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Linking long-term leaf transpiration to vegetation greening through g_{smax} - NDVI comparison in Scandinavia

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With increasing CO_2 plants downregulate transpiration rates by reducing stomatal conductance to minimize water loss, thereby affecting continental H_2O fluxes, run-off rates, cloud formation and precipitation. Alternatively, carbon fertilization can lead to more biomass in form of more or denser vegetation and more or larger growing leaves.

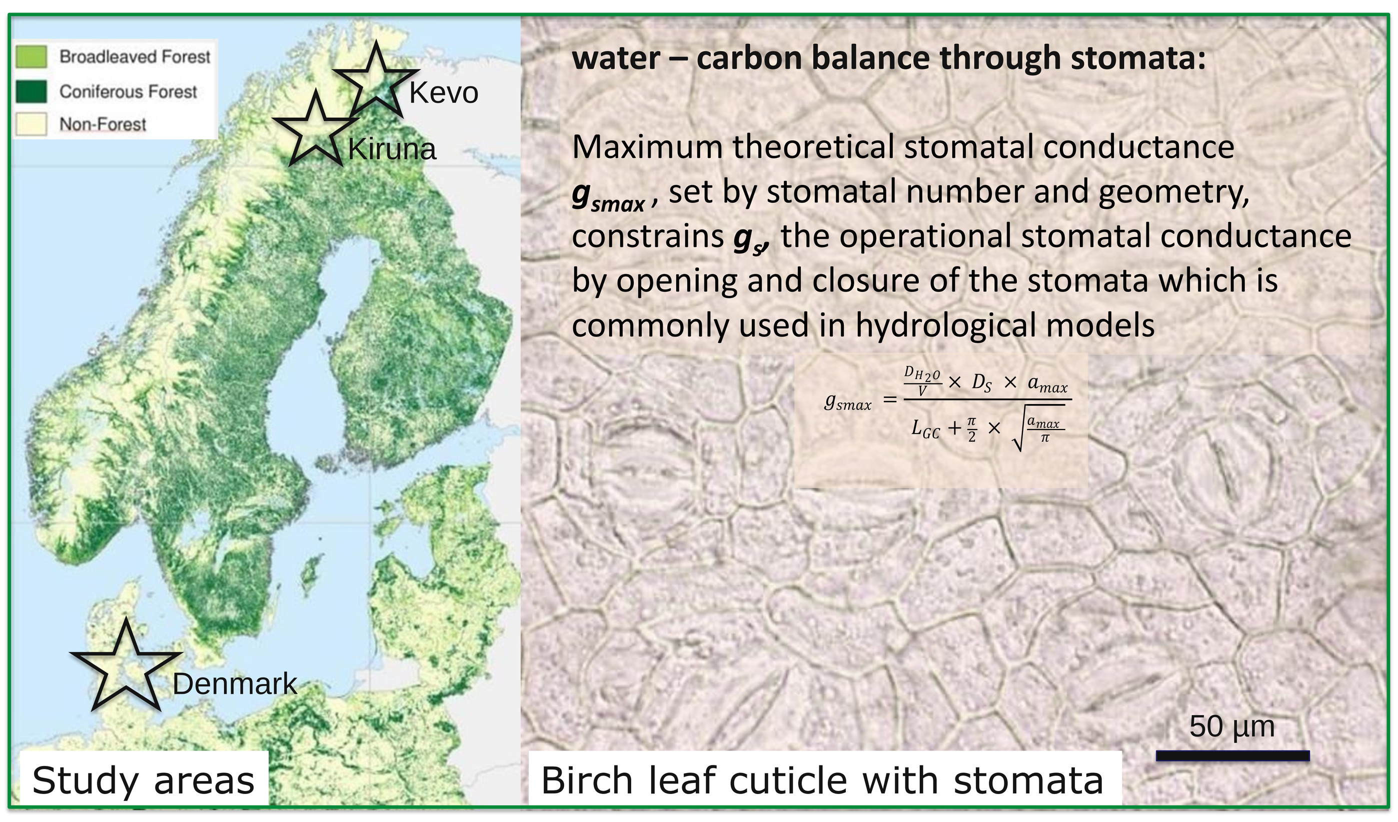
Considering the vegetation response to rising CO_2, two contrasting feedback options in the hydrological cycle are discussed:

1) Vegetation cover stays constant owing to limiting factors (nutrients, light, temperature) → runoff will increase.

2) Vegetation cover increases due to carbon fertilization and leads to net transpiration increase → runoff will decrease.

