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IDENTIFYING THE FAO-56 CROP COEFFICIENT FOR HIGH DENSITY POPLAR PLANTATION: THE ROLE OF INTERCEPTION IN ESTIMATION OF EVAPOTRANSPIRATION

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Abstract. Crop coefficients (K_c) provide simple way to estimate crop evapotranspiration (ET_c) from weather-based reference ET_0 values. This study attempts to address the lack of information on K_c and consequently on ET_c of poplars growing for bio-energy use. The first results indicate, that the annual ET_c of poplars is comparable to the ET_0 and explain how the excessive rates are linked with the interception.

Introduction

High density short rotation coppice (SRC) based on willow and poplar species has recently became promising source of bio-energy in EU countries. As their economical performance is directly related to the biomass yields, the level of yields is closely linked to the whole stand water consumption. Therefore, the selection of the new sites should especially take into account the hydric regime and the soil water holding capacity. At this point it is obvious that from a specific degree, the economic efficiency tends to be in opposite to the ecological sustainability, and high yielding large scale SRC cultures could in some areas possibly increase a risk of depleting the water resources in the landscape. Allen et al. (1998) proposed the FAO-56 methodology for estimation the water use of a wide range of agriculture crops, fruits and trees. The approach is based on the Penman-Monteith equation applied for the so called "reference crop" with a rigorously defined parameters; 0.12 m high grass with albedo 0.23, surface resistance 70 s m^{-1} and sufficient water supply. This reference evapotranspiration (ET_0) is subsequently related to the water non-limited evapotranspiration of different crops (ET_c) resulting in the crop coefficients (K_c) which reversely enable to estimate the potential (water non-limited) ET_c of specific crop wherever the ET_0 can be calculated. Although, the FAO-56 is in common use in agriculture research practise, there is very low number of published results on the K_c for willow and poplar species growing for energy use. Chronologically, Person et al. (1995) used modelled ET_c of willows related to the reference Penman open water evaporation for Sweden. Hall et al. (1998) compared transpiration of willow and poplars using sap-flow technique with ET_0 in Great Britain and Germany. Guidi et al. (2008) investigated FAO-56 K_c of both species, poplars and willows, under fertilized and non fertilized treatments growing in the field lysimeters in Italy. Since these studies carried out across various geographic conditions used different technique of determining ET of SRC and even different concepts of ET_0, it is very difficult to make general conclusions applicable for condition of Central Europe.

Following this purpose, the main goal of this work is to determine the crop coefficient of poplar cultures, usually grown in the Czech Republic, as a possible guideline for their better site selection.

Data and methods

The site itself, the investigated poplar plantation (*Populus nigra* x *P. maximowiczii*) and the complex measurement scheme were described in detail e.g. in Fischer et al. (2010). From June 2008, the Bowen ratio energy balance (BREB) measurement campaign has started to assess the actual evapotranspiration (ET_a) of the poplar stand. Further, similar BREB system was placed at the adjacent reference grass, which is additionally equipped with wind speed and direction measurement and serves as classical meteorological station, from which the daily values of ET_0 were calculated according to Allen et al. (1998). Measured ET_a can be described by following expression:

$$ET_a = K_s\ K_c\ ET_0$$

where K_s (0–1) is water stress coefficient describing the effect of water stress on crop transpiration. Assuming that the root zone of poplars reaches bellow 0.5 m in depth and that 50% of total available water is readily available, there were found no considerable water stress during 2009 and 2010 based on the soil moisture measurements.

Therefore for simplification, the K_s during the both of the investigated years were set to one and the measured ET_a could be stated as the non-limited potential crop evapotranspiration (ET_c):

$$ET_a = ET_c$$

This simplification doesn´t take into account soil evaporation and, as will be further shown, nor the interception. To deal with this uncertainty, Allen et al. (1998) recommended to separate the ET into transpiration and soil evaporation and use so called dual crop coefficient or use just the single crop coefficient based on measurements of longer period (at least 10 days). Another assumption of single K_c is that the soil wetting is regular within the averaging period, which is sporadically met in natural conditions without irrigation. However, taking into account only two growing seasons of measurement, we used ten-days averaging period to derive K_c as follows:

$$K_c = \frac{ET_c}{ET_0}$$

This study evaluate two contrasting years with regards to the stand architecture. Firstly, eighth year of the first rotation with mean tree height 12 m at the end of the season and completely closed canopy (2009). Secondly, the first year of second rotation where stumps started to resprout in the half of June, mean tree height was 2 m at the end of the season, and canopy was open during the whole season (2010).

