Diffuse vs. direct radiation effects on the net ecosystem CO_2 exchange of a mountain grassland

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Background Several studies have shown that terrestrial ecosystems are able to take up more carbon when the incident radiation is comprised of a larger fraction of diffuse radiation, which is generally attributed to the fact that diffuse radiation is distributed more evenly within plant canopies increasing total canopy carbon gain through increased photosynthesis of shaded leaves. On the other hand some studies report no effect of diffuse radiation on carbon gain (often for ecosystems with low leaf area index), while again others suggest concomitant changes in air temperature and humidity to be more important than diffuse radiation *per se*. The objective of this study is to quantify the role that i) concomitant changes in air temperature and humidity and ii) differences in leaf area index play in the sensitivity to diffuse radiation.

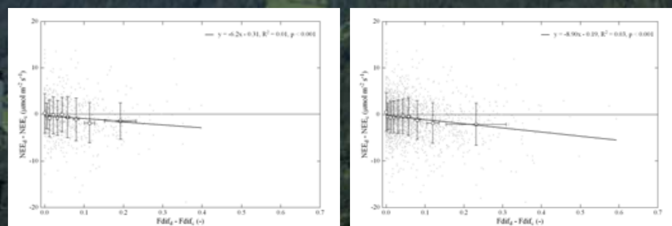

Figure 1 Sensitivity of NEE to diffuse radiation for all pairs of data which satisfy the conditions explained in the methods (left) and with the restriction of similar air temperature and humidity removed (right).

Methods Here we use five years of eddy covariance measurements of the net ecosystem CO_2 exchange (NEE) made above a temperate mountain grassland in Austria (Neustift in Stubai Valley). In order to properly quantify the diffuse radiation effect the data analysis needs to control for several variables which may confound results. Assuming the leaf angle distribution and the curvature of the leaf-level photosynthesis-light relationship to be invariant, the data analysis needs to normalise for the effect of i) the sun's elevation, ii) leaf area index, and iii) the amount of incident photosynthetically active radiation; in addition the effect of iv) air temperature and v) air humidity needs to be removed. We achieve this by analysing pairs of data from the same time of day on subsequent days (in order to minimise changes in ecosystem physiology) which have been measured during very similar environmental conditions, except for the fraction of diffuse radiation. The beauty of this approach is that statistical testing of the significance of diffuse radiation for NEE is straight forward. In order to quantify the role of confounding factors, the data selection is relaxed for certain variables at a time.

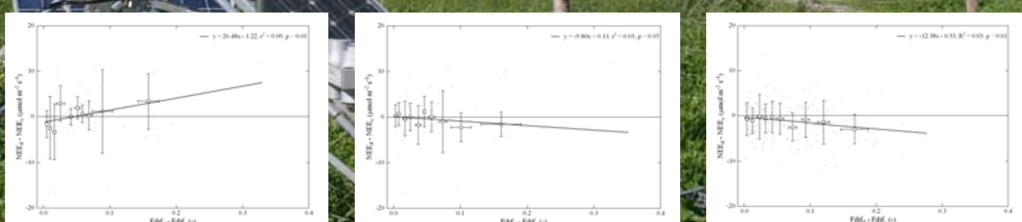

Figure 2 Sensitivity of NEE to diffuse radiation. Data are stratified into GAI classes: 0-2 $m^2 m^{-2}$ (left), 2-4 $m^2 m^{-2}$ (middle) and 4-6 $m^2 m^{-2}$ (right). Only data pair which satisfy all the conditions explained in the methods are shown.

Results As shown in Fig. 1, NEE becomes more negative (i.e. more CO_2 uptake) as the fraction of diffuse radiation increases – a paired T-test shows that NEE under diffuse radiation is more negative than under clear sky conditions ($p < 0.001$). The slope of this relationship is steeper (i.e. the sensitivity to diffuse radiation increases) when air temperature and humidity are allowed to vary concomitantly with diffuse radiation (Fig. 1). Thereby air humidity overrides the effect of air temperature, which acts as to decrease the sensitivity (data not shown). Stratifying the data into green area index (GAI) classes (Fig. 2), shows that NEE increases with the fraction of diffuse radiation at low GAI values and that the sensitivity of NEE to diffuse radiation increases from middle to large GAI values (slopes significant at $p < 0.05$). A paired T-test shows that only at GAI> 4 $m^2 m^{-2}$ NEE is significantly lower under diffuse radiation.

Conclusion The sensitivity to diffuse radiation of a temperature mountain grassland is increased due to concomitant changes in air temperature and humidity – this finding needs to be accounted for when extrapolating ecosystem response to diffuse radiation to future climatic conditions. As predicted by canopy photosynthesis-light models, the amount of above-ground plant matter decisively influences the sensitivity of NEE to diffuse radiation – in the present case increased carbon uptake with increasing diffuse radiation was only observed at GAIs > 2 $m^2 m^{-2}$.

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