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Estimates of net ecosystem productivity at Jastrebarsko forest eddy covariance site in comparison with other forest sites in FLUXNET

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Background

Forests play one of the key roles in the global carbon cycle. Measurement of forest–atmosphere exchange of various greenhouse gases, and CO_2 in particular, is important for understanding the relations between forest growth and key environmental drivers (water, light, temperature), or disturbances (harvest, fire, etc.).

Net ecosystem productivity (NEP) of forest can be estimated with eddy covariance (EC) method used for measuring net ecosystem exchange (NEE; NEP= - NEE).

Alternatively, NEP can be estimated as a difference between net primary productivity (NPP) and heterotrophic respiration (Rh; NEP=NPP-Rh). The NPP can be obtained from dendrometric measurements of tree growth, while Rh can be estimated from soil respiration measurements.

Both the annual sum and seasonal pattern of NEP exhibit large variability for different forest ecosystems and great research efforts are needed to quantify them (Luyssaert *et al* 2007).

FLUXNET network presents a most usefull platform for collecting and sharing data from flux research (Baldocchi *et al* 2001). However, not all forest types are represented equally in the FLUXNET database. Therefore, it is important to extend the FLUXNET database with data from other forests, such as forests of pedunculate oak (*Quercus robur* L.) in Croatia when such data become available.

Aim of the research

The aim of the research was to estimate the annual NEP of 35-year-old, managed, pedunculate oak (*Quercus robur* L.) stand of Jastrebarsko forest (table 1), using two independent methods: a) eddy covariance; and b) combination of dendrometric measurements of growth, litter production and soil respiration. Final goal was to compare the NEP estimate for Jastrebarsko forest site with NEP's of forest and woodland sites in the FLUXNET database.

Materials and Methods

Eddy covariance (EC), soil respiration (SR) measurements and flux partitioning for Jastrebarsko forest site are described in Marjanović et al. 2011 a & b. In short, the EC tower was installed in September 2007 (fig. 1a) to assess mass, momentum and energy ecosystem exchanges using a sonic anemometer (81000V, Young, USA) and an open path infra-red gas analyzer (LI-7500, Li-Cor, USA) mounted at 23 m above ground. The applied methodology was based on the EuroFlux protocol (Aubinet et al. 2000) with a further adjustment such as the WPL correction (Webb et al., 1980). Post processing was performed with EdiRe Data software (University of Edinburgh) and quality assessment and quality control analysis have been applied according to Foken and Vichura (1996). A gap-filling procedure was applied to obtain daily fluxes (Reichstein et al. 2005) for missing data. CO_2 concentrations were measured every 6 minutes at 1, 2, 4, 8, 16, 23 m above the ground to assess the storage term within the canopy and the real NEE was then computed according to Aubinet et al. (2000).

Soil respiration (SR) was measured every four hours during the whole year using an automated soil respiration monitoring system (fig. 1c). A detailed description of the system is reported in Delle Vedove et al. (2007). Soil flux gap filling and flux partitioning was performed using the model proposed by Reichstein et al. (2003). Based on data from literature (Hanson *et al*. 2000, Tang & Baldocchi 2005, Subke *et al*. 2006) we estimated Rh:SR ratio to 0.50.

Dendrometric NPP was estimated using from 24 permanent plots (fig. 1b) within the footprint. Tree diameter at breast height (dbh) and tree height were measured at the beginning of each vegetation (table 1 shows data at the beginning of 2008). For the assessment of weekly NPP stem circumference increment was measured weekly on 640 dendrometer bands for measurement. Species specific basic wood densities, root-to-shoot (R/S) ration of 0.257 and wood carbon content of 0.50 were used in NPP calculations from weekly wood volume increments. Twelve circular litter-traps (d=45 cm) were used for the assessment of leaf and litter production.

FLUXNET[(+)] database (http://www.fluxdata.org) was accessed in February 2011 with the aim to acquire NEP data (i.e. NEE) for comparison with NEP of Jastrebarsko forest. Values of NEE were obtained that are available under Fair Use Policy (Data Release: 2+BADM (preliminary), data as of: 2008-02-16). Sites were filtered according to IGBP vegetation type for forest or woodland vegetation types (IGBP types: DBF, DNF, EBF, ENF, MF and WSA) resulting with 139 sites. Mean annual NEP from those sites were used for comparison with Jastrebarsko forest (fig. 4).

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a)


b)


c)

Figure 1. a) Eddy covariance tower in Jastrebarsko oak forest (N45°37'10", E15°41'16''); b) One of 24 plots for estimating NPP with dendrometric measurements and litter-traps; and c) The chamber of the soil respiration measurement system.

Results

Table 1. Structure of young oak stand in the footprint of eddy covariance station (dbh lower limit for measurement was 5 cm, n=24 sampled plots, shown values are means with standard errors).