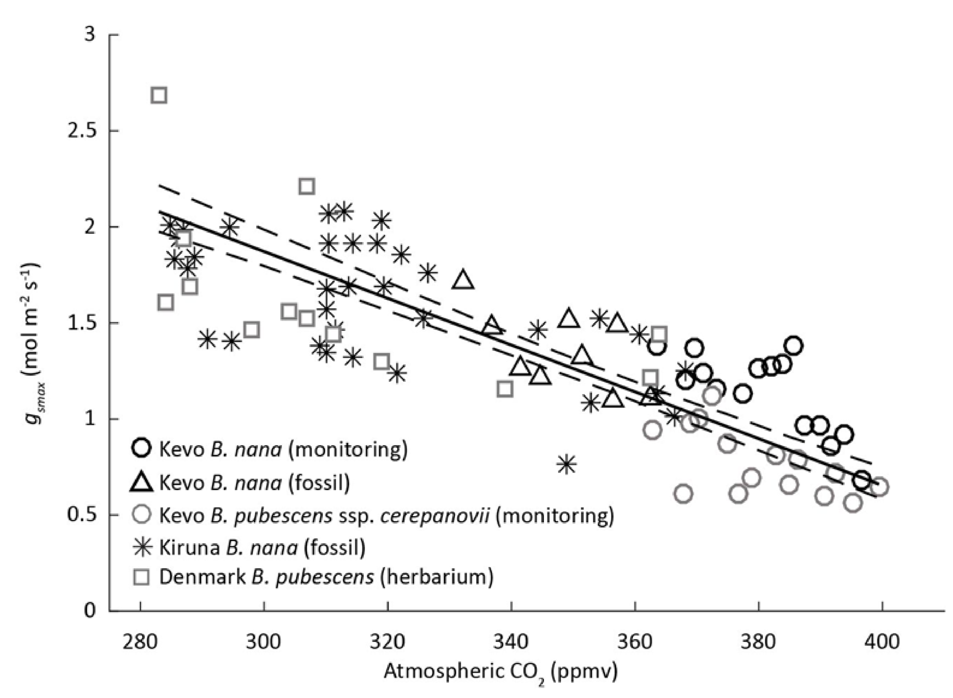
Here we test these contrasting scenarios by directly comparing time-series data of CO_2 induced anatomical maximum stomatal conductance (g_{smax}) changes and satellite observations of the NDVI over Scandinavia. By determining the rate of change for stomatal conductance and 'vegetation greenness' we evaluate the role of plants in the hydrological cycle in a long-term perspective.

