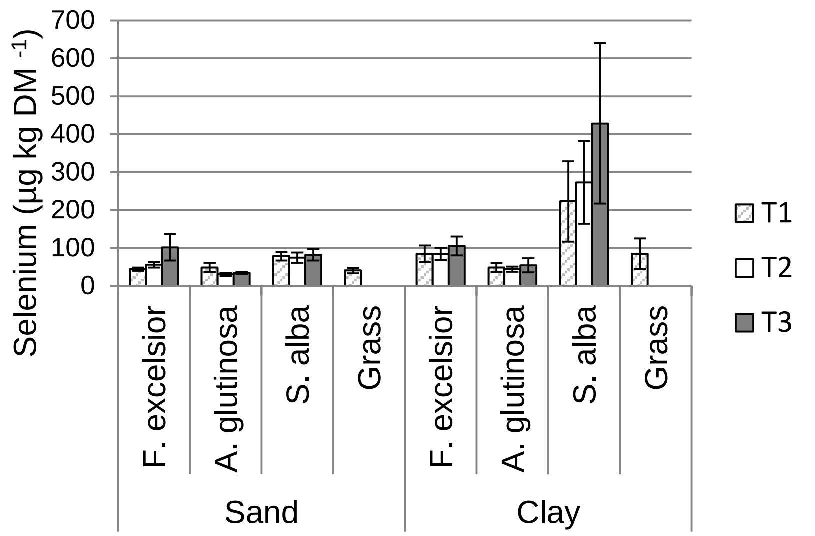

Fig 1: Selenium level of tree leaves and grass (µg kg DM $^{-1}$) at three moments in the growing season (T1, T2, T3) on sand and clay.

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Energy wood production in alley cropping agroforestry systems

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Introduction

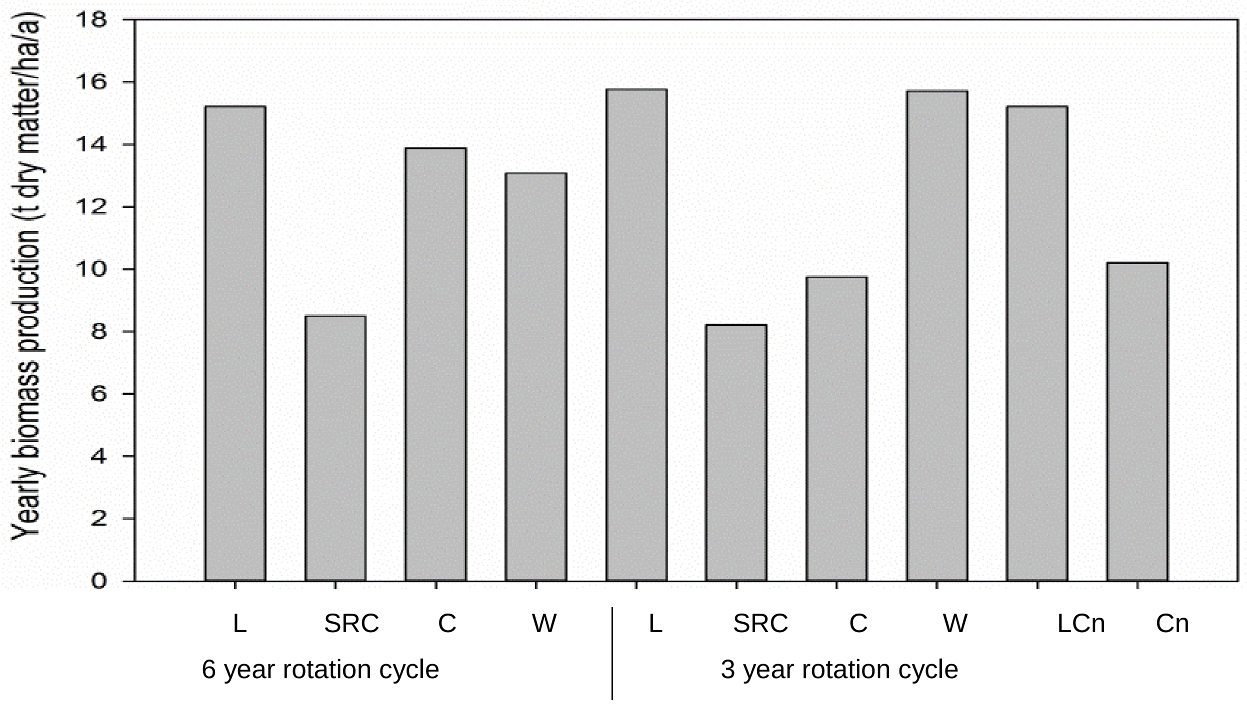
As the German government fixed an objective of 35 % of renewable resources in the final energy consumption by 2020, biomass production in Germany will continue to increase (Böhme and Musiol 2013). Wood, as a source of renewable bioenergy, can contribute to combined or separate heat and/or power production. It can be produced on farm land in short rotation coppices (SRC), mostly with poplars and willows. Such plantations have a high tree number and short harvest cycles (3 to 6 years), reaching a total of 6,000 ha in Germany.

Agroforestry systems combine tree and crop exploitation on one field, offering the possibility to simultaneously produce energy wood and food products. However, little information can be found on the productivity of short rotation coppice in alley cropping systems. The purpose of this study was to describe the productivity of poplar in a SRC alley cropping system combining 3- and 6-year rotation cycle, addressing the specific question of whether growth conditions within the SRC strips differ between border and central rows.

Material

The agroforestry alley cropping system, planted in 2008, is situated in Wendhausen (N52° 19' 54'', E10° 37' 52'', Lower Saxony, Germany) and lies 85 m above sea level. Mean annual precipitation is 580 mm and mean annual temperature is 9.2 °C. This system consists of 9 tree strips as well as a SRC-control field planted with the poplar clone "Max" (*P. nigra x P. maximowiczii*) at a density of 10,000 trees per hectare (2 x 0.5 m). Tree strips alternate with crop alleys planted with annual field crops. Five SRC-strips and the control field are cut in a regular cycle of 3 years, *i.e.* they were harvested once in 2011. Four SRC-strips are cut in a cycle of 6 years, *i.e*. so far not coppiced. Two different strip designs were laid out: a short rotation coppice design (6 poplar rows, "SRC") and a combined design of short rotation coppice and aspen production (a central aspen row (3 x 1.5 m) bordered by 2 double poplar rows at each side, "combined").

Woody biomass in the edge rows (leeward and windward) and the middle rows of "SRC" and "combined" strip design was assessed in the winter season 2013/2014. Allometric power equations have been used for each data set to predict dry matter from the stem diameters: $DM \sim \propto \times D^{\beta}$



L: Leeward; SRC: Middle SRC design; C: Middle combined design; W: Windward; LCn: Leeward of control field; Cn: Middle of control field

Fig 1: Estimated yearly biomass production (in tons dry matter per hectare and per year)

(where: DM = shoot dry mass, α and β = function parameters and D = diameter at breast height (1.30 m)). In each row, the diameters at breast height of 40% of the trees were measured. From the resulting data range 25 diameters were chosen and 25 trees having those diameters were cut and crushed into wood chips. The wood chips were weighed and the water content was estimated. On the basis of these data and the plant number per hectare and the average number of shoot per plant, the yearly biomass production per hectare was estimated for each row according to the method described by Hytönen (1987).

Results

Figure 1 shows the yearly biomass estimation for the different rows of the SRC-strips with 6- and 3- year rotation cycles, as well as for the leeward and middle rows of the control field. The ajdusted R-squares of calculated regressions were > 0.90. Yearly biomass production was highest in leeward rows with values up to 15.21 t/ha/a in the 6-year rotation cycle and 15.76 t/ha/a in the 3-year rotation cycle. In windward rows the biomass production was slightly higher in the 3-year rotation cycle. Concerning the middle rows of the combined design, a higher production compared to the other rows was observed in the 6-year rotation cycle. In the 3-year rotation cycle, the

biomass production of the middle rows of the combined design was similar to that of the middle rows of the SRC design. The latter was around 8 t/ha/a in both rotation cycles (Fig. 1). In the 6-year rotation cycle, the number of shoots per tree is relatively low, whereas the variability in diameters is high (for instance in windward rows, from 1.2 to 9.8 cm, for 1.2 shoots per tree).

In contrast, in the 3-year rotation cycle the number of shoots per tree is relatively high but the variability of diameters is lower (for instance in middle rows of SRC strip design, diameters from 1.0 to 5.3 cm and 2.8 shoots per tree). In the leeward row of the 6-year cycle, the highest mean diameter (6.2 cm) was measured and in the leeward rows of the 3-year rotation cycle, the highest amount of shoots per tree was counted (4.9).

Discussion

In our study, higher space and light availability in the edge rows of strips within the alley cropping system positively influenced the growth of poplar trees. Results obtained are in accordance with earlier studies where the effect of plant spacing on poplar tree growth was reported (Johnstone 2008; Benomar et al. 2012; DeBell et al. 1996). Moreover, the north-south orientation of tree hedges in an alley cropping system can produce an edge effect due to the availability of light (Gamble et al. 2014). However, the effects were a bit different between the rotation cycles, especially concerning middle rows. In the 6-year rotation cycle, the biomass production of the middle rows of the combined design was relatively high. Higher light availability due to the greater space between aspen and poplar trees in the combined design can explain this result and thereby indicates that an important factor for the accelerated growth of the poplars is light. Another explanation might be the higher nitrogen availability due to the proximity of the fertilized field crops. However, Hofmann-Schielle et al. (1999) found that fertilization does not have an effect on biomass production of several poplar clones. With a 3-year rotation cycle, the poplars in the middle rows of the combined design might have suffered from the shade of the uncut aspen trees after the coppicing in 2011. Indeed, some authors already mentioned the shade intolerance of poplars (Farmer 1963). This might explain the low biomass production in this row. For the middle rows of the SRC design the calculated biomass production was lowest with both, 3- and 6-year rotation cycles. It is suggested that competition for light and space affected tree growth in the middle rows, as trees growing in edge rows might have a higher density of roots and leaves.

Thus, increasing the number of edge rows in poplar SRCs within an alley-cropping system would enhance the biomass production per area. This could be done by reducing the number of

middle rows to *e.g.* a maximum of two, while increasing the number of tree strips. However, the wind protection should be still provided. Another possibility to increase the poplar productivity might be the introduction of tree rows with larger plant spacings, as in our combined design.

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The influence of policy sectors on agroforestry in Germany

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Introduction

In a political science perspective agroforestry as an integrated land use practice and as a policy approach does not play a relevant role in the field of land use policy in Germany. Comparing this with the land use policy approaches of international organizations like FAO and the World Bank, which promote agroforestry in "developing countries" as a strategy for "sustainable development", there is a gap. The promotion of agroforestry in "developing countries" is important to German development policy (German Federal Ministry for Economic Cooperation and Development 2002: 7, 21) and in ongoing "development" discourses (German Bundestag 2013: 4). As a microeconomic option for "sustainable" land use developments agroforestry at this point is irrelevant in Germany. With our paper we want to propose two hypotheses, the second one is derived from the theoretical concept of policy sectors, as possible explanations for the role of agroforestry in Germany.

Results

At first we assume that agroforestry systems could deliver interesting options for accepted land use developments, by the production of renewable energy, their climate change adaptation capacities and their potentials for sustaining biological diversity. Wood fuels and wood for other production processes are increasingly demanded and agroforestry systems could produce demanded resources on agricultural areas. Afforestation and reforestation are described as necessary measures in the process of adaptation to, and mitigation of climate change, in the context of the UN Framework Convention on Climate Change (UNFCCC). The destruction of biological diversity in monocultural farming and large-scale single species forest plantations is defined as an international political problem.

Secondly we assume that agroforestry as a policy approach and land use practice, aiming at different policy goals by combining different land use practices, is confronted with highly specialized and fragmented political structures. Agricultural, forest and nature conservation policies are developed in a multi-level governance system ranging from the international, supranational (EU), national, subnational to the regional and local levels. Designing policy instruments aiming at the promotion of agroforestry in practice is centrally influenced by this institutional background. The

legal framework of the CAP for example under Pillar 1, establishes that "hectares of agro-forestry shall be arable land eligible for the basic payment scheme or the single area payment scheme" (European Commission 2014: 41).Under Pillar 2, Art. 44 of Council Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD), provides opportunities for member states to financially support agroforestry. However, in German states (subnational level) this opportunities, mainly funding from Pillar 2, were ignored in the past. Agroforestry policy is confronted with political actors from fragmented policy sectors, such as agriculture, forestry and nature conservation, as institutional networks and "political arms" (Hubo 2013: 2) with specific legal and financial frameworks to pursue their interests in highly specialized agricultural or forestry production patterns. Furthermore policy sectors are considered as central for regulating resource conflicts, e. g. the struggle between different land users for land. They regulate conflicts following discrete programs, agricultural or silvicultural, in special public policy fields (Hubo 2013; Hubo/Krott 2010). Characteristic for policy sectors are different political programs, actors and processes. For example do agricultural and forestry land users produce against the background of different vegetation periods leading to different policy goals. Political and societal actors organized in institutionalized relationships in a certain public policy field are classified as sectoral actors. Policy sectors are competing for predominance in the policy-making processes to pursue their specific interests (agriculture: securing public financial support in liberalized markets vs. forestry: reducing ecological oriented state interventions) aggravating policy coordination and policy integration. Since policy sectors are competing for predominance in the policy-making processes, integrated policy approaches, such as agroforestry, have fewer chances to be successful. We show that agroforestry in Germany as an institutionalized policy approach has failed due to sectoral policy approaches segregating agricultural and silvicultural land use forms and their political implementation. Hence German states in the past did not provide financial support for agroforestry practices.

Discussion

Against this background, integrated land use patterns such as agroforestry could provide richer ecosystems for species, provide wood fuels and nutrition and contribute to adaptation to, and mitigation of climate change by binding carbon through afforestation and the cascade use of wood products on limited lands. In spite of the ecological advantages of integrated land use systems like agroforestry, existing policy sector structures and capitalist economic principles hinder further

acceptance of agroforestry in Germany. Policy sector structures are also challenges for invasive alien species policy (Hubo 2013; Hubo/Krott 2010) and for the integration of nature conservation goals and instruments into agricultural and forest policies. Policy change towards the promotion of agroforestry depends on challenging the power resources of status quo actors in the agricultural and forestry sectors. Therefore, besides increasing the financial supporting schemes for agroforestry, selective policy integration by building alliances with the nature conservation and environmental sector is also necessary in order to create public awareness and pressure to reduce the influence of status quo actors.

In addition to the fragmentation of the political and administrative systems by policy sectors, which can be seen as the "political arms" (Hubo 2013: 2) of capitalist actors in the fields of agriculture and forestry, capitalist economic principles stimulate the segregation and intensification of production systems. To the highly industrialized and increasingly concentrated agricultural sector in Germany, agroforestry, in contrast to other countries, is currently not a microeconomic beneficial option. Besides reducing the power resources of status quo actors Reducing the dominance of capitalist economic principles (i.e. like price volatility, the abuse of market power in nontransparent and imperfect markets, and the pressure to reduce production costs in the field of agriculture and forestry), might be another necessary step towards increasing the relevance of agroforestry.

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Tree-based intercropping: A land-use for greenhouse gas mitigation in Canadian agricultural systems

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Introduction

In tree-based intercropping (TBI) systems, the potential influence of trees in relation to carbon (C) sequestration and Greenhouse Gas (GHG) emissions reduction has been documented but the mechanisms, remain poorly understood, especially for below-ground processes. Recently, in Ontario, Canada, research was undertaken to resolve this, under the auspices of Canada's involvement in the Global Research Alliance.

C sequestration potential, nitrous oxide reduction potential and soil voids were quantified in a 25-year-old TBI system in southern Ontario for five tree species: hybrid poplar (*Populus* spp.), Norway spruce (*Picae abies),* red oak (*Quercus rubra*), black walnut (*Juglans nigra)*, and white cedar (*Thuja occidentalis*) which were intercropped with soybean (*Glycine max*). Results were compared with a conventional agricultural system in which soybean was grown as the sole crop.

Material

To quantify C content for the five tree species within a TBI system, trees were destructively harvested above- and belowground and weighed for biomass estimations. Soil organic C was determined by analyzing soil samples that were collected at varying distances and depths from the tree row. Annual litterfall, litter decomposition and soil respiration were also quantified to model carbon gains and losses from the system on an anual basis.

DNA was extracted from soil cores collected around four of the tree species (walnut, red oak, Norway spruce, poplar) and used for quantitative real-time Polymerase Chain Reaction (PCR) to determine the abundance of key functional genes in the nitrification and denitrification pathways.

To characterize the soil surface (top 3.5 cm) microstructure, soils adjacent to walnut, poplar, red oak, Norway spruce and three types of ground cover (row crop, willow, and perennial grass tree rows) were analyzed using C-ray computer microtomography. This was used to evaluate soil void phase characteristics and the heterogeneity of soil matrix radiodensity.

Results

The net C flux for poplar, spruce, oak, walnut, cedar and the soybean sole-crop were + 2.1, + 1.6, + 0.8, + 1.8, +1.4 and – 1.2 t C ha^{-1}, y^{-1}, respectively (Table 1). The results suggest a greater atmospheric CO_2 sequestration potential for all five tree species when compared to a conventional agricultural system.

Table 1. Carbon sequestration (t C ha^{-1} y^{-1}) potentials of five tree species commonly grown in tree-based intercropping systems in comparison to conventional agricultural systems in southern Ontario, Canada

Inputs	Poplar	Oak	Walnut	Spruce	Cedar	Soybean Monocrop
Aboveground tree C assimilation	0.83	0.46	0.48	0.38	0.53	
Belowground tree C assimilation	0.23	0.16	0.11	0.14	0.12	
Litterfall C inputs	1.63	1.07	1.50	1.49	0.68	
Fine root turnover	0.82	0.54	0.75	0.45	0.20	
Above and below ground Crop C input	1.22	1.22	1.22	1.22	1.22	1.40
Outputs (via decomposition)						
Litterfall C outputs	1.04	0.54	1.44	0.63	0.26	0
Root output	0.52	0.27	0.72	0.19	0.08	1.31
Crop C outputs	1.00	1.00	1.00	1.00	1.00	1.19
C leachate	0.05	0.05	0.05	0.04	0.04	0.05
Net						
Net C balance	+ 2.12	+ 1.58	+ 0.84	+ 1.81	+ 1.36	- 1.15

Results from the extracted DNA indicate that tree species can influence the abundance of key microbial groups associated with N_2O production, particularly organisms associated with denitrification, *nosZ* and *nirS* (Figure 1).

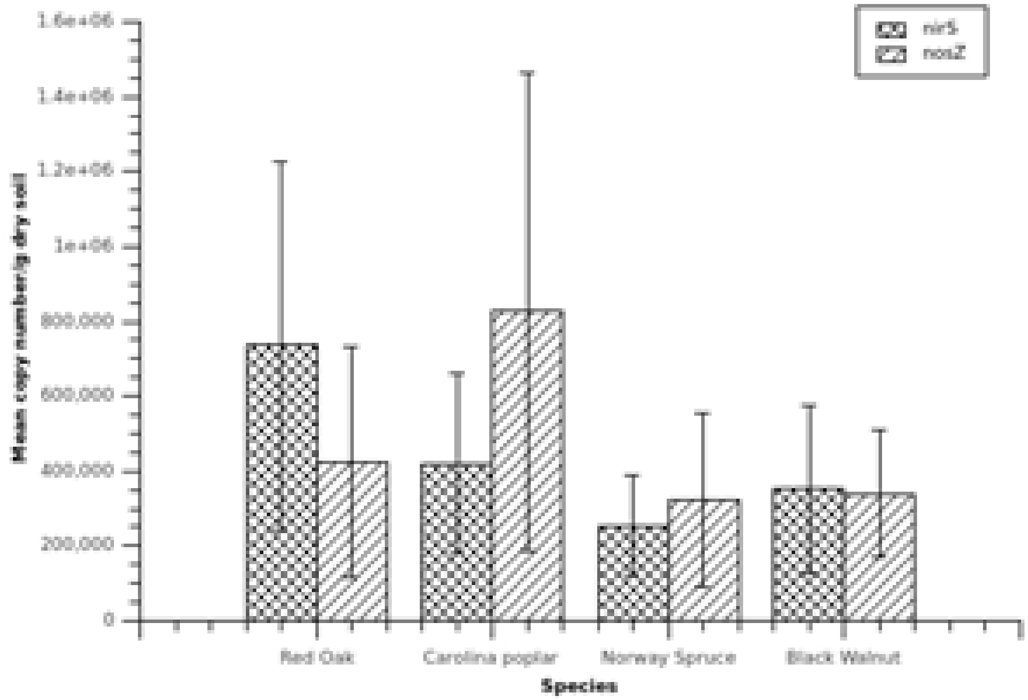

Figure 1. Organisms associated with denitrification, nosZ and nirS as influenced by tree species

The abundance of *nirS* was significantly ($p < 0.05$) higher in the soil associated with red oak and the abundance of *nosZ* was significantly ($p < 0.05$) higher in the soil associated with poplar . X-ray µCT measured void characteristics were not found to be significantly affected by the adjacent tree species and it was concluded that tree species have no effect on void characteristics at this level of observation; this being attributed to mixed leaf litter in the system, and soils being collected under perennial (grass) vegetation. Further, soil void analysis showed that there was a positive correlation between x-ray bulk radio-density and soil bulk density, and a negative correlation between mean intra-aggregate x-ray radio-density and soil organic carbon (r_s=-0.48, p=0.033), suggesting that the X-ray CT method could therefore be used to predict these soil properties.

Discussion

On a systems-level scale, regardless of which species is planted within TBI systems, TBI systems show greater net C flux when compared to a conventional sole-cropping system and therefore can promote greater atmospheric CO_2 sequestration potential. From the extracted soil DNA, the abundance of *nirS* in soil associated with red oak and the abundance of *nosZ* in the soil associated with poplar, indicates that particular tree species may be associated with unique microbial communities within TBI systems and suggests that this may play a role in ecosystem

functioning and N_2O emissions. It was also determined, through the use of geostatistics, that there were no distinct or consistent anisotropic structures evident for the various species. However, a semivariogram analysis revealed greater variability associated with less directional anisotropy within the tree row as compared to cropping alley soils. This was interpreted to mean that processes within soils in the tree rows were leading to a homogenous type of structure, and that soils under row crops exhibited a greater tendency for destruction of surface structure. This could lead to more directional anisotropy suggesting soil disturbance in the cropping alleys. This disturbance should be reduced by adopting zero tillage or other conservative soil management practices. The results from three different studies suggest that tree-based intercropping land-use systems, through the above explained processes, are contributing towards sustainability of agro-ecosystems.

Behaviour of Degradable Tree Shelters in Forestry and Agro-Forestry Environments

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Introduction

Treeshelters offer several benefits in sylviculture in forestry and agro-forestry environments such as a safe and early establishment of young trees. They provide protection against browsing and weeds, and a suitable microclimate for rapid and healthy growth[1]. Interestingly, the most advanced treeshelter that incorporates the features of high light transmission and effective ventilation has been invented and developed in the agro-forestry context[2].

A benefit that has been lacking since the invention of the treeshelters is their degradation after they have completed their functions of establishing the trees. A new generation of degradable treeshelters has been developed[3]. The treeshelters are made of a composite material of polypropylene copolymer (PP) with a starch based biopolymer

A fundamental problem is the assessment of the whole product life comprising the shelf life, the service life and the degradation period. These three time stages are important in determining the products quality for both the producers and the users. Accelerated laboratory ageing testing to determine the service life and the degradation period is not reliable. Therefore, real field testing in real time of the whole product life cycle of the treeshelters is necessary and invaluable. A field trial site of around 3 Ha has been set in the city forest of Baden-Baden in Germany. A detailed statistical study of the products life cycles (shelf life/service life/degradation period) has been undertaken. This communication reports the initial qualitative results.

Material

5000 treeshelters made of photodegradable PP, oxodegradable PP, and composite blend of oxodegradable PP and biodegradable starch based biopolymers materials along with controls have been installed in December 2010. 5.000 European sessile oak (*Quercus petraea*) saplings 1+0 have also been planted and protected by the treeshelters of the Tubex Ventex design. The 5.000 treeshelters are grouped in 50 different types of treeshelters of the Tubex Ventex design varying in their chemical compositions to provide various product life cycles. The shortest service life span designed is 1 year while the longest is 10 years. The test samples have four repetitions in a

random distribution in order to provide statistically significant results. The growth of the trees and the degradation of the treeshelters are been studied for a period of 5 years.

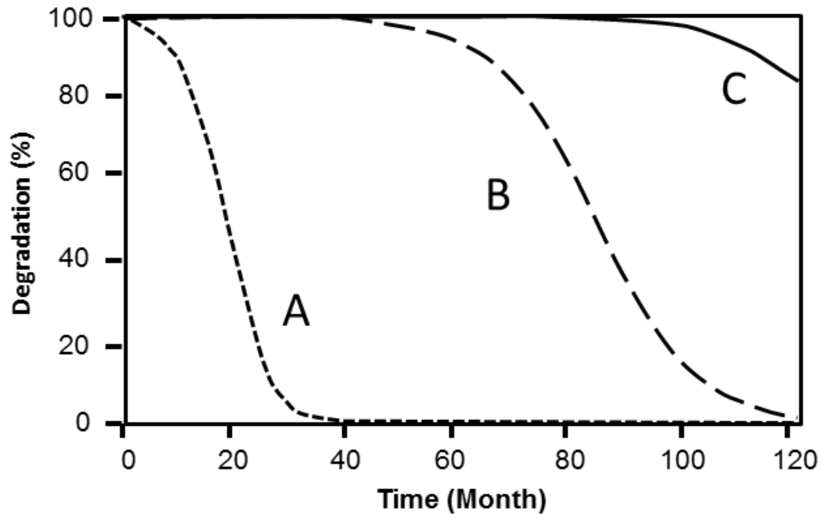

Fig 1. : Schematic representation of the service life/degradation period profile (see text).

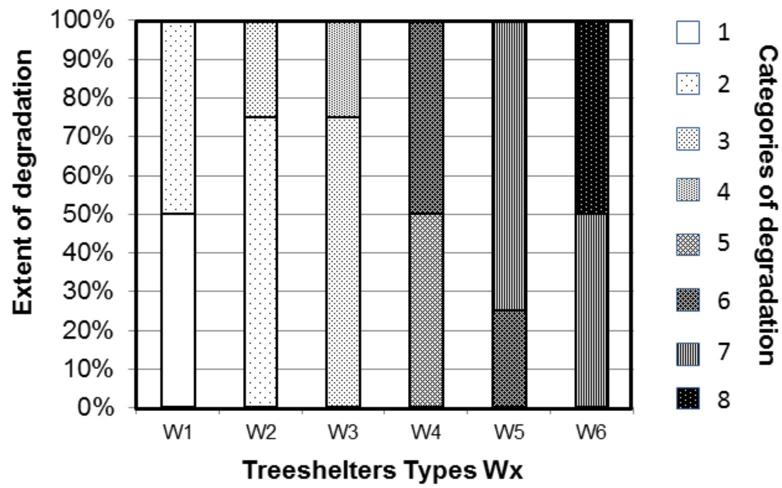

Fig 2. Six selected treeshelters (W1-W6) in various states of degradation represented by different shades, from 1 white (intact), 2 (slight degradation), 7 (advanced degradation) to 8 black (completely decomposed).

Results

Our investigation shows the first results of degradable tree shelters after 3 years of exposure to the natural elements in open field conditions. The treeshelters designed for a short service life soon showed early degradation on the interior side of the upper rim after the first growing season. Tubes with no UV stabilisers but with pro-oxidant catalysts showed advanced degradation after 1 year. Only the lower quarter part of the treeshelter was left with the strip adjacent to the stake. This particular formulation was designed to show that a PP treeshelter can indeed degrade and disappear in a very short time.

The various compositions produced various and typical product life cycles. There can be three basic different “service life-degradation period” types of profiles. Figure 1 shows the extent of degradation as a function of time of exposure. Curve A shows an early onset of degradation followed by a rapid drop in mechanical properties. Curve B shows an onset of degradation starting after 3 to 4 years and a predicted degradation after 10 years. Curve C shows a treeshelter that will

have a service life of 8 years. The products that will suit the forestry market needs will have the typical profile B.

An internal qualitative assessment of the degree of degradation has been established. Eight different categories have been identified as adequate to describe the state of degradation of each treeshelter. The assessment is done visually and through tactility. They are marked from 1 to 8, where state 1 represents the material being intact as new, keeping its plasticity. State 2 describes a material that just started degrading. At the extreme, state 7 shows advanced degradation where the material crumbles on pressure. Finally, in state 8, the material is no longer there as it has crumbled and fallen on the ground. Although the states of degradation are between 1 and 4, the treeshelter still retains its functions of protection and growth enhancement. Above state 5, the treeshelter is in its way to complete degradation. Therefore, for each treeshelter composition, one or more states of degradation can be assigned for a collection of 8 tubes. For example, for treeshelter W1 (Figure 2), 50 % are intact (State 1) and 50 % have the top starting to degrade (State 2). Averaging over 8 treeshelters of the same composition W1 and across the field allows a qualitative assessment of 50 % State 1 and 50 % State 2 extents of degradation.

Results for six treeshelters (W1 to W6) that have been 3 years in the field are shown in Figure 2 for illustration.

Discussion and conclusions

Although the study is currently based on 3 years data, statistical analysis allows some prediction to be made. As the study resumes, the results will evolve and consolidate. The pilot trial also shows that even in heterogeneous forest conditions degradation of treeshelters with time can accurately be qualified and quantified. However, factors like the competing vegetation (type, height), and the exposure of the location and the altitude (e.g. UV radiation/shade) on individual areas can alter the products life cycles. The preliminary results show that suitable blends of polymeric material, biopolymers, pigments, stabilisers and catalysts may provide treeshelters with a time-predictable shelf life, a determined service life, and a suitable period of degradation.

In parallel to this qualitative assessment supported by a statistical method, a fully quantitative analysis is carried out and will be published in the near future.

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On-farm monitoring of agroforestry innovations

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Introduction

Agroforestry systems which combine woody plants with arable crops and/or grassland provide ecological as well as economic benefits. One the one hand, agroforestry systems are characterized by higher overall productivity (Dupraz and Talbot, 2012). They are expected to provide improved resource conservation and contribute to enhanced biodiversity (Palma et al., 2007). Because of this potential win-win situation, agroforestry systems can contribute to the sustainable intensification of agriculture.

Whether the potential win-win outcome of agroforestry can be effectively realized or whether it is offset by possible drawbacks such as more complicated farm management, long term tying-up of land etc. can only be tested using empirical data from real farms. To this end, a monitoring framework was developed. It consists of indicators relating to productivity, labor costs, economic viability, management strategies, environmental factors and the perception of those working the land (Kuster et al., 2012). At the same time it should allow the parameterization of bio-physical and economic agroforestry models (e.g. Graves et al., 2010a, 2010b).

Material and methods

The monitoring was conceptualized based on existing literature and tested on three agroforestry plots which have been installed by Swiss pioneer farmers:

(i) poplar for energy wood (standard trees, not short coppice) in combination with fodder crop rotation,

(ii) apple for fruit in combination with strawberry, winter-wheat and fallow,

(iii) sweet cherry for table fruit in combination with vegetables.

Results and discussion

The framework consists of 12 indicators which inform about the bio-physical, economic, environmental and social performance of an agroforestry plot (Table 1). In 2011 an initial survey was conducted on existing agroforestry plots belonging to three farms in the Swiss lowlands. It has since then been repeated annually. Data collection on the farm is carried out together with the farmer, who keeps records on labor, the use of machinery, yields. The monitoring can be

supplemented by additional short term process studies, such as the interaction between crops and trees, etc.

Outlook

The monitoring will be pursued and, from 2014 onwards, extended to additional farms which enter start an agroforestry activity. It will continuously be adapted and improved to account for possible difficulties. By 2019, 25 agroforestry plots should be part of the monitoring and should allow to track the evolution of agroforestry in Switzerland.

Table 1. Measurements and performance indicators of the agroforestry monitoring framework (Kuster et al. 2011).

Category	**Indicator**	**Parameters and unit of measurement**	**Resulting performance indicator**
Productivity	Stem volume	Diameter at breast height [cm]	Carbon fixation [Mg C ha^{-1}]
		Tree height [cm]	
	Crown circumference	Radius of tree crown [cm]	
	Annual fruit yield	Fruit yield of trees [kg ha^{-1}]	Capital value of the agroforestry plot [CHF ha^{-1}] and input parameters for bio-physical modeling
	Annual yield of other crops in tree lines	Yield of other crops in tree line [kg ha^{-1}]	
	Annual yield of intercrops	Yield of intercrops [kg ha^{-1}] or [number ha^{-1}]	
Management cost	Annual management cost	Labour cost [h ha^{-1}]	
		Machinery cost [h ha^{-1}]	
Management strategies	Inputs	Seeding or planting [kg ha^{-1}] or [number ha^{-1}]	
		Fertilisation N, P_2O5, K_2O, Mg [kg ha^{-1}]	
		Irrigation [l ha^{-1}]	
		Pesticide application [kg ha^{-1}]	
Environmental factors	Regional climate	Annual precipitation [mm a^{-1}]	(input parameters for bio-physical modeling)
		Average monthly temp. [°C]	
		Relative humidity [in %]	
	Soil conditions	Nutrient content of soil (P, K, Mg, organic matter) [mg (kg soil)$^{-1}$]	
		Field capacity of soil [mm]	
	Diversity and abundance of bird species	Diversity and abundance of nesting birds [# breeding pairs ha^{-1}]	Biodiversity
	Diversity and abundance of vascular plants	Diversity and abundance of vascular plants in tree lines [# species ha^{-1}]	
Perception of manager	Perception of manager	Perception of manager	Acceptance by farmer

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Solid biofuel and biogas production from a grassland-willow alley cropping system

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Introduction

Worldwide the demand for renewable energy is rising and biogenic energy carriers play an important role in bioenergy provision. However, increase and intensification of biomass production for energetic use has already shown adverse impacts on agro-ecosystems, e.g., biodiversity losses, nitrate leaching, and erosion (Schulze & Koerner 2012; Righelato & Spracklen 2007). Energy cropping systems and related conversion systems should be improved in terms of their efficiency and environmental impact in future (Schmer et al. 2014). A strategy is to strive for underutilized biomasses and marginal landscapes where farmers cannot grow food crops in an efficient way. For example, modern agroforestry systems offer an alternative agro-ecological approach to a sustainable intensification of energy crop production. The present study was part of the joint research project "BEST–Strengthening Bioenergy Regions" (2010−2014) and analyzed the energetic potential of a young alley cropping system of grassland and fast-growing willows grown on a 3 to 6 year rotation.

Material

The study was conducted on an experimental area in Central Germany from 2011–2013 Additional information about the study site can be found in Hartmann et al. (2014, inside these proceedings). Two different grassland mixtures (grass/clover mixture, diversity oriented mixture with 32 species) were established in a split-plot randomized block design with three replications, and intercropped with rows of willows as short rotation coppices (SRC). Biomass sampling of the woody and herbaceous material was carried out from 2011 (year 1) to 2013 (year 3) and dry matter contribution was estimated for 2014 (year 4).

The woody biomass was converted to wood chips for thermal combustion. For the grassland biomass, two types of energetic conversion were evaluated: integrated generation of solid fuel and biogas from biomass (IFBB) (Wachendorf et al., 2009), and anaerobic digestion. Therefore, herbaceous material from the two different grassland mixtures was chopped and ensiled in 60-L polyethylene barrels. The technical approach of the IFBB technology consists of the two steps of hydrothermal conditioning and mechanical dehydration. As a result, two products emerge from the

grassland biomass: firstly, solid fuels which are the main product and secondly, as a by-product, press fluids for the fermentation process into biogas. The technology of whole crop digestion was conducted in batch experiments. The fermentation of the substrates was done in 20-L polyethylene containers. The containers were filled with 8 kg fresh matter of an inoculum of digested, active slurry and with 400 g of whole crop grassland silage. Fermentation time was 35 days. Methane volumes were measured under laboratory room conditions and converted to standard conditions (273.15 K, 101.325 kPa). Finally, gross energy yields in MWh ha^{-1} a^{-1} were calculated using a database for the biomasses in the agroforestry system and the control (grassland and willows). The data from 2014 are calculated on the base of means from the previous years.

Results

In all growing seasons grass-clover achieved higher dry matter yields compared to the diversity oriented mixture. The biomass yields ranged from approximately 5 to 10 t DM ha^{-1} a^{-1} (Fig. 1). The dry matter yield of the woody biomass was relatively low since the trees were in the establishment phase (data not shown here).

Methane yields from whole crop digestion were investigated for the two grassland mixtures. Highest methane yields were observed for grass/clover mixture ranging between 253 and 287 CH_4 kg^{-1} VS (volatile solids). Comparatively low methane yields resulted from the diversity oriented

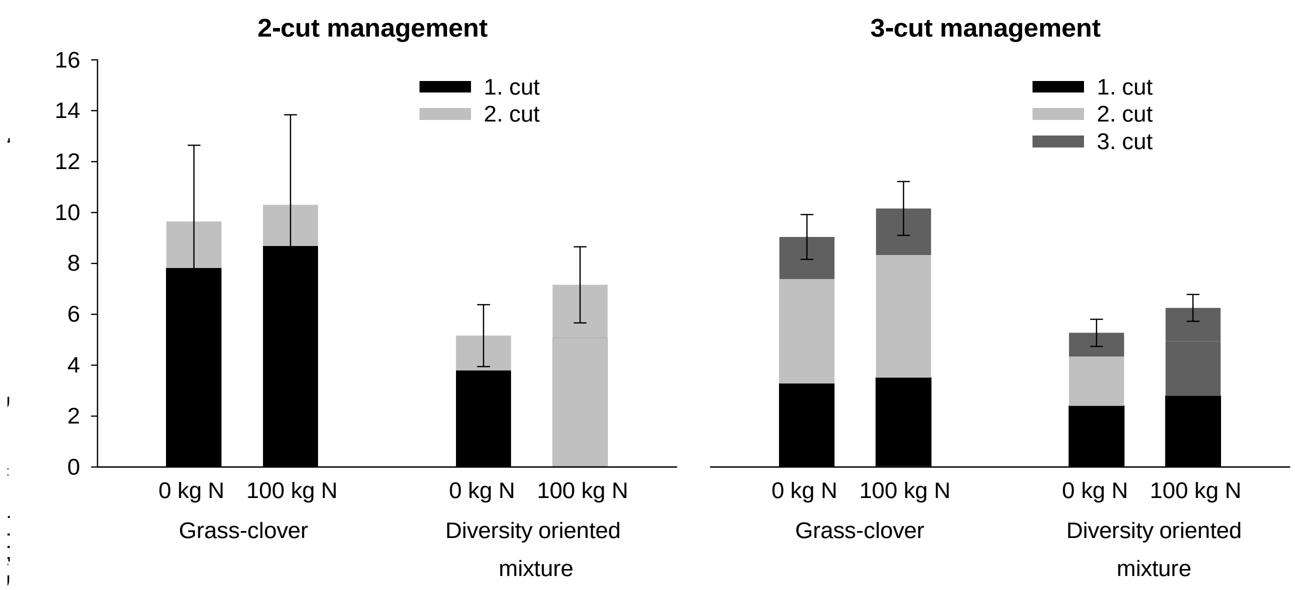

Fig 1: Annual dry matter yields of grass-clover and diversity oriented mixture in 2-cut and 3-cut management with fertilized and unfertilized treatments from 2013

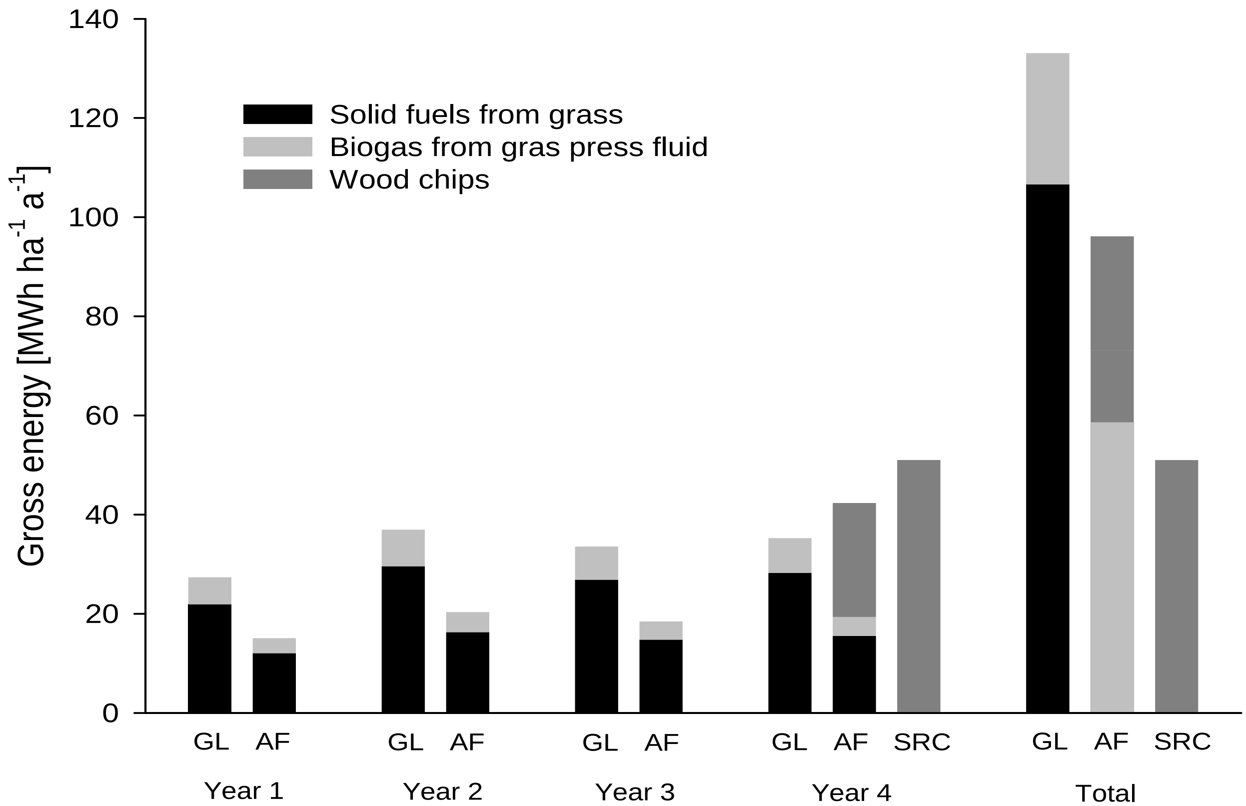

Fig 2: Gross energy yields of monocropped grassland (GL), agroforestry of intercropped grassland and willow rows (AF), monocropped willows (SRC) over a 4 year period after establishment in 2011. The IFBB procedure was applied to the grassland biomass.

mixture ranging between 244 and 253 CH_4 kg^{-1} VS. Methane yields from the press fluids generated by the IFBB technology showed in the mean of all grassland treatments 416 CH_4 kg^{-1} VS.

Gross energy yield development over a period of four years was compared in three different cropping systems (Fig. 2): grassland as single stand (GL), willow short rotation coppices (SRC) as a single stand and agroforestry system (AF) composed of grassland (55 %) and willows (45 %). The conversion technology applied for the grassland biomass was the IFBB procedure and the grassland mixture used grass/clover. Grassland as a single stand achieved continuously about 40 MWh ha^{-1} a^{-1}. For the SRC as pure stand only growth is showed in the first three years and while in the 4th year, the expected harvest is shown. Yield was calculated by using regression analysis explaining the relationship between tree growth parameters and dry weight. Gross energy yields of the grassland rows in the agroforestry system were continuously between about 15 and 20 MWh ha^{-1} a^{-1}. In total, the grassland as single stand achieved the highest gross energy yields, followed by the agroforestry system and the SRC as single stand.

Discussion and conclusions

The field experiments from 2011-2013 showed a minor growth and yield performance of the fast-growing willows during the establishment phase. A more continuous yield distribution might be expected by the combination of grassland and willows in an agroforestry system. The present agroforestry system provided annual gross energy yields between 20 and 40 MWh ha^{-1} a^{-1}. Biomass production for energetic use might be optimized in an efficient and sustainable way by establishing agroforestry systems. By applying the IFBB procedure to the grassland biomass solid fuels from grass as well as wood chips from willows are provided which can both be used for thermal combustion. This might bridge the period of tree regrowth where biomass shortages might occur.

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Analysis of a silvopastoral system with animals of the autochthonous swine breed Porco Celta in Galicia (NW Spain)

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Introduction

Pig traditional production systems in Galicia (NW Spain) are based on seasonal resources such as chestnut and pastures. The Breeders' Association of the autochthonous Celtic breed of pigs (ASOPORCEL, 2014) has developed a novel system within the traditional Galicia grazed forest areas in order to preserve landscape quality and biologic diversity, minimizing therefore the environmental impact of pig production. Galicia is the region of Europe with the highest number and hectares of land burnt in wildfires. The main tree species of Galician forest is *Pinus pinaster*, which has a high fire risk. Mechanical clearance of this forest is really expensive and usually not carried out. Understory is usually of low quality but could help to reduce feeding cost of pigs. One of the main concerns of silvopastoral system implementation is the need of fencing. Fencing costs could be reduced if animals are reared with infrastructures based on Pavlov animal condition reflex management (alarm system) in an extensive system. Therefore, cost reduction is obtained thanks to the clear reduction of personnel needs to feed animals, fencing costs and understorey clearance to reduce forest fires. This study aims at testing the effect of pigs rearing with an alarm based on Pavlov animal condition reflex on the understory surrounding this infrastructure and on animal live weight.