Results and discussion

Before the creating ten-day integrated values of K_c, the diurnal course was analyzed to reveal the short time fluctuation of K_c which is depicted in Fig. 1.

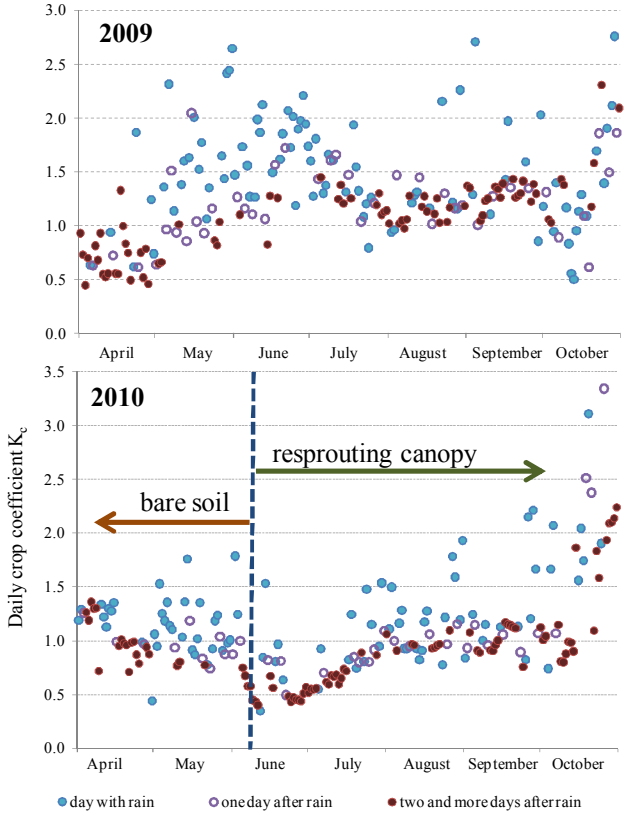

Figure 1. Time course of daily K_c in 2009 and 2010. Different colours indicate the differences between the days with and days after precipitation events.

It was hypothesized that the days with precipitation event will show higher values of ET_a compared to days with dry surfaces. Therefore, the particular days were separated into three groups – day with rain, day after rain (some precipitation occur in the late afternoon or evening and has impact on the following day), and two and more days after rain. It is obvious, that the periods when the trees are unfoliated are strongly influenced with the soil evaporation which is the most intensive when the soil surface layer is completely wet and is not shaded by leaves. After the foliating the transpiration became the major part of ET_a and soil evaporation tends to be negligible. However, our results show that the role of interception on K_c is substantial. Rather than take longer averaging period or different K_c for wet and dry surface separately, we suggest to exclude the data from days with wet surfaces and thus establish the "dry surface" K_c. This K_c should be multiplied with ET_0 to obtain ET_c. Finally, in the case of rainy periods, the value of potentially intercepted water defined by the precipitation amount and the canopy interception capacity should be summed with the above given ET_c and limited with the amount of available energy to obtain the estimation of total stand evapotranspiration.

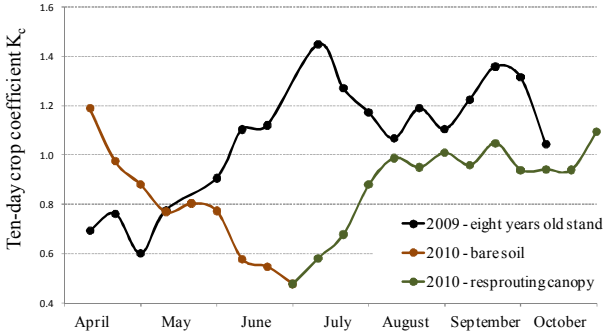

Figure 2. Time course of ten-day averaged K_c in 2009 and 2010 determined by leaving out the days with and days after precipitation events.

As it is shown on the Fig. 2, "dry surface" K_c ranged from 0.47 to 1.45 during the both of the investigated years with mean 1.07 and 0.85 for 2009 and 2010 respectively.

Conclusions

According to our results, evapotranspiration of poplar plantation with no application of fertilizers and satisfactory yield level shows comparable, and in the case of resprouting canopy even lower, rates of ET_c as those of the FAO-56 hypothetical grass surface. The higher rates were recorded only after rain, when the interception plays important role. On the other hand, the effect of interception is not included in the ET_0 calculation and in real, measured ET_a of grass shows also higher rates during the time of wet surface. Moreover, the values of high K_c as an effect of interception are usually typical during low insolation and thus low ET_0. These facts doesn´t confirm the high water demand reputation of poplar plantations.

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