Birch leaf-cuticle analysis based g_{smax} records

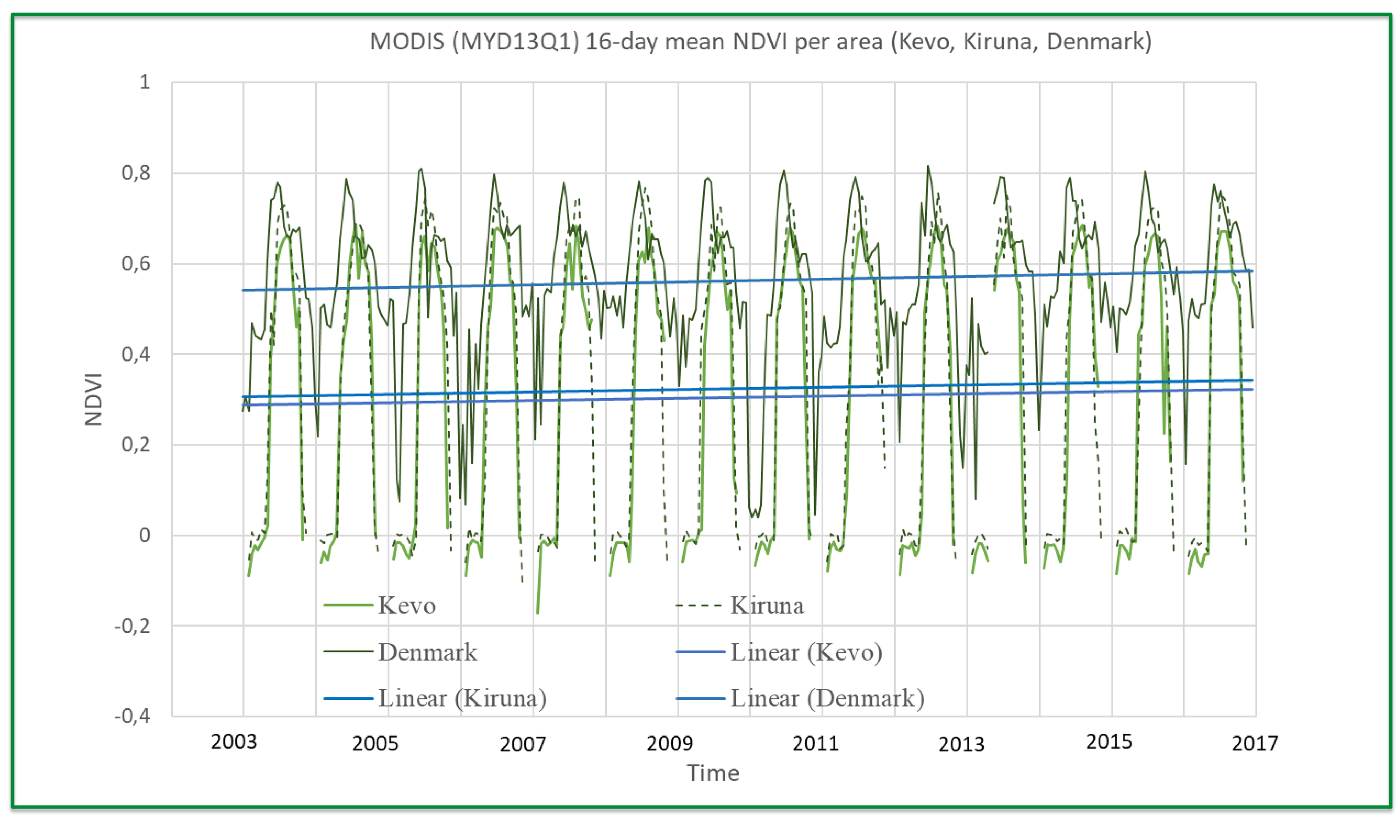


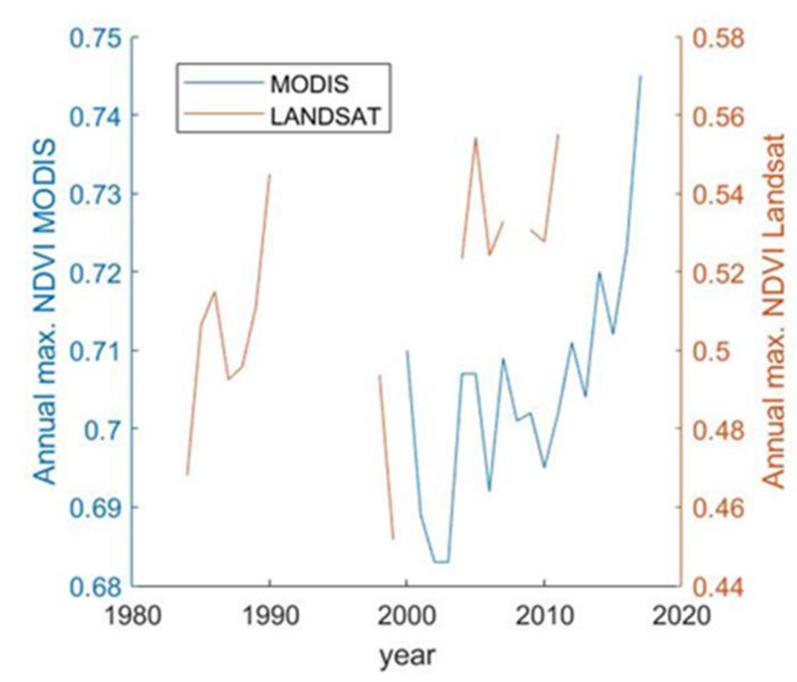
Top panel
g_{smax} is determined from leaves preserved in peat deposits and from herbarium collections between 1850 and 2018.

