Analysis of the impact of meteorological characteristics on the transpiration simulated in SIBYLA growth simulator

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Abstract

The research goal was to analyse the impact of meteorological characteristics on transpiration during the growing season of 2013 simulated in SIBYLA growth simulator. The main factors affecting simulated transpiration are global radiation, wind speed, precipitation and air temperature. The analysis of their relationship to the differences between the modelled and measured transpiration showed that the model is able to reflect the impact of precipitation, wind speed, and global radiation on simulated transpiration. The highest correlation was found between the air temperature and the differences of the modelled transpiration to measured values.

Keywords: growth simulator, SIBYLA, transpiration, meteorological characteristics, correlation

Introduction

Growth models represent important tools that can improve our understanding of growth processes because they attempt to mathematically describe and quantify the system and its behaviour. Hence, they are simplified, purpose-oriented representations of reality. Models are developed on the base of existing knowledge and information about the examined system gathered so far, and their aim is to verify the accuracy of the known facts, to perform the predictions, or to confirm the forecasts (FABRIKA and PRETZSCH 2011). In

Slovakia, the development of SIBYLA forest growth simulator began in 2002. The simulator belongs to semi-empirical individual tree growth simulators of forest ecosystems. Since at present process-based models undergo the most dynamic development, currently the process-based downscale of the model is under the development (FABRIKA and MACKOVÁ 2013). Unlike empirical models that are based on statistical description of the relationships between specific parameters, process-based models try to predict the final growth by describing the background processes driven by external conditions and interactions between the processes (LANDSBERG 2003). To be able to describe physiological processes in plants, a number of different algorithms need to be defined including absorption of solar radiation, pedotransfer functions, hydrological balance, stomatal conductance, transpiration, leaf energy balance, photosynthesis, respiration, etc. A major advantage of process-based models over empirical ones is their more general validity (FABRIKA and PRETZSCH 2011). Hence, using of process-based models should lead towards more precise results (ZEIDE 2003). However, so far not all of the processes are sufficiently understood and have been mathematically described. Therefore, the best solution seems to be the continual transition from empirical through hybrid to process-based models (MÄKELÄ *et al.* 2000).

The research goal of the presented paper was to analyse the impact of meteorological characteristics on transpiration during the growing season of 2013 simulated in SIBYLA growth simulator. Transpiration as a productive evaporation is the most important physiological process affecting tree growth. Climatic conditions are considered crucial external factors influencing transpiration. Thus, in the presented work we aimed at analysing the impact of meteorological conditions on transpiration simulated in SIBYLA growth simulator.

Material and methods

The data were obtained from the research plot situated in Bienska valley, forest stand No. 359. The area of the research plot is 80 x 92 m. All trees within the research plot were measured; calliper was used to measure their diameter and

Vertex was used to measure their crown height and height to crown base. Field – Map technology was used to measure the position of the trees and their crown projection.

On these six trees we also measured transpiration flow using EMS51A system connected to 16-channel datalogger RailBox V16.

Meteorological data were measured using EMS automatic meteorological station. Air temperature, relative air humidity, and global radiation were recorded at 5 minutes intervals. Precipitation was recorded continuously at 1 m above ground. Wind speed data were obtained from MetOne 034B anemometer installed at the plot.

In addition, from soil probes situated within the plot we took the data about soil volumetric water content, soil depth, and soil structure needed for the calculation of pedotransfer functions. Soil moisture was measured in three depths (15, 30, and 50 cm) and the data were stored at 60 minutes intervals.

A more detailed description of the equipment and the measurement methodology is given in SITKOVÁ *et al*. (2014).

The data about the individual trees comprising tree diameter, height, crown projection, and tree position were processed and uploaded in SIBYLA growth simulator. In the module called Physiologist, we simulated hourly values of transpiration during the growing season using the hourly data about global radiation under crown canopy, air temperature, air humidity, precipitation, wind speed and volumetric soil water content following the methods described in MACKOVÁ (2014). For the simulations we also used the information about soil characteristics, elevation, phenological curve (the beginning and the end of the photosynthetic activity, and the beginning and the end of the full photosynthetic activity).