Material

In 2013, an experiment was carried out in Nebra (NW of Spain) in a young *Pinus pinaster* plantation. Pig stocking rate was around 3.85 pigs per ha (25 males and 25 females) in a total surface area of 13 ha. Forest grazing program was initiated when animals were three months old in March 2013 and finished in December 2013. Animals were allowed to access the whole plot. Concentrate was provided twice every day after sounding an alarm to attract pigs. The alarm system has the patent number P201131720. All the animals adapted rapidly to the alarm system. Vegetation was evaluated by the use of transects placed at increasing distances from the “alarm” system. We performed 6 transects of 20 meters at each of the three distance ranges considered,

and point contacts were measured every 5 meters. Vegetation was determined in each contact point and height measured before and after grazing in the same month in order to avoid vegetation phenological state bias. Animals were weighed monthly. Statistics were carried out using SAS (2001).

Results

Vegetation height (Figure 1) was affected in the two first distance ranges measured (from 0-120 m and from 120-240 m), indicating that pigs did not go further than 240 m from the alarm system. An increase of pig growth was found along the study, however restrictions in the vegetation during the summer limited the growth rate (Table 1). Proximity to the "alarm system" created a gradient in the different understory vegetation. Bare soil was clearly increased by a 13 % in the first (from 0 to 120 m) and the second (120 to 240 m) distance ranges (Figure 2). The main change in the understory dealt with Erica, which was clearly reduced in the first and second distance ranges after grazing when compared with vegetation before grazing.

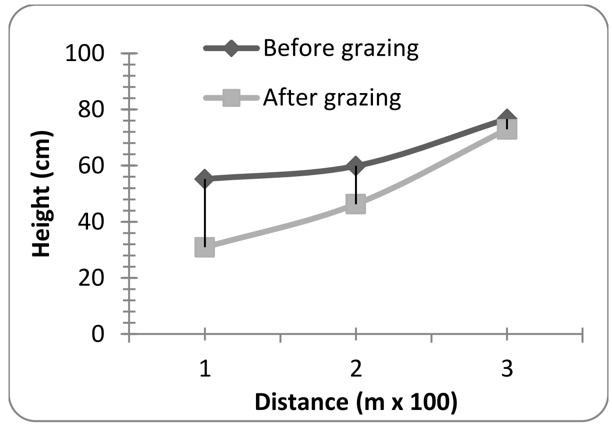

Figure 1. Tree height from close to far away of the alarm system

Table 1. Montlhy weight mean gain of pigs during the experiment.

	Month (Ap-My)	Month (My-Jn)	Month (Jn-Jl)	Month (Jl-Ag)	Month (Ag-Sp)	Month (Sp-Oc)	Month (Oc-Nv)	Month (Nv-Dc)
Initial weight Mean ± sd (kg)	34±12,26	43±12,74	51±12,38	63±11,40	73±2,19	89±11,41	94±11,33	105±12,33
Final weight Mean ± sd (Kg)	431±2,74	51±12,38	63±11,40	73±12,19	89±11,41	94±11,33	105±12,33	117±12,97
Average Daily Gain (ADG) Mean ± sd (g)	290±70	260±70	390±180	350±160	520±110	170±90	340±100	390±70

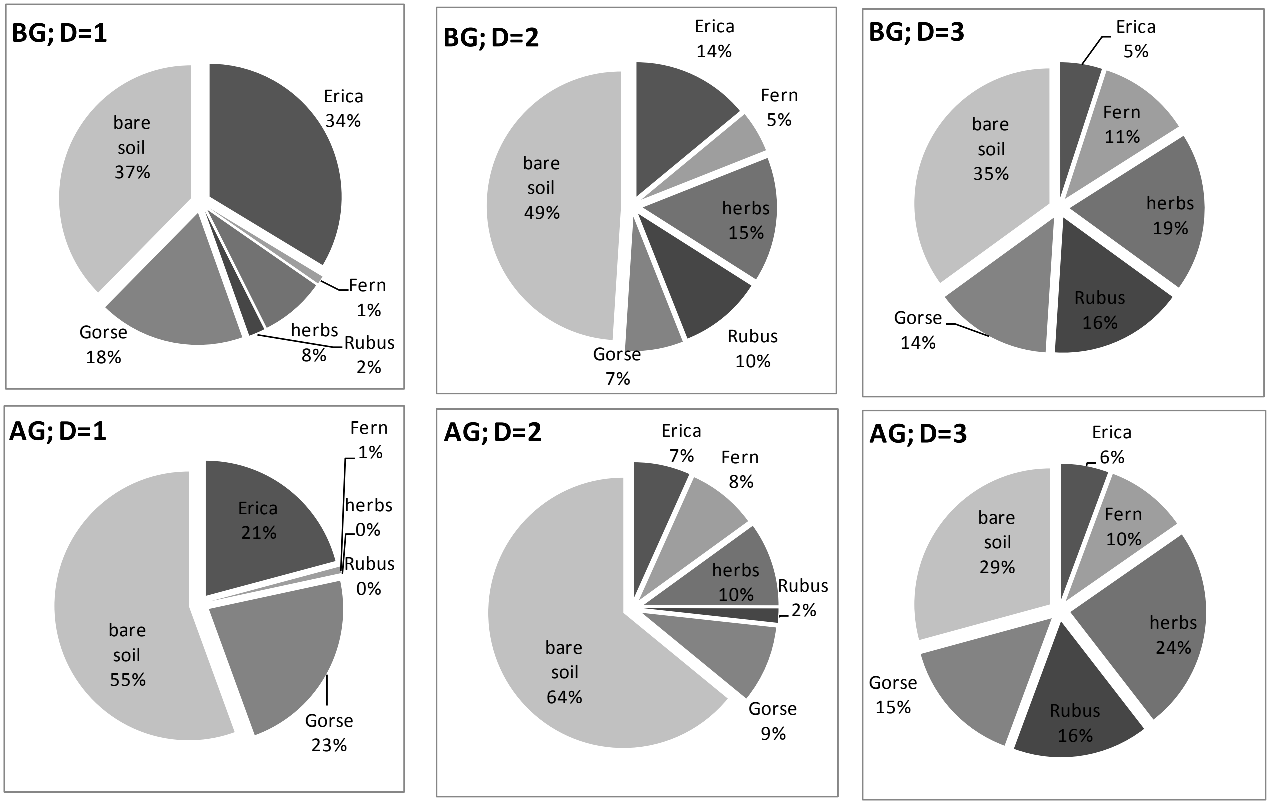

Figure 2: Understory evolution as a percentage at three distance ranges before (BG) and after (AG) grazing.

Discussion

Pigs adapted well to the alarm system and modified surrounding understory until 240 meters. Bare soil was increased as found in areas with pig grazing under chesnut trees (Santiago-Freijanes et al. 2011). The alarm system should be moved more frequently in order to reduce the bare soil in its surrounding areas.

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Indicators explaining the benefits of agroforestry systems

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Agroforestry is a traditional farming system that may offer many environmental and socio-economic benefits through an integrated management. In a context of climate change, biodiversity loss and rural abandonment, agroforestry is a viable alternative for combating those threats. Thus, there is a high potential for using agroforestry systems in their different combinations of components (trees, crops and animal species), adapted to different climate and soil conditions.

In the framework of the AGFORWARD project (AGroFORestry that Will Advance Rural Development) we aim, among other, to identify what are the driving forces for implementing Agroforestry systems or on the contrary for not applying them. In this poster we present selected indicators at European level that could explain some of the benefits of these systems.

Biodiversity loss is, among others, reflected in the **endangered species of livestock** breeds (cattle, pig, sheep, goat and poultry). Almost half of the European breeds are at risk of extinction or already extinct. Autochthonous species have been in many cases replaced by more productive species in intensive farming. Silvopastoral systems may offer an appropriate habitat for the reintroduction of some of the autochthonous and locally adapted livestock breeds (Rois et al., 2006).

Another relevant indicator for biodiversity directly linked to agroforestry systems, in particular to High Nature Value Farmlands (HNVF) are the **grasslands butterflies** that are suffering a continuous decline due to both agricultural intensification and abandonment (EEA, 2013). Traditional forms of farm management, such as extensive livestock grazing provide an ideal environment for these butterflies. In addition, butterflies are a good indicator for other insects that play a crucial role in pollination services and therefore the health of ecosystems.

There are clear trends of **rural abandonment** and migration to urban areas, and also of an ageing population. The major factor for such depopulation in areas where agriculture and forestry are the main economic activities, is the lack of economic opportunities, low competitiveness and profitability of agricultural and forestry, poorly developed infrastructure, the overall economic context of a country (territorial competitiveness), and a negative social image of agriculture and forestry (FAO, 2006). Land abandonment can lead to a substantial loss in biodiversity and genetic resources with negative consequences for future research and development, and lead also to a

reduction in land value and increased fire risk. In areas of intensive farming the abandonment may lead to a relative increase in biodiversity, though abandonment usually occurs on marginal lands that are often of high natural and cultural significance.

Expenditure of the Common Agricultural Policy (CAP) has decreased over the past 25 years, from 73 % of the total EU budget in 1985 to 41% in 2012. This decrease has taken place despite the successive EU enlargements. Taking all subsidies into account, total public support in agricultural income reached nearly 40 % of agricultural income on average in the EU. It was only in the year 2000 when Rural Development was introduced into the CAP dividing it into two pillars, namely production support and rural development. The second pillar accounts for 11 % of the total EU budget. Despite its numerous benefits, agroforestry was only recognized in 2006 in the CAP. Under the existing rules, 19 programs of rural development with agroforestry measures are implemented in 7 Member States, namely Cyprus, Italy, UK, Spain, Hungary, Portugal and France. The allocated budget amounts to 25 million Euros. Although few farmers have used these funds, there is room for improvement (EP, 2012).

In order to **map the potential area** where to implement agroforestry systems, we propose several key parameters that could be overlapped, e.g., rural abandonment, grassland butterflies, endangered livestock breeds, soil erosion, nitrate leaching, and danger of forest fires. Reisner et al. (2007) highlighted that, when considering the potential of only five tree species, 40 % of European arable land is suitable and recommended for introducing silvoarable agroforestry systems in order to solve any of the following environmental problems: soil erosion, nitrate leaching and low landscape diversity. When having into account different combinations of agroforestry systems including more tree species, the potential is even higher.

Some studies remark that despite a higher investment in the establishment of silvopastoral systems, its **profitability** was higher than with exclusively livestock (by 17 %) or forestry (by 53 %), and when environmental and ecological benefits are considered, the profitability is even higher (Fernández-Núñez et al., 2007). Agroforestry systems can provide a more efficient temporal and spatial use of the land with productivity rising between 20 % and 40 % comparing to agriculture or forestry (EP, 2012). Diverse production (wheat, rye, mushrooms, truffles, wool, meat, medicinal plants, etc.) can complement the farm owner's rent and value of his land (Rigueiro-Rodríguez et al., 2009). The production in these systems is normally linked to high quality products and organic farming, for which there is an increasing demand. Furthermore the increase in landscape amenity is a benefit for the society, increasing rural tourism and associated economic benefit for the region.

Most of the benefits of agroforestry systems have been well documented. Nevertheless, farmers still are reluctant to introduce them, due partly to high establishment costs, management, low technical support and low awareness of the different benefits. Policies may have also hindered the uptake of those systems, and should be redefined in order to promote those and be able to address some of the current problems that Europe is currently facing.

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Cattle production in agroforestry systems. An analysis on the role of intensification and dependence of subsidies

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Introduction

Extensive livestock production systems have faced socio-economic factors (such as the loss of profitability and competitiveness) that have led to modifications in their management and structure. The main changes have been the abandonment of grazing, the increase in the use of external feed, the abandonment of farms, and the intensification of the systems.

The dehesa is the consequence of human intervention in the natural Mediterranean forest. Due to this, the conservation of this ecosystem depends on the use of appropriate agricultural practices (Gaspar et al., 2007). Thus small changes in the production systems may have a great impact on its conservation and on the rural population. As consequence, the intensification of farms and the high prices of feed, make it difficult to increase farms' profitability while preserving the dehesas. In this context, dehesa livestock farms have increased their dependence on subsidies.

In view of the above it is necessary to identify the different livestock systems located in agroforestry systems, in order to allow appropriate measures to be developed for each system.

Moreover, given the lack of knowledge about the organic beef cattle sector, and its potential impacts on both the dehesa ecosystem and the rural population, this study has the objective of identifying and describing the production systems, paying special attention to their level of intensification and their dependence on subsidies.

Material

The data collected correspond to 63 dehesa beef cattle farms (30 conventional farms and 33 organic farms). The data were obtained through direct survey interviews with dehesa farmers which were carried out in 2012.

For the identification of the production systems, two steps were followed, following the methodology used by Gaspar et al. (2007; 2008). Firstly, a principal component analysis (PCA) was used. This allowed us to eliminate the redundancy involved in dealing with many variables. Secondly, a cluster analysis allowed classifying the farms into homogeneous production systems or

typologies. Descriptive statistics for the indicators were calculated. We also carried out ANOVA tests aimed at checking the existence of statistically significant differences among production systems. All the analyses were performed using the SPSS (v.21.0) statistical package.

Results

The result of the PCA gave the top three principal components (PC). The total variance explained by these three PCs was 83.5 %—a satisfactory percentage according to Malhotra (2004). These PCs were then defined by using the rotated matrix components.

PCs: **PC 1** (intensification level) explained 54.6% of the variance. This presented very high positive correlation coefficients with the variables: total stocking rate, annual work units per 100 hectares, veterinary expenditures, and livestock sales. This PC also showed medium positive correlation coefficients with the feed cost. **PC 2** (productive orientation: presence of a calves fattening period) explained the 17.1 % of the total variance. This PC presented high positive correlation coefficients with the variable fattened calves sold/total of calves sold, feed cost and

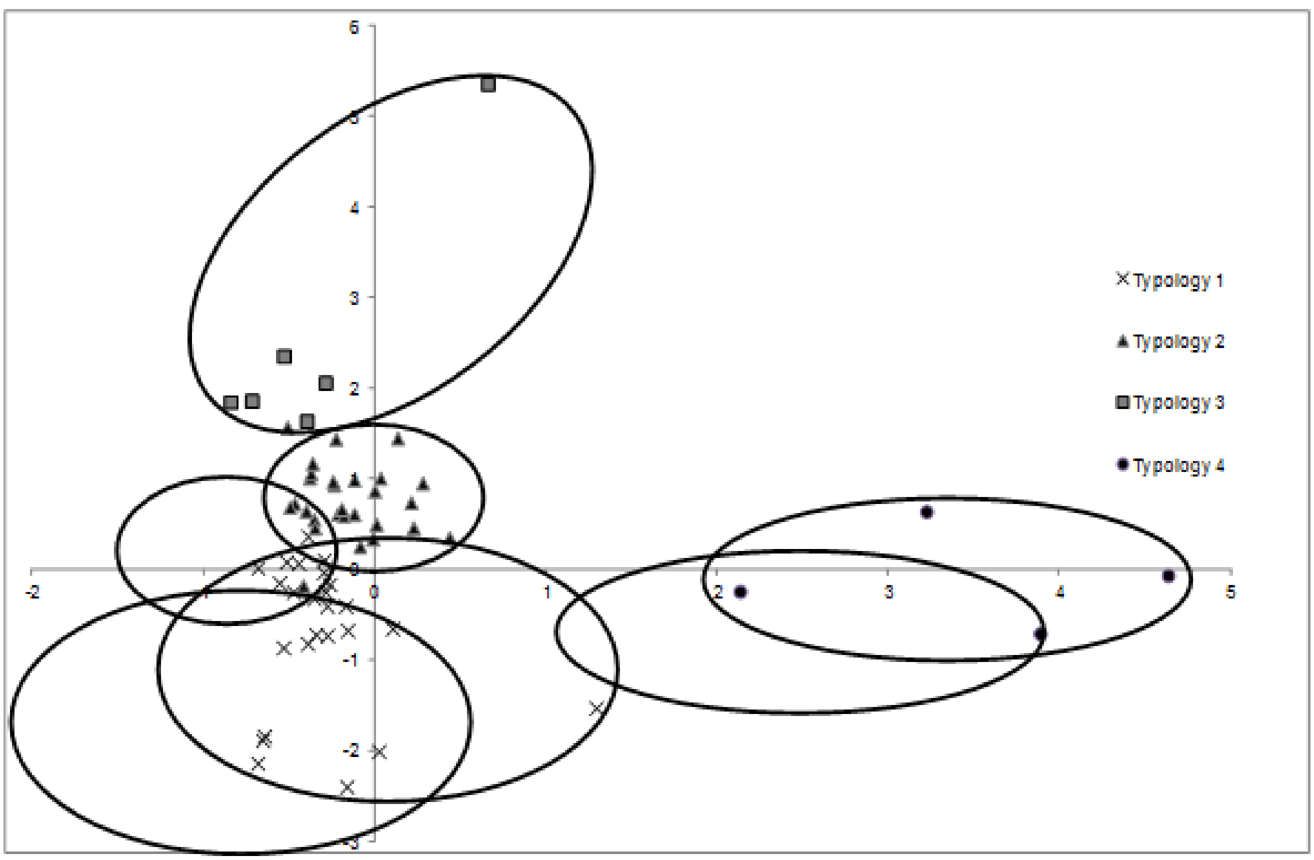

Fig 1: Positioning of the farms according to the scores for PC 1 (level of intensification) and PC 3 (dependence on subsidies)

intra-unit consumption. **PC 3** (dependence on subsidies) explained the 11.8 % of the variance. This PC only showed possitive high correlation coefficients with the variable subsidies/total income.

Cluster analysis: the cluster analysis that presented the most significant results was the solution of four groups. The groups thus obtained were compared by an analysis of variance. This allowed us to characterize the clusters (production systems). **Cluster 1**: **extensive farms with low productivity**. This group of 25 farms represents 39.7% of the sample. It is characterized by its low total stocking rate (0.41 livestock units –LU- per ha) and the absence of a calves fattening period. These farms presented low feed costs (54 €/ha), when compared to the rest of farms. Due to this, although, they obtained reduced livestock sales (171 €/ha), their depence on subsidies was the lowest (29.5%). **Cluster 2**: **diversified farms with low efficiency and high dependence on subsidies**. This cluster grouped 28 farms (44.4% of the farms). Its total stocking rate was also low (0.46 LU/ha). However, this cluster group a great number of full-cycle farms. These farms, although fattening their calves, presented lowest feed cost: 30.29 €/ha). They also showed the lowest livestock sales per ha (153 €/ha). As a consequence, their dependence on subsidies is the highest (56.4 %). **Cluster 3**: **medium stocking density farms and high profitability**. This group consisted of 6 farms (9.5 % of the total),with medium level of intensification (0.51 LU/ha) and the lowest porportion of cultivated area (5.8 %). As a consequence, they presented the highest feed costs (277.56 €/ha). Regarding the subsidies, they showed a level of dependence equal to 34.7 %. **Cluster 4**: **cultivated farms with high livestock density**. This group of 4 farms represents 6.4 % of the sample. The farms grouped into this cluster presented the highest total stocking rate (2.82 LU/ha), the highest proportion of cultivated area (72.5 %), the absence of a calves fattening period (any calve was fattened), the highest investments on fixed capital (355 €/ha). Due to their high total stocking rate, they showed the highest livestock sales per ha (846 €/ha). Their presented a medium level of dependence on subsidies (33.6 %), with respect to the rest of farm groups.

Discussion (and conclusions)

This study allowed us to identify the large diversity of beef cattle farms located in the dehesas according to the level of intensification and dependence on subsidies. In general terms, all farm groups showed adequate levels of intensification in the context of the dehesas extensive farming (Escribano et al., 2006). However, group 4 must modify its structure in order to preserve the ecosystem. This high level of intensification was related to the these farms being located in the margins of the dehesa area. Moreover, these farms needed to purchase external feed. Thus, these

two groups have a further negative characteristic with respect to their sustainability — their external dependence. However, this can be overcome by a high total income, as a consequence of growing and selling more crops than other farms.

By contrast, farms grouped in Clusters 1 and 2 are more effective in preserving the dehesa (due to a low total stocking rate) than other farms. However, as they scarcely fattened their calves, their profitability is very low. Moreover, the high dependence on subsidies showed by the Cluster 2, will hinder the future competitiveness and sustainability of the farms in this group. Finally Cluster 3 showed better structure and results as they sold the majority of fattened calves. Despite having the highest feed cost, their dependence on subsidies was not high, and their level of intensification was medium. Due to this, these farms have presumably the highest chance of success under the context of the dehesas.

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Calibration of the parameters of the Yield-SAFE model in silvopastoral systems under *Pinus radiata* D. Don

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Introduction

The establishment of silvopastoral systems in which trees, animals and pasture are integrated within the same area is promoted by the EU (Council Regulation 1305/2013 (EU 2013)) because these systems diversify and sustain production with increased social, economic and environmental benefits for land users at several levels (Mosquera-Losada et al. 2009). However, the environmental and economic benefits of silvopastoral systems are difficult to predict due to the interaction of many factors. Furthermore, research through field experiments is expensive and time-consuming when tree measurements have to be taken into account (Palma et al. 2007). One option to determine the benefits of silvopastoral systems which overcomes these drawback is the use of models like Yield-SAFE (van der Werf et al. 2007). Radiata pine (*Pinus radiata* D. Don) is one of the most widely used tree species in the establishment of silvopastoral systems in areas such as Australia, New Zealand and Chile (Benavides et al. 2009) and in Galicia (NW Spain). In this region, radiata pine covers an estimated area of 90,000 ha (11% of the total wooded area) (Xunta de Galicia 2001).

The objective of this study was to calibrate Yield-SAFE model for a silvopastoral systems established with radiata pine in Galicia to initiate the assessment of the potential environmental and economic benefits of this type of agroforestry systems.

Material

The parameter calibration of the Yield-SAFE model was performed with tree and pasture data from a silvopastoral system established in Castro Riberas de Lea (Lugo, Galicia, NW Spain). The experiment was initiated in 1995 when the land was ploughed and the experimental plots were established. The experimental design was a randomised block with twelve treatments and three replicates. We selected one of 12 treatments that simulates traditional management in Galicia of radiata pine usually established at 833 trees ha^{-1}, with a planting distance of 3m×4m and an area of 192 m^2 per replicate. In each experimental unit, 25 trees were planted with an arrangement 5×5 stems. After plantation, the plots were sown with a mixture of *Dactylis glomerata* L. var. Saborto

(25 kg ha^{-1}), *Trifolium repens* L. var. Ladino (4 kg ha^{-1}) and *Trifolium pratense* L. var. Marino (1 kg ha^{-1}). Fertiliser was not applied to replicate traditional reforestation practices for agricultural land in this area. To the parameter calibration of the Yield-SAFE model, the height and diameter of the trees were measured from 1995 to 2013 and the tree biomass was determined via the implementation of allometric equations based on diameter (Montero et al. 2005).

Pasture production was also determined in each plot from 1995 to 2013 and used to perform the calibration of the Yield-SAFE model adapted to Galicia conditions. In the first years of the experiment, the pasture was harvested between six of the nine central trees. Thus, an area of 24 m^2 was sampled for 833 trees ha^{-1}. The samples were collected in May, June, July and December, as is traditional for the area. The fresh pasture was weighed in situ and a representative subsample was taken to the laboratory. Once in the laboratory, to determine the pasture production in the understory, two subsamples (100 g each) were taken and the pine needles and the senescent material present in these samples were removed. Then, the samples were dried (72 hours at 60ºC) and weighed to estimate dry-matter production. In the final years of the study, the pasture production was only estimated by harvesting sampling quadrats of 1 m × 1 m in July and December because the tree canopies had expanded and therefore the pasture production was lower than in the first years of the experiment. Moreover, it is important to be aware that from 1995 to 2006, pine needles accumulated in the understory were removed after harvesting. Annual pasture production was calculated by summing the consecutive harvests of the pasture production in that year.

The initial estimation of the model parameters was based on an extensive literature review and on existing data sets with tree and pasture measurements. Climate data (daily temperature, radiation and precipitation) was set from a nearby weather station to the study area. The tree parameter calibration of the Yield-SAFE model was made with a Python version of the model prepared to use an optimization module with the L-BFGS-B algorithm (Byrd et al., 1995). In this technique, lower and upper bounds are set for each parameter value found in literature, and a minimization procedure is performed on the likelihood between observed vs modelled, providing the optimal set of parameters that best fit the observed measurements. A Microsoft Excel© implementation of the model was used to corroborate the calibration results and provide graphic interpretation of the results (Graves et al., 2010).

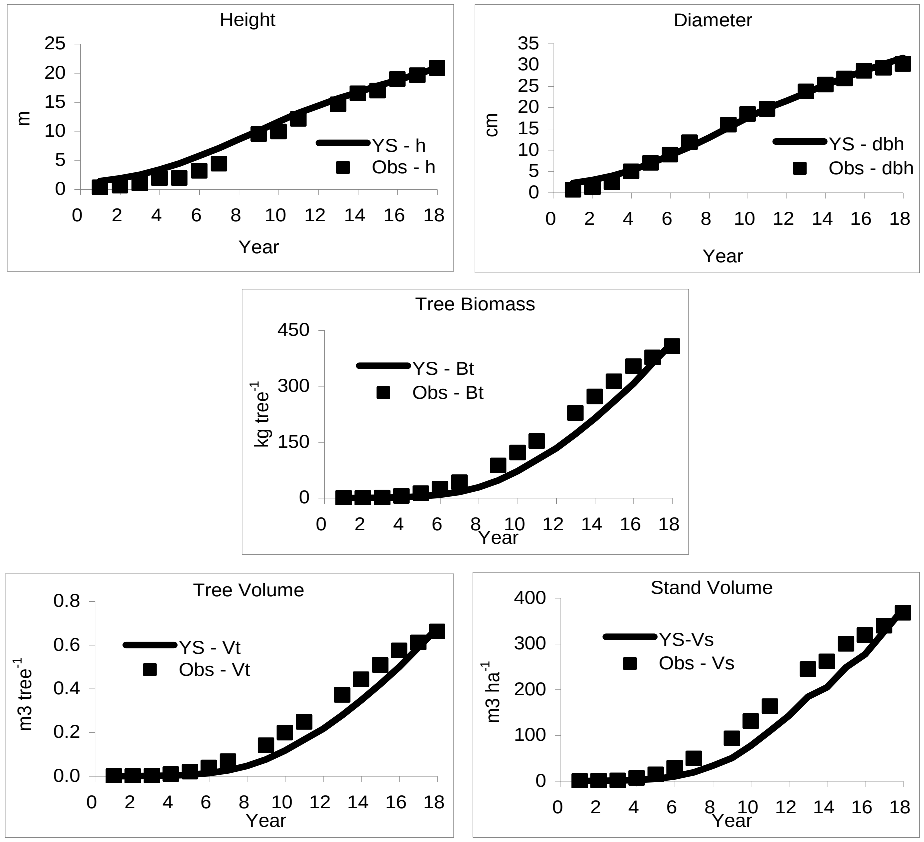

Fig 1: Calibration results of the Yield-SAFE model for *Pinus radiata* D. Don established at low density (833 trees ha^{-1}) in Galicia (NW Spain).

Results

Fig. 1 shows that the Yield-SAFE calibration procedure was successfully performed for trees. However, the Yield-SAFE model still needs improvement in the calibration of the pasture (Fig. 2).

Discussion

The Yield-SAFE model adaptation to radiata pine trees was successful and allows us to predict tree response to different situations. This model has been also successfully calibrated for other tree species established in different conditions in Europe (Graves et al., 2010). However, it was difficult to calibrate the pasture growth within the Yield-SAFE model. This may be due to the multi specific pasture composition (Rigueiro-Rodríguez et al., 2012) with different light and humidity requirements, responding differently in the intra-annual harvests. Therefore, an improvement for pasture parameters, or adaptation of model structure for multiple arable component species is needed to improve estimations.

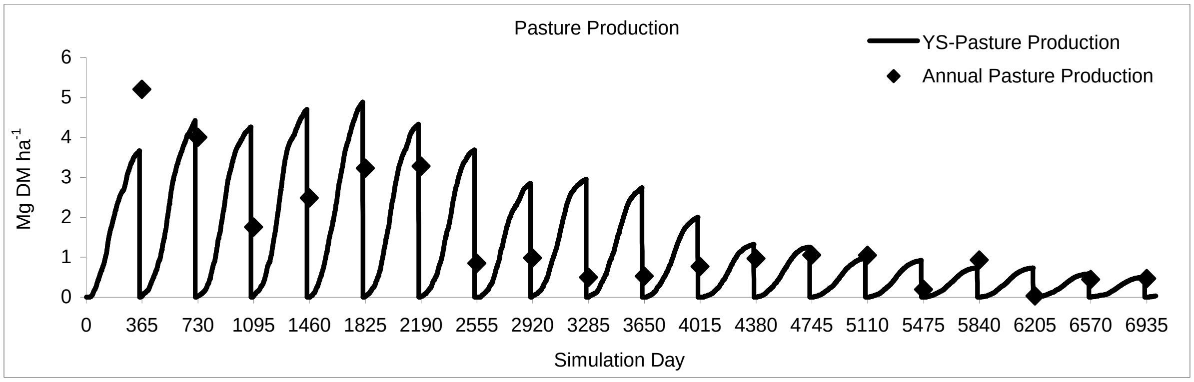

Fig 2: Calibration results of the Yield-SAFE model for annual pasture production estimated in a silvopastoral under *Pinus radiata* D. Don established at low density (833 trees ha^{-1}) in Galicia (NW Spain).

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From research to the field… developing a third generation agroforestry

“Third generation” refers to the integration of new dimensions into the agroforestry concept

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- **Mixed agricultural and forestry varieties of local origin**, specifically chosen for each site, instead of single-purpose plantations
- **Integration of nearby vegetative structures** in order to create a matrix of green spaces, e.g. natural regeneration of field margins, hedge and riparian vegetation management, hedge planting, and restoration of pollarded trees
- **Sowing of cover plants on tree lines**
- **Bioenergy or mulching with Ramial Chipped Wood (RCW)** from pruned trees or pollarded trees
- **Soil protection at the foot of trees** (with 100% biodegradable mulch : corn starch, RCW, straw)
- **Management of soil biology and fertility through simplified farming practices**

Through this kind of integrated systems, it is possible to create areas for environmental mitigation that are also highly productive. This innovative pathway should allow agriculture to meet the environmental and economical challenges: producing in accordance with the Water Framework Directive, Nitrate Directive, National Strategy for Biodiversity, the Climate Plan, reduction of pesticides through stimulation of natural regulation processes of pests and of the presence of natural enemies, improvement of the quality of crops, optimization of land productivity...

Trees and livestock

In addition to the various benefits such as protection of buildings and recycling part of the pollution linked to effluents, trees also offer a direct economic advantage for livestock.

Animals kept in fields with trees and less stressed than those raised inside. They have access to better food and are less vulnerable to disease.

Studies have shown that productivity increases 20% for meat and milk thanks to the presence of hedges and trees.

Trees and large scale crops

The presence of trees offers a climatic and biological protection of crops; it improves soil quality and their ability to retain water.

Planting trees and hedges within a farm results in an increase of overall yield of crop and animal production. Agroforestry allows a diversification of production at the field scale (softwood lumber, bioenergy, RCW, fruits...) as well as increasing overall yield by up to 30%.

Trees and soil quality

Trees have an important role in soil quality especially regarding organic matter rate and soil structure, nutrient content and soil biology. To avoid destroying this beneficial effect of the trees on the soil quality, it is essential to associate agroforestry with simplified farming techniques (non tillage, sowing under plant cover…). Soil quality is fundamental for managing plant health and for pest control.

Uses of timber

Timber produced by agroforestry (pollarded trees and hedges) can be valued in different ways: softwood lumber, fencing, bioenergy or Ramial Chipped Wood (RCW). RCW consists of ground twigs from tree pruning, incorporated into the soil in order to improve its properties. These uses generate economic resources for the farmer.

Promoting biodiversity

Thanks to the variety of plants flowering at different times, agroforestry systems offer natural enemies of crop pests the nectar and pollen resources they need all year long. These natural enemies may then pollinate crops and effectively control pests.

Native tree species

The tree species planted for rural landscaping are native varieties. Their local origin is the key to a good adaptation to environmental constraints and for maintaining or restoring genetic diversity.

Nearly two dozen of local varieties were used in the plantations

Farm characteristics

84 ha of organic agriculture

Productions :

Crops

Wheat, spring and winter barley, horsebean, oats, sorghum, sunflower, meslin, alfalfa, sainfoin, trefoil.

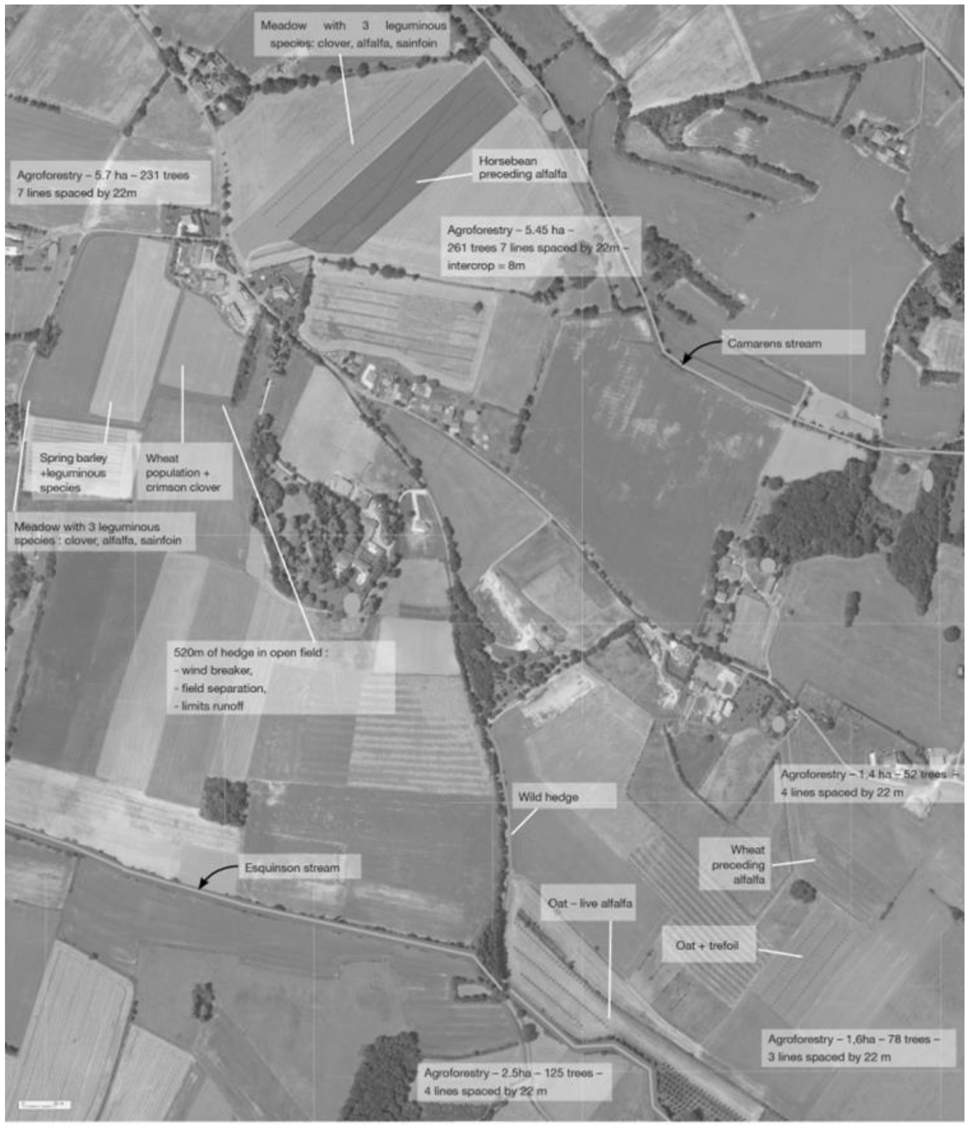
Livestock

Bovine meat, limousine breed

The animals only feed on dry grass complemented with leftover grains from seed sorting.

Agricultural practices:

Vegetative cover in intercropping; Direct seeding and cover crop seeding; superficial tilling : maximum *5 cm*



Agriculture must fit within the framework for sustainable development in order to ensure its durability. Trees and hedges are part of tomorrow's agriculture and their effect on water infiltration, carbon sequestration, useful organisms (e.g. natural enemies, pollinators) and soil conservation no longer needs to be proven. Thanks to its multiple benefits, trees in farming systems associated to cultural techniques of vegetative cover can provide simple and low-cost solutions to recover from and even prevent disturbances at all scales, from the field to the watershed. But every element is a whole issue with many questions.

Black locust (*Robinia pseudoacacia L.*) - an invasive alien species or potentially species plantation of agroforestry in Pannonian ecoregion

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Introduction

Black locust (*Robinia pseudoacacia* L.) was introduced to Europe from its natural habitat in southeastern United States more than 300 years ago. Nowadays the European Commission propose to regulate invasive alien species in the framework of the Biodiversity Strategy 2020. There are several ecological contradictions about black locust, because ecologists focus on the disadvantages of this species, however it offers many advantages for more economical sectors and the ecological service value is also important.

It is fast growing, excellent coppicing, drought tolerant, has high survival rates and yield as well as very hard durable wood. Due to its symbiosis with the nitrogen fixing bacteria, *Rhizobium* sp. black locust is capable of colonising very low nutrient substrates. Black locust is also promising tree species for short rotation forestry (SRF) including setting up energy plantations (Führer and Rédei 2003, Rédei et al. 2011).

Due to the evolved debate about black locust, a potential solution is the planting of black locust into agroforestry system **where it can offer a win-win option for agricultural-, forestry sector and ecologists. The aim of this study was to evaluate a Spatial Decision Support System (SDSS) to plantations of black locust in Hungary to mitigate ecological conflict zones based on a GIS model. The results showed that within specified conditions, black locust can be a** potential species for agroforestry.

Material

In this study, we considered suitable areas for black locust planting with different soil, weather, conservation (including NATURA2000), topograpy and land-use databases. The sites were collated in two phases. First we separated optimal site requirements for this species such as climate data, soil condition and topography. After that land use categories were selected in terms of agroforestry establishment. We selected out sites not suitable for black locust such as roads,

buildings, wetlands and conservation areas, and NATURA 2000 sites where black locust is not desirable. Finally **the layers of information were combined to identify key areas for Black locust establishment.**

Climate parameters were separated from the climatic map of Hungary. Soil data was obtained from the AGROTOPO database which was prepared by the Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences. Map data come from the 1:100.000 scaled Agrotopographic sheets of soil patches. 4.000 soil patches, cover the total area of Hungary**. From the Agrotopological Database information about** soil types and subtypes, parent material, soil texture, soil water management categories, soil reaction and carbonate-status, organic matter resource, depth of - the fertile top layer, soil productivity value (bonitation index) were obtained. The relief parameters were obtained from Digital Terrain Model of Hungary.

NATURA2000 habitat site information was obtained from the NATURA2000 database. For protection of the NATURA2000 areas we took into account a 500 m buffer zone. The suitable land use categories were selected from CORINE Land Cover (co-ordination of information on the environment). Roads, rail lines, buildings and wetlands were cropped from the DTA 50 database. The DTA 50 1:50000 scale was established with Digital Elevation Model (DEM) and the Geodetic Database (GAB). The DTA50 is a 1:50.000 scale topographic map. In our research, based on the categorisation system, a (Figure 1) Spatial Decision Support System (SDSS) was made in ArcGIS 10.2.

Results

As for climatic demands of black locust, the climatic conditions in the sessile oak-Turkey oak and forest-steppe zones of Hungary meet the requirements**. The optimal accumulated day temperature for black locust is around 11 °**C and an optimal annual precipitation of 600 mm. Temperature is not a limiting factor for establishing black locust in Hungary, as the mean annual temperature is 11 °C. However in Hungary the average annual precipitation is 500-750 mm. Fine sands and light loamy soil types are suitable for growing black locust, as the rootzone depth is

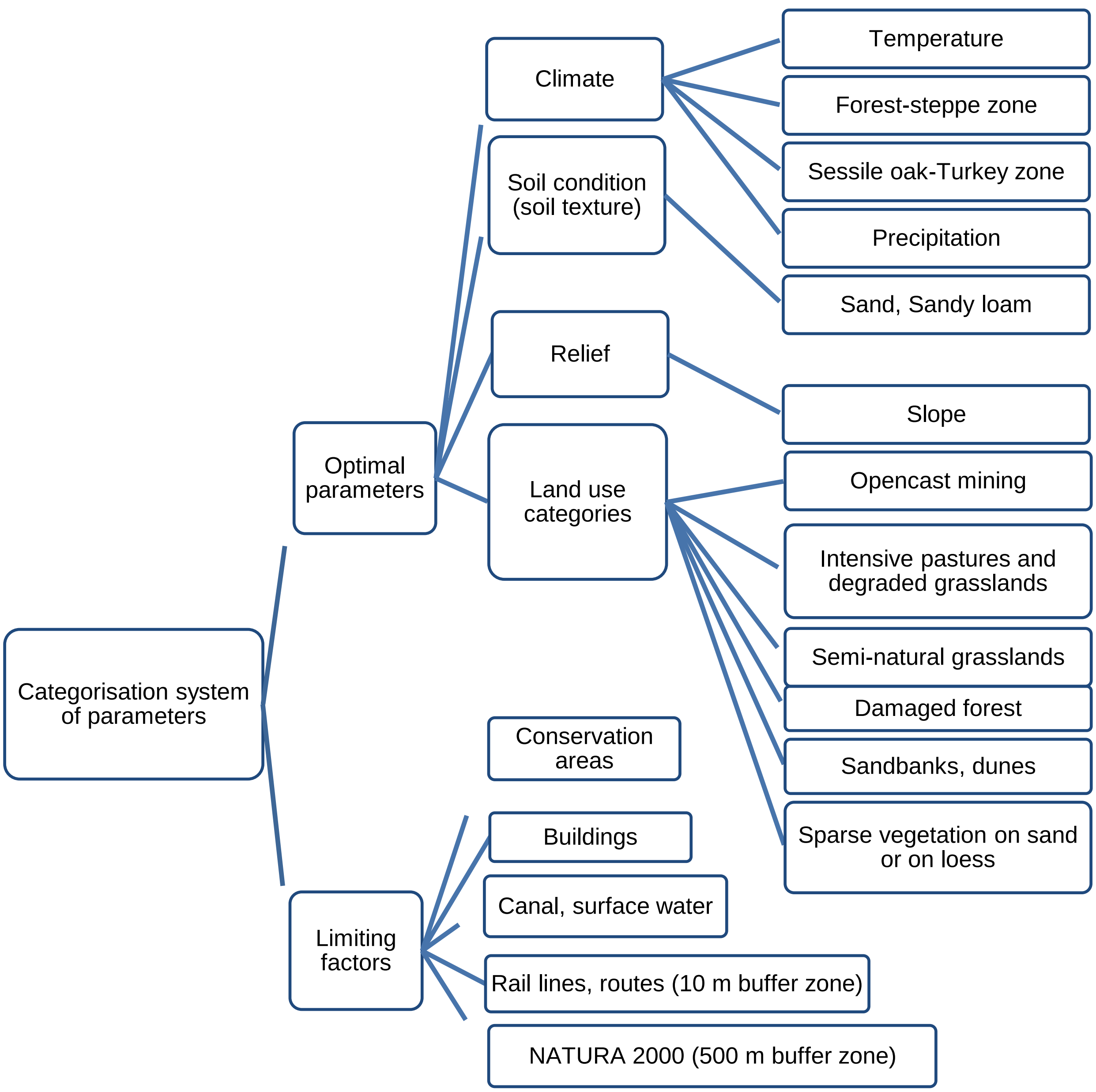

Fig1.: Categorisation system of factors

ideal. In our case soil texture was considered such as sand and sandy loam. In this context black locust can play an important role against degradation in these areas. Different relief parameters were obtained from the Hungarian DTM.

Currently NATURA2000 sites cover 19.682 km² that is 21% of the Hungary. It is accepted as plantation areas of black locust. Optional land use categories were considered e.g. abandoned opencast mining site, intensively grazed pastures and degraded grasslands, semi-natural grasslands, damaged forest, sandbanks, dunes and sparse vegetation on sand or on loess that could be suitable for agroforestry systems.

The canals, roads, surface water and buildings were selected from DTA 50 database. These areas were excluded from the categorisation system as they are not suitable for the establishment of black locust. We did however consider a 10 m buffer zone next to routes and rail lines. Considering these factors, the potential sites of black locust were determined. The concept mode is summarized in Fig.1.l.

Discussion and conclusion

In connection with the regulations of the European Commission some debate has evolved about the black locust. Nevertheless, black locust has an important role in the reclamation of natural and man-made barren lands, first of all on spoil banks and in gullies. These spoil banks are not good for agriculture but they may be suitable for afforestation. Knowledge of the ecological requirements of black locust can help to limit the invasive spread of this species. Considering these parameters, black locust can be a potential tree in agroforestry systems. Our Spatial Decision Support System has served these objectives. Currently 24% of the forest area in Hungary is covered by black locust. The invasive spread of black locust is occurring on a number of sites. The spread has been influenced by the light requirements of the species, for example it can appear in native forests that have been damaged. We would like to consider further the spread of black locust by the use of GIS and ground truthing..

