Évora, Portugal
13–16 April 2026

Challenges and innovations for grasslands resilience

Edited by

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Volume 31
Grassland Science in Europe

Changes in grass biomass and quality in silvopastoral grasslands under the influence of poplar rows

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Abstract

In many temperate silvopastoral systems, grassland is managed extensively, with timber production often the main focus. This raises the question of how the proximity of trees affects the biomass and nutritional value of grassland when it is harvested once a year. In a one-year field experiment conducted at two sites in the temperate climate of northern Germany, we investigated how the distance to tree lines affects herbage biomass accumulation and the nutritive value in relation to the harvest date. Herbage biomass accumulation was determined in the primary growth at four successive harvest dates and at three distances from the tree line within the agroforestry system and in an open-field control ($n = 4$ replicates). Herbage biomass accumulation was significantly affected by the interaction harvest date x distance position from the tree line ($P < 0.01$). At closer distance to the tree line the increase in herbage accumulation in spring was lower and the decrease during summer slower compared with further distance but showed a pronounced decrease in autumn. The crude protein content showed an interaction between site x harvest date x distance position ($P < 0.001$), driven by the timing of harvest. The CP was lowest in the early summer.

Keywords: agroforestry, grass biomass, grass quality, poplar rows, silvopastoral system

Introduction

Modern agriculture is under increasing pressure to become more sustainable and biodiversity-friendly. Grassland management is crucial for preserving biodiversity and storing carbon. Integrating trees into grassland in the form of silvopastoral systems serves the dual purpose of timber production and increasing the economic value of less productive grassland which is otherwise at risk of abandonment. Since grassland is less important in such cases, producers aim to achieve the highest possible agronomic return with the least possible input. Consequently, one cut systems are often practised, prompting the question of the extent to which tree lines influence the accumulation of grassland biomass and the nutritional value when the harvest date shifts from spring to late summer.

The aim of this study is to answer the question of how the timing of the first harvest date in poplar agroforestry systems affects the herbage biomass accumulation and nutritive value of grasslands and what effects trees have in this respect.

Materials and methods

The study was conducted in 2024 at two sites in Germany: Site A (Lüneburg, 53°12′22.8″N, 10°21′58.5″E) and site B (Niederer Fläming, 51°56′14.8″N, 13°12′27.1″E) as part of a silvopastoral experiment where poplar trees are planted in order to produce construction wood with an anticipated tree age of 10–15 years. The soil texture at both sites was sandy loam. Site A had a long-term average annual precipitation of 695 mm, while site B was considerably drier, with a long-term average annual

precipitation of 539 mm (DWD Climate Data Center (CDC), 2025). The poplars on grassland site A (Lüneburg) were planted in 2016, and those on site B (Niederer Fläming) in 2021. The experimental design followed a split-plot design in which the factor distance to the tree line was varied. Three fixed distances were placed 1 m, 4 m and in the centre between two tree lines within the agroforestry systems. One open field reference plot was established in areas of the same field without effect of trees. Each distance position had four replications. The second experimental factor consisted of the timing of the first harvest during the primary growth, which had four stages: May, June/July, August and September. At each harvest date, the standing herbage biomass was determined by means of manually cutting the above-ground biomass at a stubble height of 3 cm using electric hand shears (ComfortCut, Gardena) in a 0.18 m^2 steel frame. In the laboratory, the fresh biomass was manually separated into living green and senescent brown herbage biomass and the dry matter (48 h at 60°C in a forced air-oven) determined. Thereafter, the samples were rebulked and ground to 1 mm using a centrifugal mill (ZM 300, Retsch). The herbage nutritive value was determined using near-infrared reflectance spectroscopy (NIRS; Phoenix 5000, BlueSun Scientific) by scanning each sample twice. In the present study the crude protein concentration (CP) and the acid-detergent fibre in organic matter (ADF) are considered. The files were processed and a calibration data set was used that was based on a large data set for grass and forage (VDLUFA Qualitätssicherung NIRS, Kassel, Germany). The statistical analysis was performed in RStudio (R Core Team, version 4.0.2) using linear mixed-effects models in the package 'nlme' (Pinheiro *et al*, 2025) The fixed effects included site, distance position to the tree line, harvest date and their interactions. The replication was used as random effect. Comparisons of means were performed posthoc using Tukey's HSD method (P <0.05) in the package 'emmeans' (Lenth, 2022).

Results and discussion

The herbage biomass accumulation was significantly affected by the interaction harvest date x distance position (P <0.01). The herbage mass increase in spring was lower at a close distance to the tree line while the decrease in summer was slower compared with a further distance. The lowest values were measured in September in close proximity to the tree line, and the highest value in June/July in the open field, suggesting a time-depending growth-suppressing effect of trees (Figure 1A). This is in line with the observation that a stronger tree effect was found at the older site (tree age: 8 years, estimated height 17.20 m) compared to the younger site (tree age 3 years, estimated height 4.45 m).

