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European Forest Carbon Mass Balances Estimated with Remote Sensing and the Production Efficiency Model C-Fix: Inclusion of water limitation and its impact on model validation results.

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Abstract

Carbon emission and -fixation fluxes are key variables to guide climate change stakeholders in the use of remediation techniques as well as in the follow-up of the Kyoto protocol. A common approach to estimate forest carbon fluxes is based on the forest harvest inventory approach. However, harvest and logging inventories have their limitations in time and space. Moreover, carbon inventories are limited to the estimation of net primary productivity (NPP). Additionally, no information is available when applying inventory based methods, on the magnitude and impacts of water limitation and the water cycle. Finally, natural forest ecosystems are rarely included in inventory based methods.

To develop a Kyoto Protocol policy support tool, a good perspective towards a generalised and methodologically consistent application is offered by expert systems based on satellite remote sensing. They estimate vegetation carbon fixation using a minimum of meteorological inputs and overcome the limitations mentioned earlier for the inventory based methods. The core module of a typical expert system is a production efficiency model. In our case the C-Fix model. C-Fix estimates carbon mass fluxes

i. e., gross primary productivity (GPP), NPP and net ecosystem productivity (NEP) for various spatial scales and regions of interest (ROI's). Besides meteorological inputs, the C-Fix model is fed with data obtained by vegetation RTF (Radiative Transfer Model) inversion. The inversion is based on the use of look-up tables (LUT's). The LUT allows the extraction of per pixel biome type (e.g. forests) frequencies and the value of a biophysical variable and its uncertainty at the pixel level. The extraction by RTF inversion also allows a land cover fuzzy classification based on six major biomes. At the same time fAPAR is extracted and its uncertainty quantified.

Based on the biome classification, radiation use efficiencies are stratified according to biome type to be used in C-Fix. Water limitation is incorporated both at the GPP level using evaporative fraction (EF) and at the soil respiration level with soil moisture content (SMC). Water limitation is derived from optical and thermal information, extracted with NOAA/AVHRR and METEOSAT processing chains. A key feature of the approach outlined, is the direct inference of the bio-geophysical state of terrestrial forest cover from space borne observations. Since forest state is not estimated with deterministic models, the modelling of limiting factors like nutrient deficiency, pest and disease impacts, pollutant effects as well as any other long-term effect on forest carbon fluxes, is eliminated. The only processes still to be to be taken into account in C-Fix are by definition those that show temporal dynamics with response times shorter than the typical turnover time of chlorophyll metabolism. For example, short term hydrological cycle effects on water limiting factors like evaporative fraction and soil moisture content.

Applications of the expert system include the mapping of the spatial and temporal patterns of GPP, NPP, NEP and soil respiration as well as the impact of water stress on water use efficiency and the carbon balance. Moreover an index indicating the ratio between carbon emission en its re-fixation by forests is mapped for Europe. It reveals large imbalances between carbon emissions (IPCC, 1997) and forest carbon re-fixation (1997) for almost all European countries.

Keywords: Carbon relations, remote sensing, bio-geophysical variables, C-Fix, Kyoto protocol, water limitation.