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Tree growth in a silvopastoral system established in acid soils with *Pinus radiata* D. Don

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Introduction

In Galicia (NW Spain), the soils tend to be acidic mainly due to the high precipitation, the prevalence of subtractive systems, frequent fires and, often, acidic parent material (Álvarez et al., 2002). In silvopastoral systems, soil acidity reduces plant vigour, rendering plants uncompetitive with weeds and more susceptible to diseases, as well as limiting pasture production and causing uneven tree growth (Ferreiro-Domínguez et al., 2014). Therefore, it is advisable to perform management activities such as liming and fertilisation to neutralise acidity and to increase pasture and tree productivity. Liming is a common practice in Galician soils devoted to pasture production and sewage sludge could be used as an organic fertiliser due to its beneficial effects on the soil and the recent increases in inorganic fertiliser prices (Mosquera-Losada et al., 2010). However, as the application of sewage sludge to the soil might result in an increase in inorganic soil pollutants, optimisation of the dose is clearly desirable (Passuello et al. 2012). Moreover, the residual effect of sewage sludge is more important than that of mineral fertilisers. Long-term sewage sludge input effects should be considered when measuring the improvement in soil fertility, the understory and tree production. The objective of this experiment was to compare the effect of no fertilisation, three doses of sewage sludge (160, 320 and 480 kg N total ha^{-1}), with or without liming (2.5 t $CaCO_3$ ha^{-1}), and the mineral fertilisation usually used in the region (8% N – 24% P_2O_5 – 16% K_2O) on tree growth in a silvopastoral system established on an acidic forest soil with *Pinus radiata* D. Don in 1997.

Material

The experiment was established in Pol (Lugo, Galicia, Northwestern Spain) in 1997 and used a five-year old *Pinus radiata* D. Don planted in 1993 with a density of 1667 trees ha^{-1}. The experiment used a randomised block design with three replicates. In autumn of 1997, the soil was cleared and ploughed, and the experimental plots were established. Each plot had a square of 5×5 trees and occupied 96 m^2, and plots were sown in autumn of 1997 with a mixture of 25 kg ha^{-1} of *Lolium perenne* var. Brigantia, 10 kg ha^{-1} of *Dactylis glomerata* var. Artabro and 4 kg ha^{-1} of *Trifolium repens* cv. Huia after ploughing. All cell plots were initially fertilised with 120 kg P_2O_5 ha^{-1}

and 200 kg K_2O ha^{-1} in autumn 1997 to initially improve pasture establishment. The established nine treatments were no three sewage sludge doses based on N application (S1: 160 kg total N ha^{-1}; S2: 320 kg total N ha^{-1}; and S3: 480 kg total N ha^{-1}), with or without liming applied in 1997 before sowing (2.5 t $CaCO_3$ ha^{-1}). A no fertilisation (NF) treatment was also established as a control in the limed and unlimed plots. A control mineral treatment (MIN) in the unlimed plots was also included because the combination of lime and the MIN treatment is not usually applied in the area. The MIN treatment consisted of the application of 500 kg of 8% N – 24% P_2O_5 – 16% K_2O ha^{-1} in accordance with conventional practice for fertilising pastures from 1998 to 2003. Sewage sludge was applied in 1998, 1999 and 2000. To evaluate the residual effect of these treatments, mineral fertiliser was added in 2001, 2002 and 2003 in the plots previously fertilised with sewage sludge, initially because in the higher doses the sludge was not easily incorporated (some unincorporated sewage sludge rests were visually visible) and later to improve pasture production.

A composite soil sample per plot was randomly taken in December 1998 and 2009. An extraction with 0.6 N $BaCl_2$ was used to determine the concentrations of Al and the exchangeable cations (K, Ca, Mg and Na) in the exchange complex. The K, Ca, Mg and Na exchangeable concentrations were measured with a VARIAN 220FS Spectrophotometer. The Al concentrations were analysed after valoration with 0.01 N NaOH using phenolphthalein (1%) in an alcohol-based solution as an indicator. The effective exchange capacity (EEC) was determined by taking the sum of K + Ca + Mg + Na + Al and the saturation percentage of Al, K, Ca, Mg and Na using the quotients Al/EEC, K/EEC, Ca/EEC Mg/EEC and Na/EEC, respectively (Mosquera and Mombiela 1986). The tree total height and normal diameter at 1.30 m were measured in the inner nine trees of each plot in January 2001 and in November 2009 with a pole and callipers, respectively. Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant (SAS 2001).

Results

The saturation percentage of Ca was significantly increased by the lime inputs in 1998 when the same levels and types of fertiliser were compared which implied that the saturation percentage of Al reduced with the liming in this year of the study ($p < 0.001$) (Fig. 1). However, in 2009, it was not observed a significant effect of the treatments on the saturation percentage of Ca and Al in soil exchange complex ($p > 0.05$).

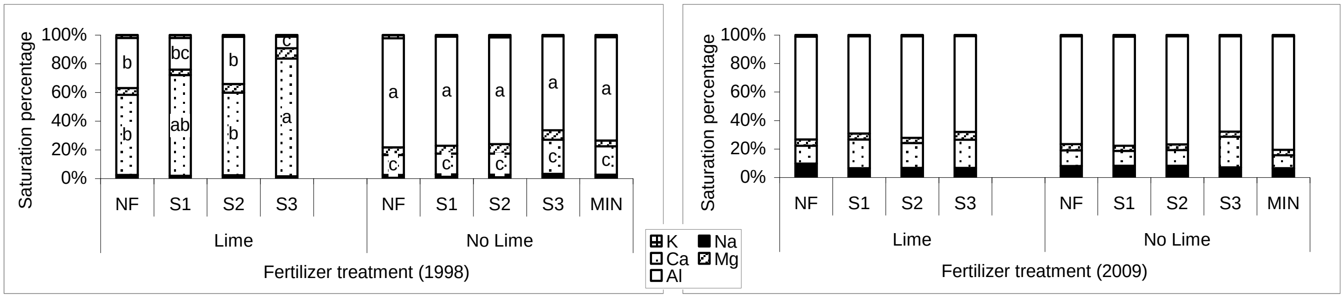

Fig 1: Saturation percentage of Al, K, Ca, Mg and Na in soil exchange complex (%) under each treatment in 1998 and 2009. Different letters indicate significant differences between fertiliser treatments.

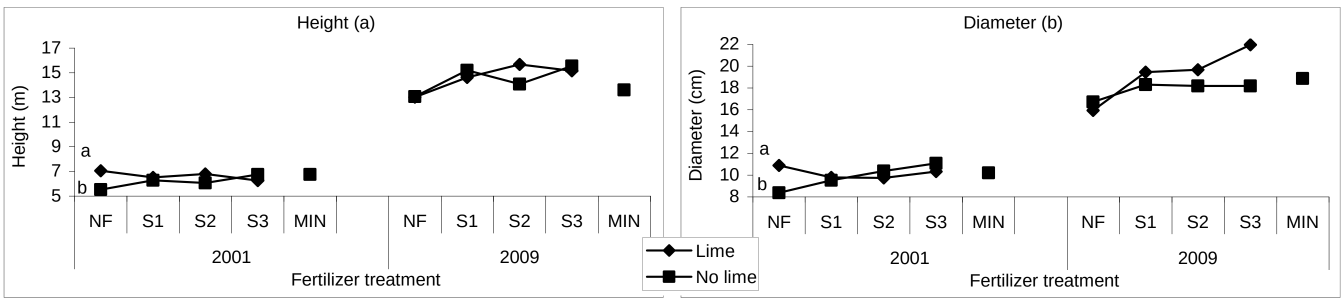

Fig 2: Tree heights (m) (a) and tree diameters (cm) (b) under each treatment in 2001 and 2009. Different letters indicate significant differences between limed treatments within each fertiliser treatment.

On the other hand, Fig. 2 shows that tree heights and diameters were significantly affected by the lime and fertilisation interaction in 2001 ($p < 0.05$). Tree variables were positively affected by the limed treatment in the NF plots. However, in the plots fertilised with sewage sludge in 2001 and in all plots in 2009 there were no observed differences across the treatments ($p > 0.05$).

Discussion

In the first years of the study, the results showed an increase of tree growth in the limed plots probably due to the input of Ca into the soil from liming which implied a reduction in the Al saturation percentage in the soil exchange complex. The input of Ca into the soil could increase the mineralisation rate of the soil organic matter and, therefore, the availability of nutrients. Pasture was not able to take up these nutrients for absorbance by trees because of the deeper root structure at that stage of development, which favoured tree growth (Mosquera-Losada et al. 2006). The positive effect of liming on tree growth was also observed by Balcar et al. (2011), who studied the growth of *Fagus sylvatica* L. and *Acer pseudoplatanus* L. over 15 years, and by Saarsalmi et al. (2011), who studied *Pinus sylvestris* L. where lime was applied to the soil surface. However, 12

years after the addition of lime to the soil and 9 years after the fertilisation with sewage sludge (2009), the Al saturation percentage in the soil exchange complex was similar in all plots to that observed at the beginning of the study. Tree growth became also similar between treatments and initial differences shown as result of treatments disappeared. **Therefore, it is necessary to maintain an adequate regime of soil fertility to guarantee a sustainable growth of the forest stand.**

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Co-Design of innovative periurban horticultural agroforestry systems: Case study of a pilot farm in the south of France

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Background

The needed reduction of agricultural inputs (especially pesticides) without productivity loss needs a fundamental redesign of cropping systems. The optimization of various ecological services (such as regulation of microclimate, soil biological processes, protection against erosion, biological control, allelopathy, pollination, etc.) susceptible to optimize biodiversity and to enhance natural enemies whilst decreasing pests will only be possible by modifying deeply the composition, structure and organization of agroecosystems. The basic principle is to act at levels that can induce a long term effect instead of only modifying at the margin some practices (in particular by simple input substitution) with a limited medium or short term effect. Another social issue deals with land scarcity, especially around cities, and need for young farmers to design viable agrosystems with a limited surface.

In these perspectives, conceiving agroforestry systems combining fruit trees, vegetables and wild trees and shrubs is one possible option. This kind of cropping system is common under tropical regions, but has not yet been investigated in temperate ones. Key challenges for these northern systems will be to optimize income, biodiversity and ecosystem functioning and to find out and test spatial combinations of trees and vegetables that fit to the growth requirements of a great diversity of species in temperate climate.

Method

We explored the basic ecological principles fundamental for natural ecosystems (Ewel 1999), for tropical agroforestry systems (Altieri 2004; Malezieux 2012) and for temperate systems (Altieri 2002) which seem to allow the stimulation of natural regulation processes of predators and to enhance plant and agroecosystem health. The main principles mostly address :

(i) intra- and interspecific diversification for enhancing food supply and housing opportunities for natural enemies and pollinators (diversification of species and of strata, floral diversity, association of varieties, in some cases integration of animal husbandry,…)

(ii) management of soil biology and fertility (soil protection, organic matter management, identification of associations and successions having a positive impact on soil activity and quality, improving the soil preparation techniques,…).

Literature also gives elements about (a) the conditions and limits of experimental design in agroforestry systems, (b) the ecological functioning and (c) trade-off between income, biodiversity and ecosystem functioning in tropical and temperate mixed cropping systems or agroforestry systems. These elements should allow orientation of experimentation for temperate linear agroecosystems (with alley-cropping) showing a high cultivated biodiversity.

Temperate systems count additional constraints compared to tropical ones :

(i) adaptation to mechanization which may limit plants intrication with perennial and/or annual crops ;

(ii) need for a high income per surface unit allowing economic viability of farms in a capital intensive economic system.

The compromise between economic/technical constraints and ecological principles for stimulation of natural regulation processes of pests is a permanent challenge while conceiving the farming system at field and farm level.

The mixture of fruit trees and vegetables possibly has an impact on biodiversity and on the presence of certain natural enemies which still has to be studied. Though it seems that canopy trees may also have an important impact on soil functioning, biological interactions and regulations, plant stress decrease, etc. which might improve the resilience and the health of agroecosystems even if these already include fruit trees. In temperate situations, one has to better identify the impact of fruit trees, the possible role of tree canopies and the optimized ratio and distances between vegetables and trees in intensified and organized alley-cropping systems.

We hereby present a co-design research project, aiming at creating a 4 ha pilot farm in the suburbs of Avignon, France. The farm will be managed by 2 farmers and shall thus be economically viable.

Results

Proposals for different spatial arrangements and prototypes have been elaborated and evaluated over two years (sept. 2011 - august 2013) through participative discussions involving scientists, advisors and farmers following an approach described by Vereijken (1997). We defined a system approach for evaluating complex agroforestry systems when factorial tools are not relevant. This approach is based on methods developed by Debaeke et. al. (2009), Drinkwater (2002) and Lamanda et. al. (2012). We defined the objectives and hypotheses for identifying parameters which will be analyzed at different periods throughout the development of the crop production system for evaluating (a) the results and (b) the extent to which the defined objectives have been reached *in fine*. The system that will be implemented on the farm has progressively been designed according to the main results to achieve and the hypotheses which can be tested. This work has been used for developing an *ex ante* multi-criteria evaluation tool (DEXi based) of the prototypes.

We considered several parameters for conceiving the spatial organization of the cropping system (vegetables/fruit trees proportion; height and shape of trees; nature of the graftholder; orientation of rows; presence of hedges and canopy trees; etc.). Necessary circulation between tree rows (for picking or treatments) with neighbouring vegetables led to alternating 12-meters double tree rows with 10 to 6-meters vegetable plots, depending on the height of the fruit trees. Single rows will be implemented at the edge of fields. Fruit trees will be placed every 5-6 m within rows with semi-vigourous to vigourous rootstocks. We studied the impact of fruit trees on the light available for annual crops using *Qualitree* (Miras-Avalos 2011). We based our analysis on the fact that C3 plants (almost all vegetables) become light saturated at approximately 50 % of full sunlight, whereas C4 plants (e.g., corn and sorghum) become light saturated at near full sunlight. If shading by the tree crop does not reduce light levels below the threshold of light saturation, then no reduction in photosynthesis (net assimilation), or ultimately crop growth or yield, should occur (Reynolds et. al., 2007). We also investigated the impact of canopy tree rows planted between two fruit tree rows or between two vegetable fields and identified possible configurations of hedges combining wild shrubs and canopy trees for reaching a minimum of 60 % total light reception by fruit trees and vegetables.

We evaluated different combinations of fruit and vegetable production through calculation of expected yield, operational costs and income, including processed and secondary products (juices,

eggs and soft fruits). The prototypes have been conceived by simulating the evolution of fruit production over 10 years which allows taking into account the progressive economic development of the production system. An expert evaluation of the time needed for each activity and each crop gives an analysis of the organizational feasibility. Data were collected from different sources to build the economic model of the pilot farm. It is thus possible to use these data for simulating prototypes according to the farmer's production objectives in order to evaluate the social and economic feasibility of such innovative systems.

At the end, simulations and expert knowledge enabled us to identify a possible combination of about 470 fruit trees and 1,5 ha of vegetables, generating an income for two farmers, in combination with the management of poultry for egg production and the presence of composite hedges on 0,75 ha.

Silvopastoral management for quality wood production

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Introduction

In the last decade, hardwood plantations have substantially increased in many Spanish regions. In order to grow trees for high quality timber in short rotations, intensive management is applied. The main problem is these operations are very expensive. In fact, plantation management costs account for more than 45 % of the total investment (Rigueiro-Rodríguez et al., 2009). Moreover, they can produce important environmental impacts similar to intensive agriculture, such as nitrate contamination, reduction of carbon and biodiversity loss (Babcok et al., 2003). Control of competing herbaceous vegetation is required for avoiding tree-herbage competition for soil resources and fire risk. The most common method is the application of herbicides, in spite of its environmental and economic cost (McAdam and Sibbald, 2000). The continued application of herbicides produces mineral soils, with low organic matter content and high dependence on fertilizers (Stoate et al., 2001). Silvopastoral management could reduce the economic costs and optimize the environmental functions of hardwood plantations. The aim of this study is to evaluate the profitability of alternative techniques of control of competing vegetation and their environmental implications.

Materials

The experiment was carried out in Extremadura (Spain) in a 15- year old hybrid walnut (*Juglans major* x *nigra* mj 209xra) plantation, with a density of 333 trees ha^{-1}. Three treatments for control of competing vegetation were applied in early spring during three years (2011-13): a) elimination of understorey vegetation (herbage and shrubs) by cutting (clearing); b) ploughing, and; c) silvopastoral system (introducing a stock of sheep), All these methods were combined with three levels of irrigation. Three replicates were used for each combination of control of competing vegetation (3) and irrigation (3) treatments which result in nine combinations and 27 plots. Each plot (95x15m) comprised two rows of 20 trees. Tree diameter at breast height (dbh) growth, organic matter content and available nutrients (N,P,K and Ca) in soil and nitrate leaching were studied. In May 2013, 12 ion exchange resins were installed at 15 cm depth in each plot (six for cations and six for aninons). In June 2013 (one month later), they were taken out and analyzed in laboratory. In

April 2013, soil samples were taken in the soil profile every 10 cm to 100 cm for analyzing organic matter content. Two ceramic cup samplers were installed in each plot at 30, 60 and 90 cm and samples were taken periodically since early 2013 and nitrate leaching was analyzed. In the same period, tree dbh was measured. Data were analysed as randomized design by ANOVA and LSD test to separate treatment means when ANOVA showed significant effects ($p<0.05$). All statistical analyses were performed using R program.

Results

The analyses of the ion exchange resings indicate that the availability of N and Ca was improved by ploughing (190.3±41.8 µg P / 50 cm^2 / month and 64.4±3.7 µg Ca / 50 cm^2 / month) (Table 1). However, this treatment produced the lowest levels of available P (1.7±0.5 µg / 50 cm^2 / month). In this case, the best values of this nutrient were obtained with silvopastoral treatment (4.8±0.9 µg P / 50 cm^2 / month) followed by clearing (3.6±0.5 µg P / 50 cm^2 / month). No differences among treatments were detected in K availability. Regarding organic matter content in soil, clearing positively affected this parameter (42.4±2.4 mg OM kg^{-1}). Moreover, this treatment reduced the nitrate leaching (10.9±1.8 mg $N\text{-}NO_3^-$ l^{-1}) in soil (in the first 30 cm depth). Below this depth, the levels were signicantly lower and the difference among treatments was not significant.

The maximum diameter increment ($p<0.001$) was observed with ploughing (7±0.3 cm) and silvopastoral treatments (6.6±0.3 cm) both combined with the highest level of irrigation. The lowest tree growth was observed with the silvopastoral management with low (42.4±2.4 mg OM kg^{-1}) and medium (32.0±1.8 mg OM kg^{-1}) irrigation (Table 2).

Table 1. Nutrient (N, P, K, Ca; μg / 50 cm^2 / month) availability and organic matter content (OM, mg kg^{-1}) in soil, and nitrate leaching (mg N-NO_3^- l^{-1}) with different treatment of vegetation competition control.

Treatments	Elements	Clearing	Ploughing	Silvopastoral	sign
Soil	N	11.3±1.7b	19.3±41.8a	25.3±16.1b	**
	P	3.6±0.5ab	1.7±0.5b	4.8±0.9a	***
	K	39.8±3.8	43.3±3.1	39.7±1.8	ns
	Ca	46.7±1.9b	64.4±3.7a	52.7±2.4b	***
	OM	42.4±2.4a	32.0±1.8b	35.6±1.4b	**
Grounwater pollution	NO_3^-	10.9±1.8b	14.9±1.3a	14.6±2.9a	0.08

Table 2. Tree diameter increment (cm) with different treatments of vegetation competition control combined with irrigation (I) levels.

Treatments	I low	I medium	I high
Clearing	5.5±0.3c	5.8±0.3bc	5.5±0.3c
Ploughing	6.0±0.3bc	6.0±0.3bc	7.0±0.3a
Silvopastoral	4.2±0.3d	4.6±0.2d	6.6±0.3ab

Discussion and conclusions

Maximum tree growth was observed in the ploughing and in the silvopastoral treatments, both combined with the highest level of irrigation, probably because of the highest availability of N and Ca in soil, due to the mineralization of organic matter as consequence of soil aeration (Whitehead, 1995) in the former, and increased P availability in soil in the latter. These results indicate that there is strong competition between herbage and trees for nutrients and water, in spite of the age of trees (15 years old). Therefore irrigation is justified not only during the early years after tree planting but also at a later stage. No response was detected due to livestock supplies of nitrogen

(silvopastoral), probably because the animal stocking level was low for reducing understorey competition. The mineralization of plant litter incorporated to the soil in the clearing treatment improved soil OM. At the same time, the understorey was able to use soil nitrate, which reduces pollution. Regarding nitrate leaching, the difference among treatments was not significant below 30 cm deep.

Therefore, silvopastoral systems with high stocking rates are compatible with hardwood production and are an environmentally efficient management practice.

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Interactions among plant layers in shrub-encroached Iberian dehesas and consequences for their persistence

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Introduction

Currently, the density and cover of shrubs in wood pastures (natural and man-made savannas, such as Iberian dehesas), have increased markedly worldwide (van Auken 2009). The increase in shrub cover in systems formerly devoid of them is considered an indicator of system degradation. In this direction, some authors argued that the proliferation of shrubs is accompanied by a reduction in pasture production and diversity and thus in the overall profitability of the system. At the same time, shrubs can also interact with overstory trees, affecting both its nutritional status and water relations (Cubera and Moreno, 2007). Competitive interaction between vegetation layers through overlapping rooting systems is considered one of the most likely explanations.

However, this view is currently questioned (Elridege 2011). Restoration ecology is increasingly considering spontaneous vegetation succession as a tool to recover degraded environments. For instance, in Mediterranean degraded pasturelands, shrub encroachment has been shown as an important step in the reversal of desertification processes and also in promoting natural regeneration in open woodlands (Ramírez and Díaz, 2008). In addition, it is not clear if all shrub species may play similar roles or their effect can be species-specific. The aim of the present study was to analyze the effect of shrub understory on the functioning and persistence of Iberian dehesas (grazed open woodlands). We evaluate the effect of two contrasted shrub species, *Retama sphaerocarpa* (a deep rooted shrub) and *Citus ladanifer* (a shallow rooted shrub), on neighboring vegetation (tree and pasture). The proper assessment of the consequences of vegetation change on the functioning and persistence of systems undergoing shrub encroachment may be of major importance to prioritizing future management interventions.

Material

The study was carried out in the North of the Extremadura region (Western Iberian Peninsula, 39º54' N, 06º30' W), located at an average 400-500 m asl. Site vegetation is a savanna-like open woodland, named Iberian dehesa, which is dominated by scattered oak overstory (*Quercus ilex*; 10 - 40 trees ha^{-1}) with native pastures as understory that is undergoing shrub encroachment, due to

abandonment of traditional practices, since the second half of the XIX century. Each study site included two adjacent plots, similar in tree cover, soil type and slope, but differing in the presence of shrubs: one plot without shrubs (control plot) and one with the presence of shrubs (encroached plot). All sites can be split in two halves in terms of the shrub species present in the encroached plot, *Cistus* or *Retama*. The total number of sites studied ranged from three to 20, per shrub type, depending on the response variable studied.

The response variables assessed with and without the presence of shrubs were: pasture and tree rooting profile (expressed as the depth where 95 % of the root system can be found), soil water availability (%, v/v), soil N availability (N, µg/10 cm^2/40d), tree and pasture production (expressed as acorn yield Kg/ha and dry mass kg/ha, respectively), tree physiological status (current year shoot growth, cm, predawn water potential, MPa and net photosynthesis, mmol m^{-2} s^{-1}) and tree regeneration (seedling emergence and survival num/100 m^2). To assess the overall difference between encroached and control plots per shrub species and dependent variables studied the standardized mean difference (d) was calculated. All statistical analysis were conducted in R (R core team 2013) with the package meta.

Results

The results showed that the presence of shrubs modify tree and pasture root systems. Trees growing either with *Cistus* or *Retama* exhibited a significantly deeper rooting profile (higher values of d_{95}), than growing without competition, whereas herbaceous species showed the opposite trend, shifting most of their roots upwards to shallower soil horizons (lower values of d_{95} in encroached plots than control) (Fig. 1). *Cistus* appeared to be a great competitor for soil resources. We observed a significant reduction in soil moisture and soil N, leading to significantly lower tree leaf water potential, leaf gas exchange parameters, acorn production and growth. Similarly, the negative effects of *Cistus* on soil resouces also affected the production of herbaceous species. By contrast, *Retama* showed a positive effect on soil resources both on

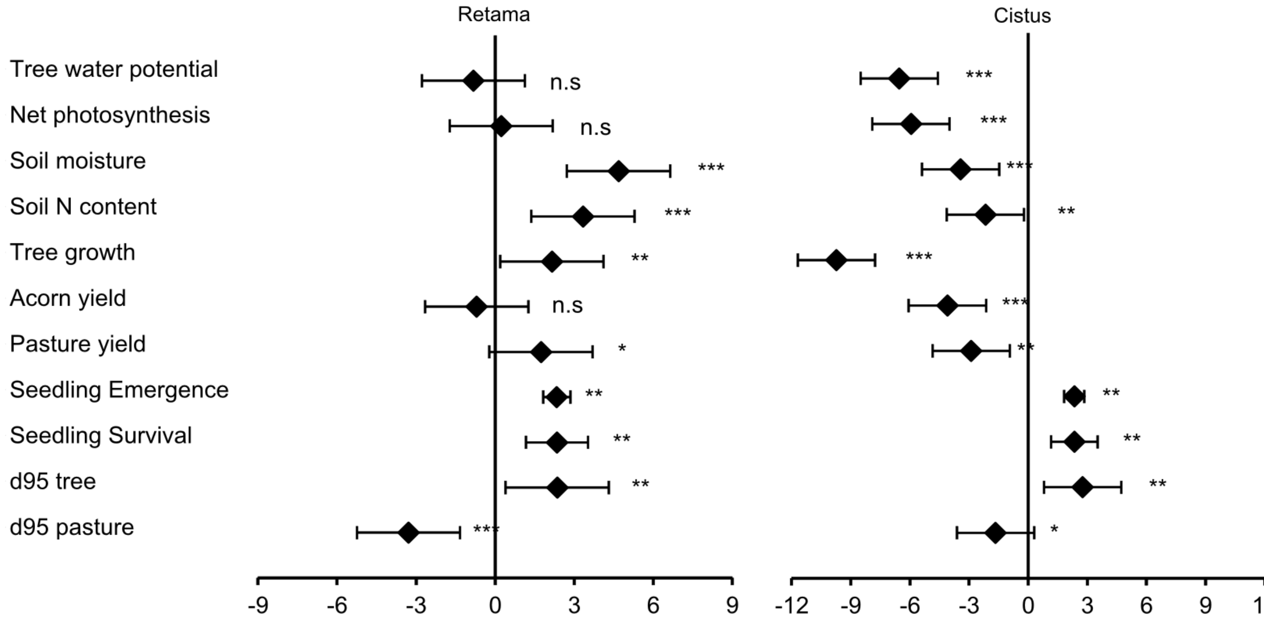

Fig 1: Effect size, difference between encroachde and control plots standardized by their pooled standard deviation, of the different response variables analyzed in sites encroached with Cistus and sites encroached with Retama. Significant effects are depicted as: n.s $P > 0.1$; * $0.05 < P < 0.1$; ** $P < 0.05$; *** $P < 0.001$.

soil water and N availability, showing an increase in tree growth and pasture yield as compared with zones without *Retama.* At the same time, this positive effect of *Retama* on soil resources was not paralleled by.an amelioration of tree functioning (tree water potential and net photosynthesis) nor acorn yield. Both shrubs showed a similar positive effect on tree seedling emergence in spring and survival after summer.

Discussion and conclusions

Our results highlight the idiosyncratic effect of shrubs species on the production and functioning of the silvopastoral system studied. The contrasted ecological nature of both types of shrub led to a differential use of the soil resources affecting the neighboring vegetation. Nevertheless, the displacement of tree and pasture root systems to deeper and shallower soil layers respectively, suggests that at least both types of shrub may compete directly for space with the neighboring vegetation (Hodge, 2004).

Retama is a leguminous deep rooted shrub, thus the amelioration of soil resources observed may be related with its ability to fix atmospheric N and with the process of water redistribution from deep soil layers (Prieto et al., 2010). Interestingly, short time measures of tree functioning did not parallel this effect, whereas long term responses such as tree growth or pasture yield did. Soil

moisture was only studied in the uppermost soil layers, thus certain overlapping between root systems at deeper soil layers among trees and *Retama* shrubs may have offset the positive effect on soil water content and led to the neutral or negative effect on tree water potential. On the other hand, the fertilization effect of *Retama* on soil N may have boosted tree and pasture production, which could also benefiting from uppermost amelioration of soil water content, highlighting the limitation in soil nutrients of this systems (Moreno and Obrador, 2007).

By contrast, *Cistus* appears to be a superior competitor for soil resources than tree and pastures which led to the worsening of most of the parameters analyzed. Nevertheless, despite its negative effects on tree and pasture functioning and production, *Cistus*, as well as *Retama*, showed a positive effect on early stages of tree regeneration. This result suggest that not only the abiotic amelioration is important for fostering tree regeneration but also the biotic protection offered by the shrub layer may be determinant (Ramírez and Díaz, 2008). In summary, future management practices must bear in mind the specificity of effects among shrub species and try to optimize the positive effect of shrubs without jeopardizing the productivity or functioning of the dehesa and similar silvopastoral systems.

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Juglans growth under ploughing and *Vicia villosa* sowing understory management

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Introduction

Inorganic fertilization has a clear impact on farm economy and carbon footprint. The reduction of the inputs of mineral fertilizers will decrease the impact of farming management on GHG emissions, as fertilizers produced in the farms are not transported before applying them on soils. Tree fertilization is not usually carried out because of the high costs and the lack of annual returns from timber until the final harvest is done. The use of legumes as fertilizer for tree timber production has shown to be a good alternative to mineral fertilization in *Pinus* (López-Díaz et al., 2008). The legume used should be adapted to climatic conditions and it could provide forage, crops or be used as a fertilizer after burying it into the soil. Legume fertilization could also provide nutrients to the trees increasing the levels of nitrogen and reducing the concentrations of Cl in soil to adequate levels. This paper aims to revaluate the use of legumes as an alternative to ploughing and nitrogen fertilization in a plantation of a high quality timber clon (*Juglans* hybrid) established in 2004.

Material

The experiment was established in the municipality of Carpio de Tajo (Toledo, Spain) in 2009. Plantation was carried out in 2004. At the start of the experiment plants had a diameter at breast height (dbh) and height of 11.4 cm and 7.30 m, respectively. Tree density was 333 trees ha^{-1} in a frame of 5 x 6 m. The experiment followed a design of randomized blocks with two replicas. Treatments consisted of different alley management 1) sowing and 2) intensive management with cultivated/ploughing land. *Vicia villosa* was established at both sides (covering 4 m out of 6 m) of tree lines in the sowing treatment in autumn 2009 and ploughed into the soil in June 2010. Intensive management included alley ploughing and herbicide applications on tree lines (33% of total land). Nitrogen was applied using fertirrigation, which was carried out during July and August implying 120 mm of water. Total macronutrient inputs (fertirrigation) include 105, 72 and 182 kg of N, P and K per hectare. Tree diameter and height was measured before and after treatment establishment. Nutritional monitoring consisted of foliar analysis (N, P, K, Ca, Mg, Na, Cl, S and

microelements) and soil and water analysis. Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant (SAS 2001).

Results

Figure 1 shows the effect of ploughing and *Vicia villosa* sowing in dbh and in the concentration of N and Cl in leaves after the legume incorporation into the soil. The presence of *Vicia villosa* improved tree dbh. Nitrogen concentration in leaves was always higher when *Vicia* was sown. The concentration of Cl in leaves was clearly lower when *Vicia* was established in combination with *Juglans*.

Discussion

Juglans spring growth was doubled when a legume was used instead of ploughing. This result is of high interest as better production is obtained in a more sustainable way. The incorporation of *Vicia* in the soil also provides an extra source of organic matter into the soil and reduces the risk of erosion. Delate et al.(2005) did not get any differences of tree growth when a *Vicia villosa* + *Avena sativa* was used in the alleys. Differences could be due to the use of the N provided by the legume by the oat that was not used in our experiment. A benefitting effect of the legume on tree growth was however found when clover was sown with *Pinus radiata* in a

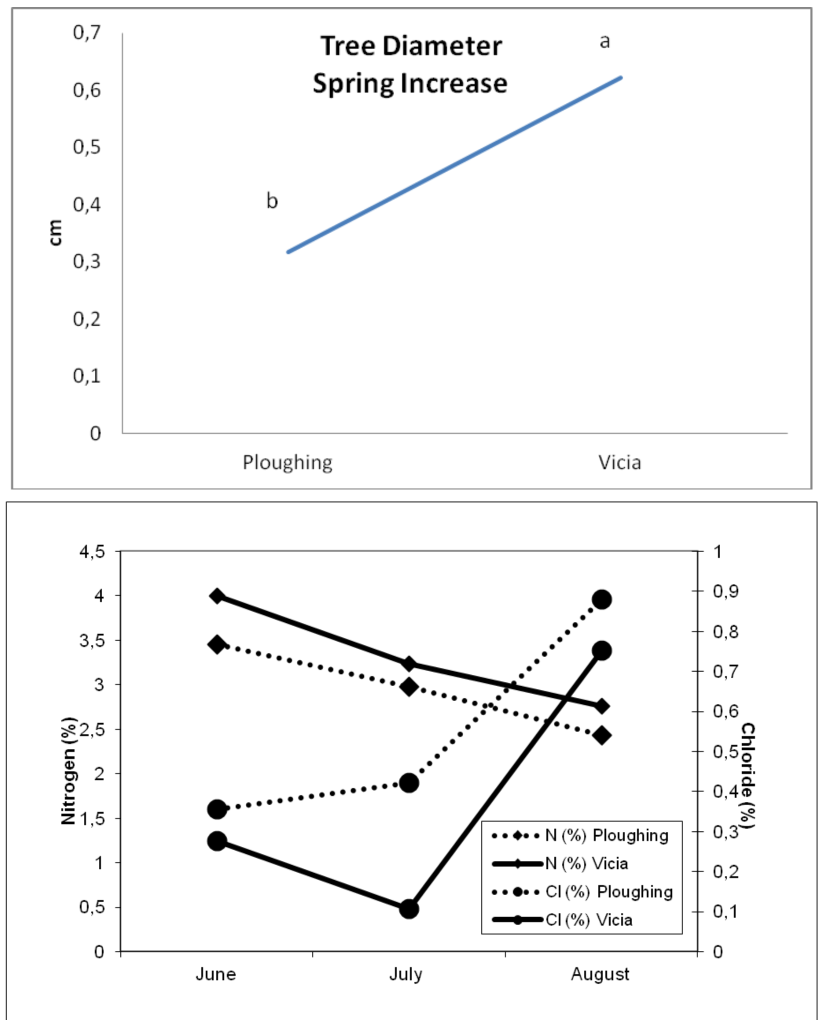

Fig 1: Tree dbh increase during the spring and N and Cl leave concentration.

temperate area (López-Díaz et al., 2008). *Vicia* cultivation with trees instead of ploughing increased the levels of N in tree leaves in spite of lacking of effects of treatments on soil (data not shown) as described Pinney et al (1998) and Catlin (1998).

Chloride levels in irrigation waters between 5 and 10 (Ibacache 2008) or below 7 mmolc L^{-1} (Ruiz 2005) and inoic relationship ($NO3^-/Cl^-$) below 0.5 (Bar 1997) can produce fitotoxicity and an excess of fitotoxicity and chloride causing leaf death). *Vicia* cropping as understory reduced the levels of Cl assimilated in soil when compared with ploughing. Cl levels below 0.3 are supposed to be adequate (Beutel et al., 1983).

Vicia sowing caused a clear improvement of tree growth and N and Cl concentration in the leaves, indicating that the combination of a legume with trees could be used to promote earlier incomes from high value timber trees.

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Nutritive value of Quercus pyrenaica Willd browse species in NE of Portugal

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Introduction

Quercus pyrenaica Willd (pyrenean oak) occurs in a transition between the Mediterranean sclerophyllous and the temperate deciduous forest, being one of the most abundant and characteristic oak species in the Iberian Peninsula, due its economical and biological importance and by several services produced (timber, firewood, pastures, soil protection from erosion, nutrient and water cycling, wildlife habitat, increased biodiversity). Its distribution area covers about 600.000 ha in Spain; and 62.000 ha in Portugal, which represents about 95 % of its natural distribution area (Castaño-Santamaría et. al., 2013). On the other hand, pyrenean oak ecosystems are seen as strategic ecosystems for nature conservation to maintain resources in a sustainable and productive way (Gómez Sal 2000). Pyrenean oak is mainly found in the form of coppice-managed or young forests. The present study concerns the role of pyrenean oak woodlands in the diet of small ruminants; particularly the aim of this study was to assess the nutritive value of key browse species of pyrenean oak forests in Trás-os-Montes region (NE of Portugal).

Material

The study was to undertake at different mature stages the evolution of chemical composition and in vitro digestibility of shrub twigs and tree leaves. The browse species evaluated were *Cytisus scoparius* (L.) Link, *Cytisus striatus* (Hill) Rothm, *Cytisus multiflorus* (LHér.) *Genista falcata* Brot. and *Quercus pyrenaica* Willd. Tree samples were formed by foliage and shrub by mixed twigs from several specimens. Hand-samples of the different shrubs species were taken along the year seasons: beginning of March (early spring), beginning of May (late spring), July (summer), end of September (autumn) and December (winter). Pyrenean oak was sampled only during the leaf production periods: May (very young leaf), July (young leaf), August (mature leaf), September (leaf in early of senescence), and October (senescent leaf). Samples were dried (60 ºC 48h) and ground. Crude protein contents (CP) were evaluated and recorded following the methods of AOAC (1997). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and sulphuric acid lignin fractions (ADL) were determined following the methods described by Soest and Wine (1967. In vitro organic

matter digestibility (IVOMD) was evaluated using the two-stage technique (Tilley and Terry 1963) modified by Marten and Barnes (1980).

Chemical composition and IVOMD were analysed by ANOVA (PROC GLM procedure) using the SAS (2001) software. Turkey´s test was used for subsequent pairwise comparisons ($P < 0.05$; $\alpha = 0.05$).

Results

Species varied widely in chemical composition (CP: 91.9-225.7 gkg^{-1}, NDF: 360.3-665.3 gkg^{-1}, ADF: 253.5-535.0 gkg^{-1}, ADL: 56.7-165.2 gkg^{-1}) and in vitro digestible organic matter (IVOMD: 41.73-70.39%) (Fig.1). CP and IVOMD were significantly increased in May in the case of *C. scoparius* and pyrenean oak, and although not significant, this trend were shown in the rest of shrubs. NDF, ADF and ADL levels were positively increased in September in the case of *C. scoparius*, and in July and October in the case of *Q. pyrenaica*.

Discussion

Pyrenean oak leaves presented a constant composition throughout the leaf cycle although this pattern changed in very young leaf stages (May) when leaves were not formed, while shrubs species showed the highest nutritive value in late spring (May) and the lowest values in autumn (September). The ligneous species present in this study are consumed by small ruminants grazing, particularly goats, in

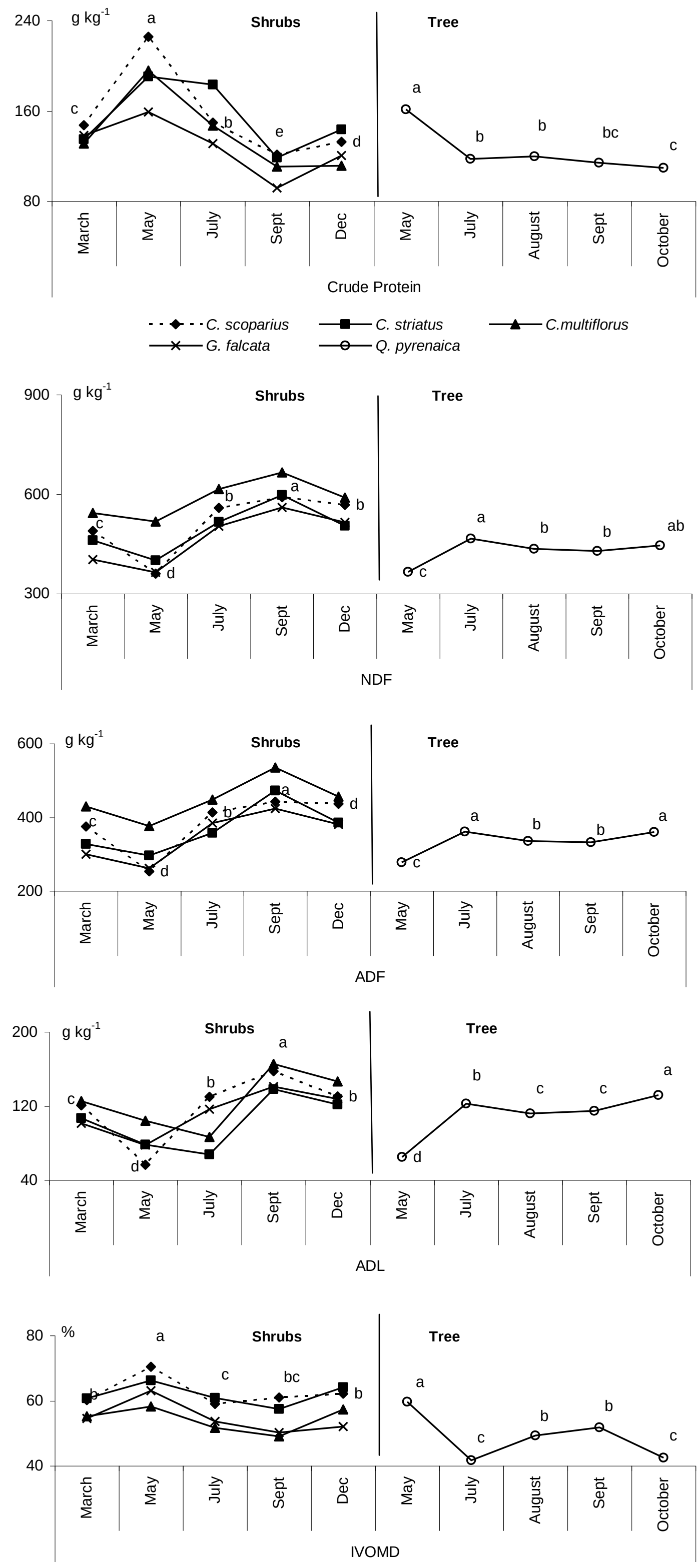

Fig 1. Dietary chemical composition (Crude protein content, NDF: neutral detergent fibre , ADF: acid detergent fibre, ADL: sulphuric acid lignin fractions) and In vitro organic matter digestibility (IVOMD) in different shrubs species and *Quercus pyrenaica* . Different letters indicate significant differences between seasons.

Mediterranean rangelands. According to Castro (2004), the consumption of leguminous shrubs such *C. scoparius*, *C. multiflorus* and *C. striatus* reaches in spring 38 %, in summer and autumn about 10 % and in winter 14 % of total goat's diets. Pyrenean oak consumption increases through the season, becoming very high in August - September, when the other resources become less abundant and with lower quality. The summer diet of goats contained about 25 % of leaves whereas it was only 2.5% in the diet of sheep (Castro et. al., 2004). The relative quality of browse resources assessed and their high consumption by extensive livestock animals, confirm the role of grazing in shrub encroachment control, as well as, in reducing the risk fire.

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Carbon balance estimation for Agroforestry land use alternatives in Portugal

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Introduction

In 2005, 11% of the anthropogenic greenhouse gases emissions (GHG) originated from agricultural activities and this value is expected to increase in the future (Smith et al 2007). With European Union's legislation supporting and promoting the conversion of land into low-carbon-integrated agriculture, new opportunities arise for the implementation of this type of land use in Europe. In Portugal, this type of agriculture is well represented by *montado*, combining low density cork oak trees (*Quercus suber* L), occupying an area of 715,922 ha partially including pastoral and/or cropping activities. Recent studies showing an extra area suitable for its implementation of around 353,000 ha (Palma et al 2014) could increase the extent of this land use.

Considering the new policies established by the EU regarding measures in agriculture for climate change mitigation, and the capacity of the agroforestry systems to act as a low-carbon system with productive agriculture, the main objective of this work is to compare the potential capacity of the *montado* to mitigate the GHG emissions by quantifying the net carbon balance of activities in comparison to two other land-use alternatives occurring in the same area: dense cork oak forestry and a conventional rotation of wheat monoculture.

Material and Methods

The estimation of the net carbon balance of the different alternatives is based on the difference between the amount of GHG emissions with Global Warming Potential (GWP) emitted for different activities and the amount of carbon the system is able to sequester by itself. The three main GHG gases with GWP were included in the study: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In this first stage of the study two main sources of emissions were considered: 1) from the combustion of fuels due to the use of machinery for the field operations and 2) from the emissions related to the application of fertilizers. The working times and fuel consumptions for the field operations were established according to national data available (CAOF, 2010). The amount of N-fertilizer applied in plantations of cork oak systems is about 125g/plant while an estimated value of 25 kg/ha of N-fertilizer was assumed for the cropping component. The GHG emissions

derived from the use of fertilizers are added to the field operations emissions considering that the 2.55% of N-fertilizer is converted to N_2O (Rajaniemi, 2011).

The most used management practices concerning the three land use alternatives were considered, including the operations for the establishment of the stand, maintenance and growth and extraction of products. The agroforestry alternative was considered to be managed similar to the forestry and wheat monoculture models combined with some differences due to lower tree density and the less area occupied by wheat (around 91%).