This paper focuses on the regression analysis between the climatic conditions and the differences of the modelled to measured transpiration values. From six trees we chose two trees (tree 4 and 6), for which the simulated transpiration best reflected the impact of the selected meteorological characteristics: global radiation (GR), wind speed (WS), precipitation (P), and air temperature (AT).

Results and discussion

Linear regressions between the differences of the modelled transpiration to measured transpiration flow and climatic characteristics, i.e. global radiation, wind speed, precipitation, and air temperature, are shown in Fig. 1. The blue line represents an ideal state when the modelled and the measured transpiration are equal. The red line is the calculated linear regression between the transpiration differences and the particular climatic characteristic. From Fig.1 it is clear that the modelled transpiration is overestimated if the values of global radiation, wind speed and air temperatures are small, and when they increase above a certain value the model begins to underestimate transpiration. In case of precipitation we see that the slight and nonsignificant underestimation of transpiration (Table 1) decreases as the amount of precipitation increases. The results of the analyses showed that the correlations between precipitation and the differences of the modellled to measured transpiration were lower in comparison to other climatic characteristics (Table 1). This indicates that the model is able to reflect the effect of precipitation on transpiration. Precipitation significantly affects transpiration, because it influences soil water content as proven by a number of papers, e.g. BOSCH *et al.* (2014), FORD *et al.* (2008), NASR and MECHLIA (2007), ČERMÁK and PRAX (2001). CLAUSNITZER *et al.* (2011) found out that the fluctuation of transpiration depends more on the number of rainy days than precipitation totals.

From the results in Tab. 1 we can see that the model of transpiration is able to reflect the impact of precipitation best (R = 0.004 and 0.012 for tree No. 4 and 6, respectively), followed by wind speed (R^2 = 0.092 and 0.191) and global radiation (R^2 = 0.140 and 0.142). The impact of temperature on transpiration seems to be least reflected in the model because the differences between the modelled and measured transpiration are significantly correlated with air temperature (R^2 = 0.365 and 0.411). The importance to include wind speed and wind direction in the transpiration model was proven by DEKKER *et al*. (2001), who showed that the results of the transpiration model significantly improved after wind speed and wind direction were incorporated in the model.

