GRASSLAND MANAGEMENT EFFECTS ON ABOVE-GROUND MATTER FLUXES IN SILVOPASTORAL AGROFORESTRY SYSTEMS

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Abstract

Agroforestry systems offer an alternative agro-ecological approach to a sustainable intensification of food/forage crop and wood production. Therefore, this study investigates the biomass yields of the growing season 2016 in a silvopastoral agroforestry system. The system combines two different grassland types (both with an intensive and extensive management) and short rotation coppice (SCR) with willows (*Salix* spp.) in an alley cropping design. The DM yields of all grassland treatments were lower in the agroforestry system compared to the usual grassland yields without influences of trees at this location. The grassland biomass yields decreased close to trees and also the composition of plant functional groups changed with decreasing distance to trees. The DM yield of woody biomass was estimated with 15.7 t DM ha^{-1} in the second year of the second tree rotation cycle. Results show that systems productivity was higher during the second rotation compared to the first rotation (2011-2015).

Keywords: silvopastoral agroforestry; short rotation coppice - willows; Grassland; biomass yield; functional groups

Introduction

The Organization for Economic Co-operation and Development (OECD) aims to halve the global emissions of CO_2 by 2050, compared to the level in 2000. In order to reach this target, the replacement of fossil fuels with renewable energy resources has to be envisioned, with a particular role of bioenergy. As a result, the demand for arable land for the cultivation of energy crops increases. Competition for land use with food and energy plants is also increasing as well as environmental hazards like soil erosion, nutrient leaching or decreased biodiversity. Modern agroforestry systems offer an alternative agro-ecological approach to a sustainable intensification of concomitant food/forage/energy crop and wood production.

Therefore, the combined effect of tree/grassland sward competition and different grassland management treatments in a silvopastoral agroforestry system on biomass yields has been investigated. The system combines grassland and short rotation coppice (SCR) in an alley [illegible] nd the willows (Salix spp.) are used as SRC for energy production. In the present paper the biomass yields of the agroforestry system obtained in 2016 are shown and further research aims are outlined.

Materials and methods

The agroforestry system has been established in March 2011 and is located in Lower Saxony, Germany (51°23´56´´N and 9°59´13´´E, 327 m a.s.l.). It covers an area of approximately 1.3 hectare (Ehret et al. 2015a). The climate is characterized as temperate with an average temperature of 9.2 °C and a mean annual precipitation of 642 mm over a 20-year period. The predominant soil type is classified as a stagnosol according to the FAO World Reference of Soil

Resources (2006) and consists of sedimentary deposits from sandstone, siltstone and claystone (Hartmann et al. 2014).

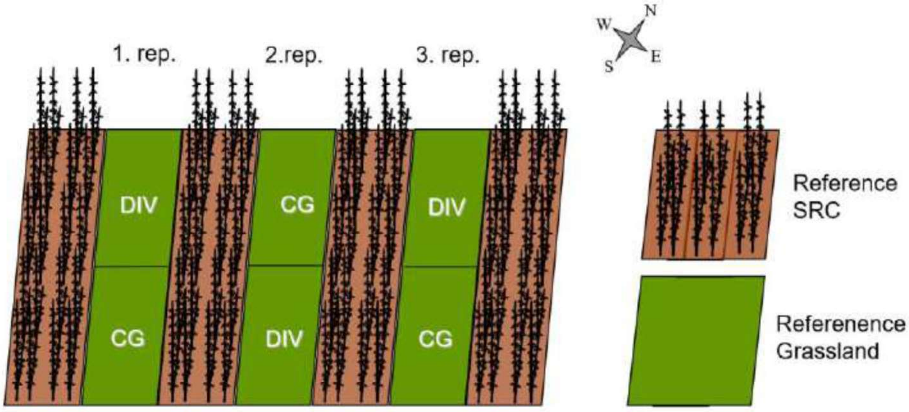

Figure 1: Alley cropping design with different grassland types (CG=clover-grass; Div=Diversity mixture) and willow stripes as short-rotation coppices (SRC), 3 replicates (rep.).

The system consists of alternating, 80-meter-long rows of willow and grassland strips each in a threefold repetition. Each tree strip consists of four double rows of willows (eight willow rows total). Alternating inter-row distances were 0.75 and 1.5 m, with a within-row spacing of 0.75 m, to yield a planting density of 12 000 trees per hectare (Ehret et al. 2015a). The grassland strips are 9-meter-wide and cultivated with two different seed mixtures, clover-grass (CG) and a biodiversity mixture containing 32 herbaceous species (DIV). Different management strategies include an extensive (2 cuts per year) and intensive (4 cuts per year) management of both grassland types. The grassland strips alternate with 7-meter-wide strips of willow hybrid ((*Salix viminalis x Salix Schwerinii*) x *Salix viminalis* = breeding Tora x Z. Ulv), which are characterized by their bushy growth making this willow variety particularly suitable for SRC (Figure 1). The trees have a rotation period of 3-4 years and the first willow harvest was in winter 2014/2015. Thus, in the growing period of 2016 the willows aged 2 years on 5-year-old stools.

The effects of different management strategies on grassland biomass yields, -quality and above ground matter fluxes are measured as a function of distance to trees along a transect. It comprises five transect points (TPs) in the grassland stripes among the willow alleys in each treatment. TP 1 and 5 are located in the edge regions of the grassland, 1 m distant from willow strips. The remaining TPs are equally distributed between them. All statistical analyses have been performed in R. For each treatment a two-sampled-t-test has been performed to investigate the difference in the means of annual biomass yields. The variance of biomass yields at each transectpoint was tested using a pairwise-t-test. As an additional parameter the composition of plant functional groups (grasses, herbs, legumes) is recorded.