For the estimation of the carbon sequestered by the different alternatives the Yield-SAFE model was used (Van der Werf et. al, 2007). The YieldSAFE model is a process-based dynamic model for predicting resource capture, growth, and production in forestry, agroforestry and agricultural systems. The model estimates the aboveground biomass of trees and stands and the crop yield. Root:shoot ratios of 0.43 and 0.31 were used to estimate the belowground biomass for cork oak and wheat respectively. The loss of biomass is considered as an extraction of a product (wood, cork or wheat) from the system. The period simulated was 50 years.

Results

The results predicted by the YieldSAFE model show that the agroforestry system has an annual average biomass growth for the period simulated of 3.13 tons/ha/year. This represents a higher growth than the wheat monoculture system (0.45 or 1,18 tons/ha/year including or excluding fallow years respectively) but lower than forestry alternative (4.45 tons/ha/year). Regarding the GHG emissions, the agroforestry system requires on average around 198 kgCO_{2eq}/ha/year. This is less than the GHG emitted by the monocropping system 212 kgCO_2eq/ha/year but higher than the GHG emissions from forestry (10.4 kgCO_{2eq}/ha/year). These values are in the same magnitude as previous studies. Gonzalez-Garcia, 2013, for a cork oak forestry system reached an average value of GHG emissions of 34.5 kgCO_{2eq}/ha/year but it was by considering a more intense management, the transport of products, and the production of fertilizers and fuels. Rajaniemi, 2011, found an average value of 2330 kgCO_{2eq}/ha/year required for wheat production in Finland but the management included higher doses of N-fertilizer applied (116 kg/ha) and the GHG emissions resulting from its production.

Related to GHG emissions mitigation, considering the cumulative amount of carbon sequestered by the three alternatives, that is the net carbon balance, the agroforestry option would be able to sequester around 300 tons of CO_{2eq}/ha for the period of 50 years (Fig.1B). The

estimated value of agroforestry lies between the forestry (Fig.1A) and the monocropping system (Fig.1C). Broadly, agroforestry sequesters similar amount as forestry and nearly the triple of monocropping.

In terms of GHG emissions from field operations the results show the importance of these in the monoculture and agroforestry alternatives compared to the forestry option due to annual activities in the cropping system. This high rate of emissions are clearly compensated in the agroforestry system by the growth of the trees' biomass while in the monocropping system, the crop biomass remains low.

Discussion

These preliminary modeling results on carbon sequestration services by cork oak agroforestry systems, support the EU policies promoting the implementation of agroforestry systems in Europe. Even if the capacity of the agroforestry systems to sequester carbon is not as high as in forestry systems, the *montado* presents a similar capacity of carbon sequestration while offering a wider set of direct products such as wheat, cork and wood and other indirect environmental services including flood mitigation capacity, reduction of soil erosion, protection for crops and improvement of the biodiversity. According

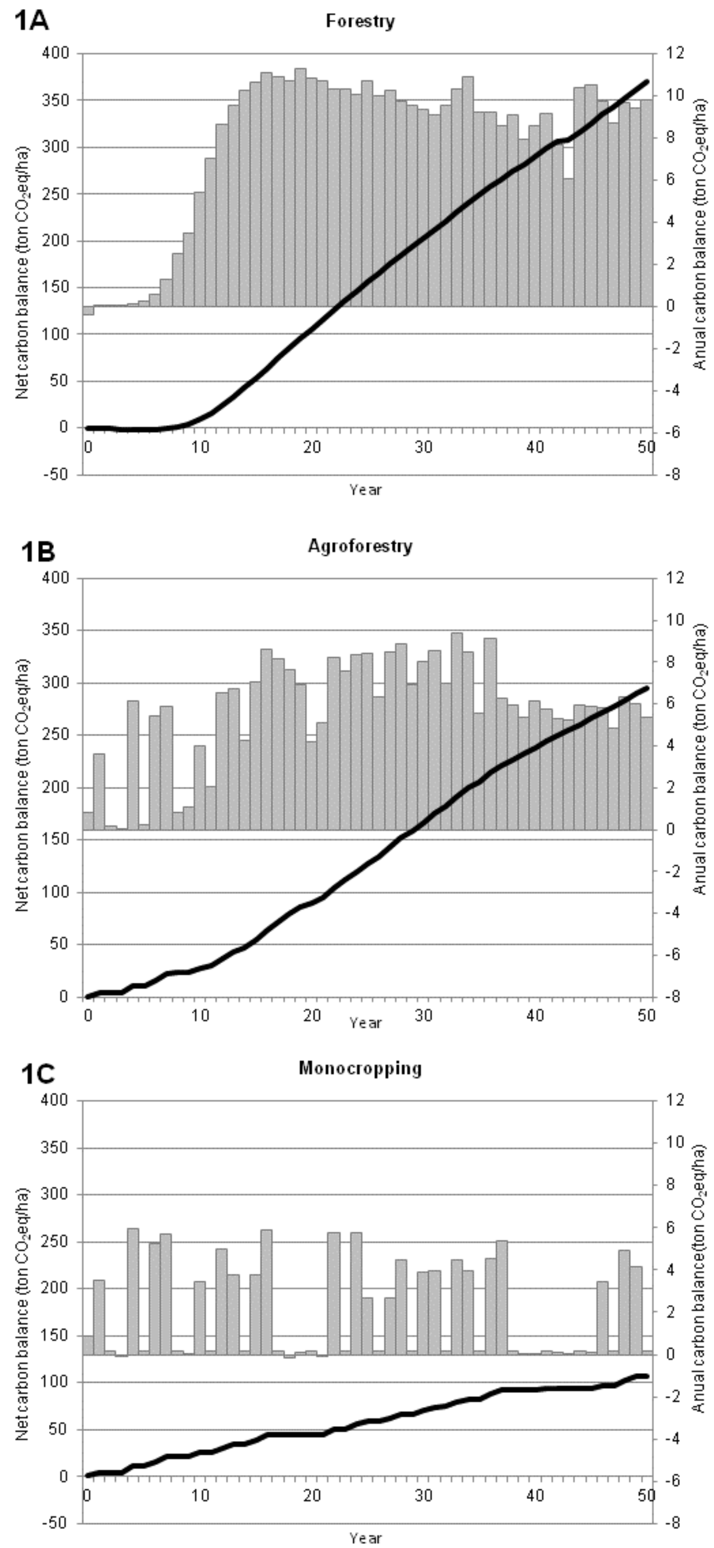

Fig 1. Net carbon balance (Cumulative carbon sequestered) and Annual carbon balance (Annual carbon sequestered) for forestry (A), agroforestry (B) and monocropping (C) alternatives for the period simulated (50 years)

to the results presented, the implementation of this type of ecosystems could reduce GHG emissions in the order of about 6 tons of CO_{2eq} per hectare every year. In a future and in order to ameliorate the results this study needs to include the GHG originated from the soil compartment and from the production of fuels and fertilizers as it has been seen to be the main sources of GHG emissions (Rajaniemi, 2011).

Acknowledgements

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The role of scattered trees and habitat diversity for biodiversity of Iberian dehesas

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Introduction

Dehesas and montados are agroforestry systems covering over 4.5 million hectares in SW of Iberian Peninsula (Moreno and Pulido, 2009). They are renowned as biodiversity-rich systems (Bugalho et al., 2011; Díaz et al., 2013) to the point of being considered as habitat to be protected under the European Habitats Directive. In this work we analyze the relative contribution of scattered trees and habitat diversity on the species richness of four key taxonomic groups, vascular plants, bees, spiders and earthworms. The effect of trees was assessed by comparing species richness of wood pastures with open pastures both at plot and landscape levels. We expected more species in wooded pastures given that scattered trees provide food, shelter and generate multiple fine-scale gradients of resources (Fischer et al., 2010; Moreno et. al, 2013). We also expected a reduction of species from open pastures due to the negative effects of woody vegetation for certain species (e.g. shade and lower soil moisture, Moreno et. al, 2013). The importance of habitat diversity, and more specifically the contribution of marginal habitats (unmanaged, low surface), was analyzed by computing the proportions of shared species among habitats and by estimating species richness at landscape scale including or not marginal habitats. Marginal habitats are expected to increase species richness at landscape scale by supporting species not found in open and wood pastures (Benton et. al, 2003).

Material

The study was conducted in C-W Spain (latitude 40º 7' to 40 º 14' N and longitude 6º 0' to 6º 21' W). The landscape is dominated by oak dehesas (38.7 % of the land) and open pastures (18.5%) devoted to livestock breeding, olive plantations (15.0 %), shrublands (12.5 %), dense forests (9.4 %), and herbaceous crops (3.1%). Dehesas are mostly dominated by scattered Quercus ilex trees, with Quercus suber and Quercus pyrenaica being present in low numbers. Ten dehesa farms (485 ha each on average) were randomly selected, mapping every habitat and linear features according to a standardized protocol developed by the European BioBio projects (Bunce et al., 2011). Within each farm, a randomly selected plot per habitat was retained for further monitoring of biodiversity. In a total of 114 areal habitats and 31 linear habitats four taxa were

monitored, attending to the four major ecological functions which are relevant for farming: Vascular plants (primary production), Wild bees and bumblebees (pollination), Spiders (predation), Earthworms (organic matter decomposition). These four biological groups are relatively easy to monitor, provide relevant information on general environmental conditions and are sensitive to management practices. All vascular plants were identified and their covers were visually estimated in a 100 m2 located by the center of the plot by mid April 2010. Bees and bumblebees (hereafter 'bees') were sampled along a slow walked transect of 100 m x 2 m per plot with a handheld net, repeated from early May to mid-July 2010. Spiders were sampled in 5 circular plots (0.357 m internal diameter) by suction, repeated three times from late April to late July 2010. Earthworms were sampled in April of 2010 in three separated quadrats per plot (30 cm x 30 cm) combining the extraction with an expellant solution (diluted allyl isothiocyanate) and the subsequent hand-sorting. For more details on sampling protocols see Dennis et al. (2012).

Results

In total, 450 plant species (on average 36 per plot of 100 m^2), 63 bee species (3.2 per plot of 200 m^2), 130 spider species (7.4 per plot of 0.5 m^2), and 17 earthworm species (2.5 per plot of 0.27 m^2) were recorded. In each taxa, only some species were abundant and ubiquitous, while most of the species were found only one or few plots. The estimated richness (Chao2 mean ±S.D.) for four biological groups was 503±20 for plants, 140±40 for bees, 161±14 for spiders and 25±7 for earthworms. At plot level, earthworms and spiders were marginally more abundant in open pastures than in wood pastures, with species richness significantly higher in open pastures. Differences were not significant for plants and bees. On the contrary pooling plots, estimated richness (Chao2) of plants and earthworms species was significantly higher in wood than in open pastures (Table 1). Differences for plants, earthworms and spiders were also confirmed by Coleman-rarefied index (Table 1). A high proportion of species (ca. 40 %) were observed only in just one habitat per farm, indicating that farm biodiversity strongly depends on the habitat diversity. The analysis of unique and shared species among habitats revealed that every habitat contribute signi-fycantly to farm biodiversity.The combination of open and wood pastures gives a higher species richness than wood pasture alone, and the combi-nation of margi-nal and produc-tive (open+wood pasture) habitats gives a higher species richness than productive habitats alone (Table 1).

Table 1: Species richness estimated by extrapolation (Chao2 index) and by rarefaction (Coleman index; set at n=40) for four different biological groups, considering only open pastures vs wood pastures, all pastures (wood + open pastures) vs marginal habitats, and all habitats together. See Colwell (2013) for the definition of Chao2 and Coleman indexes.

Chao- Estimated (±SD)	PLANTS	BEES	SPIDERS	EARTHWORMS
Open Pastures	329.93 ± 24.57	36.74 ± 8.29	130.43 ± 32.21	8 ± 0.49
Wood Pastures	381.59 ± 25.37	38.68 ± 9.42	128.64 ± 22.57	12.46 ± 2.54
All Pastures	419.88 ± 17.61	83.93 ± 30.39	145.5 ± 17.85	12.99 ± 1.8
Marginal Habitats	444.8 ± 23.57	82.79 ± 22.02	128.67 ± 11.82	20.92 ± 5.46
All Habitats	503.21 ± 20.06	139.59 ± 40.29	161.45 ± 14.13	24.95 ± 7.08
Coleman - Rarefied (±SD; n=40)				
Open Pastures	250.67 ± 1.14	25.42 ± 0.75	64.6 ± 1.16	8 ± 0
Wood Pastures	289.6 ± 1.8	25.73 ± 0.51	76.19 ± 0.89	11 ± 0.03
Marginal Habitats	325.2 ± 4.64	35.5 ± 2.38	87.21 ± 3.11	15.26 ± 0.7
All Pastures	309.55 ± 5.26	26 ± 2.41	74.78 ± 3.82	11.29 ± 0.74
All Habitats	342.5 ± 6.19	31.26 ± 3.14	83.88 ± 4.36	15.23 ± 1.15

Discussion and conclusions

While pastoral landscapes have been mostly deforested over the centuries (Bergmeier et al., 2010), the conservation of trees in a pasture matrix is still common in some Mediterranean silvopastures such as in Iberian dehesas. Trees provide multiple woody and non-woody plant products, high-quality food, livestock and game products, recreational or cultural services through multiple activities conducted with a comparatively low environmental impact (Moreno and Pulido, 2009). It has been proven that trees also provide important ecosystem services such as carbon sequestration, soil fertilization and control against erosion, microclimate amelioration, and shelter for livestock (Campos et al., 2013). Here we have shown that trees also contribute positively to the biodiversity of four biological groups. Although the high biodiversity values found in Iberian dehesas was partly explained by the existence of scattered trees, the intimate mix of tree and treeless pastures has also a significant role. While at a landscape scale the diversity of the four biological groups studied was higher in wood pastures and other woody habitats, at plot scale they were more abundant and/or biodiverse at open pastures. The low proportion of shared species among habitats and among plots within each habitat type, and the high proportion of species found in unique plots or habitats indicated that every habitat contributes to the farm biodiversity. Marginal

land uses and linear features, which occupy a low proportion of the farm area, harbored a number of species that were not found in the main field of dehesas studied. These results support policy measures implemented in many European countries, for the maintenance of farm keystone structures and reveal that these measures should not be applied exclusively in more intensive farming systems, but also in agroforestry systems, included extensive wood pastures.

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Evolution of crop yields and qualities in a short rotation coppice alley cropping system in Germany

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Introduction

A modern form of agroforestry are alley cropping systems where annual field crops are grown in combination with strips of fast-growing tree species, so-called short rotation coppices (SRCs). Besides fulfilling the farmers' requirements to keep the field in the state of production, SRC strips provide many of the well-known positive functions of hedges. They act as wind shelter, reducing soil erosion. By influencing microclimate, they can balance out short periods of extreme climatic conditions leading to higher and more stable biomass yields of the field crops. Furthermore, they may affect quality parameters of crops and disease pressure. SRCs increase the structural and habitat diversity in the landscape, thus promoting biodiversity.

Studies on these various aspects are carried out in five agroforestry systems (AFS) within the joint project "AgroForstEnergie", funded by the Federal Ministry of Food and Agriculture, Germany, since 2007. The sub-project of the Thuringian State Institute of Agriculture focuses on influences on crop yield and quality.

Material

The study site is located in Thuringia, Germany. In spring 2007, an alley cropping was established on a 50 ha large field with seven 12 m wide strips of poplar SRCs planted vertically to the main wind direction west. Distance between SRC strips (or width of field strips between SRC strips) was 48 m, 96 m or 144 m. The three westernmost SRC strips were planted with a density of 10.000 trees/ha for a rotation period of four years and were harvested in the beginning of 2011. The four SRC strips following in eastward direction have a plant density of 2.222 trees/ha for a rotation cycle of eight years. Between SRC strips, the annual crops spring barley, winter rape and winter wheat are grown in a three year crop rotation.

Crop yield data were collected by GPS-equipped harvesters. GPS data were evaluated using the software ArcGIS 10.2. In order to investigate the general trend between two SRC strips, 4-5 transects were placed vertically between two opposed SRC strips in each field strip (6 in total). In these transects, average yield was calculated for each cutting width (1., 2., 3., etc) of the harvester

across the whole field width. To the resulting 4-5 yield data points per cutting width, we fitted a linear regression model.

Quality parameters of barley and rape seed were recorded in 2012 and 2013. Barley samples were collected along a transect vertically to SRC strips in distances of 3, 8, and 16 m from the downwind (leeward) side (for main wind direction west) and upwind (windward) side of each SRC strip, respectively, and additionally in the middle of each field strip. Rape seed samples were taken directly from the harvester, one for each cutting width.

Results

In the first three years of the alley cropping system (2007-2009, crop rotation: wheat – barley – rape seed), no influence of SRC strips on yield pattern was detected: linear models fit the data best with $R^2 < 0.1$. In the following crop rotation period (2010-2013) with an increased height of SRCs, the different crops showed varying tendencies for yield patterns in response to SRC strips and data were mostly best described by quadratic models. Of the three crops, the yield pattern of wheat showed the least influences by SRC strips: in 2010 the only significant influence ($R^2 = 0.29$, $p < 0.0001$) was recorded for one 144 m wide field strip, where wheat yield was lower next to the strips and increased towards the field middle. For spring barley (Fig. 1) in 2012, the same tendency was visible in almost all, i.e. five, field strips, with an R^2 of 0.25 – 0.45 (all $p < 0.02$). Although trees of three SRC strips were harvested in 2011, they had grown back to a height of 3.2 m by the end of 2011. However, despite the differences in tree height between SRC strips with 4 year rotation (2012: 5.1 m) and SRC strips with 8 year rotation (2012: 7.8 m), there

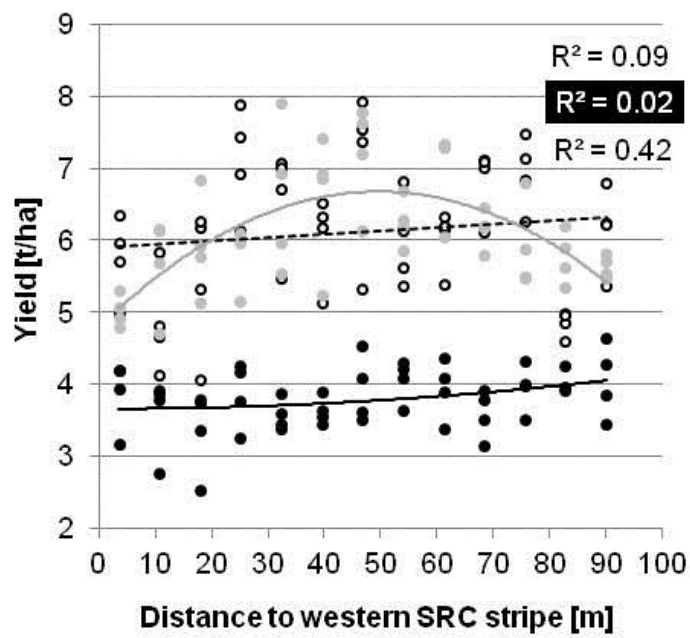

Fig 1: Yield pattern of spring barley between 2 SRC strips, 96 m apart, in an alley cropping, Germany. Dots = yield data per harvester cutting lane, lines = regression lines, black = data from 2008, white = 2011, grey 2012.

was no difference in yield pattern between respective field strips. A significant influence on the yield pattern of winter rape was only detected for 48 m wide field strips ($R^2 = 0.53$, $p < 0.0001$ and $R^2 = 0.22$, $p = 0.02$). In contrast to the other crops, rape seed showed a tendency for higher yields in close vicinity to the SRC and decreasing yields towards the field centre.

An influence of SRC strips on some quality parameters of the harvested crop was detected mainly on the leeward side and effects were lighter on the windward side. Moisture contents of the harvest were increased in spring barley in 2012 by about 0.5% up to 3 m distance (0.5fold tree height) from SRC strips, but not thereafter. In 2013, we found about 2 % higher moisture contents in winter rape up to 14 m from SRC strips on the leeward side (for both tree heights: 6.3 and 7.8 m). On the windward side this effect was much lighter (-1 % or even +0.5 % until 7 m). At no sample position, did the moisture content exceed the limit of 9 % (rape) and 16 % (barley) required for crop storage. Increased protein contents were found in the vicinity of SRC strips (leeward and windward side) in barley as well as rape seed but only in the field strips with SRCs of 8 year rotation. In spring barley this increase was about 1.5 % and limited to 3 m distance but was followed by 1.5 % decreased contents at 8 and 16 m. Only at the leeward side, protein content at 3 m exceeded with 11.9 % slightly the maximum limit for malted barley (11.5 %) according to the standards of the customer. In rape seed, protein content was increased by 2 % and 1.5 % up to 30 m distance (3.4 fold tree height) from the leeward and windward side, respectively. This may be interesting for the usage of rapeseed cake as fodder. Content of crude fat in rape seed showed the opposite pattern to protein content, i.e. a 3 % and 1.5 % reduction from the leeward and windward side, respectively (Fig. 2). Lowest crude fat content was 47.5 %, being well above the required standard minimum content of 40 %. There was no increased admixture in the rape harvest. Admixture was not determined in barley. In barley, analyses of mycotoxin contents showed slightly increased values of deoxynivalenol (DON) in 3 m vicinity of SRC strips, while no influence was

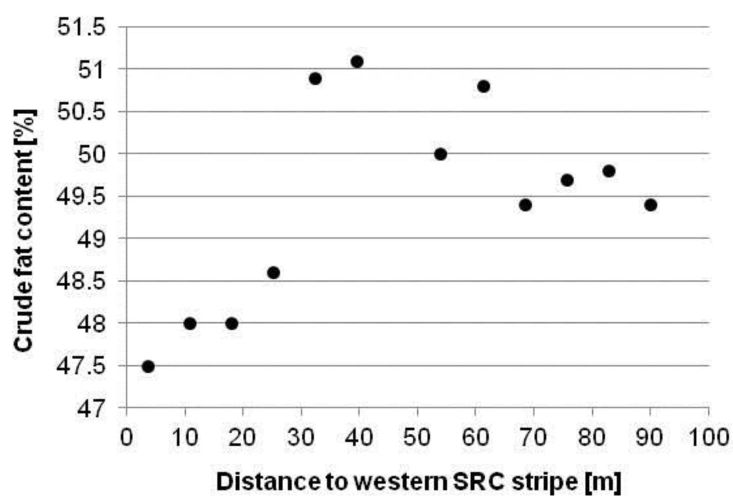

Fig 2: Crude fat content of winter rape 2013 between 2 SRC strips, 96 m apart, in an alley cropping, Germany.

detected for zearalenone (ZEA). Mycotoxin quantity was at all sample position well below the maximum level allowed according to EU legislation (EC No 1881/2006).

Discussion and conclusions

The presented study results on crop yield and quality parameters revealed existing influences of SRC strips on annual crops in the alley cropping. Influences varied with crop type and were in our study highest in spring barley and lowest in winter wheat. This is in accordance with other studies (Bruckhaus & Buchner, 1995), which state that summer crops may profit more from wind shelter than winter crops due to a higher water demand during the early summer drought. However, the yield pattern could only be explained to about 30-40 % within the alley cropping. Thus, other influences must also play an important role, e.g. soil heterogeneity, which we did, however, not investigate.

Competition for water and light between annual crops and trees may lead to quality losses in the harvest and thus prize losses. However, crop quality must drop below or exceed certain standard limits to affect the prize of the harvest. In this study, despite some reductions in crop quality, standards for all parameters were met at all sample positions (with one exception). Even if standards are not fulfilled at all distances to SRCs, the prize of a certain harvest lot must not be affected if limits are broken by e.g. only 1-3 % (as reported) and only the vicinity of field strips is affected. In this case, the harvest lot will also contain crop of “normal” quality which dilutes negative effects.

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Agroforestry at the limits: Using field scarps and lynchets for valuable wood production

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Introduction:

The usual approach of establishing and managing agroforestry systems (AFS) implies planting trees within the acreage of fields in agricultural use. Most farmers in Central Europe, however, remain reluctant to plant trees on their cultivated land. Here, we propose an alternative approach that entails planting valuable timber trees particularly at the margins of fields, on scarps, or on lynchets. These areas are commonly not used for production of any crop. Hence, any additional income derived from these areas can be attractive for farmers.

The production goal of the proposed system is valuable wood for the veneer industry. This goal can only be achieved when the trees are cultivated following a strict management agenda. In this presentation, we quantify the production costs of this cultivation approach.

Material

The production of high value timber trees for the veneer industry on field scarps and lynchets is achieved in the same way as in traditional AFS with the same aim (Morhart et al., 2012). Tree species that could be used include *Prunus avium*, *Acer pseudoplatanus, Juglans regia*, *J. intermedia* and *J. nigra*, but also *Sorbus torminalis* and *S. domestica*. The most important silvicultural treatment consists of regular and systematic pruning to an age of around 15 years to obtain a long branch-free bole length (Springmann et al., 2011) of at least 5 m. The production of high value timber trees requires a final diameter at breast height of 50 to 60 cm. Thus, the growth period of the trees is projected to take between 50 and 60 years – presuming a diameter growth of 1 cm per year as suggested by Spiecker et al. (2006). However, this is dependent on the given site conditions. The spacing between the trees is of fundamental importance as one needs to avoid mutual growth inhibition. As a rule of thumb, the minimal distance between two trees can be calculated as twenty-five times the target diameter at breast height (Spiecker and Spiecker, 1988). To ensure a high success rate of the timber trees, we propose planting trees in groups of two or three at a 2 m spacing within the rows, so that trees of poor growth can be removed from each group after several years. Only trees with the best form and rate of growth should be chosen as

future crop trees. As the trees grow only on scarps and lynchets, usual mechanized agricultural management is unaffected by the presented cultivation approach.

Results

The budgeting of expenses can be divided into three main management steps: Planting, maintenance, and harvest. Our calculation includes all material used as well as personnel expenses. A fixed interest rate of 3 % was assumed.

Planting

We recommend to plant older trees with heights of at least 1.2 m, which are consequential more expensive to purchase, the planting material together with material to protect the trees against animal damage sums up to 8.50 €. When including the time needed for planting and accumulated interest over the whole 60 year production time the planting costs amount to 106,00 € (18,00 € excluding interest).

Maintenance

Management encompasses mechanical weed control as well as pruning. Weed control around the trees is essential to assist their proper establishment during the first years. As the production of high quality timber is the ultimate goal of the timber tree strips, pruning is of absolute necessity and should be performed until the required branch-free bole length has been reached (Balandier 1997; Balandier and Dupraz, 1998). This part of the tree accounts for 90 % of the total tree value (Dupraz and Liagre, 2008), while the application of pruning treatment has been observed to more than double the value of the final timber crop (Pryor 1988). To avoid severely weakening the tree, we propose to perform pruning operations incrementally, each time with an adequate intensity. For the present calculation, we assume that the pruning is performed in four steps (after years 3, 7, 10 and 13) until a branch-free bole length of 5 m is reached. After this point, unrestricted crown development should be allowed (i.e., without further pruning treatments). Interventions are only necessary if forks, steeply angled branches or epicormics develop. The management costs total 147,60 € inclusive of interest.

Harvest

After a rotation period of 60 years, the target diameter of 60 cm is forecast to have been reached and the valuable timber trees can be harvested. We calculate with a motor-manual harvest approach and a complete removal of the tree from the site. The harvest costs total 102,00 € without incurring any interest.

Discussion

After a production period of 60 years, production costs of 355,60 € (inclusive of interest) can be expected. More than two thirds of this cost (251,80 € including interest) are represented by labor costs, while only 103,90 € pertain to material costs. Since valuable wood prices depend on tree species and the given market situation, prices vary vastly, ranging from 200,00 €/m^3 up to more than 1.000,00 €/m^3. In our calculation, we assumed an average price of 400,00 €/m^3 for valuable wood and 30,00 €/m^3 for firewood. Based on 1.4 m^3 of valuable wood and 4.4 m^3 of firewood calculated as the product of a model tree with a DBH of 60 cm and a final height of 30 m (after Grote et al. 2003), a revenue of 692,00 € can be realized. This means the financial net return per tree is 336,40 €.

Given that rural landscapes often contain many kilometers of unused field boundaries, scarps or lynchets, a considerable economic profit could thus be generated. This aside, trees growing along field edges create additional ecological niches, increase the aesthetic appearance of a landscape, stabilize scarps with their roots, and contribute to a decrease in wind erosion. Clearly, they can provide more than a mere economic potential for rural areas.

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Reduced groundwater recharge under short rotation coppice plantations – can agroforestry help?

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Introduction

Short rotation coppices (SRC) with mainly poplar and willow trees provide a high potential of renewable energy supply and thus the substitution of fossil fuels and the mitigation of greenhouse gas emissions (Don et al, 2011). One shortcoming of SRC is a negative effect on groundwater recharge (GWR), as higher rates of transpiration and interception evaporation of poplar and willow plantations can be expected (Schmidt-Walter & Lamersdorf, 2012). Therefore it is very important to measure, analyse, and model the effects of SRC-planting on landscape water budgets, which are main aims of the BEST -joint research project.

Material

To analyse the effects on the water budget, a poplar SRC was studied at a plot level by measuring soil hydrological quantities as well as sensitive parameters for hydrological modelling. Two very important model parameters are the leaf area index (LAI) and the stomatal resistance (Rsc). Both parameters affect transpiration, the LAI additionally influences soil evaporation and interception evaporation. Because values and annual courses of these parameters for SRC are rare in literature, our own measurements were carried out on a research plot of the BEST joint research project and are presented in Fig. .

Results

Fig. (a) and (b) show the interaction between the atmospheric conditions vapour pressure deficit (VPD) and precipitation (Prec.) and the plant-physiological parameters leaf area index (LAI) and stomatal resistance (Rsc). The year 2013 has an annual precipitation of 640 mm (German Weather Service (DWD) station Göttingen) which is similar to the long term mean of 676 mm (period of 1969-2013). The annual course of the LAI (Fig. (b)) was measured with two optical devices (Li-Cor LAI2000 and LI1400). Both methods are based on the extinction of light determined by radiation measurements made above and below the canopy.

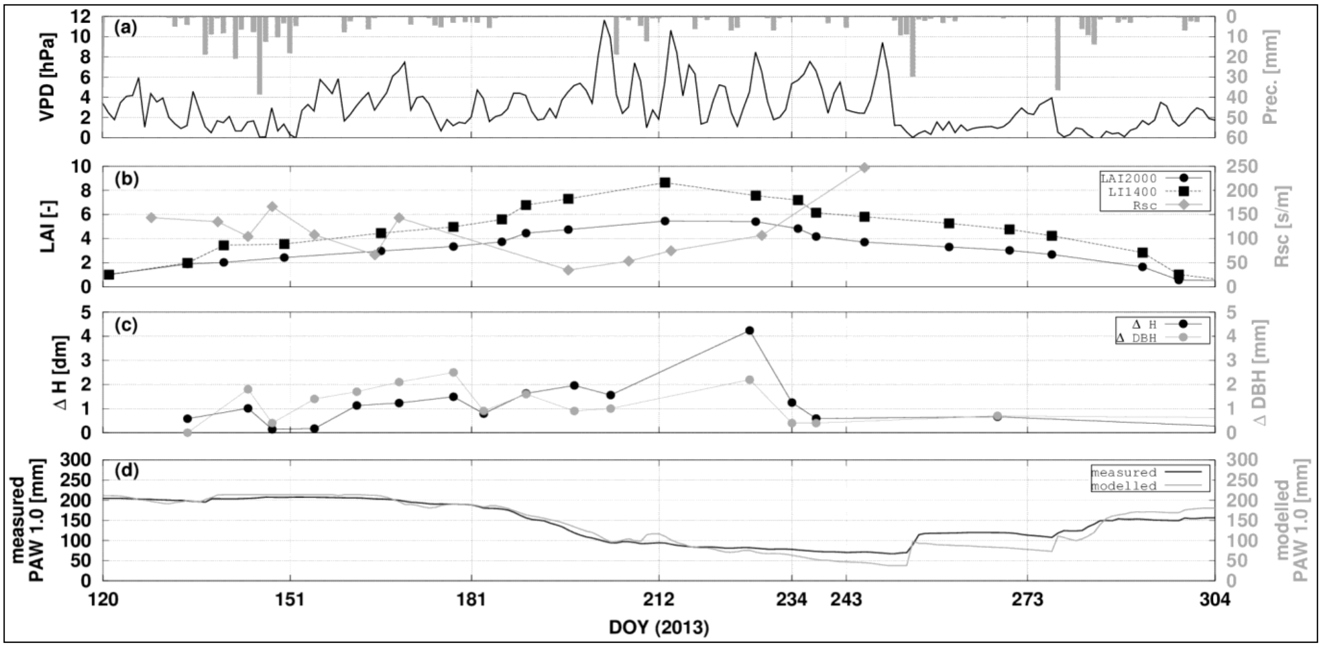

Fig. 1: Time series of atmospheric conditions, plant-physiological parameters, growth, and soil water changes of a Poplar SCR in Reiffenhausen (Lower Saxony) in 2013. (a) vapour pressure deficit (VPD) and precipitation (Prec.); (b) measured leaf area index (LAI) using optical devices LAI2000 (squares) and LI1400 (diamond) and stomatal resistance (Rsc); (c) increment of measured tree height (ΔH) and diameter at breast height (ΔDBH); (d) measured and modelled course of plant available water, calculated down to 1 m of soil depth (PAW1.0). Black drawings belong to the right axis, grey ones to left axis.

Even though these methods are quite similar, differences in LAI up to 2 m²/m² occur, illustrating the difficulties and uncertainties of such measurements. Fig. (b) shows weekly surface resistance calculated from stomatal resistance of the well-illuminated leaf measured with the SC1 Leaf Porometer (Decagon Devices). This value correlates well with the VPD and the plant available water (PAW) shown in Fig. (d) (black line). For high atmospheric demands and sufficient available soil water, Rsc is low. Starting from DOY 234 PAW is reduced significantly and Rsc rises despite of high VPD – describing drought stress conditions, which also reduces plant growth (Fig. (c)). The measurements show that the poplar SRC is able to reduce the soil water storage until drought stress occurs. So the assumption of a high water demand of poplar SRC can be confirmed with these observations as well as the link between sufficient water availability for optimal biomass growth. We used the measured plant-physiological parameters for LAI (mean of the two devices) and the minimum of Rsc together with observations of meteorological and soil-physical properties to model the water budget of the research plot Reiffenhausen using the hydrological model system WaSim. Figure 1 (d) verifies a good model agreement of PAW (Nash–Sutcliffe model efficiency

coefficient is 0.9), calculated from measured and modelled soil water contents. Based on these model-setup long term simulations were performed from 1969 to 2012 comparing three different land uses: (i) agriculture (AC), (ii) extensive grassland (GL) and (iii) poplar SRC. The parameterization for AC and GL were taken from literature, where AC is a mean agricultural summer crop. The climate forcing is taken from the DWD station Göttingen. Figure 2 compares the corresponding annual GWR of the research plot, assuming a constant soil and vegetation cover for poplar SRC as well as for AC and GL. Especially in succeeding dry years the GWR is very low or even nill for SRC compared to AC or GL. The increased occurrence of years with very low or even nill GWR under SCR has a negative impact, especially in regions with restricted groundwater availability.

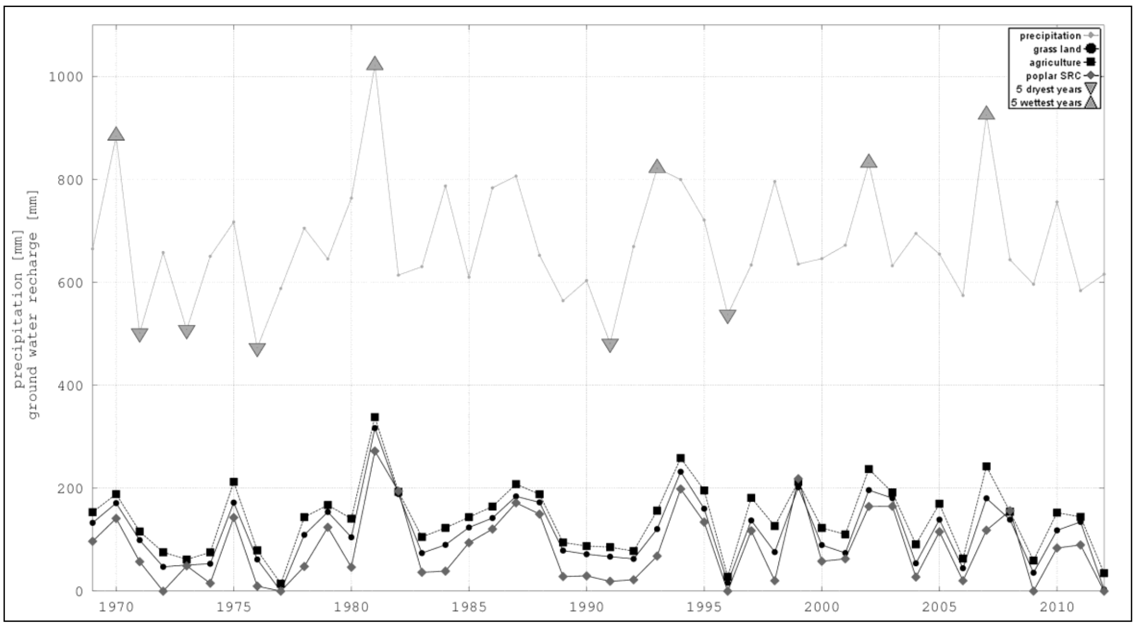

Figure 2: Annual precipitation (gray) and ground water recharge, grass land, agriculture and poplar SRC, research plot Reiffenhausen, Germany.

Discussion (and conclusions)

Agroforestry systems (AF) can be seen as an option to combine the benefits of woody biomass production by SRC and to reduce the negative effect on GWR by adding strips of grassland or other annual crops. However, further investigations and analyses are needed to study the effects of AF on the water budget. Interaction of trees and crops in AF are quite complex due to the differences in model sensitive parameters like leaf area index, transpiration, root distribution, root depth and effects on microclimate. A positive effect of AF alleviating the negative influence of SRC on GWR can be expected. Especially in regions with low water availability AF in an appropriate

extend and design can be a tradeoff between biomass production and the protection of water resources.

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Potential of growing crops between poplar rows in hybrid poplar plantations in Croatia

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Introduction

Out of 2.000.000 ha of forest land in Croatia only a small part is covered by plantations of hybrid poplars – 15.000 ha (Belčić, 2004). Such poplar stands, even with small distance between tree rows (6 m), have a great potential in alley cropping practice. This paper presents the research on light intensity in such systems. The main aim of the research was to investigate the light insolation inside hybrid poplar plantations of different age, and to address the possibility of intercropping with wheat or maize. Wheat minimum light requirement for growth is around 1.800-2.000 lx while for normal growth is 6.000 lx (Gagro, 1997). Maize requires minimum of 1.400-1.800 lx while 25.000 lx for normal growth.

Materials and methods

Research was conducted during three months (11 of April until 23 of July) in eastern Croatia. Insolation was measured before and after leaf appearance in 1-year-old, 6-year-old and 15-year-old hybrid poplar plantations and in a treeless area (which represents agriculture field light conditions). Insolation was measured only during sunny days to avoid influence of clouds on isolation, as our main interest was influence of poplar leafs.

Results

The results show statistically significant differences ($p<0,001$) in insolation between stands of different age and between the measurements before and after leaf appearance. The highest insolation was on the treeless area (arable land). In the one- and six-year-old poplar stands values of light intensity were much lower than in the fifteen-year-old stand (Table 1). With the appearance of leafs the insolation intensity differed significantly between all investigated poplar stands (Table 2). However, in the 1-year-old and 6-year-old stands the insolation values still met the minimum light requirements for crops such as wheat and maize (Figure 1).

Table 1. Insolation in poplar stands of different age (lx)

Age	n	Mean	Minimum	Maximum
Treeless	52	65.743[a]	37.674	96.876
1 year	39	49.763[b]	26.910	76.424
6 years	39	40.986[b]	10.764	78.577
15 years	39	27.495[c]	4.844	74.272

Table 2. Insolation in poplar stands of different age (lx)

		Before leafing			After leafing			
Age	n	Mean	Minimum	Maximum	n	Mean	Minimum	Maximum
Treeless	24	60.368[a]	31.276	74.272	28	70.350[a]	40.903	96.876
1 year	18	60.548[a]	49.514	76.424	21	40.519[b]	26.910	51.129
6 years	18	53.043[ab]	25.834	78.577	21	30.652[c]	10.764	47.362
15 years	18	49.395[b]	37.674	83.959	21	8.724[d]	4.844	15.070

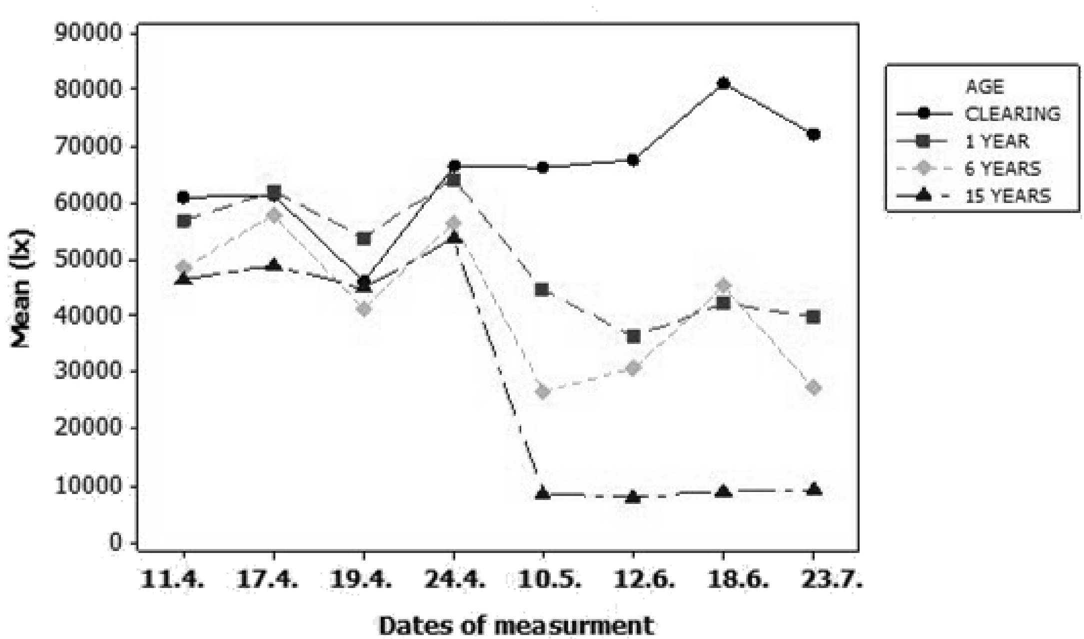

Figure 1. Insolation (lx) in poplar stands of different age (1,6 and 15 years old) and treeless area (CLEARING)

Conclusion

In conclusion the area investigated showed to have a potential in silvoarable practice. However the poplar trees should be grown in short rotation systems (3-5 years). Additional confirmation of this conclusion is the fact that the national company (Croatian forest L.t.d.) which currently manages these plantations is actually growing maize in some of them for their own needs (food for wildlife in their hunting areas).

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Valuation of grazing resources in agroforestry systems: an example of extensive livestock farms of Spanish Dehesas

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Introduction

Dehesas represent a classical model of extensive livestock production with a complex system of exchange of resources. The average farm size is around 500 ha according to recent work on dehesas (Escribano et al,. 2001; Plieninger and Wilbrand, 2001; Plieninger et al., 2004; Milán et al., 2006), and the average stocking rate is 0.37 LU/ha (Escribano et al. 2002). In these systems, humans have modified and maintained Mediterranean woodlands. The typical simultaneous land uses are livestock raising with autochthonous breeds, forestry, crops, hunting, and environmental tourism. Aside from livestock management, their multifunctional nature means that the dehesas are regarded as integrated and diversified systems – characteristics that are essential to their sustainability (Ronchi and Nardone, 2003; Gaspar et al., 2009a, 2009b). The focus of this work is on the analysis of animal production, mainly from a perspective of technical criteria, and an exploration of the use of grazing resources and their economic valuation. The essence of the results is the identification of the major factors and how they are distributed by farm type using a cluster analysis. The use of environmental resources to cover the food needs of livestock in dehesas is the main economic utility of these extensive farming systems. This takes on special relevance at present when there has been a sharp drop in the selling price of livestock but significant increases in the cost of supplementary feed. This benefit and the suitability of stocking levels are the factors that will dominate the sustainability of these farms (Gaspar et al., 2009a, 2009b).

Material

The working data were obtained from questionnaires presented to 69 holders of dehesa farms larger than 100 ha in the Autonomous Community of Extremadura (SW Spain). Forestry, livestock production, and (economic) size criteria were used to select the 69 farms with the aim of obtaining a representative sample of the dehesas existing in the region. To calculate the livestock's energy

requirements and determine the degree of use of environmental resources, we applied the method for calculating stocking rates in extensive systems developed by Martín et al. (1986). This allows one to evaluate both the energy requirements of each animal type and physiological state, and the contribution from grazing. The overall requirements and the requirements covered by grazing are expressed in kcal of metabolizable energy (ME). For the economic valuation the cost of the re-used raw materials were calculated. The valuation of the resources was established according to the local market values of rent, pasture and stubble grazing, forestry crops, and acorns for forage feeding, and taking into account the specific characteristics of each farm. The distribution of these resources is estimated by the use and the requirements covered for the farms' different livestock species.

Results

The analysis of the farms are presented according to four different types taking in account their technical and economics characteristics (full description of the typology construction process is developed in Gaspar et al. 2007). The main characteristics of the types are included in this paper as additional information.