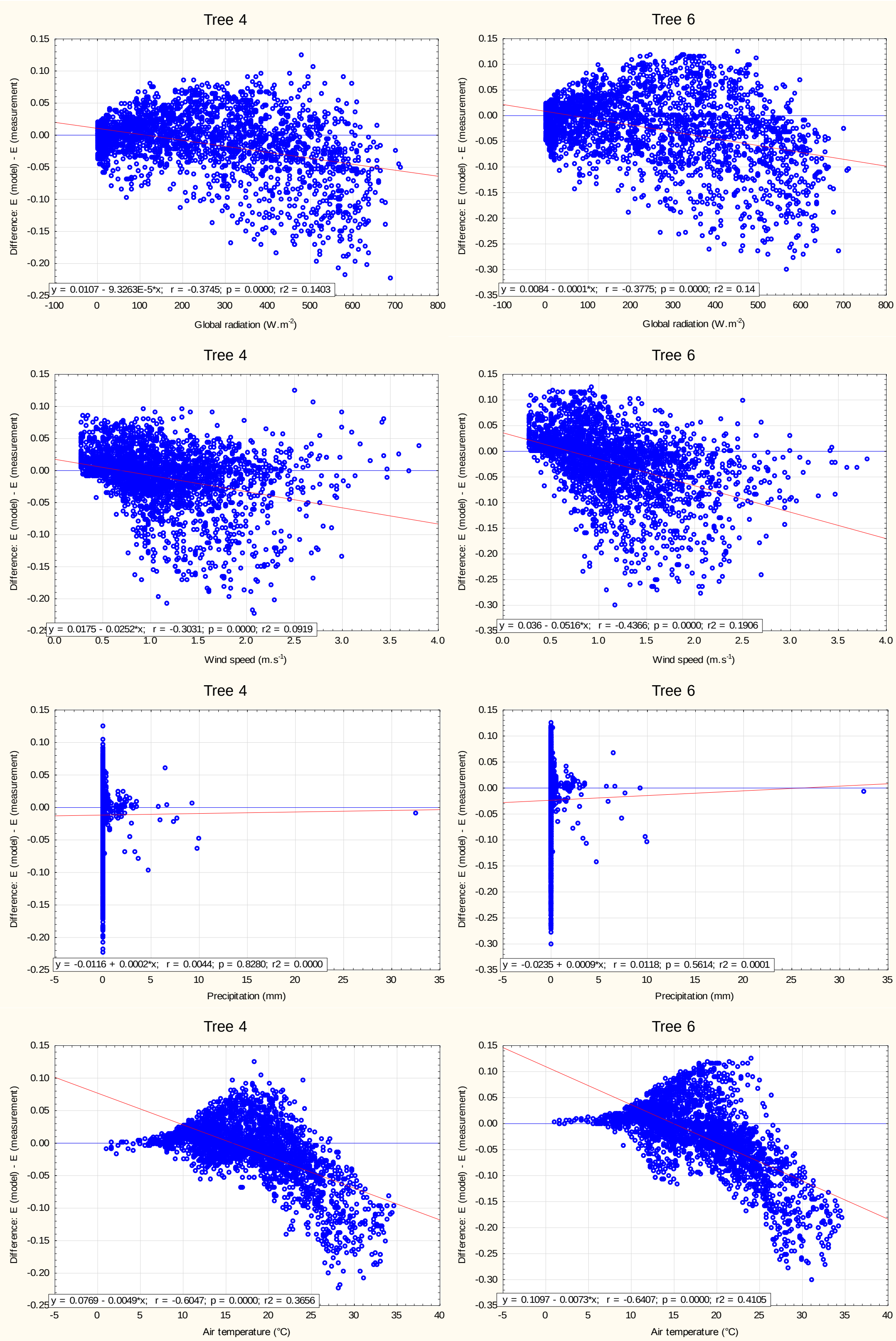

Fig. 1 Linear regression between the differences of modelled transpiration to measured values and climatic characteristics

Tab. 1 Statistical evaluation of linear regression between the climatic characteristics and the differences of modelled transpiration to measured transpiration flow

Climatic characteristic	Tree No.	R	R^2	Standard error of estimates	F	p	Significance level ** 99%
GR	**4**	-0.375	0.140	0.044	396.121	0.000	**
GR	**6**	-0.378	0.143	0.062	403.615	0.000	**
WS	**4**	-0.303	0.092	0.045	245.631	0.000	**
WS	**6**	-0.437	0.191	0.061	571.897	0.000	**
P	**4**	0.004	0.000	0.048	0.047	0.828	
P	**6**	0.012	0.000	0.067	0.337	0.561	
AT	**4**	-0.605	0.366	0.038	1399.404	0.000	**
AT	**6**	-0.641	0.411	0.052	1690.725	0.000	**

Conclusion

The assessment of the impact of climatic characteristics incorporated in the transpiration model on the simulated transpiration showed that the model can best reflect the influence of precipitation followed by wind speed and global radiation. The highest correlation was found between air temperature and the differences of modelled transpiration to measured transpiration flow indicating that the impact of temperature on transpiration is not sufficiently addressed in the model. The causes behind this result need to be thoroughly examined in the future. Nevertheless, the results showed that the model is able to elastically react on the changes of climatic conditions that are correctly transformed into modelled transpiration.

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Summary

Príspevok sa zaoberá hodnotením vplyvu vybraných meteorologických charakteristík na transpiračný prúd buka lesného (*Fagus sylvatica* L.) počas vegetačnej sezóny roku 2013. Analýza bola vykonaná v prostredí rastového simulátora SIBYLA. Transpiračný prúd dospelých jedincov buka bol na výskumnej ploche meraný pomocou metódy tepelnej bilancie, zariadením EMS51A. Medzi najdôležitejšie vonkajšie faktory, ktoré ovplyvňujú transpiráciu patria globálna radiácia, rýchlosť vetra, zrážky a teplota vzduchu. Pri posudzovaní vplyvu týchto faktorov na diferencie hodnôt modelovej a meranej transpirácie sme zistili, že model pri simulovaní transpirácie najlepšie odráža vplyv zrážok, rýchlosti vetra a globálnej radiácie. Najmenšia závislosť bola zistená medzi diferenciami odchýlok modelu transpirácie od reality a teplotou vzduchu.

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