Replies to the comments by F. Hupet, M. Vanclooster on 'Water flux estimates from a Belgian Scots pine stand: a comparison of different approaches'

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1. Introduction

When studying or quantifying any type of process or property, a correct use of the methodology and/or the instrumentation is of utmost importance. Probably no single instrument, technique, model or method provides the perfect solution to quantify, e.g. the water flux of a forest (or of any other ecosystem type). As was clearly indicated on page 231 of the Meiresonne et al. (2003) paper, the objectives of our paper wete: (i) to compare different methods and techniques; (ii) to identify and evaluate the strengths and shortcomings of each approach; and (iii) to try to quantify the water flux between the forest ecosystem and the atmosphere. Our objectives neither included the validation of the WAVE (Vanclooster et al., 1994) or SECRETS (Sampson and Ceulemans, 1999; Sampson et al., 2001) model, nor the promotion or evaluation of one or another method, but a relative comparison. After our study, we still believe that there is no perfect technique or model or approach to obtain the water flux of the forest. The discussion should be focused on how to further improve our techniques, models and instruments.

2. Discussion

2.1. Estimation of the potential crop evapotranspiration

In the manuscript, we used climatological data measured on top of the measuring tower, at a height of 39 m, which means 18 m above the average canopy height. These meteorological data are used to calculate the potential evapotranspiration of a reference surface (ET_0), according to the Penman-Monteith equation (Monteith, 1965). The reference surface concerned here is short cut grass with a roughness length of 0.0015 m, a zero plane displacement of 0.08 m and canopy resistance of 70 s m^{-1}.

To calculate the potential crop evapotranspiration of the coniferous stand at the experimental site of Brasschaat, we multiplied the ET_0 with a crop factor, the *Kc* value. Monthly *K,* values were obtained by dividing the monthly means of the potential evapotranspiration of coniferous forest by those of grass. These potential evapotranspiration data were calculated by Gellens-Meulenberghs and Gellens (1992) with data from a standard weather station at about 40 km from the experimental site (Mol), using a 20-year reference period (1967-1986). Their calculation of the potential evapotranspiration is based on the approach of Penman (1948) and Bultot and Dupriez (1974).

The base of both calculation methods for potential evapotranspiration is different: the Penman-Monteith equation incorporates directly the impact of the vegetation cover (grass), whilst the approach of Penman (1948) and Bultot and Dupriez (1974) combines the open water surface evaporation with a transfer factor expressing the difference between the energy balance of the crop or canopy cover with that of the open water surface. Applied for grass as a crop cover, the Penman-Monteith equation produces values that differ from the approach followed by Gellens-Meulenberghs and Gellens (1992), sometimes smaller (occuring in winter time), often higher (strikingly in summer time with an average of approximately 0.5 mm d^{-1}) (Hupet and Vanclooster, 2003). Direct comparison or combination of absolute outputs of evapotranspiration values derived from these two different methods could lead to inaccurate conclusions.

2.2. *Use of the crop factor*

In this study, the approach of Gellens-Meulenberghs and Gellens (1992) is used to provide in the potential evapotranspiration of both grass and coniferous forest, using identical meteorological data and an identical calculation method (Penman, 1948; Bultot and Dupriez, 1974). It can be assumed that the potential evapotranspiration of coniferous forest calculated by Gellens-Meulenberghs and Gellens (1992) will have the tendency to be underestimated (data not available) in comparison with the Penman-Monteith approach, as it is the case for grass (Hupet and Vanclooster, 2003). As no specific crop factors for forest conditions exist, the crop factor *K,* is obtained by the division of the potential evapotranspiration of coniferous forest by those of grass. Dividing both underestimated values derived from identical methods lead to a relative value that expresses the relationship between both crop covers under identical conditions. It reflects the impact that can be attributed to the land use of coniferous forest in comparison to grass, which is the rule of the crop factor *Kc*. The *K*, factor was calculated with data from a weather station in the vicinity of the experimental site, using a 20-year reference period. Bias generated from the use of *Kc* values obtained by this procedure cannot be excluded, but will be of minor impact.

2.3. *The reference potential evapotranspiration (ET_0)*

For the calculation of the reference potential evapotranspiration (ET_0), we used in this study the Penman-Monteith equation (Monteith, 1965), as recommended by the panel of FAO experts in May 1990 as a new standard (Allen et al., 1998). The reference crop is a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m-^{1} and an albedo of 0.23, closely resembling the evaporation of an extension surface of green grass of uniform height, actively growing and adequately watered. Hupet and Vanclooster (2003) compare the calculation of the reference evapotranspiration making use of this standard method (ET_0) with the calculation of the reference evapotranspiration of a grass surface (ET•'"') by the method of Gellens-Meulenberghs and Gellens (1992) for a climatic data set provided by a meteorological station in Louvain-la-Neuve, at about 90 km of the experimental site of Brasschaat. The latter method shows an underestimation of ET_{grass} in 90% of the cases, with a mean square error equal to 0.49 mm d-^{1} (Hupet and Vanclooster, 2003). This can lead to a serious underestimation of the atmospheric vapour demand and the water supply by the crop.

