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SIMPLE MODELLING OF BIOMASS INCREMENT IN SHORT ROTATION POPLAR COPPICE

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Abstract. This paper deals with relationship between selected meteorological variables and above-ground biomass increment in short rotation poplar coppice using multiple linear regression method. This approach provides a simple top-down model estimating the aboveground biomass growth rate from amount of radiant energy which short-rotation coppice absorbs, precipitation totals, mean temperature totals and actual / reference evapotranspiration ratio. Examined data set contained vegetation seasons 2008 and 2009. Our results revealed a statistically significant relationship with adjusted coefficients of determination reaching R_{adj}^2 = 0.90 in 2008 and R_{adj}^2 = 0.58 in year 2009 respectively.

Introduction

As the prices of fossil fuels gradually rises and fossil fuels itself slowly heads toward its irreversible depletion, fast growing trees grown under short rotation system might play an important role as a renewable energy source in future energy mix. SRC plantations are also well known for its ability to sequester and store atmospheric CO_2. Its potential consist in high productivity rates immediately after planting, high efficiency of wood accumulation in relation to total biomass produced, rapid and reliable sprouting when coppiced and ability to supply potentially profitable agricultural crop on redundant agricultural land, not to mention its positive affecting of surrounding landscape. Typical plantation is based on high-yielding woody trees culture, such as Poplar, Willow and Eucalyptus genera. Trees are grown as a dense woody coppice, harvested each3 – 7 years and such plantation can provide profitable energy crop for 15 – 30 years. Mean annual increments range between 10 – 15 t of dry matter (DMT) (Kauter *et al*. 2003. Poplar clone J-105 (*Populus nigra* × *Populus maximowiczii*) provides in the first cycle under conditions of Czech-Moravian highland mean annual increment close to 14 DMT (dry matter ton), with no irrigation, fertilization or herbicides applied (Trnka *et al.,* 2008). For the following cycles nutrients has to be replenished to sustain high productivity. The key question for establishing new SRC plantation is achievable yield, depending on particular site characteristic and climate. From that reason is biomass estimation very important for future SRC extension, unfortunately usually requires some destructive sampling. Combination of allometric relationships based on volume index (height x diameter squared) with several meteorological variables provides a simple multi regression model for accurate and non-destructive estimation of stem biomass.

Data and methods

Examined data comes from poplar based (clone J-105) high-density experimental SRC plantation near Bystřice nad Pernštejnem (Czech Republic, 49° 32´ N, 16° 15´ E, 530 m a.s.l., mean annual precipitation sum 580.6 mm), containing substantial part of vegetation seasons 2008 and 2009. Hardwood cuttings were planted in a double row design with inter-row distances of 2.5 m and spacing of 0.7 m within rows accommodating a density of 10.000 trees/ha. Soil conditions are representative to the wider region with deep luvic cambisol with limited amount of stones in the profile. The site itself is situated on a mild slope of 3° with an eastern aspect and is generally subject to cool and relatively wet temperate climate (Trnka *et al*., 2008). Biomass increment in 2008 was measured by an array of 15 mechanical (DB20) and 3 automatic (DRL26) dendrometers (EMS Brno, Czech Republic), supplemented by other 20 DB20 and 1 DRL26 in 2009. Mechanical dendrometers were monitored manually in time span of one week. Calculation of gradual totals of AB increments per hectare in week step consisted of several phases further described in Fischer, 2010 (submitted). Necessary meteorological variables as well as ET_a by Bowen ratio-energy balance method were measured from 14 m high mast (EMS Brno, Czech Republic), placed in the centre of plantation. Precipitation amounts were monitored by tipping bucket rain gauge MetOne 370 (MetOne Instruments, USA), placed next to the poplar plantation. Meteorological data such as global solar radiation (GR), daily mean temperature (T), precipitation (P) were sorted into totals corresponding with totals of AB increments (AB_i) measurement steps. Moreover, a ratio between daily mean ET_a and ET_o (ET_a/ET_o, calculated according FAO Penman-Monteith equation) was incorporated into regression as additional parameter expressing possible water stress. Finally a relationship between biomass increment (dependent variable) and global radiation, temperature, precipitation totals and ET_a/ET_o ratio (independent variables) was processed by multiple regression method.

