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Increased carbon sequestration in a Danish beech forest during 1996-2016: Observations and hypotheses.

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A study of the net exchange of CO_2 (NEE) between the atmosphere and a beech forest near Sorø, Denmark, during 14 years (1996-2009) showed that the beech forest acted as an increasing sink of CO_2 [1]. A significant increase in gross primary production (GPP) and a smaller and not significant increase in ecosystem respiration (RE) were also found. Thus, the increased NEE was mainly attributed to an increase in GPP. The length of the carbon uptake period (CUP) significantly increased, whereas there was a no increase in the leafed period (LP). This means that the leaves stayed active longer. The increase in the carbon uptake period explained about half of the increasing NEE. The remaining increase was believed to be due to an observed increased uptake capacity of the canopy and increased annual radiation efficiency[2]. The causes for this were hypothesized to be a combination of increase in atmospheric CO_2 concentration, higher summer precipitation, and increased availability of N. A higher nitrogen content in the leaves was observed towards the end of the observation period.

An updated analysis of the flux data, now including the years 1996-2016, confirms the increasing trend in carbon sequestration of the forest, an increasingly longer growing season, and a significant correlation of NEE and CUP, however, similarly to the first study, the increase in CUP only explains about half of the total increase.

Here we investigate three hypotheses for the remaining reasons for the increase:

H1: increased canopy nitrogen content

H2: carbon dioxide fertilisation

H3: increased water availability due to changing precipitation patterns.

We describe the multiannual development of canopy photosynthesis capacity with regression analysis and perform sensitivity studies with the canopy model MAESTRA [3] to investigate the above hypotheses. The results will be presented, critically discussed and interpreted with respect to general effects of global climate change and site specific, local effects that affect forest dynamics.

[1] Pilegaard, K., Ibrom, A., Courtney, M.S., Hummelshøj, P. and Jensen, N.O., 2011. Increasing net CO_2 uptake by a Danish beech forest during the period from 1996 to 2009. Agricultural and Forest Meteorology, 151: 934–946.

[2] Wu, J. et al., 2013. Modelling the decadal trend of ecosystem carbon fluxes demonstrates the important role of biotic changes in a temperate deciduous forest. Ecological Modelling, 260: 50-61.

[3] Duursma, R. and Medlyn, B., 2012. MAESPA: a model to study interactions between water limitation, environmental drivers and vegetation function at tree and stand levels, with an example application to $[CO_2] \times$ drought interactions. Geosci. Model Dev, 5: 919-940.