2.4. Source of meteorological data

We were aware of the fact that the location of our **measurements could generate different climatic conditions** than those used in the Penman-Monteith **equation and those used to obtain the *Kc* values.** However, no nearby meteorological station with data at the reference height was at our disposal. Wind **speed is recognised as being an important driving force of the potential evapotranspiration. To have an** idea of the potential influence of the measuring height on wind speed, we compared mean monthly values of wind speed of the standard KMI station at Deurne (distance 10 km from the experimental site of Brasschaat) with the wind speed measurements at Brasschaat, 39 m above ground level, 18 m above canopy level. At the meteorological station of Deurne, the wind speed is measured at 10 m above the ground. The results of this comparison can be found in Fig. 1.

As can be observed in Fig. 1, mean monthly wind speed is always (except in September 1997) slightly higher (mean over 1997 and 1998: +0.7 m s^{-1}) at 10 m height at a level, open terrain at Deurne, in **comparison to the tower measurements in Brasschaat.** The slightly reduced wind speed above the forest canopy can be explained by the roughness of the canopy cover as the aerodynamic roughness of a forest is much greater than that of short cut grass.

The use of wind speed data measured at 39 m above ground level and 18 m above canopy level can, **therefore not be a source of overestimation of the potential evapotranspiration.**

In agrometeorological stations, climatic data are typically measured at 2 m height. The meteorological **station of Deurne is an aeronautic station where wind** speed is commonly measured at 10 m height above the ground surface, which is prescribed as the standard in the Manual on the Global Observing System (GOS) (World Meteorological Organization, WMO No. 544, Part III, 2.4.4.7). Due to the close vicinity of the meteorological weather station of Deurne, with similar relief and exposure to the dominant winds, **we preferred therefore to use the data measured on top** of the tower, located at the experimental site itself. We are convinced that those data reflect better the local **climatic fluctuations and occasional circumstances.**

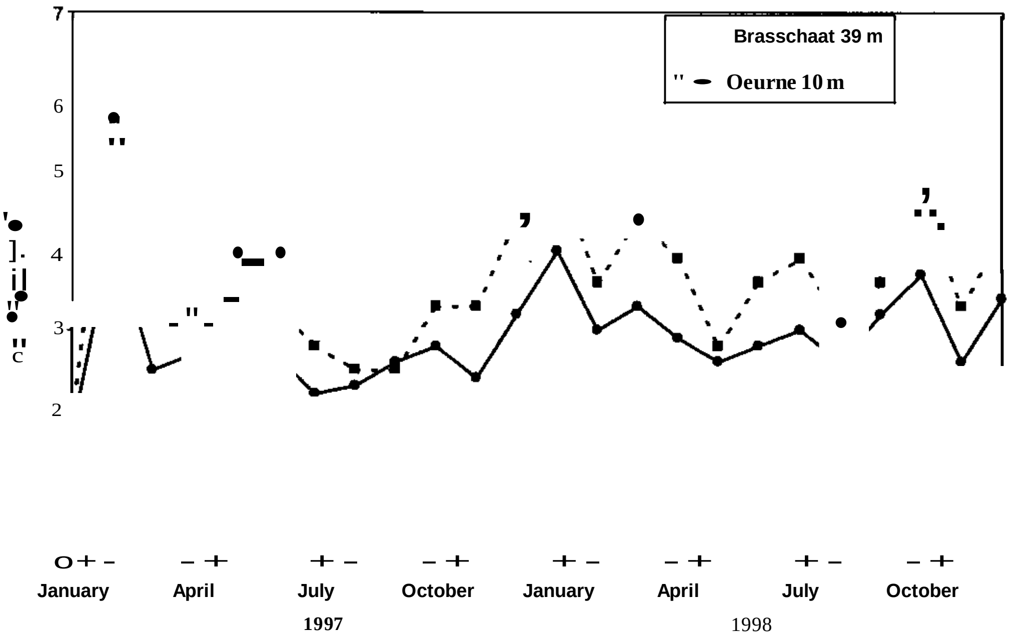

Fig. 1. Comparison between wind speed measured at a height of 39 m at the experimental site of Brasschaat and wind speed measured at a height of 10 m at the standard KMI station at Deurne (distance 10 km from the experimental site of Brasschaat): mean monthly values of wind speed for 1997 and 1998.

3. Conclusions

We are convinced that it would be preferable to use consequently the same calculation methods in all direct and absolute comparisons of data of potential evapotranspiration. However. as no *K,* values are at our disposal from literature, the use of *Kc* values derived from a deviant method can be sound, as *Kc* values are relative values, the ratio of data originating from the same method.

We prefer the use of the Penman-Monteith equation (Monteith, 1965), as recommended by the panel of FAO experts in May 1990 as a new standard (Allen et al., 1998) for the calculation of the potential evapotranspiration. Climatic data to calculate potential evapotranspiration are preferably generated at the standard height of 2 m. Wind speed is recognised as being an important driving force of the potential evapotranspiration. Comparison of the wind speed at 39 m above ground level, 18 m above canopy level with a nearby standardised weather station at 10 m height, reveals wind speed data that are slightly lower on top of the tower and therefore cannot be a source of overestimation of the potential evapotranspiration.

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