TYPE 1: Large sheep farms and with low stocking rates

TYPE 2: Medium-sized farms oriented towards beef cattle production

TYPE 3: Small-scale, high stocking rate, sheep farms

TYPE 4: Mixed beef cattle, sheep, and Iberian pig farms

Analysis of grazing resources

The total livestock energy requirements of dehesa farms analyzed are 314 10^4 kcal ME per ha per year, of which 215.83 10^4 kcal ME are extracted from the environment through grazing and foraging on wooded and/or crop land, and open-range acorn feeding, meaning that the livestock get 71.2 % of their resources from the environment.

By farm type, the grazing resources cover 76.0 % of the livestock requirements in Type 1, 74.1 % in Type 2, 60.0 % in small-sized sheep farms with high stocking rate levels, and 59.2 % in mixed farms with Iberian pig. Indeed, wooded estates with Iberian pig (Type 4) obtain 274 10^4 kcal ME per ha per year from the environment.

By livestock species, cattle obtain 82.1 % of their energy requirements by grazing, small ruminants 76.9 %, sows 48.7 %, and open-range acorn-fed pigs 79.7 %.

Economic value of grazing resource re-use and supplements

In the analysis by farm type, it was found that the cost of grazing resources at local market prices in the mixed farms with pigs (Type 4) represented 54.6 % of the total of cost of animal feed (grazing resources and supplements). However, in the sheep farms of Type 3, this proportion was only 30.1 %, meaning a significant level of acquisition of material from outside the farm for animal feed (feed supplements). In Types 1 and 2, the corresponding values were 59.4 % and 63.0 %, respectively.

The average cost of grazing feed units is 0.54 €/10^4 kcal ME. This data contrast with the average cost of supplements per feed units for supplementary feed for the overall sample of farms (1.37 €/10^4 kcal ME), reflecting the utility of the grazing resources in these dehesa systems.

The average total cost per feed unit was 0.58 €/104 kcal ME, increasing in Type 4 to 0.69 €/104 kcal ME, and it corresponds to the mean the cost of grazing feed and the costs of the feed supplements, according to the percentage of the requirements cover by grazing/supplementing for types and species.

Overall, the total feed costs (grazing and supplements) were higher in the farms of Types 3 and 4. In the case of the pig farms (type 4), however, these costs corresponded to foraging, especially on oak-acorn. This, coupled with these farms' diversity of livestock species and their strongly wooded nature, is the reason that this group has the highest profitability rate. In contrast, the Type 3 farms increase their stocking rates partially to compensate for their relatively small sizes, with the result of high feed costs mostly due to the need to cover the livestock's requirements by purchasing feed supplements.

Discussion and conclusions

In dehesa systems, grazing resources cover a major part of the livestock's nutritional requirements, and this was especially notable in the case of the beef cattle farms. The use of grazing resources is conditioned by the size of the holding in the sense that the smaller the farm, the greater the pressure.

The use of the pasture as livestock feed was one of the principal economic benefits in these extensive animal production systems, since it was generally associated with a reduction in livestock feed costs compared with more intensive systems.

The greatest costs were observed to correspond to open-range acorn feeding in the Iberian pig farms. It was also observed that there was a major difference in the value of the grazing resources and the feed supplements. This indicates the benefits of the grazing resources of the dehesa

systems studied, since the difference in value between the raw materials used for feed determines their overall costs. As an overall conclusion, we think that this paper contributes to a better understanding of extensive systems performance, due to the inclusion in the study of the grazing rents which are charged at market prices.

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Environmental, economic and social indicators of rural development in agroforestry areas

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Introduction

The sustainable development of rural areas has become a key point of social and agricultural policies. Its objective is to improve both the quality of life and the economic well-being of the residents of relatively isolated and depopulated areas. In this context, organic farming has been identified as an approach with a high potential to contribute to the development of rural areas, since organic farmers could benefit from payments for ecosystem services, from non-farming activities such as environmental education and agro-tourism related to this mode of production and as a consequence of meeting specific consumer demands. Although such contribution to the rural development has been addressed by several authors, there is lttle consensus, as the externalities of organic farming depend on many factors (Lobley et al., 2009). Moreover, the number of studies addressing this issue in relation to the extensive livestock farms is scarce. Due to this, the study of the potential contribution of different organic and conventional livestock systems in the “dehesas” is interesting, since this agroforestry system has a high environmental value and is located in unpopulated areas with few job opportunities outside the agricultural sector. In this context, the objective of the present work is to determine whether organic beef cattle farms located in the dehesas contribute to rural development in a higher degree than conventional ones.

Material

The data collected correspond to 63 dehesa beef cattle farms (30 conventional farms and 33 organic farms). The data were obtained through direct survey interviews with dehesa farmers which were carried out in 2012. The analysis were carried out on the basis of three gruops of farms. The first group comprised 30 conventional farms (named 'Conventional'). The second group (designated as ‘OFWOOS’: Organic farms without organic sales) included 22 holdings certified as organic but which neither fattened their calves nor sold them as organic. The third group (called 'Fully organic') comprised 11 organic-certified farms that fattened their animals and sold them as organic. Descriptive statistics and frequencies for the quantitative and qualitative indicators were calculated. We carried out ANOVA and Chi-square tests with the aim to check the existence of

statistically significant differences among the group of farms. All the analyses were performed using the SPSS (v.21.0) statistical package.

Results

In relation to the social aspects, the two groups of organic farms showed a higher level of diversification (39.1 % of OFWOOS farms and 50.0 % of fully organic farms carried out more than one productive activities at the farm level). These farms also showed increased rates in social interaction (68.2 % of OFWOOS and 100 % of fully organic farmers belonged to cattlemen's associations). However, the involvement of farmers in selling their products was low, as only some of the fully organic managers (10.1 %) carried out direct sales to consumers. With regard to the workforce, fully organic farms used more labour (2.1 Annual Work Units (AWU) per farm). Moreover, 'fully organic' farms had a greater percentage of non-family workers (51.3 %).The ratio of permanent to temporary workers was also substantially higher in these farms (37.8 %). However, the per AWU salaries paid in the organic farms (7.187 € in OFWOOS, and 8.355 € in fully organic farms) were lower than those of the conventional ones (10.396 €). With regard to the economic analysis, fully organic farms sold more yearlings per cow (0.45) than conventional farms (0.07). However, the latter sold more calves per cow (0.81) than the OFWOOS (0.71) and fully organic (0.65). In relation to the environmental analysis, organic farms (especially the fully organic ones) were observed to carry out more environmentally-friendly farm-management practice. Such practices included a a higher integration of crops and livestock species (81.8 % in fully organic farms, 59.1 % in OFWOOS, and 40.0 % on conventional farms), a greater level of natural heritage conservation (81.8 %, 40.9 % and 30.0 % respectively), better manure management (54.5 %, 18.1 %, and 3.3 %), reduced use of pesticides, herbicides and mineral fertilizers (90.9 %, 100.0 %, and 63.3 %), and a lower reliance on veterinary medicines (36.4 %, 63.3 %, and 6.7 %) (Fig. 1).

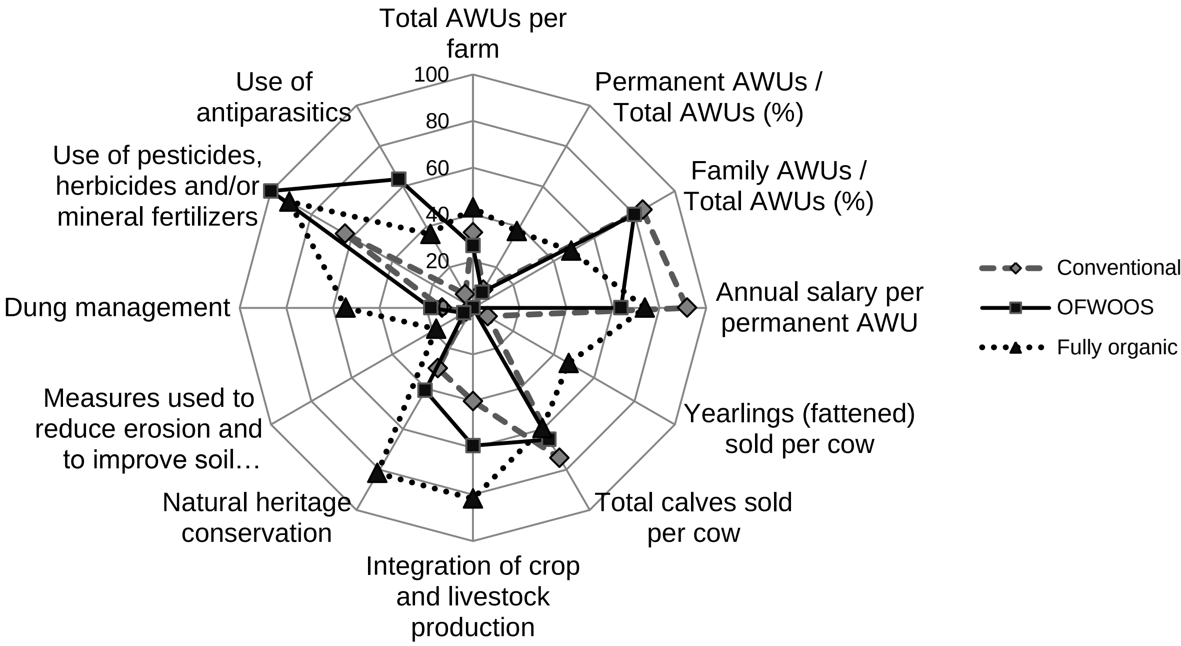

Fig 1: Main results of the three farming systems (% of max. value).

Discussion and conclusions

From the resuls of the social indicators, it is remarkable that the involvement of organic producers in selling their products was low, despite this practice being a key to the profitability and survival of the organic farms. Other authors also found a weak relationship between the condition of being organic and direct sales (Lobley et al, 2013). The higher presence of workforce implies a greater potential for rural development, and it could be explained both by the higher degree of business diversification and the higher integration of crop and livestock production, as these aspects increase the need for labour. This could also be explained by the fact that the managers of the fully organic farms have another job apart from being farm managers. According to Lobley et al. (2009), the differences found among organic and conventional farms in this sense, are mainly due to the characteristics of the production system, instead of being due to the condition of being organic. With regard to the economic analysis, the results were greatly influenced by the fact that the fully organic group fattened their calves.This allowed them to sell their calves at a higher price. However, the higher price of the organic feedstuff and the longer productive period of these farms explained the scarcity of differences found among the groups of farms. However, other authors found that organic beef cattle farms had lower economic results in this sense (Blanco-Penedo et

al., 2012; Gillespie and Nehring, 2013). In accordance with our study, Hrabalová and Zander (2006) did not find differences between organic and conventional beef cattle farms with regard to their dependence on subsidies. In relation to the environmental analysis, several authors have demonstrated the better performance of organic beef cattle farms (Blanco-Penedo et al., 2012). The set of practices implemented in such farms have been identified as recommendable options for a sustainable land use management (Dumont et al., 2013) that deserves to be taken into account and promoted by policymakers due to their positive agro-environmental and socio-economic externalities.

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Where to implement Short Rotation Agroforestry Systems? A spatially-explicit approach to derive site suitability from site conditions and field geometries

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Introduction

Woody perennial crops such as Short Rotation Coppice (SRC) systems are a cost-efficient type of land use in terms of CO_2 mitigation and they provide beneficial effects on ecosystem services (e.g., erosion protection, water retention, groundwater quality protection) when located properly. In our study area, the Göttingen district (1.117 km²) in Central Germany, climate protection is high on the regional political agenda while many arable sites are prone to erosion. Hence, there is ample opportunity to implement woody biomass systems and to generate synergies by addressing both issues. However, woody biomass crops have to compete with annual crops regarding economic return. One initial step to convince farmers to shift from annual cropping to perennial crops is to identify fields with comparably high woody biomass productivity and a shape or size that results in an inefficient and costly annual cropping. In this study we provide a methodology that allows identifying arable fields which are particularly suitable to implement woody biomass systems as (a) agroforestry systems or (b) plantations implying a shift from annual to perennial systems. The latter would be selected according to non-optimal field geometry and/or small field size, so as to obtain the highest reduction of annual cropping costs.

Methodology

Based on an extensive aerial image analysis, we derived an agricultural site map comprising around 30.000 agricultural sites within our study area. With this database we were able to analyze the agricultural site characteristics with respect to their area and geometric shape. Building on KTBL-methodology (KTBL, 2014), we derived a set of indicators to characterize 6 typical shapes of agricultural sites. We then linked a type-specific function expressing tillage time per hectare (“area-performance-function”). As a result, it was possible to determine sites being inefficient for arable cropping and to quantify this inefficiency in terms of time consumption as a proxy for costs.

A potential shift to perennial crops could follow different pathways: (1) the field geometry could be optimized by transferring parts to a short rotation coppice (SRC) - The threshold condition for this pathway is a field size larger than 2 ha to meet the criteria of a minimum SRC field size (0.3ha). Since this shift would take place on the same field we understand the SRC implementation as an establishment of an agroforestry system (AFS) and address this option as SRC-AFS. (2) Very complex shape geometries and/or field sizes smaller than 2 ha are not suitable to optimize the shape geometry via SRC-AFS since the resulting SRC fields would not meet the minimum SRC field-size criteria of 0.3 ha. In this case, SRC should cover the total field area. We address this option as SRC. We then used the assessment of potential soil erosion, carried out by LBEG (2010), to analyze the options of erosion protection due to woody biomass implementation.

Finally, we combined our findings from the arable field classification with SRC-specific site suitability criteria to reveal preference sites for SRC or SRC-AFS.

Results

With a median of 1.5 ha, arable sites are quite small in our study region – only 12 % of arable land shows a field size larger than 5 ha. Area performance of field sizes below 5 ha is strongly influenced by shape size and shape geometry. Figure 1 shows the average type-specific area-performance-function with box-plots indicating the variation within our field classification (6 types). Taking a 5ha rectangle site as reference, inefficient shapes need 15 – 50 % more time per hectare for tilling. We considered an inclination below 0.1 ha/h of the logarithmic function (see Figure 1) as a threshold for optimization and thus for implementation of “AFS-SRC”. This threshold corresponds to an area performance value of 3.13 ha/h (see Figure 1). Given the particular shape geometries in our study area, it turned out that SRC implementation is preferable up to 6.1 ha on complex field shapes. Due to the small field sizes, Table 1 reveals that the “SRC” pathway is preferable on around 50 % of the arable fields, while optimization of field geometries via “AFS-SRC” is a viable on only 11 % of the arable plots. In terms of field area, however, the ratio of the two pathways is almost balanced. Water erosion protection as an additional environmental benefit could be generated on more than half of the selected sites (see Table 1).

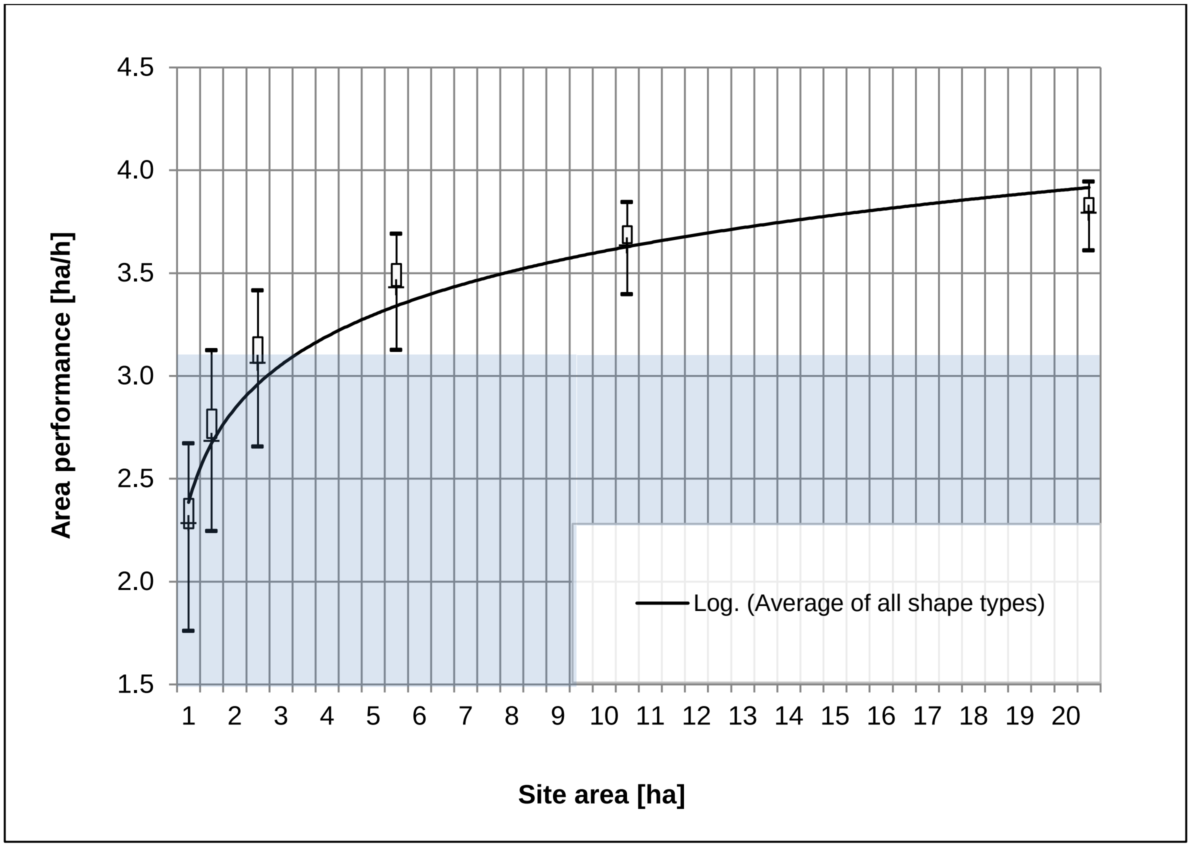

Figure 1: Average type-specific area-performance function and type-specific variation

Table 1 – Characteristics of “AFS-SRC” and “SRC” cultivation systems

Cultivation System	Allocation to Shape Types	Criteria	Share of arable sites	Share of arable area	Disposition to Water Erosion (CC)
AFS-SRC	non-optimal shape	2 – 10 ha	11 %	21 %	54 %
SRC	low area performance complex/small	< 3,13 ha/h >0.3< 6 ha	48 %	20 %	62 %
Sum			**59 %**	**41 %**	**58 %**

Conclusion

With a total share of 41 % (of all arable fields in our study area), this study showed that there is a substantial scope of action for a potential shift to perennial cropping systems. On more than 50 % of the potential sites management aspects could be combined with environmental issues. Extended with yield information, this analysis could be used to identify high productivity plots that lack efficiency in annual cropping. Given the spatial structure of the agricultural landscape in our study area, and following the described methodology, we deem both pathways as variations of agroforestry systems – with AFS-SRC as a patch-oriented perception and SRC from a landscape-oriented perspective.

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Innovating tree plantation design: Spiralographing agroforestry

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Introduction

Most forestry and agroforestry planting designs are either orthogonal or curvilinear under contour lines to prevent soil erosion. These designs are known to maximize machinery workflow or erosion control respectively. On many occasions, the optimum design for machinery operation is different from that for the prevention of soil loss and vice versa. An alternative and intermediate design system such as an Archimedes spiral could offer i) equidistant lines to facilitate machinery operation and ii) greater reduction in soil loss than orthogonal designs, whilst providing iii) aesthetic benefits.

Although the spiral land use design is present in permaculture related literature, scaling up the methodology to forestry is practically absent in literature. This work tries to contribute to the knowledge of planting trees in an Archimedes spiral design and explores an option on how achieve a spiral plantation in practical terms.

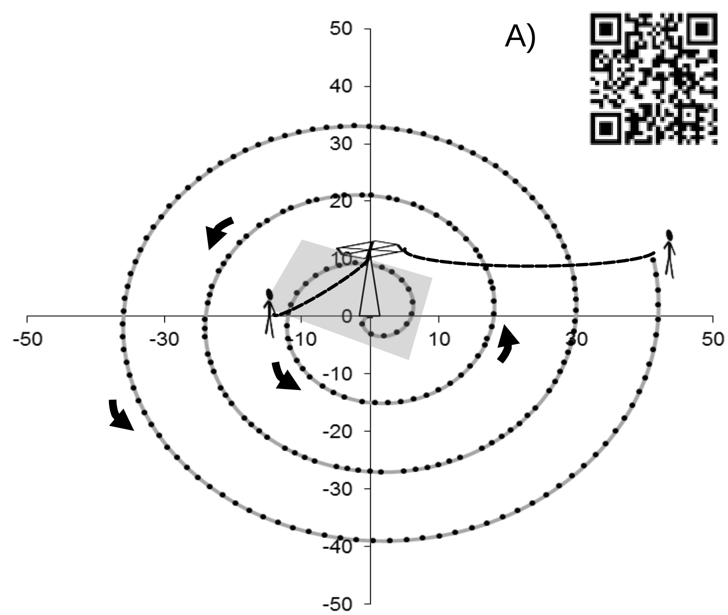

Figure 1: Schematics to implement a spiral plantation. A "field spiralographer" in the centre serves as axe to unroll a rope to serve as guide to mark the location for tree plantation. Grey area shows initial locations to avoid plantation to enable future machinery manoeuvring inside the spiral. A) Quick Response (QR) code for online demonstration video or follow this link: http://goo.gl/VxYL1S

Material and Method

Making a spiral has become a trivial command in computer assisted design, but this work envisaged the creation of the spiral in the field without any high technology software (e.g. tractor with laser technology) to enlarge the scope of possible application.

We used the spiral equation to explore and define in the spiral: 1) the number of turns, 2) the distance between the arms and 3) the tree density. The widest machinery of the farmer was 5 m so, to allow the tractor to move inwards and outwards inside the

spiral, we opted to design 12 m between rows to allow 1 m safety distance to the tree line. The final spiral would have three arms with 2 m between trees in the line (240 trees). Part of the challenge was to implement the spiral in the field with the exact dimensions in order to respect the farmer needs.

To implement the spiral in the field a "***field spiralographer***" was made with the following description: an axis about 1 m high was used with a platform on top with six equidistant arms. Each arm was made telescopic to allow different lengths of the arms. At 2 m from the centre the arms were marked and a screw pin was placed on the mark. A rope was rolled up around the screw pins. The number of complete turns is equal to the number of lines existing in the field spiral. Because the union of the screw pins in the arms' builds a hexagon with 6 x 2 m perimeter, a full turn has 12 m length. To mark the spiral in the field, we unrolled the rope and walked at the same time avoiding a loose rope, marking the place for planting the trees (Figure 1). By the end of a full turn around the "spiralographer" there should be 12 m distance between the first and last tree mark. By keeping unrolling the rope until needed, the spiral keeps being designed in the field depending on the turns needed. In other words, the "spiralographer" could be a hexagon with R radius, being 6xR, the distance between the lines in the spiral. Unrolling and keeping the rope unloose will provide a guide to mark the spiral in the field. Because the description might be unclear on the method used, a video was made showing the "making of" this spiral preparation (Figure 1A).

Results

The execution of the proposed methodology, including planting, resulted in Figure 2:

Figure 2: Spiral agroforestry with 12 meters between rows, allowing 5 meters machinery width to go in and outwards in the spiral, leaving one meter security distance to tree line.

Discussion

Spiral plantation is frequent in permaculture practices. However, the scale of the spiral is often small and developed without the need for specific tools and, for the scale we envisaged, literature was absent regarding tools and methodologies.

The choice of using non high-tech tools to implement the spiral plantation posed interesting challenges. Firstly, the rationale on how to actually draw the spiral in the field, and secondly how to develop a tool, named as “field spiralographer”, that could follow the drawing rationale.

Although the set-up of the field spiralographer initially took some time, the marking was relatively straight forward once the starting point was marked. Given the result obtained, we consider that the tool and method used contributes to the knowledge on planting trees in a spiral design.

After a brief explanation regarding the functioning of the tool to the team involved in the field, we noted a comment from the farmer: “kids should come and see what a hexagon could be used for. Sometimes at school we learn abstract mathematics, but it’s much more fun when actually seeing applied basic mathematics growing in front of our eyes”. Another interesting comment was from the tractor driver. At the beginning he was “worried” and somehow “lost”, just following orders for drilling. When the holes started to bring visibility to the spiral he commented to the farmer “this is not so nonsense after all… It might actually work”.

The benefits and challenges of this plantation design compared to conventional practices are still under study. The design does not seem to optimize any individual aspect as there are other techniques, such as contour planting that can help minimize soil erosion. However, aesthetics is not so easy to measure and maximization might not be the proper method to improve its value. The farmer was satisfied with the final result, both in terms of the aesthetics and the innovation itself.

We thank the farmer Rosário Queiroga for her innovative personality and accepting this experimental challenge on her farm.

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How two business models respond to current challenges of agrowood production: The case of Brandenburg/Germany.

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Introduction

In Brandenburg the significance of renewable energies has risen in the last decade. This is against the political background of the updated regional energy strategy 'Energiestrategie 2030 des Landes Brandenburg' approved by the regional government in 2012 and the biomass strategy 'Biomassestrategie des Landes Brandenburg' from 2010. The former clearly defines objectives for future energy policies within the region to achieve 32 % of the primary energy consumption with a combination of renewable energies (wind solar and biomass) by 2030. The latter document addresses and promotes the development of biomass as a renewable energy source. In addition to such political guidance, the development of energy crops in Brandenburg is also determined by commitments from industrial actors such as energy suppliers. As a consequence of both interventions, new patterns of land use and technological innovations are being introduced in Brandenburg.

One new land use system is the cultivation of fast growing tree species as poplar, willow and robinia on agricultural land. Two types of this land use exist in Brandenburg: Short rotation coppice (SRC) either as monoculture stands, or as agroforestry systems (AFS) which alternate rows of trees with other agricultural uses. Both systems are being studied under the term “agrowood”. Such SRC systems are also compatible with the harsh unfavorable agricultural conditions found in Brandenburg (Murach et al. 2008). Hence the “agrowood” area in the region that has been increased fifteen-fold since 2008 reaching 1819 ha in 2013 (Ministerium für Infrastruktur und Landwirtschaft 2013), the largest agrowood area of any federal state in Germany.

Despite this increase, potential producers face a wide range of challenges: uncertainties about yields, high initial investments, a locking-up of land as an agrowood plantation for the 20 years and an irregular cash flow. Other negative issues include a non-transparent market, the lack of long term experiences and machinery availability.

This paper addresses two prevailing business models in the agrowood sector in Brandenburg: comprehensive cooperation agreements and independent farming, and how they respond to the described challenges of this energy crop.

Material

We combined a qualitative method with guided interviews focusing on planting decision making processes with a modeling approach. In total 32 particpants were interviewed mainly in Brandenburg and Berlin between December 2011 and May 2012. Thereby we investigated which business models exist in the research area, how they were perceived and the experiences from their application. The data collection mainly included agrowood producers but also related actors such as service companies, energy suppliers/ contracts providers, scientists, authorities/ administration and consultants. All interviews were documented by taking notes and most were also recorded. All data were analyzed by the qualitative content analysis following Mayring 2008 and Schreier 2012, using MaxQDA software. The modelling component of our research was used to analyze characteristics and comparative advantages of the two business models. The annuities of common agrowood systems of SRC and AFS (specified according to variety, site condition and management) were calculated. Scenarios of market price developments and differentiated entrepreneurial risk levels allow the screening of opportunity costs related to the perennial life span of agrowood systems.

Results

The two most common business models for the production of agrowood in Brandenburg are the independent production and comprehensive cooperation agreements mainly offered by big energy suppliers or associated companies like Energy Crops, a subsidiary of Vattenfall. For those agreements concluded with Energy Crops a standard model exists which includes the tasks and responsibilities of each party. The company assumes the costs and the organization of planting (including planting material), harvesting, transport and recultivation while the farmer remains the land manager and responses for the soil preparation and the maintenance of the plantation supported by technical advice given by Energy Crops. The harvested raw material is delivered to the Vattenfall power plants. Despite being a widely accepted approach, known as 'annual pension-model', each agreement is negotiated individually. Hereby the farmers get a guaranteed annual remuneration per hectare that depends on the yield expectations and the transport distance, starting in the year of planting. Even the costs for follow-up or replacement planting due to for

example weather events or pest infestations are born by Energy Crops (Ehm 2013). The interviewed farmers using these contracts expressed satisfaction about their experiences.

In contrast independent agrowood producers bear all the expenses and risks themselves without having any guarantee for profit or success. The few independent producers currently face suboptimal conditions. They are a very heterogeneous group including a part-time farmer with a small test plot, a farmer producing at large scale with an own innovative utilization concept, and a leading agribusiness in Europe with strategic plans. Only a minority were producing agrowood for the commodity market as the market is perceived as non-transparent, underdeveloped and strongly influenced by a few powerful actors. By contrast the majority have sought direct sales or alternative utilization concepts to avoid the dependence on the market.

Our results show that cooperation agreements can help motivate farmers to decide in favour of agrowood. The interviewees affirmed that such agreements can help overcome economic, trade and machinery related constraints of agrowood, secure long-term incomes and increase creditworthiness of producers. In contrast, independent producers had a burden of higher risks, but may benefit from government support programs which do not apply to contract farmers. They are also able to benefit from potential future price increases for agrowood products which is not possible for contractual producers who have fixed conditions in their 15 to 20 year contracts.

Discussion

In line with the observations of Setzer (2013) and Bemmann (2012), the market situation was identified by interviewees as a crucial challenge for agrowood production. Consequently cooperation agreements have been developed to guarantee a fixed price for harvested material and thereby ensure an annual income paid by Energy Crops to the producers. They have also contributed to an expansion of the agrowood area by almost 40 % in Brandenburg in 2012 (Ehm 2013).

Although innovative business models are demanded for a further development of this energy crop (Bemmann 2012) and these cooperation agreements seem to have mainly positive effects for the involved actors, they still need to be carefully assessed.

Conclusions

The interactions between the two presented business models are important. As the underdeveloped market is identified as one of the main obstacles, a larger trade volume of agrowood is needed to remedy this shortcoming. But the relatively high proportion of the area

under contracts means that the wooden biomass produced is not entering the market but is delivered directly to the power plants. Although the agreements obviously enlarge the experiences concerning the production processes, the number of market participants is not growing and thus they are not contributing to healthy market development. This severe adverse effect cannot be ignored because it implies a strong competition between both models raising the questions if both models will coexist in future and which factors will influence their relationship and in which way. Our analysis is a first step towards a better understanding of the development of the agrowood market in Brandenburg.

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How could Agroforestry Systems provide beneficial effects on ecosystem services? – An assessment framework to support regional governance of climate protection goals in the Göttingen district

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Introduction

As in many German regions, climate protection is high on the regional political agenda in the district of Göttingen. Recently, core action of regional governance has been defined via an "Integrated Climate Protection Plan". The major goal of this participatory approach is to establish a roadmap towards a 100 % Renewable Energy supply by 2050. Though innovative, this approach lacks the linkage of climate protection-related governance activities with a multidisciplinary view on ecosystem services. Given the fact that woody biomass utilization in energy plants is deemed to be the pathway with largest CO_2 mitigation potential and highest regional added value, this is an important missing link to sustainable land use. Within the BEST project („Bioenergieregionen stärken" – www.best-forschung.de) we try to bridge parts of this gap by investigating the impact of SRC (Short Rotation Coppice) on (1) ecosystem functions and its associated ecosystem services, (2) the economic return compared to specific annual crops. For this reason, we developed a tool that allows combining ecological assessments with economic numbers as a starting point for a participative regional dialogue on sustainable land use and climate protection goals. Flexible sets of rules serve as a means to translate actor-oriented goals to a multi-criteria evaluation of economic and ecological indicators.

Study area and Methodology

The study was carried out in the administrative district of Göttingen (Lower Saxony, Germany, 1.117,73 km²), which is dominated by agricultural land use, covering 54 % of the total area. Arable land in turn accounts for more than 80 % of the agricultural area, with many small field sizes. Arable field size was derived by digitizing boundaries based on aerial image analysis (average field size: 2.4 ha). Given an average annual precipitation of around 680 mm, a mean temperature of 8.3°C, and a majority of medium to high productivity soils, natural conditions to establish short rotation coppice systems (SRC) are very good. Taking our arable field mapping (around 20.000

arable fields) as a spatial basis, we derived multiple ecological criteria. In this study we refer to: (1) landscape diver-sity, (2) patch complexity, (3) disposition to water erosion, to assess prefer-encial sites for SRC systems via multi-criteria eva-luation. Further, we relate the landscape ecological evaluation with calculations of economic return by comparing “reference crops” (rapeseed, wheat, barley) with a Poplar-SRC (5 year-rotation, 11.000 saplings, MAX1- clone). To describe landscape diversity, we calculated the edge length of arable fields being adjacent to distinct land-cover types within a 1 km radius of each arable field. This “ecotone density” indicator could be accompanied by a patch complexity indicator, describing the patch geometry and patch size of each arable field.

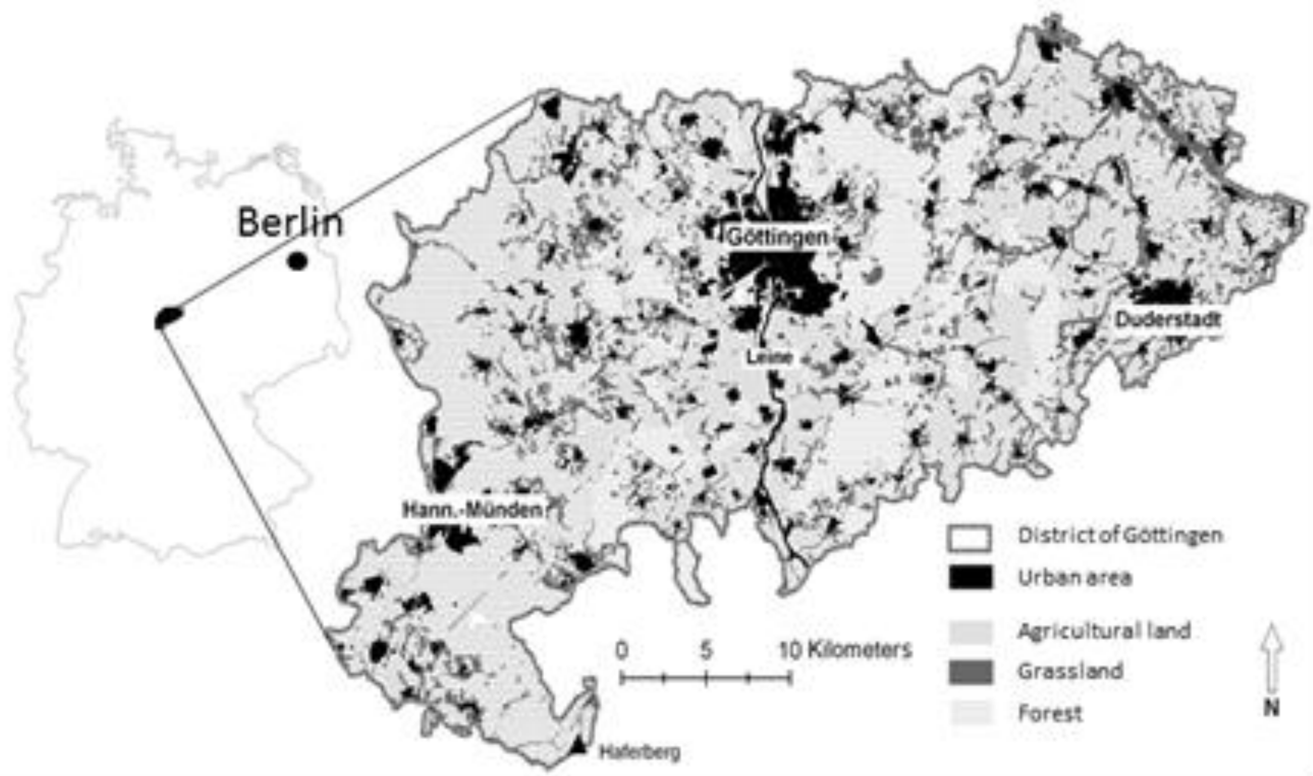

Fig.1: Case study area: The Göttingen district

Disposition to water erosion was calculated by using a DEM with a 12.5 m resolution and soil texture data from soil maps by following the calculation rules published by LBEG [1]. Deep percolation water of SRC was calculated by fitting a multiple linear regression function of soil texture and precipitation parameters to various results of water balance modelling [2]. For annual crops we calculated deep water percolation from the balance of crop-specific actual evapotranspiration, precipitation, surface runoff, and soil water holding capacity. We used statistical crop yield modeling by deriving a weighted multiple linear regression function of climate and soil variables to predict average decadal crop yield. Yield data from field experiments all over Lower

Saxony were used to derive the crop-related statistical yield functions. For SRC, we used long-term (15 years) yield data of three sites in Thuringia to develop a statistical yield model. The yield model is based on precipitation, soil water holding capacity, soil quality index, and plantation age as input parameters. To link yield modeling with the calculation of economic return, we used information from the Agricultural Chamber of Lower Saxony [3] and from the German Farmer's Association [4], among other sources. Taking one of the regional climate protection scenarios as a reference [5], we provide some first results referring to a regional energy supply from woody biomass of about 500 GWh per year. Here, we focus on a scenario that puts solely emphasis on economic return – potential SRC sites were considered only when the annual profit margin was positive compared to an annual crop rotation of rapeseed-wheat-barley. Further, potential SRC implementation on arable land was limited to a fraction of 10 % outside FFH areas and nature conservation zones. The arable field size was restricted to a maximum of 10 ha and site-specific slopes had to be below 20 %. We assumed an annual increase in crop productivity of 0.5 %, and a discount rate of 3 % per year. Input prices and costs are constant.

Results

Given the depicted scenario, a 3.400 ha (8 % of the arable land) implementation of SRC could generate around 330 GWh per year while being economically competitive to a reference crop rotation of rapeseed, wheat and barley. Thus, energy supply from SRC could account for around 5 % of current annual energy demand (6.600 GWh) of the Göttingen district. Due to ambitious climate protection goals – with a total energy demand of 2.200 GWh in 2040, this supply-ratio would increase to 15 % [5]. This energy supply reflects a biomass production of around 67.000 t (dry matter) per year. The sites selected show an average productivity of 16.8 t of dry matter y^{-1} with a minimum of 13 t and a maximum productivity of 20 t per year. The SRC productivity corresponds to a mean annual surplus in gross margin of about 80 € per ha and reveals that SRC could be economically competitive when sites are adequately selected. Figure 2a stresses this aspect by depicting the large range of annual economic return. Figure 2b in turn shows that SRC with a mean annual increment of more than 12.5 t (dry matter) per year is economically competitive to a rapeseed-wheat-barley crop rotation. There is a tendency that economically suitable sites are preferably selected on arable patches with higher complexity (Fig 2c), which is due to comparably higher harvesting and management costs of these sites and thus, resulting in less competitive annual cropping. In addition, around 20 % of the selected SRC sites are situated in homogeneous

landscapes. Here, SRC could play a beneficial role to enrich landscape structure. Around 39 % (19.567 ha) of all arable sites in the Göttingen district are subject to Cross Compliance measures - meaning that the risk of water erosion has to be reduced. The current selection of SRC sites reflects the overall disposition to water erosion and could therefore be used to generate erosion protection (Fig. 2d). When aiming at combining multiple ecological effects with our selected set of potential SRC sites, around 500 ha (15%) could be identified. The surplus in gross margin slightly diminishes to 60 € per ha and year.

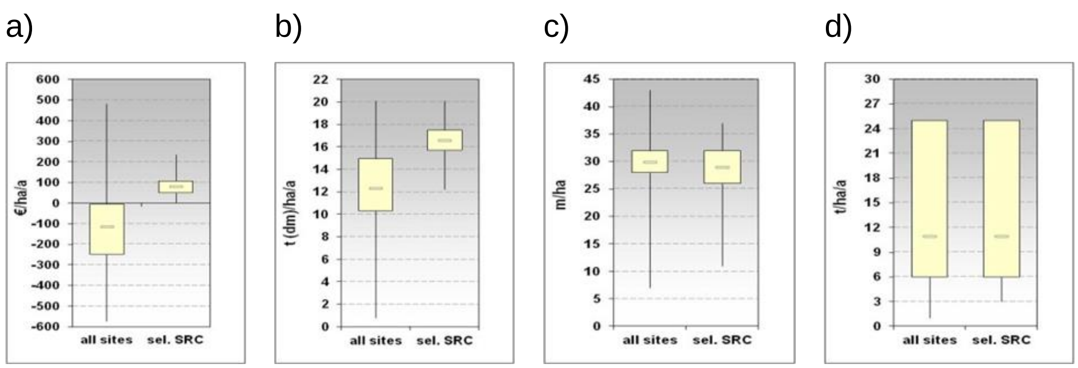

Fig 2: Selected indicators of the scenario assessment. a) Gross margin, b) dry matter, c) patch complexity and d) soil erosion

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Effect of tree species and location within tree strips on plant species richness and composition in agroforestry systems

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Introduction

A future increase in fast growing tree plantations for biomass production is likely. Agroforestry, as one option, has many favourable properties. However, effects on biodiversity are little known. The aim of our study was to evaluate richness and composition of vascular plants in agroforestry systems in relation to tree species and location within strips of trees. Recent surveys showed that the ground vegetation of short-rotation coppice plantings is diverse, but often dominated by ruderal or weed species (Britt et al., 2007). Only few or no rare or endangered species are likely to occur (Weih et al. ,2003). High species richness is mainly caused by ecotone effects and the remaining in an early secondary succession stage due to the mixing of species from arable land, grassland and disturbed areas (Baum et al., 2012). We asked (i) how species richness is influenced by tree species and (ii) how species richness is influenced by location within tree strips?

Material

Data was collected at Scheyern Research Station (48° 24′ N, 11° 45′ O) located in the Bavarian tertiary hills in southern Germany. Predominant soils are thin loess-loam or loess deposits. Two organically managed fields with seven crops in rotation (winter wheat and winter barley in 2013) and two integrated managed fields with four crops in rotation (winter wheat and maize in 2013) were transformed to agroforestry systems in 2009. Thus four short-rotation coppice systems comprising three 8.25 m wide tree strips were planted. Each strip consists of three double rows spaced 1.5 m apart. Eight tree species change randomly every 30 m. After first harvest in May 2013 vegetation was recorded in 105 plots (0.75 x 1.5 m). Five tree species were sampled including black alder (*Alnus glutinosa*), a mixture of regionally common hedge trees, poplar Max 3 (*Populus maximowiczii x Populus nigra*), black locust (*Robinia pseudoacacia*), and willow Inger (*Salix triandra x Salix viminalis*). The sample plots were 1.5 m x 1 m or 0.75 m x 2 m. The vegetation sampling involved listing all plant species at the sample plots. The collected plant specimens were identified and named according to Rothmaler (2000). Species abundance was measured based on ground coverage according to the Braun-Blanquet (1965) scale.

Results

Sites with different trees showed distinct species composition and richness (Fig. 1a). 36 species belonging to 28 genera and 19 families were recorded. The most frequent families were *Poaceae*, followed by *Fabaceae* and *Polygonaceae*. Highest species richness was recorded in willow (25 species), followed by mixture of regionally common hedge trees. Poplar showed lowest species richness (16 species). Location within strips affected richness as well (Fig. 1b). Most species were recorded at the sunlit side (24 species). In the middle species richness was lowest (15 species). Legume species (*Trifolium dubium, T. pratense, T. repens* and *Vicia tetrasperma*) were recorded at all sites except in black locust and black alder. *Urtica dioica* was recorded only in black locust and black alder, indicating the trees' ability of nitrogen fixation. Ruderal plant species (e. g. *Cirsium arvense* and *Rumex* sp.) and forest species (e. g. *Geum urbanum*) were observed as well.

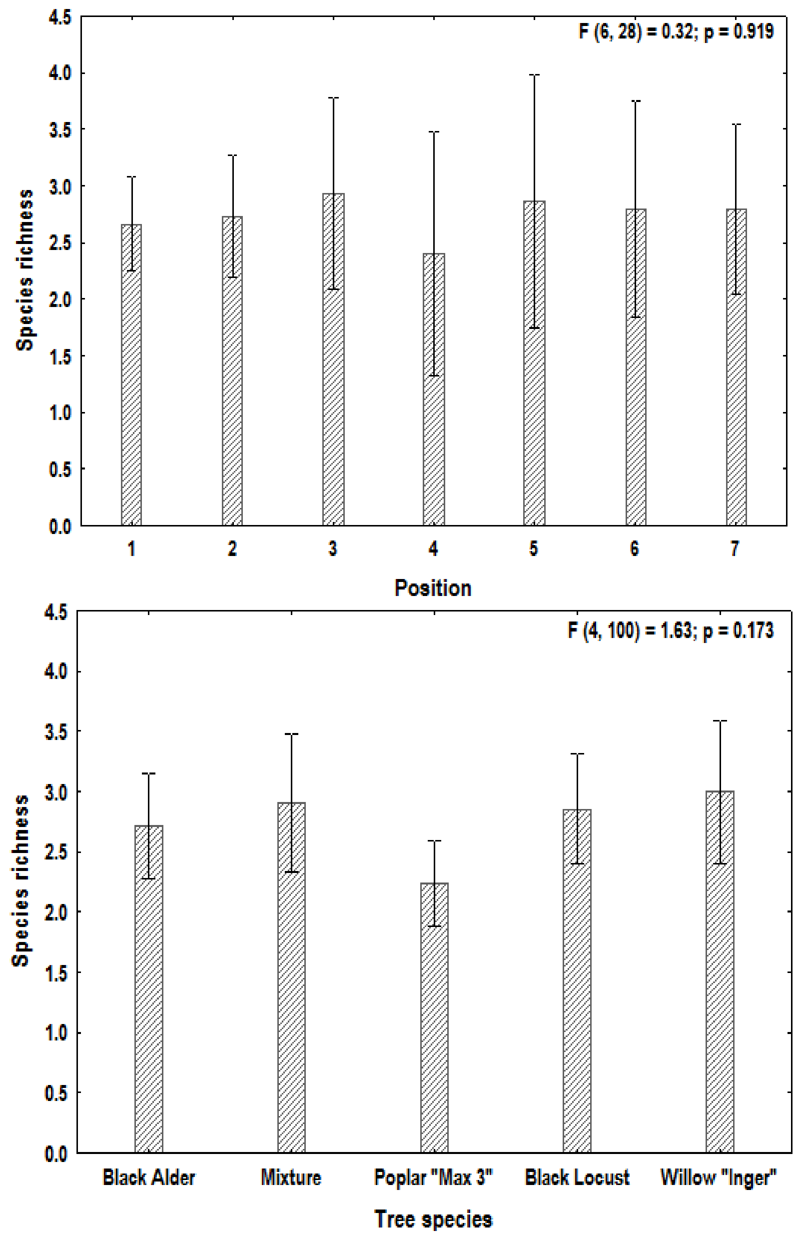

Fig 1: Species richness (ground coverage of species > 6%) according to (a) tree species and (b) tree position (1 sunlit edge, 4 middle, 7 shadow edge). Error bars represent standard errors of the means (SE). F and p values in the upper right hand corner of each figure represent results of one-way ANOVA.

