Energy wood production in alley cropping agroforestry systems

Lamerre J*[1], Schwarz K-U[1], Langhof M[1], Bliefernich S[1], Greef J-M[1],von Wühlisch G[2]
* Corresponding author: justine.lamerre@jki.bund.de
[1]Julius Kühn-Institute for Crop and Soil Science, Braunschweig.
[2]Thünen-Institute for Forest Genetics, Grosshansdorf.

Introduction

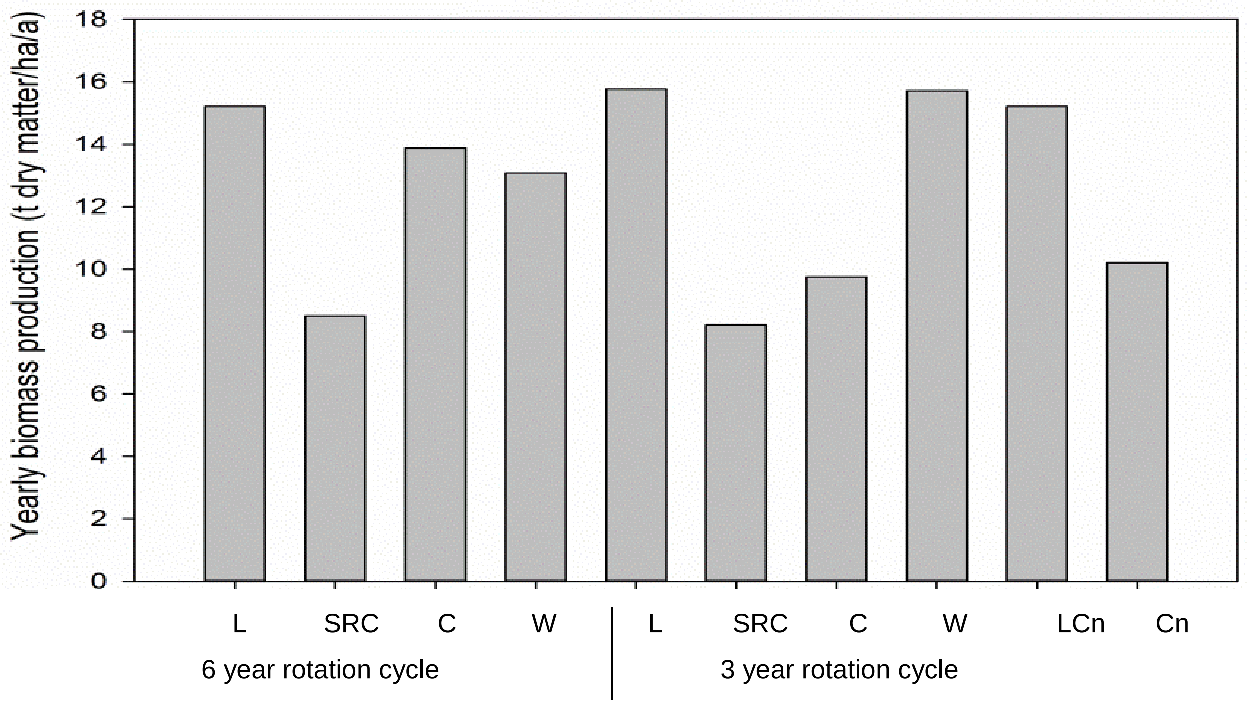
As the German government fixed an objective of 35 % of renewable resources in the final energy consumption by 2020, biomass production in Germany will continue to increase (Böhme and Musiol 2013). Wood, as a source of renewable bioenergy, can contribute to combined or separate heat and/or power production. 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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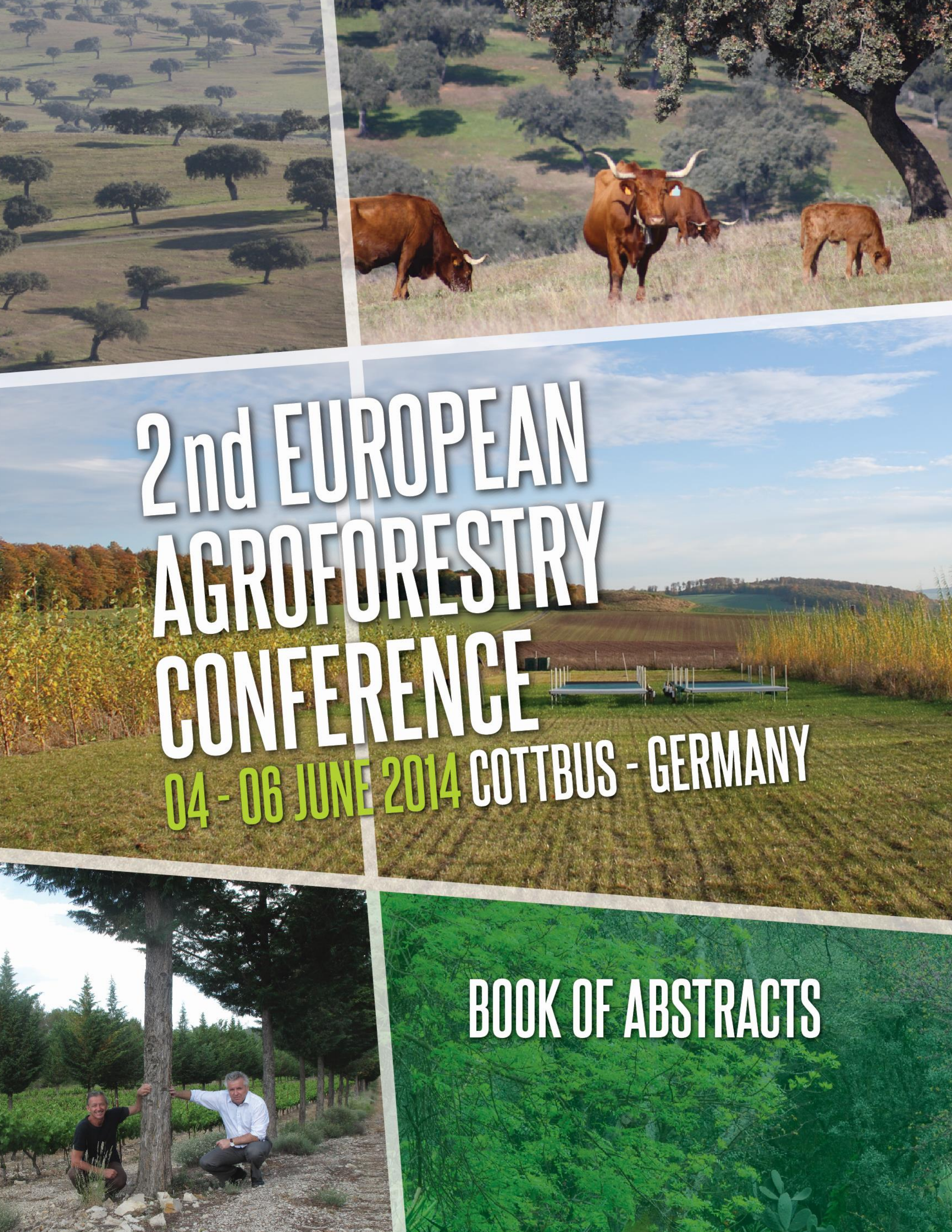

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