Tree species	Stand structure[(a)] in the footprint (Mean ± Std. err.)							
	Living trees					Standing snags		
	N (n ha^{-1})	G (m^2 ha^{-1})	V (m^3 ha^{-1})	d_g (cm)	h_g (m)	N (n ha^{-1})	G (m^2 ha^{-1})	V[(b)] (m^3 ha^{-1})
Q. robur L.	575 ±63	12.4 ±1.3	117.1 ±13.6	16.5	17.7	229 ±48	1.5 ±0.3	10.2 ±2.1
C. betulus L.	426 ±122	3.5 ±1.5	26.8 ±14.4	10.2	13.9	25 ±17	0.2 ±0.2	1.7 ±1.4
A. glutinosa Gearnt.	380 ±93	6.4 ±1.3	51.6 ±10.8	14.6	16.9	39 ±12	0.4 ±0.2	3.0 ±1.4
F. angustifolia L.	159 ±50	2.7 ±0.7	19.2 ±5.0	14.5	16.4	12 ±5	0.1 ±0.1	0.6 ±0.4
Other tree sp.	35 ±17	0.3 ±0.1	2.6 ±1.2	11.1	12.1	3 ±3	0.1 ±0.1	0.7 ±0.7
Total	1575 ±116	25.2 ±1.0	217.3 ±10.9	14.2	16.6	308 ±48	2.3 ±0.3	16.3 ±2.2

N – number of trees, G –basal area, V – wood volume (>3 cm), d_g – mean basal area diameter at 1.30 m, h_g –height of mean tree.
(a) Data from plots in the area with high influence on measured fluxes (n=24).
(b) In volume calculation height curves of living trees were used (i.e. values for V are upper limit).

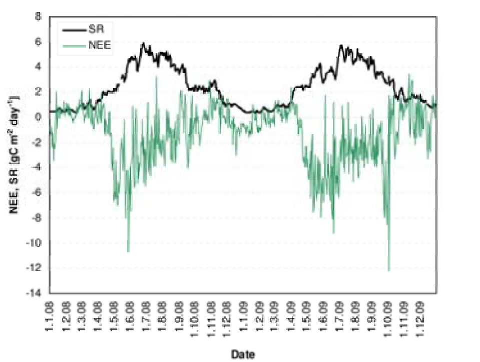

Figure 2. Daily NEE (measured and gapfilled) and modelled SR using SR measurements and model of Reichstein (2003).

Maximal measured daily NEP from eddy covariance was 10,7 gC m^{-2} day^{-1} in 2008., and 12,2 gC m^{-2} day^{-1} in 2009 (fig. 2). The annual NEP was 384 gC m^{-2} yr^{-1} in 2008 and 584 gC m^{-2} yr^{-1} in 2009 indicating that the forest was actively storing carbon during both years.

Using weekly measurements of stem increment from dendrometer bands, annual height increment and litter production we obtained an estimate of the NPP of the stands in the footprint of 777 gC m^{-2} yr^{-1} in 2008 and 846 gC m^{-2} yr^{-1} in 2009.

Heterotrophic respiration (Rh) , estimated from soil respiration measurements was 438 gC m^{-2} yr^{-1} in 2008 and 441 gC m^{-2} yr^{-1} in 2009. By subtracting Rh from NPP, we obtained NEP of 339 and 405 gC m^{-2} yr^{-1} in 2008 and 2009, respectively.

Comparison of results for NEP during vegetation season reveals that agreement between the two methods was very good until July. Later in the summer and autumn, discrepancy occurs when stem growth ceases but trees continue to store carbon. This leads to the underestimation of NEP from combined method during that period, leading to the overall lower values of NEP when compared with NEP values from eddy covariance.

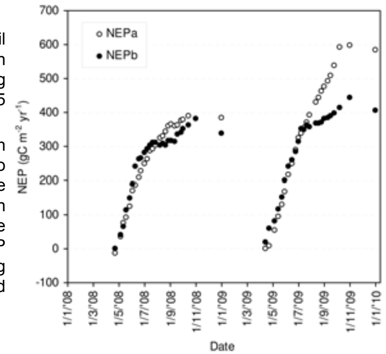

Figure 3. NEP during two vegetation seasons estimated using EC (a); biometric and SR measurements (b).

Conclusions

Forest in to fetch of Jastrebarsko EC tower was acting as a net sink for 484 gC m^{-2} yr^{-1} on average.

Alternative approach for estimating NEP (NEP^b) yielded lower average value of 372 gC m^{-2} yr^{-1}. However, uncertainties related to the Rh:SR and R/S ratios, and root growth dynamics limit the reliability of this method.

Comparison of NEE for Jastrebarsko forest with NEE's from other forest sites in FLUXNET network shows that pedunculate oak forest has great potential for carbon sequestration.

Continuation of EC measurements at Jastrebarsko is needed for validating these results. Also, research of SR partitioning should be a high in the list of future research priorities.

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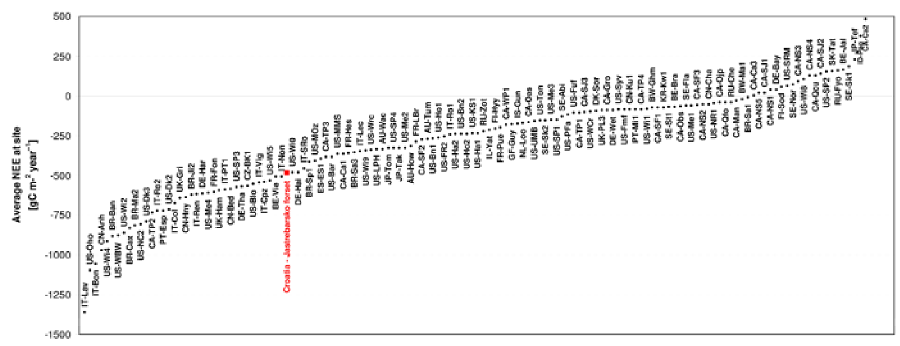

Figure 4. Average reported NEE for forest and woodland sites in FLUXNET database available under Fair Use Policy (data as of 16.02.2008) in comparison with NEE measured with eddy covariance in pedunculate oak forest at Jastrebarsko (shown in red).