Discussion and conclusions

The plant species composition differed according to tree species and tree position. However these influences were not significant in Scheyern. The different plant composition seems to be important for biodiversity, with higher species numbers recorded at the edge of a plantation than within it, as suggested Weih et al. (2003). According to Baum et al. (2009) species richness depends on light intensity, which is dependent on canopy closure of individual trees. The lowest canopy closure was recorded in willow, where the highest species richness was recorded. However, differences in species richness were not significant. This is probably because the plantation was established recently. As suggested by Delarze and Ciardo (2002) early stages are typically colonized by species with demand of light and nutrients

independent of tree species, In accordance with Gustafsson (1987) ruderal species were recorded as well. The present forest species indicate a shift in ground vegetation from the initially ruderal and pioneer species towards woodland species and from annuals and biennials towards perennials during time (Britt et al. 2007). In further research other environmental factors as well as the development of species richness during the time should be taken into account.

In conclusion plant species richness and composition in the agroforestry systems in Scheyern suggested little limitation by nutrient availability but more by light conditions.

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Agroforestry research and development in Hungary

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Introduction

In the last century agroforestry was a widespread technology of land use in Hungary. During the last decades it has declined and disappeared from large areas of the Hungarian countryside. The aim of this document is to give a general overview of the role of agroforestry, with special regard to its development and recently running research projects in Hungary.

Past and present of agroforestry in Hungary

Hungary is a traditionally agricultural country, therefore traditional agroforestry technologies such as windbreaks, shelter-belts, hedgerows, small-scale orchards and vineyards, wooded meadows, grazed forest and wood pastures had been applied on a large scale in the past centuries.

With the aim to increase domestic agricultural productivity and wood production basis, and to decrease national wood import dependency, a large-scale state-financed research project on protective woodlands started in the early sixties, led by the University of Forestry and Timber Industry (today called University of West Hungary - UWH). The aim of the research was to identify the ecosystem services and effects on agricultural productivity of protective woodlands, so as to justify the positive effects observed or measured only fragmentally up to that time. (Gál, 1961;1963) As a result of that multi-annual research and development activity the area of forest belts increased further until the 80's.

From the early nineties the positive trend of increasing the area of protective forest belts first stopped, then reversed. As an outcome of privatization, the landscape of the Great Plain had undergone a structural transformation, resulting in more diversified land use, a lot of small parcels together with new large estates. The former area of forest belts (35.000 hectares) has decreased by 50 % up to this time.

In Hungary the total ratio of agricultural territories - croplands, pastures, plantations, and grasslands - is 60 % of the territory. 85 % of these are classified agro-environmentally sensitive

areas. The high ratio of “risky” territories demonstrates the strong need for the development of rural areas, among others the implementation of innovative agricultural technology able to increase social-economic sustainability. As a consequence rural development has become one of the hot issues in the last years in Hungary (Vityi and Marosvölgyi, 2012).

Current State of Agroforestry-Related Research in Hungary

Following on from the forest belt research project started in the ’60s and run over the course of several decades, a new line of experiments started some years ago in the UWH Faculty of Forestry. The aim of this research program is to develop a model for the design and construction of forest belts by the combination of digital modelling and field sampling with analytical methods. The examination and development of windbreaks and shelter belt systems will be continued within the frame of a national project focused on the climate – vegetation relationship.

In 2012 the UWH Cooperational Research Centre, together with local cooperatives and farmers set the objective of integrating modern agroforestry technologies in their on-farm agricultural activity and establishing new experimental sites available for future research and demonstration purposes. The long-term goal is to study and develop agroforestry technologies under domestic circumstances able to support the development of the Hungarian countryside in its complexity. This cooperation will also contribute to the „AGFORWARD” international research project on agroforestry.

Research on traditional wood pastures, wood meadows and grazed forest has started at the Institute of Ecology and Botany, Centre for Ecological Research, Hungarian Academy of Science in 2006. The aim of our work is to encourage sustainable silvopastoral management. This work focuses on vegetation, landscape history, traditional ecological knowledge and nature conservation issues of the wood pastures, grazed forest and wooded meadows at country level and at 10 field sites in different part of Hungary. Currently approximately 5500 ha of wood-pasture can be found. This area now appears small compared to its former significance. The main tree species are oak, wild pear, beech, hornbeam, ash and willow. The growing interest of farmers and conservationist in the traditional silvopastoral systems is highlighting the importance of traditional ecological knowledge of the agroforestry systems. Our work will contribute to the High Nature Value Farming project of the "AGFORWARD".

In the Corvinus University of Budapest, Department of Ecological Farming and Sustainable Production Systems an R&D project on forest gardens started in 2010. They established a test

plantation on the Department's Experiment Field near Budapest, on a 1,7 ha territory. Materials were mainly fruit trees combined with forest trees and bushes from 14 species with 36 cultivars planted on the plot. The purpose of the forest garden was both educational and experimental by collecting experiences with the establishment, maintenance and utilization of forest garden under the given site conditions.

From this year agroforestry appears among the "determinative research and development subjects" of the Ministry of Rural Development. This development and the increasing number of research projects show agroforestry rising again in Hungary.

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Holistic Management approach

as a tool for *dehesa/montado* restoration

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Introduction

Dehesa/montado can be defined as a multi-purpose agroforestry system with scattered oak trees. This ecosystem covers an estimated 3.1 million ha and is the most extended silvopastoral area and the largest High Nature Value Farming System in Europe (Pulido and Picardo, 2010). However, their sustainability has been questioned in recent years because of trends towards more intensive and simplified management, which in turn have led to changes in vegetation and soil properties and increased soil erosion rates (Papanastasis 2004; Moreno and Pulido, 2009).

The most important economic activity is the extensive livestock farming. Therefore, natural pastures, as the main source of fodder for livestock, are an essential component of the system. The management of natural pastures is aimed at increasing their quality (legumes: protein, minerals) and quantity. As a consequence, that management is based on three fundamental issues: livestock management, legumes introduction and phosphoric fertilization (Olea and San-Miguel Ayanz 2006).

A sustainable livestock management could imply important improvements in *dehesa/montado* ecosystem such as preventing colonization of pastures by invading shrubs, improving grassland quality, ameliorating soil fertility and quickening the nutrient cycle (Montero et al 1998).

Holistic Management (HM) is a decision-making framework which integrates social, ecological and economic factors. In the HM process, practitioners develop a holistic goal which includes: (1) quality of life values, (2) forms of production to support those values, and (3) landscape planning, which should protect and enhance biodiversity and support ecosystem processes of succession, energy flow, hydrological and nutrient cycling (Savory and Butterfield 1999). In ‘‘brittle’’ environments, where humidity is particularly uneven throughout the year, HM advocates managing high densities of large herding animals to produce heavy grazing and trampling impact for brief periods at appropriate intervals(Savory and Butterfield 1999).

Although this approach has been developed in different countries and ecosystems reporting an enhancement of ecosystem process, biodiversity, economic profitability and quality of life (Joyce 2000; McCosker 2000; Stinner et al 1997), there is a lack of scientific studies that evaluate the effects of HM approach in *dehesa/montado* ecosystems. How do short grazing periods and adequate pasture rest affect vegetation cover and pasture yield? How does the Holistic Management approach influence pasture biodiversity and tree regeneration? How do this approach relate to soil proprieties? These are some questions that need to be answered.

Objectives and hypotheses

In order to evaluate the effect of Holistic Management approach on *dehesa/montado* ecosystems, we propose an experimental project based on time-controlled grazing systems.

Our hypothesis is that the Holistic Management, not only increases productivity but also implies ecosystem improvements: improving soil properties (soil structure, amount of organic matter, water efficiency, and availability soil nutrients), pasture species cover and composition, and trees regeneration.

Materials and methods

Study area

The study farm is a *Q. ilex dehesa* located in Cabeza del Buey (Badajoz, Extremadura), in the southwest of Spain (38°75′ N, 5°02′ W; 503 m a.s.l.). The Mediterranean climate, characterized by a severe summer drought and great annual and interannual rainfall variability, and the poorly and incipient soils are the main limiting factors to ecosystem process. The main economic activity is extensive livestock farming. The merino sheep and iberian pigs are managed in rotational grazing systems.

Experimental design

A factorial experimental project has been designed (3 treatment x 3 places).Three different managements (Holistic Management, Conventional Grazing and Phosphate Fertilization) will be implemented in three different sites (plots of 1 ha. each). The Holistic Management approach will be developed through high animal density in a short grazing time period and an adequate pasture rest.

The effects of these treatments will be compared by monitoring different ecosystem indicators The tables 1 and 2 below show the variables that will be monitored. We have already started to do

the initial measurement (May 2014). In September 2014 and during the upcoming three years we will apply the different proposed managements in the experimental plots.

Table 1 &2: Soil and vegetation indicators, sample sizes (N) and methods.

Soil Indicators	**N**	**Method**
Compaction	90	Soil penetrometer
Water infiltration rate	27	Infiltrometer
Mineral N and available P	54	Ion-exchange resin membrane
Soil organic matter	54	Wet oxidation
Bulk density	54	Soil cores of 192,42 cm^3
Soil respiration	54	Portable soil respiration system measuring soil CO_2 flux

Vegetation Indicators	**N**	**Method**
Productivity	27	Exclusion cage andbiomass weight
Functional diversity	27	15 m transect
Vegetation cover	27	15 m transect
Tree recovery	27	30 m transect

Expected Results

With a Holistic Management grazing approach, based on short grazing periods and adequate pasture rest, we expect an improvement in ecosystem functions and therefore an enhancement of economic profitability.

A vegetation cover restoration could be produce, enhancing infiltration rate and holding water capacity. The soils proprieties also could be enhancement, increasing organic matter, nutrient and biological activity. We also expect an increase in pasture biodiversity and tree recovery. McCoster (2000) has described a synergistic effect between a cell grazing (similar to HM) and trees regeneration in Australia.

Conclusion

Holistic Management approach implies integration between ecosystem process and management grazing systems. The development of this approach could be an opportunity to increase the sustainability of *dehesa/montado* ecosystems.

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Social and economic evaluation of innovative alley coppice systems mixing timber trees with bioenergy wood crops in agroforestry systems

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Introduction

Alley coppice (AC) is an innovative agroforestry system where high value timber trees, or standard trees,are planted in lines with bioenergy short rotation coppice (SRC) as intercrop. AC is a new studied system whose rationale is based on already known tree based systems, like traditional coppice with standards, and modern SRC, alley cropping and mixed plantations (Morhart et al., 2014). AC potentially provides several benefits, in terms ofenvironment, increasing biodiversity and reducing soil erosion; wood quality of standard trees, increasing their stem formand branching habit, as well as reducing pruningintensity thanks to light competition between species; economically, providing an income to farmers due to the biomass production during the standard trees growth. Being innovative, AC needs to be tested and assessed in terms of social acceptability, as well as profitability. The objective of this paper is to: i) assess the farmers' interest in AC systems; ii) evaluate the economic profitability of AC systems. The study has been carried out within the framework of the AgroCop European project (www.agrocop.com).

Material

An on-farm survey was conducted with the aim to identify farmers who more likely would be interested to test and adopt AC system on farm land, according to their socio-economic characteristics, knowledge and awareness. A structured questionnaire was prepared and submitted to a sample of farmers located in Italy. Farmers were chosen among those with experience in alley coppice or short rotation coppice.

An economic simulation comparing AC (poplar SRC mixed with wild cherry) and monocultures of the same species was run. For this purpose, we developed a database on costs and prices of timber and SRC plantation forestry across Europe. AC system was simulated according to a standard scheme taken from Morhart et al (2014). In both cases standard trees have to be thinned

at the 9th and 20th year, leaving the best 30 trees in AC system and the best 70 trees in monoculture. The site conditions are optimal in all three cases, without the need for irrigation.

Table 1: Main cultural characteristics of the compared tree systems for economic simulation

	Alley Coppice		SRC	PlantationForestry
Tree species	W. Cherry	Poplar SRC	Hybridpoplars	W. Cherry
Spacing (m)	28 x 12	2.5 x 0.5	2.5 x 0.5	12 x 12
Number of trees	30 (at 60 years)	4800 (planting time)	8000 (planting time)	70 (at 60 years)
RotationCycle (year)	60	2 years x 20 years x 3 cycles	2 years x 20 years x 3 cycles	60
Cover Area %	22	78	100	100
Yield: Timber in m^3 Biomass in Mg_{DM}	42.3 m^3ha^{-1} 16.8Mg_{DM} ha^{-1}	1-20 years: 6 Mg_{DM} $ha^{-1}y^{-1}$ 21-40 years: 5 Mg_{DM} $ha^{-1}y^{-1}$ 41-50 years: 4.2 Mg_{DM} $ha^{-1}y^{-1}$	1-60 years: 10 $Mg_{DM}ha^{-1}y^{-1}$	98.7 m^3ha-1 39.2 Mg_{DM} ha^{-1}

According to our experience, we estimated an average biennial yield of 20 t_{odt}/ha of biomass for pure poplar, which decreases in AC system, due to the reduction of land used for SRC and the light competition between species. For standard trees, we assume a final dimension of about 60 cm DBH and a total stem height of 28 m, with an average of 5 m of branch-free trunk for veneering or sawing. During the first 20 years of the AC system, we assumed a SRC yield reduction equal to the area occupied by the standard trees. During the second 20 years, to the above mentioned yield reduction of SRC we added a further -15 %, equal to the standard tree canopy closure at age 30. For the third 20 years, a further yield reduction of -40 %, equal to the standard tree canopy closure at age 30. Finally, we estimate a production of 1.41 m^3/tree of valuable wood and 0.56Mg_{DM}/tree of firewood, sold as biomass for energy.

For the economic comparison, we use Net Present Value (NPV):

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

Where *n* is cycle length (years), *t* is year, *C* is cashflow (revenues – costs), *i* is discount rate. NPV is an estimate of the current value of all future incomes from an investment.

A discount rate of 3 % was used.Considering the high uncertainly of timber and biomass prices, and the consequent difficulty to predict revenues for a long period, a comparison was made between three level prices at farmgate both for biomass (40, 60, 100 €/t_{DM}) and for valuable woods (150, 300, 500 €/m^3). For costs, we used data from German experimental fields of the Agrocop project.

Results

A total amount of 20 questionnaires was completed and returned.

Most of the interviewed farmers are located in Northern Italy, in the Po Valley plain.

Table 2: Farmers' evaluation of the most important expected benefits from AC system. Farmers were asked to score from 1 (low) to 5 (high) the expected benefits according to their experience and knowledge

Expected benefit	Average score
economic benefits	4.27
social benefits	3.37
biodiversity conservation	4.33
landscape improvement	4.40
soil quality improvement	4.22

The survey evidenced that farmers have a great awareness and experience concerning plantation forestry. Most of them, in fact, manage various typology of plantation forestry, combining different design and planting scheme, planting several woody species. Among them, the most common are walnut and cherry as primary species aimed producing timber; hornbeam, ash and oaks, as species aimed producing biomass or other secondary products or services. Concerning the management aspects of these plantations, most of the farmers claim that the weed control represents the main constraint. Nevertheless, farmers report satisfactory tree growth rates.

Economic analysis is currently underway. From the very early results it seems that pure SRC plantation should be the more profitable system, without considering the many risks over a 60 year period.

Discussion

The interviewed farmers appeared to be familiar with managing forest plantations as species mixtures and with the value of fuel wood. However, the value of the timber and biomass produced during the rotation appeared to be farmers' main source of uncertainty, with no clear idea of what demand there would be for both wood products, and they assigned a higher rank to the importance

of environmental benefits such as biodiversity, landscape, soil fertility improvement (table 2).Thus, farmers are interested on mixed cultural models of plantation forestry, although the economic final objective is not very clear.

AC could be an innovative option for timber and bioenergy production, integrating some of the advantages that are characteristic of agroforestry systems into mixed tree plantations. Economic simulations, under optimal site conditions, will demonstrate the most profitable cultural option (AC vs SRC vs Plantation forestry) under various scenarios of wood prices and discount rates. The SRC component has an important role to play, not only producing biomass, but also increasing the quality of the valuable timber by improving timber tree form, reducing the costs of management operations and for giving a revenue during the growth of standard trees. SRC should be a continuous source of revenue for farmers during the growth of standard trees, and should guarantee a profit even when the valuable wood price should be low. This is an important issue, considering the uncertainty of timber wood price. However in our economic simulations we considered only a moderate competition between tree species, assuming a loss of yield for SRC equal to reduction of canopy closure. Further economic simulations should include possible realistic scenarios of the mutual detrimental competitions.

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Agr'eau

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Introduction

Another view on the water cycle

Even though they are often neglected, soil and vegetation play a fundamental role in the water cycle. The condition of water bodies is largely dependent of the physical occupation and functional land use. Valid on a qualitative point of view, this relationship is also quantitative, since the amount of water permanently available in a given area is entirely dependent on the type of soil and vegetation cover. Thus, the protection of water resources and optimizing its use, especially in agriculture, are closely linked to how the soil and vegetation absorb and retain water that is brought to them by precipitation.

The couple soil/crop mobilizes water over time, has a great resilience and is responsible for the quality, quantity and availability of water in a territory.

Nowadays, classical farming schemes involve destroying vegetation located between two cash crops, and this helps kill the soil and promotes erosion.

But soil protection can become a source of fertility and money saving through reducing the need of inputs and obtaining more production with less pollution, thanks to knowledge and techniques.

Method

A plan to implement eco-friendly agriculture in Adour-Garonne watershed (south west of France, Fig 1): Agroforestry and cover crops

A simple, flexible, but ambitious project and within reach...

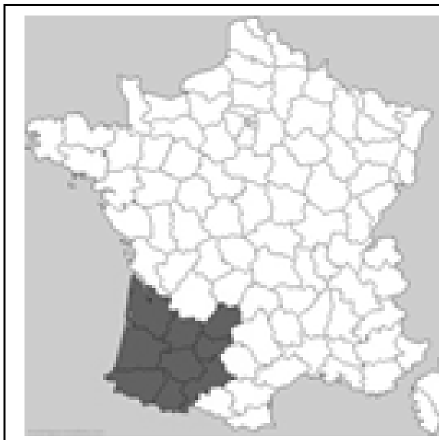

Figure 1: Adour-Garonne watershed

Repositioning soil and plant at the heart of agronomy sciences and associating them with collective water savings represents a double challenge that fills many cross-purposes. The idea is to take the initiative and to experiment a diffuse and preventive action in order to have a sustainable and transposable reply to the challenges we face at all territorial

scales. By valuing achievements, by enhancing the existing tools, and by betting on the large capacity of agro-ecosystems to regenerate naturally, we can radically transform our territories without costly investments, just by changing our point of view and our practices.

Uniting farming approachs

Agr'eau is a multi -partner program, built to develop soil cover in Adour-Garonne through knowledge dissemination, local actors support, and communication. Agr'Eau is the first development program aiming soil cover and built across a watershed as large as Adour-Garonne. It takes its origin from farmer's initiative, this major operation spreads over years and offers a multi-stakeholder approach while it crosses sustainable development practices coming from agroforestry and plant cover techniques. Thus, in order to amplify the existing large-scale movement, this program aims to create a development dynamic by relying on the diversity of experiences, creating reliable technical and economical references, and by valuing and disseminating technical knowledge in which farmers are key players.

A project with, for and by farmers

Beyond an important information program, agr'eau is a recovery operation of technical and economic references, open to all farmers and putting the farmer at the heart of the plan. The idea is to connect different actors of the territory, and implement "Agricultural knowledge transfer". This knowledge sharing approach is open to all forms of agriculture. To highlight the initiatives of farmers, a network of over 125 pilot farms will be used to create a monitoring tool and acquire new technical references.

Results

The expected results will contribute to:

- The goal of reducing diffuse agricultural pollution and achieving good ecological status of rivers (Directive Cadre surl'eau)
- The goal of reducing nitrate levels (Nitrates Directive)
- Phytosanitary reduction plan (Ecophyto 2018)
- The Sustainable Development Strategy of the Ministry of Agriculture and Fisheries
- The process "Agriculture produces otherwise"
- The development of green and blue corridors (la trame verte et bleue)
- Programs for maintaining biodiversity (National Strategy for Biodiversity Atlas of Biodiversity in common, comprehensive plan for sustainable beekeeping)

- Conservation and the reduction of soil sealing

The aim is to coordinate primarily local actions implemented in areas with "water" issues that differentiate themselves and participate in the construction of new projects in areas where problems have been identified (creation of new regional action plan and other devices). This approach is in line with the 10th intervention program of the Water Agency Adour-Garonne which is moving towards a territorial approach to water management.

Additional regional development programs agroforestry,Agr'Eau involved at all territorial level and is part of several priorities established in the 10th program:

- Preservation and restoration of water intended for drinking water,
- Restore the proper functioning of aquatic
- Quantitative management of water resources.

Indeed, the establishment of vegetation cover contributes to the fight against diffuse pollution from agricultural sources and to improve the quality of raw water before purification. Agr'Eau creates a preventive dynamic on areas with high stakes.

Discussion (and conclusions)

Its mission of promoting the Natural Regeneration of vegetation as well as the development of wild trees and hedgerows on the land also contributes to the goal of green and blue corridors, ecological continuity and preservation of wetlands. Developing actions tests and participation in research programs will develop and implement innovative actions, always with a view of sharing knowledge and expertise.

Instead of consuming water, this agriculture produces water by retaining it where it falls and delivering it little by little with less pollution. The aim is to produce maximum biomass to restore the organo-biological functionality of the soil and raise the organic matter rate in order to allow it to filter and store water while fighting against erosion and pollution. In one way, with no plant, there is no water and with no water, there is no plant.

The vegetation is primarily a means of increasing the agronomic and economic efficiency of agricultural areas.

Restoring a plant cover is restoring the green and blue belt, enhancing the air - carbon audits and energy issues and mitigating the climate change, in terms of landscape quality and the attractiveness of the regions.

All "regular" and productive areas are concerned, beyond refuges, sanctuaries or buffers...

In fact, 80 % of water ending in a river comes from the ordinary agricultural areas. Marginal areas devoted to compensation or restoring damage suffered by landscaped and environments aren't sufficient because they only represent 20 % of the water ending in the river.

The objective is twofold: fewer inputs, less tillage, less water pollution, but also more plant, more service provided by agriculture to environment. To achieve this, it uses techniques based on the preservation of soil "capital": permanent crop and tree cover.

More information at: http://www.agroforesterie.fr/agreau.php

Agroforestry in Czech Republic – history, present state and perspectives

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Introduction

Agroforestry has been practiced from the beginning of agriculture in the whole of Europe; however, currently it is not a common landuse system in Czech Republic. Traditional agroforestry practically disappeared during the era of collective farming throughout of 20th century, except for small remnants and modern agroforestry systems are not practiced yet. In this contribution we have tried to review the historical background, present state and future perspectives of agroforestry in Czech Republic.

Results

Nowadays, the most extended traditional agroforestry practice in Czech Republic is silvopastoral form of *streuobst* (*streuobstwiesen* - extensive fruit orchards with tree density usually between 50 and 200 trees·ha^{-1} grazed by sheep or cattle) remaining in sites with less favourable conditions for intensive agriculture (e.g. mountains – regions of White Carpathians and Bohemian Forest).

Silvoarable *streuobst* (*streuobstäcker* – intercropping under fruit orchards) is of no importance but nowadays some organic farmers are interested in implementing this practice. Usually the streuobst is based on cultivation of local fruit high-stemmed tree varieties (e.g. apples, pears, plums and cherries) and thus possess high value for in-situ conservation of this traditional germplasm, and has immense cultural heritage value.

The use of *hedges and live fences* along the field borders, streams and slope contours has also a long tradition in Czech Republic and can also be classified as agroforestry. Unfortunately, the era of collective farming and joining fields to larger block led to their drastic reduction, however some remnants can still be found in mountain areas. The importance of these systems for biodiversity conservation (so called ecologic networks) is now recognized and the new establishment supported.

We can also find other agroforestry systems with lower extension: forest trees on pasture (found in mountain areas – e.g. Jeseníky), intercropping of forest trees and forest

farming/gardening. The *trees on pastures* system does not usually have productive functions (e.g. timber) but they are planted because they provide some important services: animal welfare (shading, wind-speed reduction, scratching), protection from soil erosion, habitat for insect and birds, drainage of pastures or microclimate for rare plants. Very important for production of feed for animals are seed crop tress (oaks, chestnut) in game reserves too. *Intercropping of forest trees* involves interplanting trees in forest during first years after establishment. In past it was practiced in various forms until the 19th century when it was promoted by foresters in lowland alluvial forests e.g in Southern Moravia. Now this system is practiced only in a small part of the floodplain forest, where crop cultivation helps weed reduction. In the Židlochovice region it persisted even during the era of collective farming because arable land was not available for private farmers, so they rented land in young forests. Crop cultivation is usually practiced for the first three years of plantation before severe completion prevents further intercropping. This practice is beneficial for trees due to weed eradication. We can find also few examples of *forest farming/gardening* scattered around Czech Republic, usually as hobby farming.

Currently, to our knowledge, there are not practiced and modern agroforestry systems (e.g. alley cropping) for timber production yet, however, potential for production of quality timber (e.g. wild cherry, walnut) and wood biomass (e.g. poplar) exists. Rapid development of short rotation coppice systems (based on willows and poplars for fuel biomass) during last decade also makes growing potential and interest in establishment of these systems in agroforestry schemes (e.g. in combination with timber trees or agricultural crops).

We have no data about extension of these agroforestry systems, but it is rather insignificant. Now, there is a change in European and Czech agricultural policy leading to more environmentally friendly agricultural production, sustainability, rural development and biodiversity enhancement. The current shift in agricultural policy that could also support tree growing on agricultural land, may foster agroforestry development, especially in organic farming and less favoured areas (e.g. mountains, protected landscapes).

Discussion and conclusion

We can probably divide the future development of agroforestry in Czech Republic into four types: (i) maintenance of traditional agroforestry as *Streuobst*, interesting for their high agrobiodiversity and cultural values; (ii) development of modern, intensive agroforestry practices such as alley cropping with the focus for diversification of agriculture through production of quality

timber (e.g. wild cherry, walnut) and wood biomass (e.g. poplar, willow); (iii) conservation and establishment of hedges, live fences and buffer strips for service function such as erosion control, demarcation, shelter for domestic animals, water quality maintenance, biodiversity corridors etc; and (iv) management of smaller private woodlots with specific component (e.g. mushrooms, berries, medicinal plants) – forest farming and permaculture gardening, however mainly as a hobby farming.

According to national legislation we can distinguish agroforestry systems in forest land, agriculture land and in other lands (gardens, and so on). For the future development of agroforestry systems it is necessary to change forestry (grazing in forest) as well as agriculture (trees on agriculture lands) policy. In the near future, we cannot expect implementation of European legislation concerning agroforestry into Czech legislation and also any direct financial support for agroforestry, because of low extension and non-existent awareness.

There is a strong potential for development of agroforestry in the future in order to increase productivity (wood biomass, agriculture product), to reduce environmental risk (drought, erosion), increase biodiversity (forest pasture, ecological networks) and keep social stability. The Czech Agroforestry Association has been recently established, with the aim to lead and support development of agroforestry in Czech Republic.

Trees for bees and sustainability

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Introduction

Modern agroforestry's overall approach combines, in the same space, wild tree species, vegetative covers (clover, trefoil, sainfoin, alfalfa, buckwheat, etc…) and cash crops. Whenever possible, it uses existing old trees and young wild trees growing naturally. It relies on synergies between various elements to solve some major agricultural issues, such as pollinators (especially bees) population decline.

During its life, a bee will consume sixty times its weight of honey. Obviously, feeding bees with natural nectar is a key element to their survival. Starting the season with willow, ending it with chestnut, bees have access to maple, acacia, mountain ash or lime, not forgetting ivy. Tree flowers, shrubs and lianas offer, over seasons, their nectar and pollen to pollinators. Others, such as oak and some conifers are exclusive sources of honeydew that bees are very fond of. Buds of poplar and beech are main propolis providers. Cash crops, vegetative covers and diversified hedges composed of blackthorn, hawthorn, quince, elderberry, wild roses or brambles complete the production of nectar and pollen from late winter to the end of summer.

Beyond the honey resource, agroforestry creates habitats for wild pollinators, moderates the adverse climatic variations that bring prejudice to crops and insects. It avoids setting aside lands for flower fallow and doesn't need EU subsidies to be maintained.

Methods

Studies and reviews on this subject are missing, that is why AFAF has many questions that require answers through research programs on this subject. Thesis and CASDAR programs are the tools AFAF has for implementing this work.

The two main topics concerning bees related to agroforestry are about feeding bees and avoiding pesticides use through mixing different crops, trees and shrubs and so integrating pest control.

In fact, agroforestry is a way to enhance the volume and diversity of flowers that can grow in a crop field through trees, shrubs and various herbaceous species that will grow naturally near the trees. Trees are essential to bees because they are the only ones to produce propolis and have the exclusivity on honeydew production. The first step is to create an application that can calculate the

potential quantity of nectar produced at a territorial scale and the way blooming seasons follow one another. The next step is to measure how plants can interact in a beneficial way for themselves and for nectar production when they are mixed together by comparing different situations.

Expected results

We expect from our work to clarify how, when, and why agroforestry systems enhance the presence of bees and modulate their activities. It will be important to study also how certain pollinators impact the abundance and activity of some other pollinators in order to better understand the relationships with general pollination in agricultural fields. This will lead us to the possibility of building improved agroforestry systems that will take into account the needs of bees. The advantage for farmers will be a better yield because of a better pollination.

The calculation application will help us to assess the best way to build an agroforestry system after taking into account the constraints on the ground. It will take into account the volumes and the date of blossom in order to have the possibilities to take into account the potentially positive effects between trees shrubs and crops on issues such as stress limitation, which is especially important in a climate change context. Agroforestry could potentially improve nectar secretion which relies greatly on weather condition (temperature and moist conditions). Thereby its role in bee conservation could be essential in the future, and its impact on the balance between wild pollinators and honey bees could be very important too.

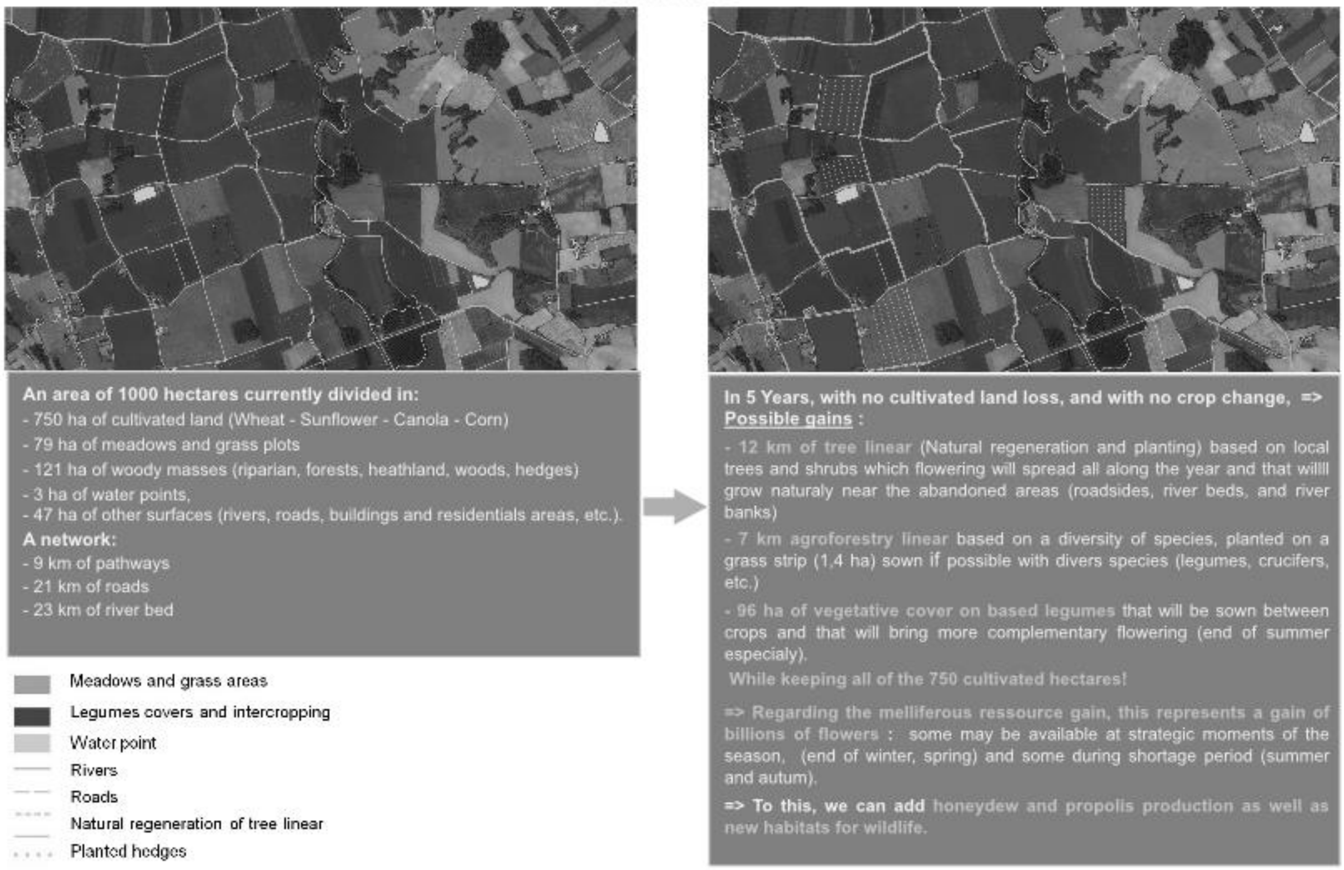
Discussion (and conclusions)

Calculating the quantities of resources potentially interesting for bees produced by plants means having a list of plants with the quantity of nectar produced per species and their period of flowering. These values can change widely, according to the climate, the soil and the weather conditions of the year. These parameters can change the quantities of nectar as well as the date of production. So according to the year and the place where the values were measured, two papers can deliver different information on the same species.

According to late researches, climate change could turn out to become reality threw hotter springs but shouldn’t change too much summer, winter and autumn temperatures. This means spring could become hotter and dryer then usually, impacting greatly the life cycles of bees and the availability of nectar. Meanwhile these months are very important for the honey production and for swarming. If trees have an effect and adaption of plants and crops to stresses related to climate change, they could also have a very important effect on maintaining bee populations.

Trees are very long to grow, and having the conclusion to these elements will take a very long time. But agroforestry seems to be a promising way to tackle bee population decline and more generally helps pollinator survival. In a complementary loop, solving bee issues may bring back trees in our countryside and fostering trees insertion may help prevent bees decline.

Possible evolutions on an area of 1000ha to support polinators with no cultivated land loss



Growth performance and survival of poplar and willow in waterlogged soils – a comparison of two sites

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Introduction

The predicted impacts of climate change for Central Europe discuss a higher likeliness for an uneven distribution of rainfall throughout the year, although total amounts are not expected to decrease. In the state of Brandenburg in northeastern Germany, this could lead to higher local occurrences of waterlogging as the landscape features mild elevations and depressions. After heavy or prolonged periods of rainfall, depressions with fairly high groundwater tables may waterlog for several weeks or repeatedly for shorter periods, causing farmers to lose investments in annual crops. Short rotation coppice with fast-growing tree species represent a valid alternative land-use option on these sites as, in general, they are more tolerant to a temporary water surplus than annual cultures. However, in 2011 and 2012 extreme reactions of poplar clones to prolonged waterlogging were observed on two plantations in northern and southern Brandenburg: one being the complete die-off (Site A), the other being the survival and even continued growth (Site B) of those poplars located in waterlogged parts of the plantation (though it must be noted that this changed when the flooding lasted through a second vegetation period).

Material

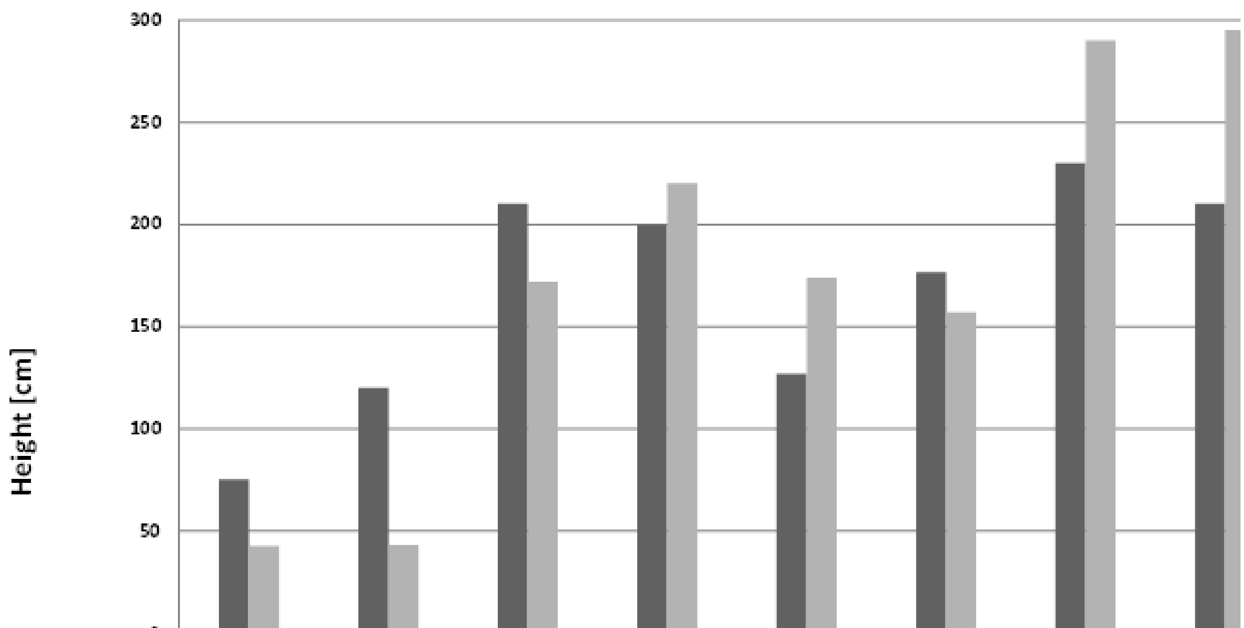
As the two plantations featured different poplar clones, an experimental trial was set up on the University compound in order to complement and verify the field observations, using the same clones in both soils and including willow in the trial. We used willow hybrids 'Tordis' (*Salix viminalis x Salix Schwerinii) x Salix viminalis*) and 'Inger' (*Salix triandra x Salix viminalis*) as well as poplar hybrids 'Max 1' (*Populus maximowiczii x Populus nigra*) and 'AF 2' (*Populus nigra x Populus deltoides*). As planting substrate, soil was extracted from the two plantations (Sites A and B) in Brandenburg where the different reactions of poplar hybrids to waterlogging had been observed. With each hybrid featuring 36 repetitions, a total of 72 cuttings was planted in each soil. The hybrids were planted as cuttings of 20 cm length. During growth all shoots except one were removed to grant comparibility in height which was measured every two weeks. At the age of nine months, half of the plants in each soil were exposed to induced flooding, completely saturating the

soil for more than one year. The other half was left growing under unchanged conditions without water excess.

Results

The results from the experimental trial are displayed in Figure 1 showing the differences in height growth of the four clones at 16 months of age in the two soils. Both poplars were affected by induced waterlogging in Soil A; in Soil B clone ‘Max 1’ was positively, clone ‘AF 2’ neatively affected by the water surplus.

Both clones reached a greater average height in Soil B. The two willows had similar average heights in both soils when not flooded. In waterlogged soil the average height in Soil B increased compared to the non-flooded soil, in Soil A this was only true for clone ‘Inger’. Plant mortality, which was not considered in this graph, occured among both clones in Soil A in flooded and non-flooded conditions (average: 22 %) and only in one case (‘AF 2’ without flooding) in Soil B. Overall tree survival rates was 87,5 % among poplars and 97,2 % among willows.



	Max 1 Soil A	AF 2 Soil A	Tordis Soil A	Inger Soil A	Max 1 Soil B	AF 2 Soil B	Tordis Soil B	Inge Soil
not flooded	75,00	120,00	210,00	200,00	127,00	176,50	230,00	210,
flooded	42,50	43,00	172,00	220,00	174,00	157,00	290,00	295,

Fig 1: Comparison between the average height of surviving flooded and non-flooded poplar and willow clones planted in two different soils at 16 months of age. Flooding was induced at 6 months of age and to this point had uninterruptedly lastet 10 months, including during winter.

Discussion and conclusions

In this first trial, the poplar clones tested showed a greater variation in growth performance and survival rates than the willow clones when exposed to waterlogging or high groundwater tables. Willow clones tested were in general less susceptible to waterlogging. The results suggests that site conditions such as soil and water chemistry may have a greater influence on growth performance and tree survival than the duration and intensity of waterlogging; this seems especially true for poplars. As seen above, growth performance and survival of poplar clones in Soil A was minor compared to Soil B even in non-flooded soil. This suggests that the induced waterlogging worsened growth conditions for poplars in Soil A, whereas the same clones in Soil B seemed unaffected or even positively affected by the water surplus. Therefore it is likely to assume that if site conditions are suitable a water surplus does not necessarily result in increased die-back or impaired growth of the clones tested.

Willow short rotation plantation as an alley cropping system – aspects on yield development and nutrient cycling

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Introduction

Amongst the renewable feedstock production in agriculture, growing of willow and poplar as short rotation coppice (SRC) to produce woody biomass is the most cost- and impact-effective land-use system to avoid CO_2 emissions. This is mainly due to reduced management input (e.g. ploughing) and less or even no need of fertilizer caused by lower nutrient demand of trees and a sufficient nutrient stock from former agricultural land-use. Negative effects of SRC plantations may arise from i) a generally enhanced water use by trees, leading to a reduced ground water recharge, ii) a distinct change of landscape view and iii) economic uncertainties, mainly as a result of lack of subsidies as given for other crops.

However, trees on agricultural ground also supply a set of ecological services, e.g. reduction of soil nutrient leaching by intensified deep-rooting and soil erosion by breaking wind speeds, improvement of C-sequestration quality and quantities by enhanced above and belowground litter production.

As a compromise, SRC plantations can be arranged as agroforestry systems (AFS), e.g. as an alley cropping systems with stripes of SRC plantings between common crops. In this context, data from a 2011 newly installed grassland / SRC willow (AFS willow) experimental intercropping system, established within the joint research project BEST[1] near Göttingen, central Germany will be presented. Given results will focus on tree growth as well as nutrient cycling and will use a directly neighboring pure willow SRC (SRC willow) plantation as a reference. Specific aspects related to the grassland will be covered by a contribution of Ehret et al.

Material

Both plantations, the pure SRC willow and the AFS willow plot were installed in March 2011 and planted with 0.2 m long cuttings of willow clone "Tordis" ((*Salix viminalis x Salix schwerinii) x Salix viminalis*)) in a double row system with alternating inter-row distances of 0.75 m and 1.50 m, and a

[1] BEST: **B**io**E**nergie Regionen **ST**ärken (see also: www.best-foschung.de)

spacing of 0.75 m within the rows. The SRC willow plot has a dimension of 0.6 ha and a planting density of 11850 cuttings ha^{-1}. The AFS consists of 3 strips with each 4 double rows of willow and a plant density of 5330 trees ha^{-1}. The resulting alleys have a width of 7,5 m and the net grassland cover per ha is 55%.

The bedrock material of the study site is Triassic sandstone material, covered by loess deposit and main soil types present are cambisol (Braunerde) and stagnosol (Pseudogley). Soil texture is dominated by loamy sand or silty clay material. The climate is characterized by an average temperature of 9.2 °C and a mean precipitation of 642 mm (period 1991-2010 station Göttingen: DWD station-ID 1691).

A full plot survey of the plant survival rate for all plots was applied in March 2012. The above-ground biomass production (without leaves) was estimated by measuring the diameter at breast height (dbh, 1.3 m) at randomly selected trees (n=240) in winter 2012 and by subsequent harvesting of 15 representative trees per plot at 10 cm above soil level. Tree dry masswas determined using allometric power equations given by Röhle and Skibbe 2012. Finally these estimates were scaled up with the number of survived trees to calculate dry matter (DM) yields per hectare.