The annual DM growth of willows is estimated by an allometric functions based on diameter increment at breast height (1.30 m) and their associated DM yield. A non-linear least squares model was used to fit both parameters for 25 sampled shoots. The model was used to predict the DM yield of 68 trees with 284 shoots in total. Subsequently the total annual DM yield per hectare was calculated based on the mean stool method after Hytönen et al. (1987). Pure willow and grassland stands of each treatment serve as location specific reference value.

Results

The biomass yields of grassland sampling for the growing season 2016 are shown in Figure 2a. The DM yields of all treatments were lower in the agroforestry system compared to the usual grassland yields without influences of trees at this location. The 3-cut-system in the agroforestry yielded 9 t DM ha^{-1} for CG and 6.9 t DM ha^{-1} for DIV. The DM yield of the 2-cut-system was with 6.3 t DM ha^{-1} for CG and 6 t DM ha^{-1} for DIV lower (Figure 2a). In comparison, the yield of pure grassland stands of each treatment (3-cut) measured at this location reached 12.7 t DM ha^{-1} for

CG and 9 t DM ha^{-1} for DIV. The 2-cut-system produced 8.9 t DM ha^{-1} for CG and 10.7 t DM ha^{-1} for DIV.

A detailed analysis of the biomass yields at the single TPs (Figure 2b) showed the lowest biomass values close to the trees (TP 1 and 5). Simultaneously, the composition of plant functional groups changed with decreasing distance to trees (Figure 2c), particularly in the 3-cut-system, where the fraction of legumes also decreased with decreasing distance to trees, while the share of grasses increased.

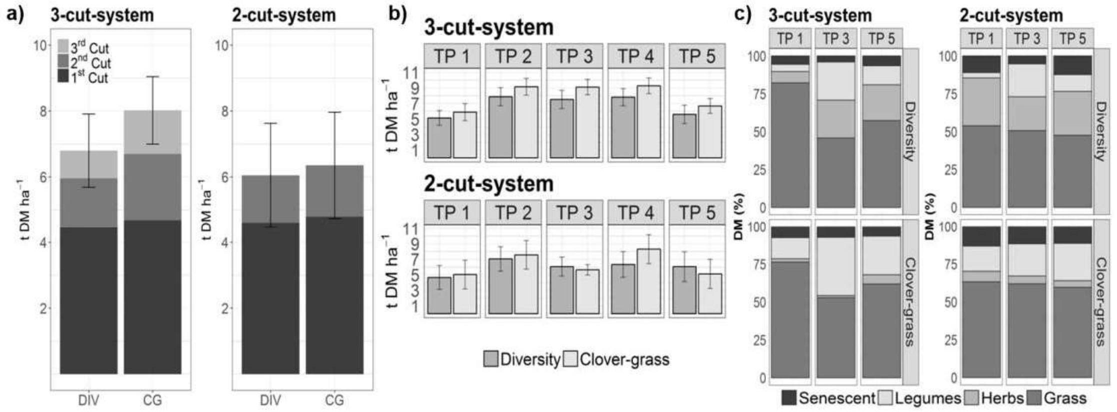

Figure 2: a) Annual biomass yield per cut for different grassland mixtures (DIV=diversity mixture; CG=clover-grass) and cutting regimes in the agroforestry system, b) annual biomass yield of treatments at TPs and c) fractions of plant functional groups at selected TPs.

The average tree height across all tree strips was 3.69 m with a mean Diameter at Breast Height (DBH) of 1.3 cm. The DM yield of woody willow biomass was estimated with 15.7 t DM ha^{-1} in 2016, the second year of the second rotation.

Discussion and outlook

The observed changes in the composition of plant functional groups along the transect can most likely be explained by shading of the grassland from trees. This assumption is consistent with findings of Ehret et al. (2015b), who showed that an increasing shading of grassland results in decreasing biomass production of herbs and legumes. The extensive managed grassland seems to benefit from this shading effect as the biomass yields are lower in areas where no shadow influenced the grassland (TP 3) then on the partially shaded areas (TP 2 and 4). The reason for that might be related to the relatively dry climatic conditions in 2016 with a strong drought period during early summer. Even though these assumptions cannot be validated statistically for 2016 the analyses will be extended by the integration of multitemporal yield data. Further analysis are planned to test the hypotheses of shading and water availability on grassland biomass yield based on illumination data derived from canopy models and soil moisture information at TP 1 and 3. During the first rotation period the agroforestry-system showed no significant economic benefits compared to conventional systems, which was expected due to the short-term establishment of the system (Ehret et al. 2016) and poor growth conditions with severe dryness during the establishment of the agroforestry-system. The productivity of the system seemed to be higher during the second rotation: the yield of the willow biomass was in 2016 higher compared to the woody biomass yield after the first rotation (2011-2015). Further research activities will use these parameters for the calculation of energy balances and the evaluation of further utilization paths. Once the data acquisition is concluded an agronomic assessment of the agroforestry system for a period of six years will be realised. Additionally, an agronomic assessment of woody biomass will be tested using a 3-D-data modelling approach based on terrestrial lidar scans.

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