In May the proportion of biomass of senescent tissue was low, increasing with vegetation dynamics and reached highest values in June/July. An exception was the first distance position (1 m), which showed higher values in May, but then lower values compared to other distances positions, obviously related to the lower biomass growth (Figure 1B). The CP concentration was affected by a site x distance x harvest date interaction (P <0.01); however, the dominating effect was the time of harvest with a decline from May to June/July, and recovery in late summer due to regrowth. Comparing the sites, site A had generally higher CP concentrations than site B (Figure 1C–D). Similar results had been found by Opitz von Boberfeld (1996) with decreasing CP concentrations below 12 % after May. There was a significant interaction of site x harvest date (P <0.05) on the ADF concentration. Related to the dynamics of the CP concentration, at site A the ADF values increased from 27.5% in May to 40.8% in August and 42.7% in September. At site B, the ADF concentration increased from 26.7% in May to 43.2% in August and 42.9% in September. The dynamics of the CP- and ADF-concentrations indicate the considerable decrease of the nutritive value, with harvest date being more influential than tree distance. The increasing proportion of senescent biomass during the growing season reduced the overall nutritive value of the herbage, further reinforced by the concurrently rising fibre content. The

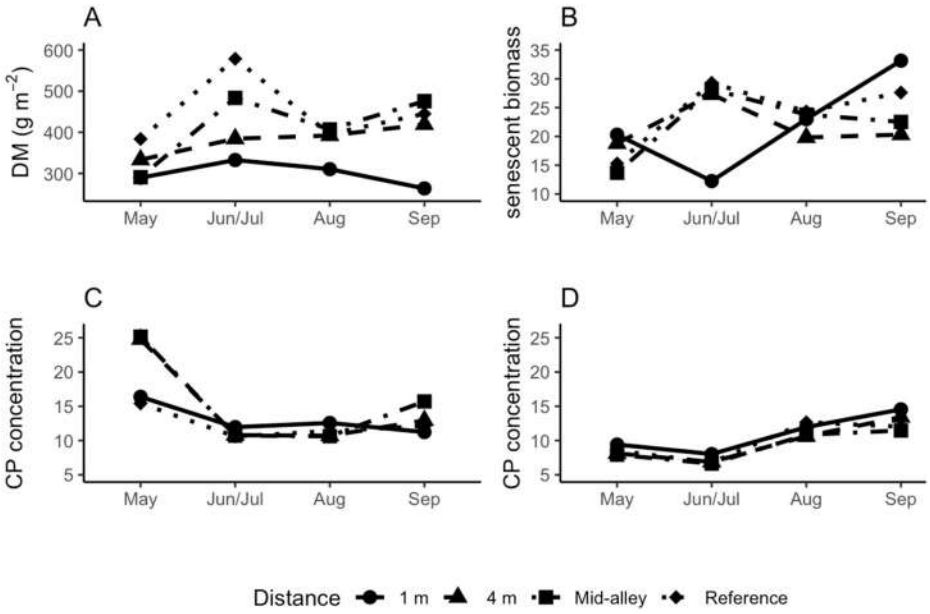

Figure 1. Herbage biomass accumulation (g DM m^{--2}) (A). Results of ANOVA: S (site)×H (harvest date), $P < 0.01$; D (distance to the tree line)×H, $P < 0.01$)), proportion of senescent herbage biomass in the dried sample (%) (B: S × H, $P < 0.01$; D × H, $P < 0.05$; S × D, $P < 0.001$) and CP concentration (%) (S×H × D, $P < 0.001$) for Site A (C) and Site B (D) of the four different distances to the tree line (1 m distance, 4 m distance, mid-alley (centre between the rows of trees) and reference) over the four harvest dates (May, June/July, August, September).

herbage nutritive value in the present study is to be considered too low for dairy cows, while sufficiently high CP concentration was achieved for beef cattle (DLG, 2025).

Conclusion

Trees in silvopastoral systems affect the dynamics of herbage mass accumulation and nutritive value of the herbage. There is indication that the effect of trees on the herbage accumulation and tissue senescence is stronger than on the nutritive value of the herbage. However, the response is affected by complex interactions with site and the age and height of the trees. This has to be studied in more detail with more years and sites in future research.

Acknowledgement

This study is funded by the Federal Ministry of Agriculture, Nutrition and Regional Identity via the agency of renewable resources (FNR) (FKZ: 2222NR070E).

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