Litter dry weight production was determined through collection and drying (60 °C) of fallen leaves on the ground from six 1 m x 1 m permanent quadrats per plot.The litter bag technique according to Guo and Sims (1999, 2001; polyester with 1 mm mesh size, 15 cm x 15 cm, n = 16 / plot, standardized litter from a 9-year-old willow clone) was used to determine litter dry weight loss and nutrient release.

Results

The tree survival rate was 88 % for SRC willow and 94 % for AFS willow. The mean dbh was 10.3 mm (± 6.7 mm) for AFS willow and 10.7 mm (± 8.2 mm) for SRC willow. An above-ground biomass production of 1.1 Mg DM ha^{-1} $year^{-1}$ was observed after the first two years in SRC willow, whereas the AFS willow showed a an above-ground biomass production of 0.9 Mg DM ha^{-1} $year^{-1}$. Litter dry weight production was significant higher in SRC willow in comparison to AFS willow (Table 1). No significant differences in litter dry weight loss and nutrient-release from litterbags between SRC willow and AFS willow were detected (Table1).

Table 1 Mean (SD) of litter dry weight production, litter dry weight loss and nutrient release of the litterbags after one year of application to soil (November 2011 - November 2012).

	Litter dry weight production [kg ha^{-1} a^{-1}]	Litter dry weight loss	N-release	P-release	K-release	Ca-release	Mg-release
		[%]					
SRC willow	359.9 (143.5)*	49.7 (6.0)	40.3 (9.1)	44.0 (11.7)	62.3 (18.5)	60.1 (9.5)*	36.8 (22.8)
AFS willow	136.9 (78.3)*	47.5 (4.4)	29.4 (4.4)	27.6 (13.7)	87.1 (5.2)	42.6 (6.9)*	73.3 (4.3)

* significant differences between SRC willow and AFS willow $p<0.05$

Discussion

A high biomass production depends on the availability of nutrients, light and water (Sage 1999; Truax et al. 2012; Headlee et al. 2013). With respect to the nutrient supply, we can exclude that the relative poor above-ground biomass production was caused by nutrient deficiencies. According to leaf analysis investigated in 2011 and 2012 the nutrient supply was in an optimal status and the soil is classified as fertile.

Our agroforestry approach in Göttingen, i.e. the application of grassland stripes with willow stripes seems to have an effect on plant growth. A slightly higher above-ground biomass production was observed in SRC willow with values of 1.1 Mg DM ha^{-1} $year^{-1}$ after the first two years, whereas in AFS willow an above-ground biomass production of only 0.9 Mg DM ha^{-1} $year^{-1}$ was achieved in the same period. It is suspected that the willow stripes which grow directly next to the grassland stripes compete with the annuals of the grassland for light and especially water. Stoll and Dohrenbusch (2009) already investigated the impact of grassland vegetation and management on the survival rate and growth of fast growing tree species on grassland in Northwest Germany. It was shown that the survival and growth of the trees were significant lower on grassland, compared to neighboring former arable land. Thus we suspect that grassland compete with the young trees for water and light and this competition may led to lower yield and dbh in the willow stripes of AFS willow in comparison to SRC willow.

Similar litter dry weight loss and nutrient release from litterbags after one year of application to soil were observed for both systems.

The litter production is directly linked to above-ground biomass production (Guo and Sims 1999; Berthelot et al. 2000). According to a higher aboveground-biomass production and a significant higher litter dry weight production a higher nutrient uptake and return to soil was observed for SRC willow. We conclude that the nutrient cycling through above-ground biomass and litter production was more intensive in SRC willow in comparison to AFS willow.

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Different trees - different regeneration ability: assessing the number of sprouts after first harvest in organic and integrated agroforestry systems

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Introduction

In short rotation coppice systems for biomass production fast growing trees are cultivated. These trees are supposed to regenerate fast and reliably from stumps after harvest. However, this depends on the species' sprouting ability. We aimed to investigate the effect of harvest on sprouting of four tree species and one mixture of regionally common hedge trees in organic and integrated agroforestry systems after first harvest. We asked (i) how tree sprouting differs according to species and (ii) is there any difference in sprouting of trees in organic and integrated agroforestry systems?

Material

Our study was conducted at Scheyern Research Station (48° 24′ N, 11° 45′ E) in the Bavarian tertiary hills of southern Germany. Predominant soils are thin loess-loam or loess deposits. Two organically managed fields with seven crops in rotation (winter wheat and winter barley in 2013) and two integrated managed fields with four crops in rotation (winter wheat and maize in 2013) were transformed to agroforestry systems in 2009. Thus four short-rotation coppice systems comprising three 8.25 m wide tree strips were planted. Each strip consists of three double rows spaced 1.5 m apart. Eight tree species change randomly every 30 m. Sprouts were counted in October 2013 after the first harvest. Only sprouts developing directly from the stump were recorded. Black locust (*Robinia pseudoacacia*), willow “Inger” (*Salix triandra x Salix viminalis*), black alder (*Alnus glutinosa*), a mixture of regionally common hedge trees and poplar “Max 3” (*Populus maximowiczii x Populus nigra*) were sampled. In both farming systems three plots per tree species comprising 20 individuals from the inner four rows were evaluated.

Results

Sprouting differed between species in both systems. Differences are shown in Fig. 1 for (a) organic and for (b) integrated agroforestry systems. Willow produced the highest number of sprouts (27) irrespective of farming system. Mean number of sprouts for willow “Inger” was 10.9 in organic and 10.2 in conventional farming, followed by poplar “Max 3” (9.1; 10.9), mixture of regionally common hedge trees (7.7; 8.5), black alder (5.0; 6.5). Black locust showed the lowest numbers of sprouts (1; 1.3). The sprouts from the Black locust were mainly derived from roots. Significant differences ($p < 0.05$) between farming systems were only observed for black alder, poplar Max 3 and black locust.

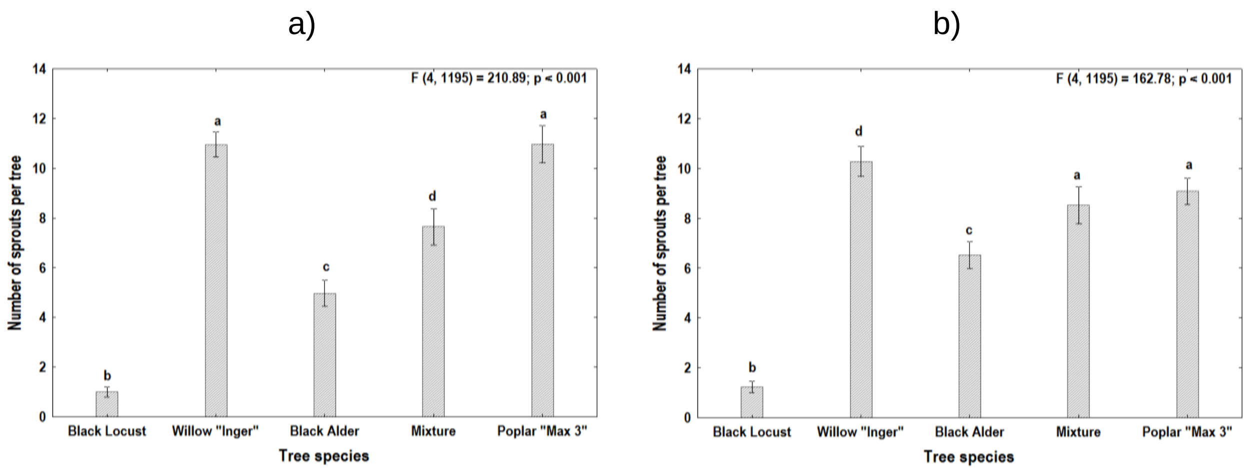

Fig 1: Number of sprouts per tree between different tree species in (a) organic and (b) integrated agroforestry systems. Error bars represent standard errors of the means (SE). F and p values in the upper right hand corner of each figure represent results of one-way ANOVA. Using Tukey’s post hoc test, treatments with the same letter were not significantly different at the 0.05 probability value.

Discussion and conclusions

The sprouting ability differed with tree species. Willow “Inger” sprouted much more than the other tree species including poplar “Max 3”. This is in accordance with results of Ceulemans et al. (1996), reporting only 5 to 8 shoots per poplar stump, but often 20-25 sprouts per willow stump. The lowest sprouting number was recorded for black locust. As described by Chang et al. (1989), black locust sprouts quickly from roots. The sprouting from roots can be explained by its life strategy, which is described as that of a competitor (Grime, 2001). Nevertheless, species is not the only factor determining sprouting ability: the tree species are affected differently by environmental

conditions. According to Rodriguez-Gonzalez et al. (2010) black alder growth is negatively correlated with waterlogging and fine-textured soils. In contrast, willow “Inger” growth is more affected by nutrient limitation. Sprouting is also determined by stump characteristics. Blujdea et al. (2011) identified the importance of stump height above the soil, stump diameter and other cut features on sprout numbers.

In further research other influences on sprouting ability should be taken into account. In conclusion, specially bred varieties of willow and poplar showed the best ability to regenerate. Mixtures of regionally common hedge trees performed well, too, suggesting that in terms of regeneration ability, they are suitable for nature conservation.

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CliPick – Climate Change Web Picker. Bridging climate and biological modeling scientific communities

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Introduction

Climate change impact is a transversal assessment in different studies. However, there is often a complex pathway, usually requiring programming skills, from the need to the usage of climate data for different kind of modeling purposes.

The most common format used by climate modellers to exchange data is the network common data format (NETCDF) which is a binary file containing array-oriented scientific data that ease data exchange between climate modelers. Another common characteristic of climate datasets is their large size. Even with binary formats, the large areas (e.g. European scale, including oceans) and the time span (often 100 years in future) delivers an amount of information that needs to be mined to use for other modelling areas requiring simpler and easy access data.

In the context of the EU collaborative project AGFORWARD (2014-2017), agroforestry process-based models are being used to provide field and farm scale evaluation of different agroforestry systems. Such evaluation will consider the impact of future climate change and therefore, a common framework on future climate datasets needs to be developed to achieve a consistent assessment throughout Europe.

A tool, called CliPick, is proposed to provide a user-friendly interface accessing climate datasets and deliver climate files in a format ready to be used by process based agroforestry models YieldSAFE (van der Werf et al. 2007) or HiSAFE (Talbot 2011).

Material and Methods

The ENSEMBLES datasets repository (http://www.ensembles-eu.org/) was used to provide the NETCDF files because these datasets are used to supply climate scenarios for the International Panel on Climate Change (IPCC). The Hadley Center Regional Model 3Q0 (HadRM3Q0) was the model initially chosen because Clipick was firstly developed in Portugal and, according to Soares et al. (2012), this is the most suited model for Portuguese context.

Eight climate variables across continental Europe (minimum, mean and maximum temperature, precipitation, radiation, minimum and maximum relative humidity and wind speed) were collected

from the repository. Each variable is stored in 15 blocks of ten years each (1951-2100) and each block of ten years has about 450 MB (daily data). In total there are about 54GB of data for a climate scenario, for the eight climate variables.

To ease the provision of data, Clipick was developed as a web based interface. The interface uses the application programming interface (API) of Google Maps and the JavaScript libraries of DOJO 1.7.5 (http://dojotoolkit.org/) and JQuery 1.10.3 (http://jquery.com/) as client side programming while PHP (www.php.net) and Python (www.python.org) languages were used at server side. Asynchronous JavaScript and XML (AJAX), a programming technique bridging client and server sides, eases the communication between the user inputs and translates them into server requests to access the data.

Results

The Clipick tool can be currently accessed at a public webserver @:

http://home.isa.utl.pt/~joaopalma/projects/agforward/clipick/index.html

There are three steps to retrieve data from an end user point of view (Figure 1):

1) **Provide** the following details:

a. time span to retrieve data (between 1951 to 2100)

b. time step of the data to be retrieved (daily or monthly)

c. file format for use of the data (YieldSAFE (van der Werf et al. 2007) or HiSAFE models (Talbot 2011)

d. dataset source (currently only HadRM3Q0, but other may be added as needed)

2) **Select** an approximate location of the plot/stand to simulate, by moving an icon in the map through the GoogleMaps interface

3) Data **extraction**.

After the last step a link is built to download a text file with the data. Additional extractions can be executed as they will be queued.

The interface has been tested throughout the EU project AGFORWARD with overall success.

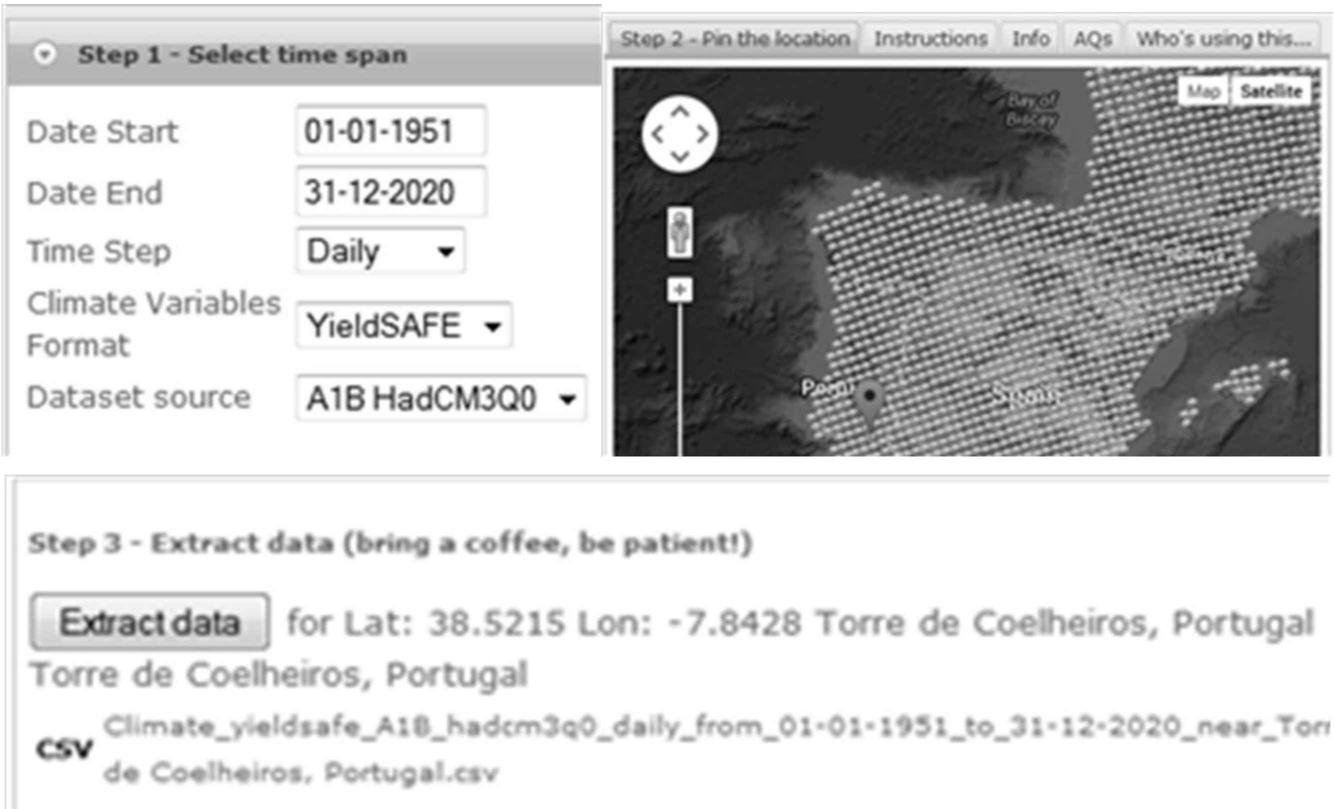

Figure1: Steps of the CliPick interface. 1) Select time span, 2) Pin the the location, 3) Extract and download data

Discussion

The use of the interface for retrieving data from the climate model and scenario HadRM3Q0 has been compared for several locations with climate data within the AGFORWARD experimental network or with national climate databases. So far the comparisons have provided good indications that this climate database could be used for climate driven agroforestry modelling assessments.

However, due to the resolution of the dataset (25 km), caution should be taken when climate extracted for study areas where known geomorphology or closeness to seashore is likely to influence the climate of the target area of study should be treated with caution

The interface architecture is ready to add other ENSEMBLES datasets if needed. The scenario A1B is considered a moderate climate change scenario that is being widely used by the scientific community. However, other scenarios can be added if needed with minor programming editions due to the consistency of the NETCDF files.

Given the (arguable) complexity of NETCDF files usage, Clipick provides an alternative to access future climate scenarios for biological modelling purposes requiring simpler and human readable information.

Climate impact assessments could be made through the comparison of current climate (e.g. 1970 – 2000) with future identical time spans (e.g. 2000-2030).

Acknowledgements

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Water use and productivity of poplar and willow in SRC plan-tations in NE Germany along gradients of groundwater depth

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Introduction

Fast-growing tree species planted as short rotation coppice (SRC) may provide multiple ecosystem services, particularly in agroforestry systems such as alley cropping, e.g. wind and soil erosion control, soil fertility protection, carbon sequestration, increasing landscape structural heterogeneity and biodiversity, in addition to supplying a renewable source of biomass and energy. In the federal state of Brandenburg, NE Germany, a large proportion of the arable land is characterized by sandy soils and relatively shallow groundwater levels of 1–2 m. Precipitation during the growing season is typically scarce (≤ 300 mm). Therefore, a deep-rooting, woody plant cover in SRC systems may survive dry spells with only minor or no reductions in yield and additionally offer benefits to adjacent annual crops. The productivity of SRC, however, may vary greatly depending on soil type, nutrient and soil water availability. Here we studied water use and productivity of willow and poplar trees in SRC plantations on agricultural land in relation to soil water availability, atmospheric conditions and stand structure on sites with gradients in groundwater depth.

Material

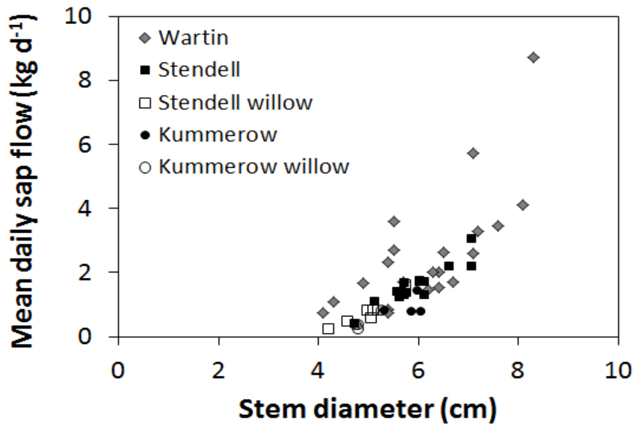
Two nearby (< 10 km distance) SRC plantations (2–7 ha) in northeastern Brandenburg (c. 53.20 N, 14.17 E) were selected for this study.Tthe first, Wartin, with a larger elevation gradient (c. 10 m along a 60 m transect) and temporarily inundated lower slope on sandy loam, and the second, Stendell, with a smaller elevation gradient (c. 2.5 m along a 130 m transect), close to and perpendicular to a stream on humous sand. Mean annual and growing season air temperature is c. 8 °C and 15 °C, respectively, and annual and growing season precipitation approx. 500 mm and 300 mm, respectively. Both plantations were established in 2008 at an initial density of about 19.000 stools ha^{-1}, and only Stendell harvested once since then (end of 2010). At the two sites, one target planting row was selected for the poplar clone ‘Max1’ (*Populus nigra* x *P. Maximowiczii*; Wartin and Stendell) and the willow cultivar ‘Inger’ (*Salix triandra* x *S. viminalis*; Stendell only) along the transects, where the seasonal minimum soil depth to the water table ranged from < 0.1 m to > 1.8 m (measured in observation wells). Volumetric soil water content was assessed along

these transects in six soil depths (10–100 cm) in permanently installed access tubes with FDR-probes (PR2/6 Profile Probe, Delta-T Devices Ltd., UK). Additionally, a third plantation, Kummerow, close and similar to Stendell was selected. The trees studied here grew close to each other, with no gradient in groundwater depth; seasonal minimum depth to the water table was 80 cm, the maximum recorded 140 cm. Water use was measured directly as xylem sap flow on up to 20 trees per site and species. The thermal dissipation method (Granier 1985; probes built in-house) was used on larger trees and the stem heat balance method (EXO-Skin probes, Dynamax Inc., USA) on smaller diameter trees. Some trees were equipped with electronic diameter dendrometers (DD-S, Ecomatik, Germany). Trees were harvested the following winter and woody aboveground biomass estimated from measurements of annual radial increments and annual height growth. Water use efficiency (WUE_p) was calculated as the amount of woody aboveground biomass produced per amount of water used over the growing season. Meteorological data were collected in open fields in the vicinity of the plantations. Tree height and diameter and leaf area index (LAI; LAI2000 Plant Canopy Analyzer, LI-COR Inc., USA) were recorded at all sites.

Results

Daily water use of poplar and willow shoots averaged over the growing season was 0.4–8.7 and 0.2–3.1 kg d^{-1}, respectively, for trees aged 3–5 years (Fig. 1). Water use was reduced on drier sites during summer drought: Figure 2 shows for the site Wartin a decrease of sap flow relative to one of the most important atmospheric drivers, the vapour pressure deficit of the air (VPD), in hilltop and particularly in upper and middle slope trees already in August, while sap flow remained high until September in lower slope and downhill trees. At the latter slope positions soil water content in 30 cm depth decreased by

only 2–4 Vol.-% over the growing season due to the high water table while it decreased by > 10 Vol.-% higher on the slope (not shown). The leaf area index correspondingly decreased earlier in the season at the upper and middle slope as well, whereas it was very small (1 m^2 m^{-2}) throughout the season at the hilltop (not shown). At the site Stendell, radial stem growth ceased > 7 weeks earlier for a willow growing where the water table was at a depth >1.8 m compared to a willow at a water table level of c. 1.5 m (Fig. 3).



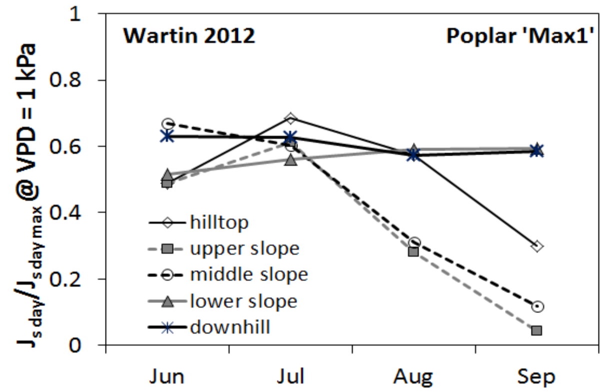
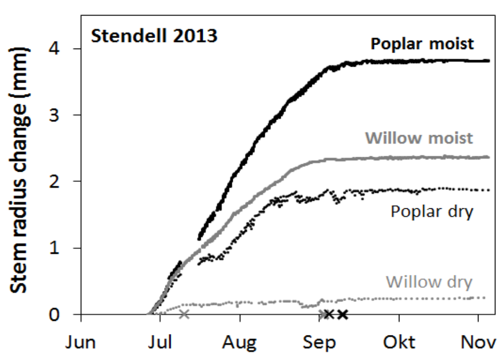


Fig. 1: Seasonal mean daily sap flow (kg of water per tree and day) for poplar ‘Max1’ and willow ‘Inger’ and stem diameter for shoots from different plantations aged 3 years (except Wartin: 5 years).

Fig. 2: Seasonal course of sap flux density J_s (sap flow normalised with sapwood area) relative to vapour pressure defizit of the air (VPD) for 5 representative trees along the slope transect. The daily sum of sap flux density is shown relative to the seasonal maximum ($J_{s\ day}/J_{sday\ max}$) at a reference VPD_{max} of 1 kPa (based on regression equations of $J_{s\ day}/J_{sday\ max}$ with VPD_{max} for each month).



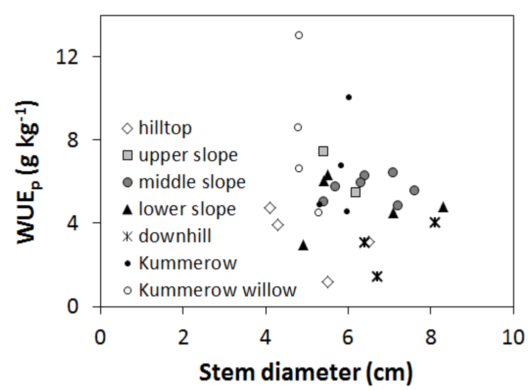


Fig. 3: Stem radius change of two poplar and two willow trees with different distance to water table (“moist” and “dry”). Cessation of radial growth is marked on the x-axis.

Fig. 4: Water use efficiency for poplar trees at the site Wartin and poplar or willow at the site Kummerow.

In the poplars studied the difference in growth cessation was only marginal, and the water table was below 1.8 m soil depth (deeper than the observation wells). Preliminary results for the water use efficiency (WUE_p), the amount of woody aboveground biomass produced per kg of water used, ranged from 1.2 to 10 (poplar) and from 4 to 13 g kg-1 (willow shoots; Fig. 4). Up to 7 kg of dry woody biomass was produced by a well-water supplied tree in its fifth year (not shown). The variability of WUE_p within one site was rather large presumably due to the differing soil water supply along the transect (Wartin) and varying stand structure (Wartin and Kummerow, not shown). The broad range of of WUE_p is indicative of a loose control of water use by the plants as long as water supply is non-limiting and/or indicates a less efficient photosynthesis in denser parts of the canopy due to increased (self-) shading at high leaf area index.

Discussion and conclusions

Stand structure is an important determinant of water use and water use efficiency in SRC plantations as fast growing tree species suitable for SRC usually are often also shade intolerant. Planting density should reflect the site conditions (water supply) and the intended coppicing interval to minimise excessive water consumption and shading where optimisation of water use and productivity is required or desired.

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Biomimicry, Ecomimetism, Agroforestry and Landscapes

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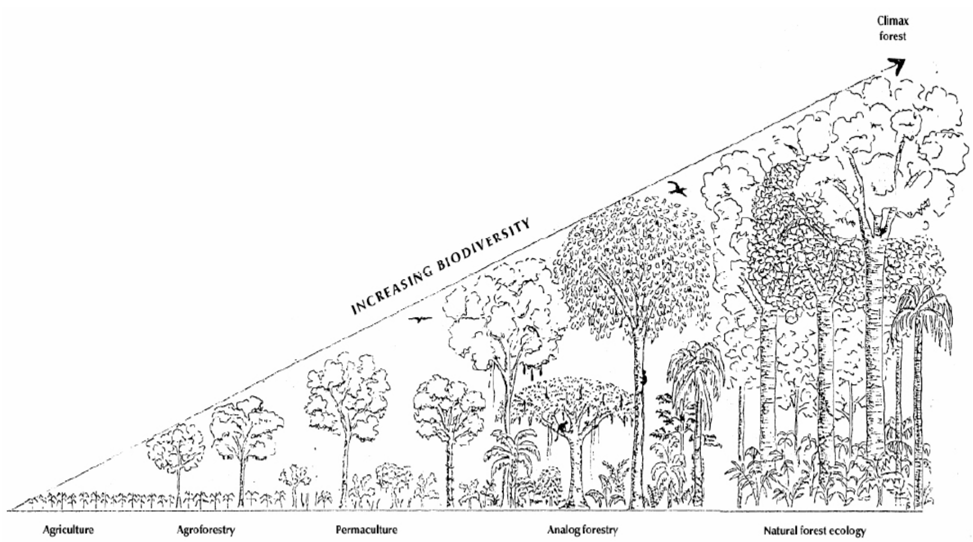
Unlike what reading a truncated Darwin has long suggested, evolution is not just a matter of fighting for the survival of the fittest, but appeals for cooperation; and economy is not just a matter of competition, conquest or domination.

Sharing, cooperation and the search for synergies win/win, is also the economy! And between living organisms, since more than 3.8 billion years, takes place permanent dynamic adjustments, variations, of cooperation, symbiosis, selection of coevolution.

This very long story, punctuated with episodes of radical change, leaves much to chance, contingencies, and uncertainty. And faced with this degree of uncertainty, the best adaptation strategy, the key to resilience will be biodiversity.



<u>Agriculture Agroforestry Permaculture</u>

This phenomenon calls for new approaches to sustainable innovation, including in agriculture, to address global and rapid changes that characterize our time.

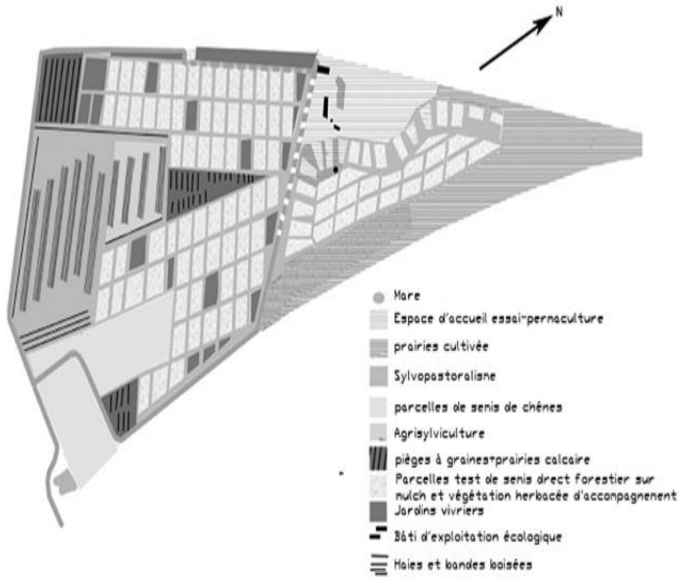
And from this point of view the concept of biomimicry, an approach booming since the 1990s, could better synthesize social and ecological issues.

For actors of the world's urban and agroforestry, - the latter being specifically concerned by ecomimetism – to mimic natural ecosystems would reconcile sustainable uses and high productivity with maintenance of regulations and resources of the biosphere. To implement a

feature and circular economy without having to throw it, but trying instead to capitalize to the maximum on what exists, is an ecomimetism called exaptation and found applied below.

Ecomimetism in “Monts-Gardés”, Essonne, France

An experimental site for an agroforestry landscape



Agroforestry Park in ” Monts Gardés”

Regardless of all labels, it is above all an approach to environmentalism that puts forward respect of soils, the concept of cycle and the decompartmentalization of the forest and agricultural disciplines, which is developed in the “Monts Gardés”. Agroforestry practices allow here to mix the functions and create a landscape of production which is lobbying on behalf of the living. For a fertile, agroforestry landscape, coexist in interaction: farming, market gardening, food gardens, forestry, orcharding, beekeeping, annual crops and green manures, hunting, picking and

It remains that, if it would benefit from an inexhaustible flow of the nature of creativity, adaptability, the ecomimetism, as a scientific approach, entering still too timidly in Europe our businesses and our territories, lack of public financial aid for investment, and support policy. It appears as an extraordinary vehicle for sustainable innovations, a way of rethinking uses, the valorization of know-how, a way to look differently at our agrarian structures, the organization of the “terroirs”, asking us how otherwise exploit them in a resolutely forward-looking context.

Territorial agroforestry design using GIS-KB for catchment water quality recovery

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Introduction

If in France, almost half of the agricultural territories were classified as "vulnerable" and a specific action program established and applied according to the 91/676/CEE Council Directive, water quality in 2014 is still questionable (CJUE, 2013). Therefore, we actually assist from most of operators having in charge the responsibility to protect and/or recover water quality in a certain area, to the empowerment of these programs and locally, to its deployment by proposing innovative and effective measures to voluntary farmers. Converse to small catchment areas where water users are generally living close to the catchment, in the case of major cities such as Paris, a large part of the supplies are coming from groundwater catchments generally located up to 200km from the consumers place. Consequently, within the frame of the "Nitrate" directive, this off-site resource mobilization requires a particular management programme where mediation with agricultural representatives and co-decisions together with individual farmers are essential. Since mid-2000, Eau de Paris (EDP), the public entity in charge of water purification and delivery to Paris has decided (i) to secure the actual water quality or to recover it, and (ii) to anticipate any possible infringement that could applied in case of water contaminations by setting up an upstream water protection strategy across territories housing its groundwater catchments. Depending on the hydro-geomorphologic particularities of these areas and of the local farming systems, EDP is proposing incentives to farmers for, among others, the (re)conversion to organic farming or to grass covering of very vulnerable areas. Despite these financial enticements, water quality at the Vanne catchment (one of the 7 catchment areas exploited by EDP) is still uncertain. Several reasons are suggested. First of all, the nature of the aquifer is karstic and is particularly susceptible to chemical contaminations from land surface activities. Second, the site topology is very variable favoring water through lines in parcels then water run-off and soil erosion towards ditches or rivers or again towards ponds down to the aquifer. Finally, because of the soil-limited crop productivity, agriculture simplification has made very common conventional farming and practices, mostly dedicated to the production of cereals and oils seed rape. Altogether, this results in the continuous detection of

nitrate, pesticides residues as well as suspended matters within groundwater, punctually by exceeding portability thresholds (Eau de Paris, 2012; personal communication).

Therefore, to ensure water run-off and infiltration limitation by not asking for a complete modification of the local cropping systems to farmers, EDP has decided in 2012 to conduct an experimental project for the development of agroforestry systems onto the Vanne catchment basin in order to limit nitrate, suspended matters and pesticides' transfers to surface and groundwater. Objectives of this work were to establish an integrated Geographic Information System (GIS) -KB (knowledge based) decision support system (DSS), for each one of the parcel embedded in the Vanne catchment (i) to combine the parcels' intrinsic hydro-pedologic vulnerabilities to their morphological characteristics and to their immediate environment in order (ii) to attribute the most suitable agroforestry models to priority parcels and (iii) to propose when necessary auxiliary component at parcel scale.

Material

A previously-developed multi-criteria and GIS-based methodology (PREVALTERA; Grandgirard et al., 2011) has been adapted to provide a decision support system (DSS) to recommend for each parcel, when needed, efficient and appropriate agroforestry and/or agro-technical alternatives to farm advisers, territorial managers and village mayors. The methodology is considering both (i) the nature and the level of intrinsic vulnerability of the parcels to erosion, runoff, infiltration risks and the potential benefit for the local ecological connectivity of its land improvement, (ii) the morphological and hydrological characteristics of the parcels and its close environment. It results by allocating different agroforestry and/or agro-technical alternatives to individual parcels or to groups of parcels when local particularities (e.g. ponor) asked for a collective management plan.

Results

From continuous 25m-precision DEM, 2m-precision land cover map, 250m-precision soils and lithologic maps and from the historical 5-years (2006-2011), Land Parcel Identification System, erosion (Cerdan et al., 2006), run-off (Jauffret et al., 2001), infiltration (Mardhel, 2003) and ecological connectivity (Michelot et al., 2011) quantitative intrinsic vulnerability indicators ($_{p}$IVI) have been calculated for each one of the 9853 parcels of the Vanne catchment area.

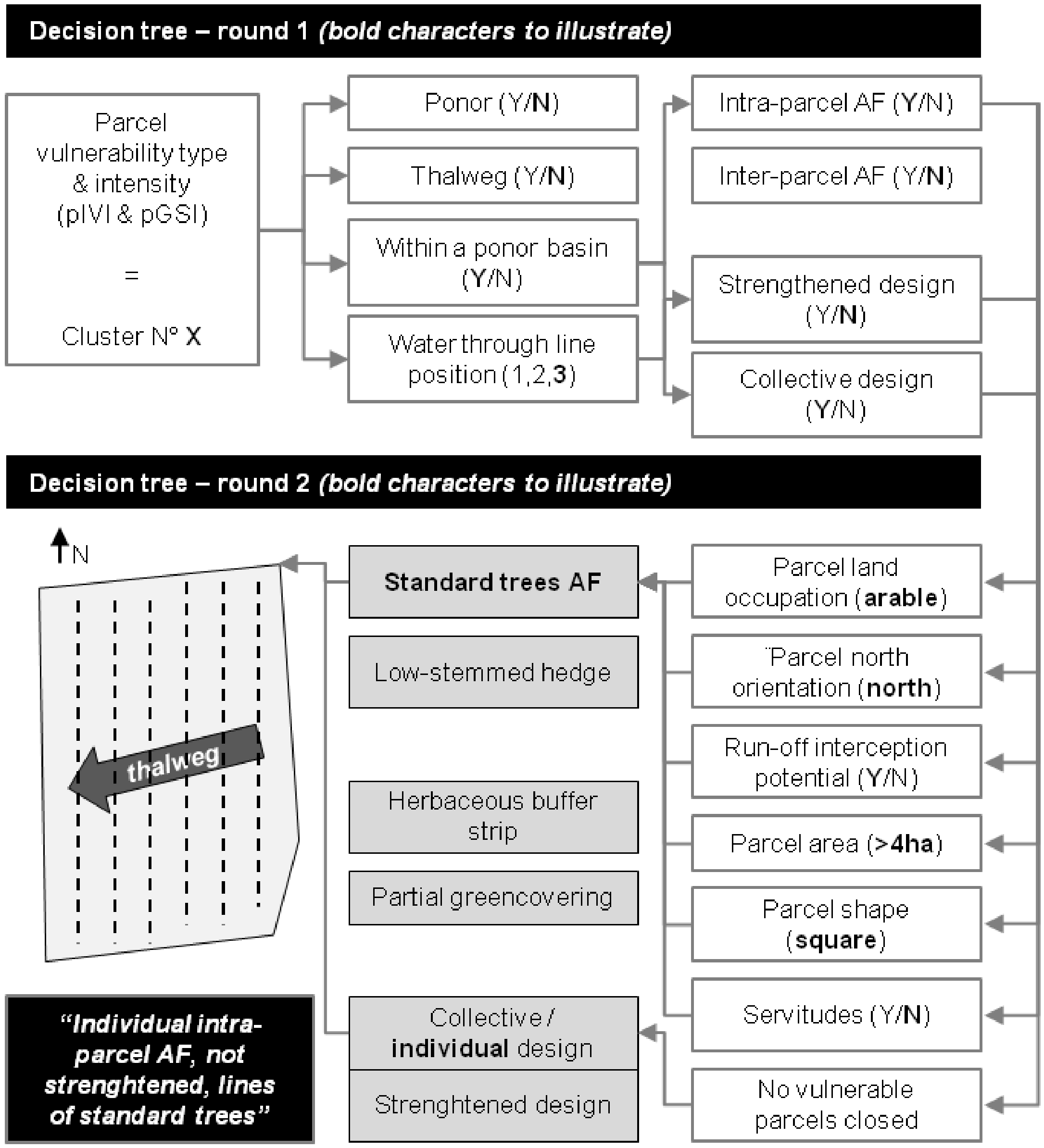

Fig 1: Illustration of the GIS-KB DSS algoritm functioning in the case of one arable parcel belonging to a ponor basin and located at the bottom of a water through line (thalweg). GIS-KB DSS recommendation is individual intra-parcel agroforestry with standard trees in lines enable to intercept orthogonal water run-off line.

All of these indicators were weighted according to the EDP hydrology experts' perception of the origin of the groundwater contaminations and summed in order to obtain a unique global sensitivity indicator per parcel ($_{p}$GSI). Therefore, after correlation analysis to verify that $_{p}$IVI were not strongly correlated ($r<0.25$; $\alpha=.05$), parcels were classified in 11 different clusters depending of their individual vulnerability type and intensity.

Supplementary criteria describing the parcels morphology (e.g. parcel shape, size, land occupation, relative to-the-north orientation, location within water through line, pole/wind turbine

presence…) and close environment particularities (e.g. run-off interception potential of a parcel, soils productivity potential, within parcel thalweg presence, parcel position along a given thalweg, distance to other very vulnerable parcels …) were then sequentially considered inside a decision tree (Fig.1) in order to decide of the best suited agroforestry solution for each parcel. Results were then discussed locally together with advisers or land managers in order to assess the realism of the results. They are actually used as reference maps to undertake with voluntary farmers prefeasibility studies or to confirm of the agroforestry systems to be set up.

Discussion and conclusions

If results and recommendations obtained from the GIS-KB DSS can be used as *references* (1) to localize hot spots and conduct deeper *in situ* vulnerability diagnosis (2) to envisage the technical and economic feasibility of these alternatives, two main improvements are possible (Grandgirard et al., 2011). First, the methodology makes possible the integration of (i) *farmers' preferences* about agroecological alternatives (fascines, faggots, reforestation, short rotation coppice, ponds, ditches … underseed…) and the *expert-based estimated efficiency* of alternatives to decide on adapted, efficient but also acceptable solutions. Second, it is possible to have recourse to multicriteria forecasting methodologies (e.g. ELECTRE…) to attribute to each one of the alternatives conceivable locally one unique rank per parcel and decide jointly with the farmer of the consensual one; this, by respecting his unique vision and his own farm strategy.

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Pasture production and quality in silvopastoral systems established with pine and downy birch after fourteen years of development

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Introduction

In silvopastoral systems, grazing animals coexist with tree production. In these systems, competitiveness among tree and herbaceous plants for light, water and soil nutrients, are likely to impact pasture production and quality (Rigueiro-Rodríguez et al 2011). Understory competitiveness, production and pasture quality could also be positively affected by management practices like fertilization and the appropriate choice of tree species. The aim of this study was to evaluate the effect of fertilization on pasture production and quality (protein, phosphorus and calcium) under *Pinus radiata* D. Don (pine) and *Betula pubescens* Ehrh (birch) silvopastoral systems after 14 years of establishment.

Material

The experiment was established in Castro Riberas de Lea (Lugo, NW Spain, 43º01´N; 7º40´W) at 439 m a.s.l. In April 1995, the soil was ploughed, and the pasture was sown with *Dactylis glomerata* L. var. Saborto + *Trifolium repens* L. var. Ladino + *Trifolium pratense* L. var. Marino (25:4:1 kg ha^{-1}). Birch and pine plants were planted at 833 trees ha^{-1}. In each experimental unit, 25 trees were planted with an arrangement of 5 × 5 stems. The experimental design was a completely randomized block with three replicates of four treatments. The treatments were a) no fertilisation (NF) for the duration of the experiment; b) mineral fertilisation (M) every year throughout the experiment following a standard procedure for the region: 500 kg ha^{-1} of 8:24:16 ($N:P_2O_5:K_2O$) fertiliser complex in March and 40 kg of N (calcium ammonium nitrate 26 per cent N) ha^{-1} in May. At the end of 2002, formation pruning was carried out on birch trees and the first 2 meters were pruned in both tree species in order to produce quality timber. During 2009 and 2010, two pasture harvests were performed per year in May and July under birch; and in July under pine. Pasture samples were weighed in situ, and a representative subsample was taken to the laboratory. At the laboratory, one subsample (100 g) was dried (72 h at 60 ºC) and weighed to estimate pasture production. These pasture samples were analysed for total N, P and Ca concentration by micro-Kjeldahl technique. N was determined following the method nº US-786-86 A (Bran and Luebbe,

1979) then, crude protein concentration was calculated as 6.25 x N concentration. P was determined by the method nº USED-787-86 (multitest) of Bran & Luebbe (1979); and Ca was measured by atomic absorption spectrophotometer (VARIAN 220FS). Pasture production and quality were analysed with ANOVA. The LSD test was used for subsequent pairwise comparisons ($P < 0.05$; $\alpha = 0.05$). The statistical software package SAS (2001) was used for all these analyses.

Results

The results showed that mineral fertilisation treatment (M) significantly increased pasture production (Table 1), crude protein, Ca and P levels (Fig 1) compared with no fertilisation (NF) (Table 1). Birch systems showed higher Ca and P levels than pine independent of fertilisation treatment and harvest.

Table 1. Pasture production (Mg DM ha^{-1}) under the different treatments studied in 2009 and 2010. M: mineral fertilisation, NF: no fertilisation. Different letters indicate significant differences between treatments in the same harvest and tree.

	Pasture production (Mg DM ha^{-1}) Year 2009				Year 2010			
	May		July		May		July	
	M	NF	M	NF	M	NF	M	NF
Birch	0.68a	0.13b	0.13a	0.10b	0.60a	0.15b	0.26a	0.14b
Pine			0.56a	0.05b			0.53a	0.05b

Discussion

After 14 years, M fertilisation led to better pasture production than NF. However, pasture production during the spring was different between tree species. Spring pasture production was higher (44% and 62% in M treatment in 2009 and 2010, respectively and almost five times more in NF treatment in both years) under birch than pine due to the lack of leaves on the birch trees during part of the spring, which allows better light use by the understory. Birch also provided better levels of protein, phosphorus and calcium in pasture probably due to 1) the low growth and extraction of nutrients by birch compared with pine 2) the high proportion of dicots (with high capacity of Ca extraction) in pasture under birch than pine (Rigueiro-Rodríguez et al 2011) and 3) the better incorporation of tree leaves of birch than pine (Fernández-Núñez 2004) allowing better nutrient return of the former. Pine and birch silvopastoral systems contained Ca and P above of the

recommended levels for cattle and small ruminant’s maintenance requirements (NRC 2000, 1985) while crude protein contents were insufficient and therefore, supplemental protein is required.

