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Net Ecosystem Exchange of CO2 from crops at the European scale: variability and climate-related trends

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The Net Ecosystem Exchange of CO2 (NEE) is a major component of the greenhouse gas budget of arable land. It is therefore essential to have reliable NEE estimates in order to obtain Greenhouse Gas (GHG) budget estimates for croplands. Various causes of NEE variability and trends render it extremely difficult to establish a GHG budget over domains of a size relevant to GHG reporting obligations. Crops respond nonlinearly to changes in their growing conditions and are subject to combinations of stress factors that affect their growth and therefore NEE. Seasonal and spatial variations in the weather pattern may affect crop development, production and water consumption differently, depending on crop type, region, soil characteristics and season.

The objective of this research is to estimate the inter-species variability of NEE and to assess at the European scale present trends in NEE due to changing weather patterns and the increasing atmospheric CO2 concentration.

Our analyses rely on observations as well as on a modeling study. To assess the inter-species NEE, observed variability of the NEE during 45 cropping periods was analyzed. The data were obtained in a European context at 17 cropland sites, using the eddy covariance method. The results reveal an average loss of 38 gCm-2 per cropping period. The variation of NEE among crops is considerable, with a standard deviation of 251 gCm-2. Biomass production appears to be a reasonable estimator of NEE. This allows further analyses of NEE variability and trends at regional to continental scales, initially using biomass production as a proxy.

Estimation of crop biomass production is typically the domain of crop growth models. We used the European Crop Growth Monitoring System (CGMS) to investigate at the European scale changes in crop biomass production caused by changes in temperature and radiation patterns in the period 1976-2005. We also tried to assess the CO2-fertilization effect on biomass production, that is, the stimulating effect of the increasing atmospheric CO2 concentration on crop growth. Since CGMS simulates biomass production instead of NEE, the relation between biomass production and NEE from the measurements was used to construct NEE estimates at the European scale. The trend analyses do not include trends in management practices, implying that we strictly limit our analysis to the effect of weather patterns. The crops examined here are winter wheat, spring barley, maize, winter rapeseed, potato, sugar beet, pulses and sunflower. Simulations are executed at NUTS2 level.

Observed weather pattern changes are not uniformly distributed across Europe. Moreover, simulated impacts of the changing weather patterns on biomass production differ per crop and per region. The biomass production of Maize and sugar beet was least affected by changing temperature and global radiation patterns. In Italy and southern central Europe, temperature and radiation change effects are found to have a larger impact than elsewhere in Europe. For optimal conditions, the effect of the rising CO2 concentrations during the period investigated here is found to be about 6%. However, due to suboptimal conditions, mainly because of water requirements that also respond to weather patterns, the CO2-fertilization effect appears to be almost negligible.