Results and discussion

The relationship between measured and modelled aboveground biomass increments is expressed here with equation: $AB_i = - 0.2518 + (0.0092*GR_{sum}) + (0.0090*P_{sum}) - (0.0032*T_{sum}) - (0.0223*ET_a/ET_o)$. Fig. 1 depicts relationship between measured and modelled aboveground biomass increments in year 2008. Linkage is expressed by regression equation y = 1.027x (R_{adj}^2 = 0.90, n = 12), showing good agreement between modelled and measured results.

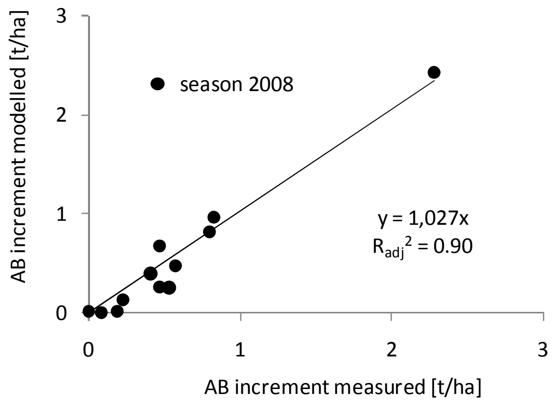

Figure 1. Relationship between aboveground biomass increment [DMT] modelled and measured in season 2008.

Fig. 2 shows relationship between AB biomass modelled and measured for year 2009. Regression equation describes foregoing linkage as y = 0.986x (R_{adj}^2 = 0.584, n = 23). Considering both years 2008 and 2009, there is narrower linkage in the year 2008 with R_{adj}^2 = 0.90 compared to lower 0.58 in 2009.

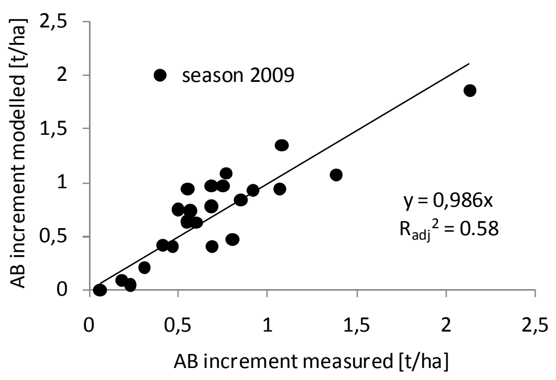

Figure 2. Relationship between aboveground biomass increment [DMT] modelled and measured in season 2009.

The correlation in 2009 was more often based on shorter time span between particular integrations (n = 12 for year 2008, compared to n = 23 for year 2009) and thus the other factors such as the root-shoot carbon allocation and the stem shrinking and swelling linked with precipitation influenced the DBH fluctuation and thus affected more the estimated biomass increments in year 2009. Taking into account the precipitation totals in vegetation seasons (1. 4. – 30. 9.) 2008, which reached only 313.2 mm and 2009 with 510.5 mm, compared with average precipitation sum for same the time period (359.6 mm, long-term average 1961 – 2000), there is an apparent deviation in year 2009, which was exceptionally wet (in 2009 the annual precipitation total reached 845.3 mm, compared with 580.6 mm, according long-term average precipitation 1961 – 2000). Higher precipitation most likely affected the lower R_{adj}^2 = 0.584 in 2009 more than the other meteorological variables, whose totals were in years 2008 and 2009 more or less comparable.

Conclusions

Biomass production generally signifies direct consequence of photosynthesis rate - the primary production process, driven by solar energy. This relationship is mechanistically probable, but it is also well established empirically, since number of experiments provided convincing demonstration that it is possible to establish a linear relationship between biomass production, and the amount of energy absorbed by forest stands. Adding other variables such as precipitation and temperature totals or parameter (ET_a/ET_o ratio) expressing level of possible water stress into multiple regression equation brings more accurate modelled results.

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