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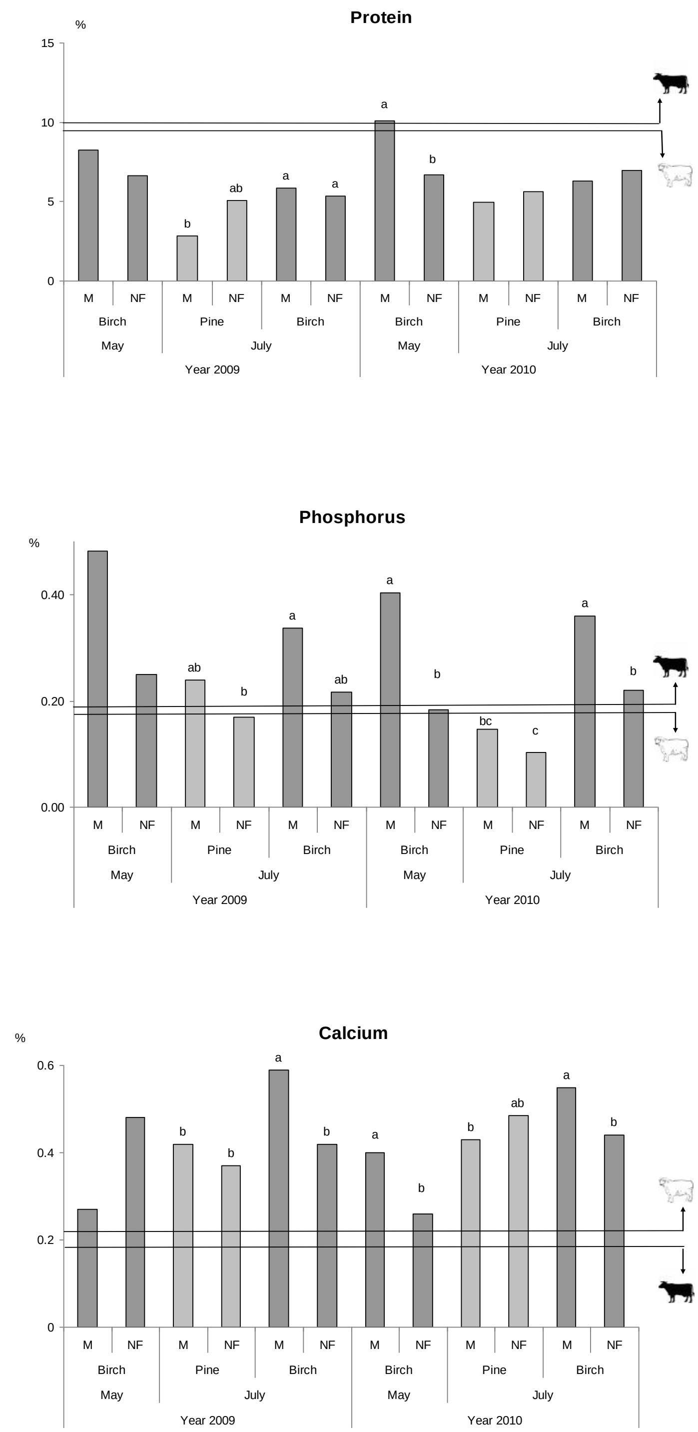

Fig. 1: Percentage of Protein, Calcium and Phosphorus in pasture under the different treatments studied in 2009 and 2010. M: mineral fertilisation, NF: no fertilisation. Different letters indicate significant differences between treatments in the same year and harvest. Lines show maintenance level requirements for cows and sheep.

Goats choose to eat trees when having free choice

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Introduction

Dutch dairy goat farmers introduced trees on their farms (www.voederbomen.nl) as an additional natural feed source, but more importantly to give goats the possibility to perform their natural feeding behaviour. Since goats naturally are more browsers than grazers, we want to know which part of the ration should be from trees to meet their natural 'demands'. A Norwegian study showed that goats in natural rangeland ate ferns, sedges, blueberry, birch in early summer and a more diverse diet in late summer (Joergensen et al., 2012). We wanted to investigate grazing preference under Dutch conditions, where we have other plant species than in Norway.

Material

Thirty young female goats (white dairy goats) were released in nature area 'De Leemkuilen'. Later some goats were removed and others were added. The maximum number of goats was 71. The Leemkuilen area is 12 hectares. Half of its surface was covered by a lake, a quarter was covered with grass and herbs and a quarter with young trees and bushes: willow, poplar, birch, elder, blackberry. The goats were fed daily a limited amount of concentrates. A simple wooden shelter (roof on four poles) was available. We observed the eating behaviour and monitored goat health in the period June – August 2013. Every two weeks half a day was spend in the area observing the behaviour of the goats and what they were eating. The observations were done between 10 and 15 o'clock. Fourteen goats were weighedon the first observation day in June and 4 weeks later again. After that date they were too heavy to lift them manually. Body condition was scored from the same 14 goats: during the first observation day and again 4 and 8 weeks later. Body condition was assessed on a scale of 'thin to fat', hair 'dull to shiny' and hoof infections. In September all goats went back to the farm.

Results

Totally 479 records are available of a goat eating something. The food sources were divided in 'tree' (313 records; 65 %), 'grass' (6 records; 1 %), 'herb' (151 records; 32 %) and 'concentrate' (9 records; 2 %). With 6 5% of the records being trees, this category was eaten most frequently: birch 85 records (27 %), willow 69 records (22 %), blackberry 59 records (19 %), poplar 40 records (13 %) and elder 34 records (11 %). The remaining 8 % were salix caprea, wild rose and broom.

Leaves, branches and bark were eaten from the trees. Grass and herbs together were eaten in 33 % of the records. Some of the herbs grew in shallow pools and one goat was repeatedly observed standing in the water till her armpits.

The 14 goats that were weighed, started with a mean body weight of 33.2 kg (28 - 41 kg) and four weeks later their mean body weight was 34.9 kg (28.5 – 44.4 kg). The mean growth per animal was 1.7 kg (- 0.1 – 4.6 kg). The goats grew less fast than their conspecifics that stayed on the farm all the time and which were kept on a ration of grass-clover and concentrates, but after they were moved to the 'barn herd' again, they quickly caught up again with the others (personal information from the owner). The body condition stayed 'good' all the time. No hoof problems were seen.

Discussion (and conclusions)

Our results show that goats grazing in a Dutch nature area (but also fed daily with concentrates) prefer to eat leafs, branches and bark from trees above grass and herbs. They grow less fast than when kept on the farm and fed grass-clover and concentrates, but their body condition stays good. The farmer reported that they grew fast after their return to the farm and caught up again with the others, which he regards as positive. Goats not only prefer to eat from trees, but they also perform well on it. For the farmers in our project this is good news and they want to continue optimising their system of growing, harvesting, storing and feeding 'fodder trees'.

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The potential function of short rotation coppice strips for birds and ground beetles (Coleoptera, Carabidae)

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The presented study tries to identify the habitat potential of short rotation coppice strips (SRCs) for birds and ground beetles. The basic assumption of the study is, that the species composition of SRCs in agricultural landscapes is a function of the regional and local species pool, the site conditions, the characteristics of the SRCs (e.g. width and rotation length, age of the SRCs) and species characteristics.

The study is mainly based on a literature research. In a first step studies about the establishment of birds and ground beetles in short rotation coppices were analyzed. Because most of the studies have researched young short rotation coppices an additional literature research was carried out for birds and ground beetles in hedges. The intention was to get an impression of the long-term development of the species composition. It is assumed, especially for ground beetles, that hedges have a similar species composition as the SRCs.

In order to identify the causes for successful establishment of some and the failure of other species to establish, several environmental parameters (e.g. soil moisture and grain size of the soil, age of the hedge), corresponding species characteristics like habitat preferences and flight ability and information about the regional species pools were integrated into the analysis. For the birds the literature research about short rotation coppices was supplemented by an expert assessment.

Lists of expected species in SRCs are presented. The list is differentiated geographically and in time (time since establishment and last cutting, respectively) where necessary. For ground beetles the influence of distance to woodlands or other woody habitat, width and area of the hedge and of the mobility of the species for the establishment of woodland species is described.

Model-based analysis of the carbon sequestration potential of short rotation coppices on reclaimed lignite mine sites

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In Central Europe, short rotation coppice systems for the production of woody biomass come increasingly into focus as these wood plantations offer an opportunity to sustainably produce biomass for energy production and to sequester substantial amounts of CO_2 within the plantations and the soils at the same time. In this study, a modeling analysis of the C cycle of a poplar (*Populus suaveolens* Fisch. x *Populus trichocarpa* Torr. et Gray cv Androscoggin) and a black locust (*Robinia pseudoacacia* L.) SRC is presented. The calculations were performed with the bookkeeping C-model shortcar. The calculated estimates of C accumulation within the biomass, the litter layer, and the soil were validated against field data and published results from a selection of scientific studies. For the SRC on reclaimed mine sites a high C sequestration potential was found which amounted in the reference scenario over a period of 36 years to an accumulated net biome production of about 65 Mg C ha^{-1} for *R. pseudoacacia* and about 9 Mg C ha^{-1} for poplar, while the latter clearly suffered from the harsh growth conditions at the reclamation sites. Summarizing, the results suggested a high potential of SRC for C sequestration and C emission mitigation, especially on marginal sites.

Soil respiration in alley-cropping system composed of black locust and poplar trees, Germany.

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Understanding of soil carbon dynamics after establishment of alley-cropping systems is crucial for mitigation of greenhouse gas CO_2. This study investigates soil CO_2 flux in an alley-cropping system composed of black locust (*Robinia pseudoacacia L.*) and poplar (*Max 1*) tree strips and adjacent to them crop strips (*Lupinus/ Solarigol*). Soil CO_2 flux was measured monthly over the March – November 2012 period, using a LI-COR LI-8100A automated device. Simultaneously with CO_2 flux measurements, soil and air temperature, soil moisture, microbial C and hot water-

extractable carbon (HWC) were determined for soils collected nearby each measurement collar. Root biomass was measured to a depth of 15 cm. In all sampling areas, soil CO_2 flux increased from May to July, showing a significant positive correlation with air and soil temperature, which can be a reflection of increase in photosynthetic activity over the warm summer months. The relationships between soil moisture and CO_2 flux showed positive correlation only for the warm period (May - October), indicating enhancing role of soil moisture on microbial mineralization and root respiration. CO_2 flux values varied between sampling areas at different vegetation periods, with significantly higher values in trees over the summer. This could be attributed to the higher photosynthetic activity and higher root density in trees coppices compared to crops. In autumn, after seeding catch crop mix *Solarigol*, CO_2 flux was significantly higher in crops compared to trees, which could be related to soil tillage prior to seeding of crops, as well as to the higher photosynthetic activity of newly seeded crops at the period of rapid plant growth. Despite a seasonal variation in CO_2 flux between sampling areas, aaverage CO_2 flux values observed over March – November period did not differ significantly between sampling areas, showing 2.5, 3.2, and 2.9 µmol m^{-2} s^{-1} values for black locust, poplar and crops, respectively. A greater C loss with soil respiration under trees in summer period may be compensated by greater C assimilation and storage in woody biomass, and the greater respiration from crop strips after tillage in autumn.

Shelterbelt of fast growing tree species for mitigation of wind erosion and carbon sequestration in an open landscape of northeast Germany

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The aim of this project (running 2010–2014) was to investigate the effects of a shelterbelt of fast-growing trees in a short rotation system on an adjacent wind-exposed field in the federal state of Brandenburg in terms of soil erosion protection, carbon sequestration in the soil and increasing landscape structuring and richness, biodiversity and microclimate. Moreover, it should be examined whether the energetic use of fast-growing trees is an economical alternative for farmers to the

cultivation of annual crops, and general recommendations for practical use shall be derived from the project results.

This project is financed by the Volkswagen AG. It is part of the larger framework ‘Biomasse für Sunfuel’ wherein the federal states of Lower Saxony, Hesse and Brandenburg and the Volkswagen AG join forces to achieve new knowledge for the development and introduction of synthetic biofuels.

At the study site in Casekow, county Uckermark, NE Brandenburg, a short rotation coppice plantation (SRC) was established in spring 2010, dividing a 90-hectare field in north-south direction, the main wind direction being west.

The shelterbelt of SRC has a width of 40 m and a length of 800 m. Different tree species and clones as well as different planting densities were considered. The aim was to manage the middle part of the shelterbelt with wider spaced poplars in a longer rotation (5–8 years), while its edges, composed of densely planted poplars and willows, should be harvested in a short rotation (3–4 years), in order to provide a continuous (but not identical) windbreak effect on the leeward adjacent arable land.

The presentation will introduce and discuss results of the project e.g. biomass data from the different tree species and clones, results from wind measurements on the adjacent field and results from an ornithological investigation in the shelterbelt.

Alley Coppice: Combining Willow SRC with Poplar and Cherry trees

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Short Rotation willow Coppice (SRC) is an important source of biomass energy in Ireland. Growing and intensively managing trees at wide spacing generates high value timber, sequesters carbon and delivers other ecosystem services. The alley coppice system combines the production of SRC with high value timber trees. Three alley coppice experiments were established to study the interaction of SRC with high value timber trees. In Experiment 1 the cherry variety - willow interaction is investigated: 5 willow varieties (and a mixture of all 5); (‘Resolution’, ‘Beagle’, ‘Endeavour’, ‘Olaf’ and ‘Terra Nova’) interact with rows of clonal wild cherry: ‘Neso’, ‘Pluto’, ‘Saturn’, ‘Hermes’ and ‘Concordia’ and one control of seedlings. The willow is planted in double

rows 0.75 m by 1.5 m apart. Cherry trees are planted at an intra-row tree to tree spacing of 2.5 m and inter-row spacing of 12.75 m and alley widths of 1 m & 2 m. In Experiment 2, 18 year old poplars (‘Hoogwoorst’, ‘Beaupre’, ‘Gebec’ ‘Trichobel’) are 5 m apart in 14 m wide alleys, planted with each of the 7 willow varieties (6 monoculture – as above in Experiment 1 but including ‘Tora’ & one mixed willow treatment simulating commercial planting). In Experiment 3, cherry are inter-planted along an existing commercial SRC as single tree plots in a linear randomised design. Cherry trees are 2.5 m apart in rows; each is 2.5 m from nearest willow stool. Each block contains 5 sub plots. Each sub plot contains 26 tree genotypes: 22 German varieties, 2 French varieties and seedlings as controls. For each experiment the growth and yield of the tree and SRC components and their interactions will be measured and evaluated.

Short rotation coppices along watercourses – an innovative combination of sustainable agriculture and water protection

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The multiple advantages of short rotation coppices (SRC) such as sustainable energy wood production, income diversification, and ecological services are well known and investigated in various projects. Additionally, strips of SRC present an innovative solution to buffer nutrient and pesticide contamination of watercourses induced by soil erosion. Through extensive management, provision of permanent plant cover, soil improvement, and long rotations, SRC-strips on arable land could help to achieve the goals of the EU Water Framework Directive (i.e., reduction of nutrient contamination of water bodies). In comparison to near-natural buffer strips, SRC also provides monetary benefits for farmers and therefore is a sustainable combination of agriculture production and water pollution control.

SRC-strips represent a special form of agroforestry systems. From the aspect of erosion control and runoff reduction, strips should have a width of 12 - 18 m; therefore, the SRC-strips are small in comparison to conventional SRCs. This requires adapted planting strategies such as a reduced tree number (3.000 trees/ha), a rotation period of at least 10 years and manual harvest to optimise labour input and revenues.

The project “Short rotation coppice along a watercourse” investigates the anticipated environmental advantages of SRC-strips. The study site, installed in 2011, is situated near

Wolferschwenda in Thuringia on the edge of a field, slightly sloping towards the Bennebach stream. The experiment compares three management options for the buffer strip: arable, grassland, and SRC (willow). Two main objectives of the project are (i) simulation of potential soil input by erosion on the study site under different crops and (ii) investigation of the retention capacity of SRC, grassland, and cropland. Intensive soil measurements carried out from 2012 until present show initial trends that SRC may be a more effective nutrient buffer than grassland. More detailed results are expected from irrigation experiments in spring 2014.

Is light competition between trees and crops a limiting factor for agroforestry systems at high latitudes?

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While agroforestry systems are more attractive in Southern Europe, some northern latitude farmers are reluctant to adopt such systems. They fear that tree-crop competition for light would be too high due to lower sun elevations. However, how latitude is influencing light competition between trees and crops is not intuitive. We used a simulation model to explore how factors dependent on latitude (day duration, sun elevation, nebulosity and total irradiation), impacted on light competition between crop and agroforestry trees.

Our virtual experiment design combined 3 factors: latitude (30; 40; 50; 60°N), tree line spacing (13m; 35m) and tree line orientation (North-South; East-West). We used the sAFe-light model that is included in the Hi-sAFe model (Talbot *et al* 2012) to simulate a deciduous tree species. Competition for light was assessed for the duration of the crop life and at 4 key days of the year (equinoxes and solstices). The comparison between different latitudes is made explained further by comparing agroforestry plots with trees of similar sizes but different ages. Tree to tree and tree to crop competition for light is documented.

A key result is that the relative light irradiance on the crop is not dependent on latitude. Trees do not shade more crops at higher latitudes. However, lower incoming irradiation at high latitudes may result in very low absolute levels of irradiation on the crop during some stages of the crop cycle. We therefore suggest rules for designing agroforestry systems that differ depending on the

latitude. However, the shade tolerance and phenology of the local crops and trees still have to be taken into account.

The state of alley cropping systems for bioenergy

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In any country, the main challenge is how do to make bioenergy economically competitive at a commercial scale. Complementary integrated cropping systems, such as agroforestry, are suggested as ways to provide multiple benefits, including energy feedstocks, simultaneously across the landscape. Can agroforestry systems provide feasible supplies of bioenergy feedstocks? How can energy crops be integrated in agroforestry systems? Understanding the types of agroforestry systems, and their design for energy crop production, is crucial to sustainable land use. Riparian buffers, windbreaks and alley cropping have been touted as possible systems for commercial bioenergy production. Will enough biomass be available continuously in these systems, and not compromise environmental benefits? This paper examines the literature and assesses the state of research and practice of intercropping for bioenergy. Few studies were found that explicitly intercrop energy crops. The case studies all show potential for intercropping energy crops in agroforestry systems, especially potential environmental benefits and farm diversification. Issues include scaling up production, economic tradeoffs, long term impacts, and alternative energy prices.

Ecologically sound sites for the establishment and cultivation of short rotation coppice (SRC) and SRC-strips

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This research project develops possibilities for the ecologically compatible cultivation of short rotation coppice (SRC) in a manner which avoids conflicts but rather promotes synergies with conservation. The project draws up criteria for the selection of an ecologically compatible site for

SRC as well as measures regarding the ecologically-sound appreciation of SRC. It also examines the usefulness of these measures in the development of biodiversity within the plantation. Here, we distinguish between planes and strips of short rotation coppice.

The presentation's focus lies on the methodology regarding the participative development of the ecologically sound criteria for site selection for SRC and SRC-strips. It also presents the current state of discussion on selected criteria. These criteria should serve the purpose of evaluating arable areas and to identify ecologically compatible sites for both SRC-operators and environmental agencies. Potential conflicts with the requirements of ecological protection are therefore already avoided in the planning process of SRC cultivation. Furthermore, sites are identified which will appreciate with the cultivation of SRC or SRC-strips.

Further synergies with environmental protection can be promoted within the framework of the process of planting and cultivation of SRC/SRC-strips through the procedure for the upvaluation of plantations. The presentation will also show the process and intermediate data of a three-year field study. Different procedures which are expected to promote biodiversity (e.g. planting of field-flower strips) are analyzed based on their effectiveness.

Lastly, possibilities are shown on how the criteria regarding the site selection and the provisions regarding the ecologically compatible appreciation of SRCs can be implemented formally.

Framework of the research project
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Mycelium patterns of two edible ectomycorrhizal mushrooms in the soil of a chestnut grove

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Chestnut groves in the Sierra de Aracena (Huelva, SW Spain) constitute one of the most attractive landscapes. The wood, but especially the fruit have been involved in the economic consolidation of this area. However the current situation is not favorable for production and some of

these groves are being abandoned due to the low return. Despite all this, chestnut forests still constitute an important natural tourist resource and also host a great mycological wealth.

Wild edible fungi have been collected and consumed by man from time immemorial and today some of them are considered authentic gastronomic delights. Certain fungi form symbiotic associations with the roots of the trees called ectomycorrhizas (ECM) through which the fungus provides minerals and water to the plant and the plant supplies carbohydrates to the fungus. That is why ECM are considered good indicators of forest health. Several ectomycorrhizal mushrooms highly appreciated as edible appear in this area associated with the roots of adult chestnut trees. Among them are *Amanita caesarea* and *Boletus aereus*, both thermophilic species fruiting in early autumn. The production of fruiting bodies depends on many factors, so it may be little or even null depending on the year, which hinders their exploitation. To date the artificial reproduction of these fungi to the fruiting stage continues to elude the efforts of researchers. As a complementary approach, in this work we analyzed the mycelium status of these ectomycorrhizal fungi in a chestnut grove soil. Later, different cultural practices including irrigation and shallow plowing will be performed and the effect on soil mycelium development and subsequent fruiting will be studied. For this, soil samples were taken over time and analyzed by molecular techniques through the restriction analysis of amplified rDNA using as control the DNA extracted from the respective fruiting bodies.

Allometry of green ash (*Fraxinus pennsylvanica* Marsh.) in shelterbelts: The determination of porosity and stem/branch distribution by image analysis and field measurements.

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Analysis of high resolution photos of dormant green ash trees in shelterbelts was done manually using the software WinRHIZO Tron to determine branch diameters and lengths and to relate it to actual biomass of destructively sampled trees. The allometric relationship of various diameters was related to the biomass.

Although previous studies have reported that diameter at breast height (DBH) can be used as an allometric indicator of total tree biomass, this study showed that branch diameters of 10 cm or less need to be taken into account in order to be able to accurately predict biomass. The analysis

of dormant green ash crowns was automated by converting high contrast photos into black and white images and analyzing them with predetermined settings using the software WinRHIZO.

The high contrast images were acquired using nighttime photography of floodlit trees to create white-on-black images. The software-aided analysis resulted in a good estimate of biomass distribution by branch diameter categories and also yielded a measurement of the two-dimensional porosity. Five green ash trees which had been photographed while dormant were subsequently photographed at night when they were fully foliated, which resulted in a comparison of optical porosity of the same trees in summer and winter.

The software-aided analysis also gave the branch volume and surface area, by diameter class, which resulted in the ability to compare the three-dimensional properties of the trees with their two-dimensional porosity. This was important because two-dimensional porosity is commonly considered as a way to estimate functional shelterbelt porosity, even though it is recognized that the three-dimensional nature of tree crowns creates a more complex barrier to wind.

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Agroforestry for Greenhouse Gas Mitigation in Canada

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The Agricultural Greenhouse Gases Program (AGGP) is part of Canada’s contribution to the Global Research Alliance. It is a proposal-based federally-funded program running from September 1, 2010 to August 31, 2015. Canada is focussing on four priority areas through this program, including agroforestry. The focus of the research is on discovery science and also the transfer of technology and best practices to local producers and farmers.

The objective of the AGGP is to enhance the understanding and accessibility of agricultural technologies, beneficial management practices (BMPs) and processes that can be adopted by farmers to mitigate greenhouse gas emissions in Canada. Results will contribute to research efforts that can be shared with other countries to realize a more environmentally sustainable and food-secure world.

Six projects were approved for total funding of $4.45 million within the priority area of agroforestry. These projects have a good mix of partners and supporters, both from Canada and abroad. The agroforestry projects are focusing on the development of beneficial management practices for Canada, particularly as they relate to shelterbelts, riparian buffers, alley cropping and silvopastoral systems.

The intended outcome of these projects is to bring farmers, the agricultural community and academia together to work towards a common goal advancing research, technology transfer and the adoption of beneficial management practices to mitigate agricultural greenhouse gas emissions. The results of these projects will help to elevate Canada's international reputation in agroforestry science and greenhouse gas mitigation.

Sea buckthorn (*Hippophae rhamnoides*); breeding for commercial production and phytochemical profile, and incorporation in agroforestry systems in Canada

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Sea buckthorn (*Hippophae rhamnoides* L.) is a nitrogen-fixing berry-producing shrub with a long history of use by humans for food, medicine and cosmetics. The species is extremely hardy with low fertility requirements, good attributes for use in agroforestry systems in Canada. The plant has been used as a shelterbelt species for soil erosion control in the Prairies since the 1960's, with more than 3 million planted. Breeding efforts at Agriculture and Agri-Food Canada (AAFC) since 1997 have focussed on traits of interest (thornless or soft thorns, minimal suckering, pest and disease resistance, pedicel length, skin toughness, ripening period) and resulted in some well-adapted elite cultivars, such as AC Harvest Moon™, AC Orange September™, AC Autumn Glow™, AC Prairie Sunset™. Agronomic practices for production in Prairie agriculture were

developed and Sea Buckthorn was identified as a potential alley cropping species. The current project work expands on the completed projects, to examine the evolutionary divergence of Elaeagnaceae genera (*Hippophae* and *Shepherdia*), conduct metabolite profiling of Sea buckthorn and Buffalo berry (*Shepherdia argentea* Nutt.) cultivars, to elucidate propagation techniques and to evaluate the establishment, growth and productivity of alley cropping systems in both western and maritime Canada, along with cost/benefit comparison between Sea buckthorn in plantation and in alley cropping. Alley cropping experiments were designed for three sites (Saskatchewan, Manitoba and New Brunswick) with treatment factors common to all sites (inter-row spacing treatments of 5, 10 and 15 m; N-fixing and non-N-fixing alley crops). In western Canada, both Seabuckthorn and Buffaloberry alley cropping is examined within conventional agricultural systems, while in New Brunswick, Sea buckthorn alone is examined in an organic system on a commercial organic farm. Since establishment of Sea buckthorn in organic systems in eastern Canada is slow, the use of plastic tree shelter tubes in the first year of growth after planting is being tested at the same site to determine whether they can increase plant growth and reduce the number of years until a marketable yield can be harvested.

Black locust (*Robinia pseudoacacia* L.) in agroforestry systems: spatial and temporal variation of the plant water status and growth

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Short-rotation forestry and agroforestry systems have the potential to become an ecologically valuable and economically profitable land use alternative on marginal lands. Therefore, our project focuses on determining the water demand for biomass production of black locust in the Lusatia region (Eastern Germany). The area is characterized by relative low annual rainfall (560-600 mm/yr) and drought periods during spring and summer. Black locust (*Robinia pseudoacacia* L.) is planted in short rotation plantations as well as in agroforestry systems at reclaimed post-mining sites of the opencast mining area “Welzow Süd” and on a conventionally managed field near the town Forst (both study sites are located about 120 km to the south of Berlin). Due to mining activities the ground water table in “Welzow-Süd” is below 100 m, while on the field site in Forst the ground water table is about 2 m below the soil surface. Because of the water accessibility directly

affecting the yield, it is crucial to identify the spatial variation of the soil water availability and its influence on black locust growth. The main question of this study is how the drought periods affect black locust's growth and recovery and about the drought mitigation effect obtainable by an accessible water table. The growth rate is being estimated monthly by measuring the maximum height and the trunk diameter at 10 and 130 cm. Furthermore, several trees are equipped with dendrometers to record their diameter increment in daily intervals. The pre-dawn water potential for selected trees is evaluated periodically to quantify plant water stress and relate it to the growth pattern. Water availability and microclimatic condition are monitored continuously. At the end of the vegetation period, information gathered from the field will be used to develop a growth model to link the soil water availability and plant water status with the growth rate of the trees.

Black locust (*Robinia pseudoacacia* L.) adaptability and plasticity to drought

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Robinia pseudoacacia L. is a pioneer tree species which grows under a wide range of edaphic and climatic conditions. It is native from North America and its original range is a climatic region classified as humid to sub-humid, with a mean annual precipitation of 1.020 to 1.830 mm. However, in Central Europe the species has proven to be relatively drought tolerant in comparison to other temperate deciduous tree species. In the State of Brandenburg (Germany) for instance, with a continental climate and annual precipitation below 600 mm, the species has been successfully cropped for wood production for more than 250 years. The tree notably grows also in post-mining recultivated sites where soil water availability is limited and in spring and summer drought can occur. The importance of the species has increased over the lasts decades, after the CO_2 reduction policy spread across the world, just as did the need for further sources for renewable energy. Therefore, due to its adaptability to water constraints, its fast growing and resprouting rate, together with the ability of nitrogen fixation, black locust could become a key species for short-rotation plantation on marginal land. Several studies have been already carried out to quantify the production and water use efficiency of the black locust. However, the effect of water scarcity on biomass production and the plant's response to drought stress has still to be examined. In our

investigation we aim to evaluate the growth performance and the ecophysiological response of black locust to water limitation. The study of the soil-plant-atmosphere system for the evaluation of the relation between water availability, atmospheric evaporative demand and plant water status is critical to identify the ecophysiological adaptation and growth response in relation to different edaphic and climatic conditions. Different irrigation regimes and cycles of drought were chosen, to test the plant's performance in a lysimeter experiment for the duration of two vegetation periods, under semi-controlled environmental conditions. The results obtained from studies were satisfactory. We assessed the drought tolerance and resilience of black locust, together with its water use efficiency. Both at whole-plant and leaf level the link between the soil water retention, plant water status and growth rate has been elucidated and the intertwined relation between primary production, transpiration, CO_2 uptake and water limitation, together with the evaporative atmospheric demand, has been clarified.

Profitability of sheep grazing in young conifer plantations of British Columbia, Canada

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In British Columbia (BC), sheep grazing, as a silvopastoral system, is occasionally used as a biological weed control method in young conifer plantations. As it is a relatively new method in BC, there is presently a lack of information about the profitability of the practice. For instance, there is no scientific data about the gain in profitability as a function of the number of grazing treatments applied. What is known is that at least two grazing treatments in a given year or one treatment per year for two or more consecutive years are required to effectively deplete fireweed (*Epilobium angustifolium*) root reserves, the predominant herbaceous competing vegetation. Our main objective was to analyze the profitability of sheep grazing for herbaceous vegetation control in young conifer plantations. The profitability was tested under two grazing treatments: a single sheep grazing treatment and two sheep grazing treatments applied over two years. Since comparing the profitability of treatments requires financial data on all the rotational period and is often not available, we used a simple approach that can determine profitability with little detailed information.

Using this approach, grazing treatments could be compared in terms of time gain. Assuming that a grazing treatment shortens the rotational period by "X" years allowing a certain time gain, the additional relative cost can be compared with the break-even additional relative cost. Preliminary results indicated that two grazing treatments have the potential to decrease the time to declare a stand free-growing compared to one grazing treatment. Thus, this time gain, at a young age (e.g., 10 yr) could potentially result in a time gain at the end of the rotational period (e.g., 80 yr). This presentation will examinate the profitability of sheep grazing with more detail and show how this method has the potential to shortened the rotational period.

RMT "AgroforesterieS": a new Mixed Technological Network for agroforestry development in France

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Facing new challenges of agriculture, the research for more sustainable agrosystems includes a growing interest in agroforestry practices. Over the past years, a large number of experimental and demonstration plots have been established all around France. However, coordination between research and extension partners is lacking.

In order to support innovations in agriculture, the French government encourages partnership between research, development and education stakeholders, through the creation of Mixed Technological Networks (Réseaux Mixtes Technologiques, RMT). These RMTs benefit from national recognition and receive a grant for network coordination and communication. In 2014, a new network was created: the RMT "AgroforesterieS" brings together about fifty members involved in agroforestry, from research, semi-public and associative farmers' organizations, technical institutes, engineering offices, and agricultural schools.

By sharing expertise, databases, and demonstration sites, the network aims at

(i) promoting collective dynamics for the development of sustainable and innovative agroforestry systems adapted to the French territorial constraints, and

(ii) developing technical and methodological tools for the setting up and management of agroforestry systems. It will particularly achieve these by:

Creating an observatory of agroforestry practices, including both experimental and commercial sites, in order to provide technical references for farmers;

Carrying out a multicriteria assessment of agroforestry systems, in terms of economical, technical, agronomical and environmental performances, as well as adoption factors;

Ensuring the coordination of scientific and technical stakeholders in order to initiate new collectively-thought projects of research and development in agroforestry;

Developing and/or improve decision support tools for farmers and land managers for the design and management of agroforestry systems;

Drawing up a strategy for knowledge diffusion towards future advisors, learners, and users.

Impact of black locust hedgerows on wind velocity and wind erosion in Eastern Germany

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The production of energy wood on arable land increased in Germany during the last years. Black locust (*Robinia pseudoacacia* L.) is a suitable tree species in order to ensure substantial woody biomass yields on agricultural sites in eastern Germany. Arranged in hedge structures (alley cropping) positive effects on wind velocity and hence on soil erosion can be expected for the whole agricultural production area.

Results of field measurements carried out in several alley cropping sites located in eastern Germany show that wind velocity can be reduced by more than 50 %, even though tree hedgerows were not higher than four meters. Here, the reduction of wind speed was dependent on the distance to woody crops, the width of the crop alleys and the orientation of hedgerows. As a result of wind speeds reduction the potential of soil erosion by wind decreases considerably. The risk of wind erosion is even nearly negligible for 24 m wide or smaller crop alleys.

The establishment of short rotation hedgerows could contribute to an enhanced protection against wind erosion and thus to an ecological and possible long-term economic appreciation of agricultural sites. Aside from erosion control, further advantages such as a lower evaporation rate, and thus a crop yield increase, may be connected to the establishment of such agroforestry systems. Against the background of the increasing demand for woody biomass for bioenergy, the cultivation of fast growing trees on agricultural sites can furthermore result in an additional income

for farmers. This is a prerequisite for the spread of this kind of agroforestry in Germany, because a comparable large share of an unprotected field has to be planted with trees in order to ensure an efficient windbreak.

Carabid beetles in agroforestry systems: reducing complexity of life styles through energy budgets

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Agroforestry can promote biological control of economically important crop pests by favouring habitats that are suitable for the native useful fauna. Predator–prey energy relationships are critical to the success of biological pest-control strategies as energy budgets constitute a basic tool to quantitatively assess the role of organisms in ecosystems and the way they allocate resources. This implies to take a mechanistic approach to study how beneficial organisms present in agorforestry systems take up and use energy and material from prey and hosts. Estimating the energy budgets or dynamics of insect predators has the potential not only to assess the utilisation efficiency of prey but also to estimate the potential of a predator as a biological control agent (Du et al., 2003; Gao et al., 2007). In addition, natural enemies are an important component of integrated pest management (IPM) programs in many agroecosystems as they can be used to control pest populations. However, their energy budgets are often ignored in many IPM programs.

Several studies of beetle fauna in agroforestry systems and hedge-rows showed a large variety of species (Varchola and Dunn, 2001; Bhagwat et al. 2008), often with strongly fluctuating overall composition. It is therefore difficult to know which species to study in detail and whether the analogies between species are stronger than the differences. In this study we used the Dynamic Energy Budget (DEB) theory to build a generic model framework for holometabolous insects, i.e. insects that show four life stages: embryo, larva, pupa and imago. We apply the model to two species of carabid beetles that are species of major relevance as predators of pest species: *Abax ater* and *Pterostichus versicolor*. The model computes the flux of energy investment in growth, maturation, maintenance and reproduction during the life cycle of both carabid species. The energy equivalent of prey (energy ingested by the carabid) was estimated for each life stage of both carabid species. Assimilation efficiency and net production efficiency were also calculated for each species and life stage as well as the energy invested in reproduction. The results demonstrate how

P. versicolor and *A. ater* differ and how they are similar. Beyond specific differences, the **DEB model highlights the physiological bottlenecks** as well as the **potential for prey regulation,** opening the venue for **interspecific comparison of carabid species of importance in Agroforestry**.

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The Knowledge Data Bank, (KBD), in the AgroFE project (EU Leonardo ToI project)

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In the Leonardo-ToI AgroFE project, the Knowledge Data Bank (KBD), Banque de connaissances (BdC) in French, is one of the 3 supports, 1 of the 3 pillars of the project training components. In the medium term, this tool will allow the cross fertilisation between all Agroforestry actors and stakeholders, and the exchange of information with the highest added value, information enriched at each step of their production process.

Research – Training – Mutual apprenticeship – Transmission of knowledge, 4 elements which are present, which are at the core of the AgroFE, a project which is involving UK, BE, CZ, HU, RO partners, central Europe partners:

- institutions acting in technical and professional training (VET), Higher Ed – Universities and Adults training organisations : U. of Warwick, EPLEA Aube, EPLEA Vosges, CULS-CZU, U. of Debrecen, Liceul ‘’Ovidius’’;

- Research and knowledge transfer organisation, researchers, and extension actors, publishing house: EURAF, INRA, ITF, AGROSUP, Eduter;

- Professional organisations / unions and federation of actors with support of local & regional authorities: AFAF, AWAF;

- Profit / not for profit organisations involved in the transfer of knowledge, competences and professional-applied innovative practices: Abacus, Mare-nostrum.

The need of training in the domain of Agroforestry is real and it has been evaluated, proven and established in several countries like, for instance, in France. The Ministry of Agriculture (in charge of Ag. Ed. & tr.) began to update the books of specifications, including Agroforestry in the curricula. One of the main issues is the ''How to develop'' these trainings, plural, because the needs are shared between L3 and L7, following different pathways, different modalities, from the face to face to the distance learning. These constraints are taking into account in AgroFE and the project will propose different modalities for the trainings. And once again the cross fertilisation between Agroforestry stakeholders, authorities included, should guarantee the best and highest level of competencies and knowledge that will be transferred to the learners, to the students, to the different target group of the trainings. Professionals are strongly involved in the training processes. In this context, the Knowledge Data Bank, (KBD-BdC), will be at the core of the system of ''Knowledge Capitalisation – K. Diffusion – Training'', one of the three components of the technology part of the project, the ICT part, together with collaborative system and devices and the DL platform and tools. The contents of the KDB, called digital contents or digital resources (if they are focused on training, they can be called pedagogical resources or digital Ed. materials or …as well) are under different forms and types (documents, maps, photos, videos, research outcomes, report about experiences from farmers, from technical institutes, from extension, …) and the KDB will include URL-links targeting other sources of information, other deposits – repositories, other existing KDB whatever the continents they are located. An in-depth, detailed process of KDB enrichment will be established by the partners, and the issues like metadata, issues about vocabulary and thesaurus or taxonomies will be among the project tasks. During the first year of the project, the KDB-BdC will be made up of identified and assessed resources, validated by partners, with selection criteria linked to the first object: usefulness in education (formal, non-formal, informal), being a support of the curricula, of the trainings, targeting pedagogical activities, whatever the level. After, it is in our mind to enlarge KDB users and usages, in the project second step. The modalities or rules for the KDB-BDC feeding should evolve in order to extend the group

of ''feeders'' to other stakeholders, from research and extension to farmers, agro-foresters and ''practitioners'', trainers and teachers, to other groups like ''Agro-ecology'' or ''Organic Farming'', why not to the ''general public'' interested in the subject. Professionals are strongly involved in the training processes.

The paper will present the 3 components of the ICT project part, with an emphasis on the KDB, elements of its implementation, the process (workflow) of feeding, and the content usages the project is considering as support of training activities. The 2 other components will be shortly presented as support of the KDB feeding or support of the curricula and their training activities.

Conclusion and perspectives: the KDB-BdC and their future in formal, non-formal, informal education and training, perspectives in Europe and outside Europe.

New experience in Mediterranean areas: production and nutritional value of perennial forage species in agroforestry rainfed systems

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In the twenty-first century, climate change, caused by the rising concentrations of CO_2 and other greenhouse gases, leads agriculture to apply techniques for reducing its emissions and to adapt to the changed conditions. In such a context, perennial forage cropping systems would increase the capacity to store carbon in the soil and therefore agroforestry represents an important tool. Agroforestry systems can be established by planting trees on cropland or introducing herbaceous plant species in forests or orchards. Trees can store CO_2 in the form of organic carbon in their woody tissues, reduce the risk of soil erosion as they cover the ground for almost all the year, and reduce the speed of the wind and hence wind erosion. In addition, during the warm season the canopy shadow of the trees can create a cooler microclimate for grazing and a diurnal shelter for the livestock.

The aim of the present study was to evaluate the sustainability of agro-silvo-pasture systems under Mediterranean conditions in order to improve our understanding of the productivity and the nutritional value of under canopy meadows. Poplar plantations (*Populus deltoides* Marsch, var. Dvina) and olive orchards (*Olea europea* L.) were identified as agro-silvo-pasture systems.

The poplar plantations are in the Natural Park of Migliarino San Rossore Massaciuccoli (Pisa, Italy), while the olive orchards in Manciano (Grosseto, Italy). The soil of the poplar trial is a loam

with a sub-alkaline pH. The trial followed a randomized block design with two shadow treatments (shadowed and non-shadowed), eight pure plant species and three mixtures and four replicates. Plant species were: five legumes (*Medicago sativa* L., *Trifolium repens* L., *Hedisarium coronarium*, *Onobrychis viciifolia* Scop., *Trifolium brachycalycinum* Katzn et Morley), and three grasses (*Dactylis glomerata* L., *Lolium perenne* L., *Bromus catharticus* Vahl) and three mixtures (*M. sativa* and *Dactylis glomerata*; *T. repens* and *L. perenne*; *B. catharticus* and *O. viciifolia*). The poplar plantation layout is 6 x 6 m.

The soil of the olive orchard trial is a clay-loam with sub-alkaline pH. The olive orchard systems followed the same experimental design as above. Plant species were: *M.sativa* and a six perennial species meadow composed by three grasses (*D. glomerata*, *Festuca arundinacea* L., *B. catharticus*) and three perennial legumes (*O. viciifolia*, *T. brachycalycinum*, *M. sativa*). The layout of the olive orchards is 10 x 5 m, equivalents to 200 trees per hectare. The plots of each trial were sown on March 2014.

During 2014 the forage will be harvested using the modified Corral method in order to assess the growth and re-growth of the different species and mixtures. We will totally harvest the plots to assess the curve of re-growth of each species and the time to a boot stage, in order to describe their management in an alley-cropping system model. In further harvests, we will mow without returning the portion already harvested. The harvest will occur at the same sward height over a one square meter surface in each replicate. The harvests, at regular intervals of about 15 days, will start in spring and continue until the end of the growing season. The nutritional value will be determined using parameters such as crude protein, fibre quality and the *in vitro* digestibility by anaerobic batches.

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Agroforestry and the Afforestation Programme in the Republic of Ireland

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By the turn of the twentieth century, the forest cover in Ireland had fallen to the seriously low level of 1 % of the land mass. Most of this woodland was broadleaf high forest dominated by oak and ash with some Scots pine on the higher and peaty ground. A series of grant aided initiatives were put in place to increase this percentage level. Currently the Irish forest cover is approximately 11 %, while the EU average is around 34 %. Since the late 1980s, afforestation in the Republic of Ireland has almost completely changed from public planting to private planting. Farmers are now the main contributors of land for afforestation. However, planting levels have fallen from a high of 20.000 hectares to 7.000 hectares per annum, mainly due to environmental constraints, silvicultural suitability, competing agricultural systems and land availability. Planting is now confined to better quality land, which farmers can be reluctant to plant. Agroforestry could be a way to help encourage farmers to put more trees into this high quality land.

In 2011, the Department of Agriculture started to investigate the potential of agroforestry. In 1989, pioneering trial plots were established in Northern Ireland by Professor Jim McAdam (Agri-Food and Biosciences Institute and Queens University Belfast). One of the silvopastoral trials was chosen for replication in the Republic. A suitable farm in West Cork was sourced and a demonstration plot of 1.89 hectares was planted. This involved ash (*Fraxinus excelsior*) planted at 5 x 5 metre spacing and using tree shelters. The farmer grazed sheep in the early and late spring, then cut silage (50 large bales per annum) and hay (40 small bales per annum) during the summer. In the spring of 2012 and 2014, the weather in Ireland was wetter than usual and animals had to be kept indoors as the ground was too soft to support them. As a result there was a huge shortage of animal fodder. The demonstration plot produced silage and hay for the farmer in this time of need and so the system had a practical application for a real problem, and correspondingly could prove beneficial to other farmers in similar circumstances. For foresters the need for early pruning/shaping is removed, there is less pressure to thin and the process will result in woodland similar to one planted in a conventional way. The system will suit young active farmers that want to retain access to the land, while producing agricultural produce in the short term and timber in the

medium to long term. In addition the farmer will not need any new skills or machinery and can carry out agricultural practices that he is familiar with.

The Republic of Ireland intends to have an agroforestry content in the new round of afforestation initiatives (2014 – 2020). Stake holder consultation by the Department of Agriculture has taken place using the above demonstration plot as a proposed approach to establishing an agroforestry system on a farm. Feedback from this process has highlighted a number of challenges.

One issue relates to whether the land will be classified as forestry land or agricultural land and what potential effects this could have on other farm payments. Another major issue is how current legislation in the Republic of Ireland will affect any plantations established under agroforestry. Current policy is that land planted and classified as forestry needs to be replanted if clearfelled. This is part of the country's approach to increasing tree cover in Ireland.

Another aspect worth considering in Ireland is that most planting is carried out by forestry companies. These companies contact farmers and look for business through planting land and managing it in return for afforestation grants. It will be important for these companies to understand and value any new system as they are the ones that will promote it to farmers. Similarly farmers will need to be happy with agroforestry systems and satisfied that they will be able to continue to carry out agricultural practices that they are familiar with.

It is clear that if agroforestry is to succeed in the Republic of Ireland more demonstration plots on farmland would be helpful. Training of contractors, farmers and foresters would also be necessary. Currently Teagasc (Agriculture and Food Development Authority) is involved in a European project 'Agrocop' which is investigating a short rotation coppice intercropping system for biomass and timber production. Additional research into different tree species, shade-bearing grass species suitable for agroforestry and different agroforestry systems would be helpful.

It is thought that the initial grant scheme for agroforestry will be on a pilot basis so that the interest in the scheme and its strengths and weaknesses can be assessed over a number of years.

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