Right panel
All individual data sets show similar g_{smax} reductions over the anthropogenic CO_2 increase



Satellite imagery based NDVI records





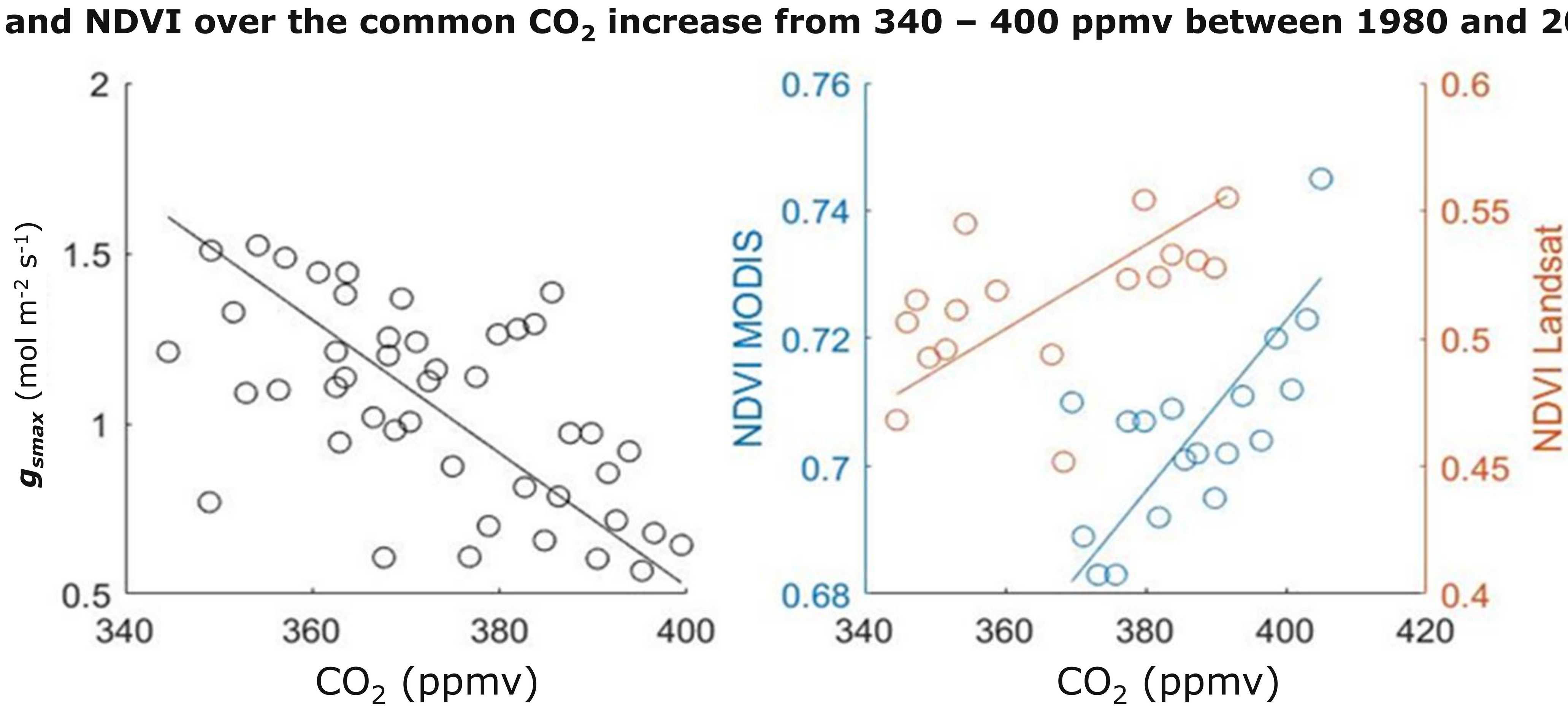
Top panel
MODIS time series **NDVI** data for study sites since 2003.

Left panel
Combined MODIS and Landsat data sets for summer months JJA. Both showing moderate **NDVI** increases over ~40 years covered in record.

g_{smax} and NDVI over the common CO_2 increase from 340 – 400 ppmv between 1980 and 2018

Left panel
g_{smax} in birch from Scandinavia decreased by ~ -70%.

Scaling between g_s and g_{smax} is postulated to be 0.25; g_s operates on 25% of g_{smax}



Right panel
NDVI data for summer months JJA increases over CO_2 rise with

MODIS:
~+7.5% over 30 ppmv

Landsat:
~ +14% over 50 ppmv

Resume: A strong CO_2 related decrease in g_{smax} is determined for birch, the second most important canopy tree in Scandinavia. Over the common CO_2 rise, NDVI data from Landsat and MODIS show more intense greenness of the vegetation in the areas studied.

The rates of change, however, are lower in NDVI than g_{smax}.

The transpiration decrease is likely buffered, but not compensated by CO_2 fertilization effects.

Vegetation response under changing CO_2 is an important parameter in the hydrological cycle and exact quantification needs more attention in biosphere – atmosphere – hydrosphere modeling.