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# A pre-market service to map biomass potentials on a regional level

Markus Tum[1], Kurt P. Günther[1]

**Abstract**

In the framework of the EU FP7 project ENDORSE (Energy Downstream Services – Providing energy components for GMES) a pre-market service is developed to estimate the annual above ground biomass increase for forests in Germany. This development is driven by the requirements of a prime user (Forest Competence Center Eberswalde) and done in close cooperation with experts in the field of forestry. One aim of the service is to develop a cost and time efficient method to deliver yearly estimates of above ground forest biomass increase using satellite measurements and modelling techniques as the BETHY/DLR SVAT model. Another aim is to use mainly satellite observations coming from GMES services and/or GMES space components. Our yearly estimates of above ground forest biomass increase covering the time span from 2000 to 2012 will fill the gaps of the national forest inventories. In Germany the first and second National Forest Inventory (NFI) took place in the years 1987 and 2002 while the third inventory was performed in 2011 and 2012. This large-scale ground mapping of the forest status and forest productivity uses random sampling of forest parameters for the entire territory of the Federal Republic of Germany. The new pre-market service allows monitoring forest growth on a regional level with 1km x 1km spatial resolution with respect to local meteorological conditions

## 1. Product Development and Method

Our method is based on the estimation of Net Primary Productivity (NPP), using a process based model. The German Aerospace Center (DLR) operates the modified model BETHY/DLR (Biosphere Energy Transfer Hydrology) to simulate the carbon cycle of vegetation for different regions on regional to national scales. BETHY/DLR belongs to the family of Soil Vegetation Atmosphere Transport (SVAT) models, which primarily compute the photosynthetic rate of vegetation types, taking into account the water balance and the radiative energy transfer between atmosphere, soil and vegetation.

The model is driven by remote sensing data, derived from SPOT-VEGETATION, meteorological time series, provided by the European Center for Medium range Weather Forecast (ECMWF) and soil type information, provided by the Food (FAO) of the United Nations and Agriculture Organisation and International Institute for Applied System Analysis (IIASA).

Time series of the Leaf Area Index (LAI), a parameter which describes the condition of vegetation and a land cover classification are derived from remote sensing data. They are based on geoland2 10 day composite datasets with a spatial resolution of about 1km x 1km, which can be downloaded from the geoland2 database. For each pixel a time series analysis has to be applied in order to eliminate data gaps and outliers. For the purpose of this study the method of the harmonic analysis was used. The geoland2 dataset also provides information of land cover and land use and is available as Global Land Cover 2000 (GLC2000). GLC2000 is representative for the year 2000 and provides 22 vegetation classes, which have to be translated into the currently 33 vegetation types of BETHY/DLR. Vegetation types differ in their plant-physiologic parameters, i.e. the maximum electron transport rate and the maximum carboxylation rate, as well as the plant height and rooting depth.

The ECMWF provides meteorological data with a spatial resolution of 0.25° x 0.25° and a temporal resolution of up to four times a day. These are model analysis of the air temperature in 2m height; the

[1] German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Münchner Straße 20, D-82234 Weßling

wind speed at 10 m above ground; the cloud cover fractionized into high, medium and low clouds and precipitation. From this the daily mean, minimum and maximum of temperature are calculated, as well as the daily mean of cloud cover over all three strata (high, medium and low). The daily temperature values are scaled with the difference of ECMWF and ETOP-elevation and the temperature gradient of the U.S. Standard Atmosphere, which is -0.65 K per 100 m.

BETHY/DLR has a particular focus on a detailed parameterization of photosynthesis, and tracks the plant-mediated transformation of atmospheric carbon dioxide into energy-storing hydrocarbons. We take into account environmental conditions that affect photosynthesis. As example reduced water availability, light or temperature excess limits plant growth. The model separately treats the light and dark reactions of photosynthesis at leaf level, making it possible to mechanistically limiting photosynthesis by either light availability or by the abundance of the carboxylation enzyme Rubisco. The output of BETHY/DLR, daily time series of Gross Primary Productivity (GPP), is converted to NPP by subtracting the cumulative plant maintenance and growth respiration. NPP is converted into above ground biomass increase by using conversion factors, which describe the relation of above-to-below ground biomass and the relation of carbon to non-carbon compartments of forest biomass. These conversion factors were taken from Pistorius and Zell (2005).

In order to validate our results of the current annual increment (CAI) of above ground forest biomass, as estimated from our modelled NPP, we used mean annual increment data, which was calculated from empirical data. The empirical data was taken from Germany's National Forest Inventory (NFI) and yield tables. The NFI data contains information on tree species and age distribution for the main tree species (for Germany: oak, beech, spruce, pine) on state level and is available for the years 1988 and 2003. The AGBi as calculated for our product was aggregated to state level and then directly compared with the empirical data. A detailed description of this approach can be found in Tum et al. (2011).

## 2. Product Example and Results

An exemplary result of our service showing the averaged above ground biomass (AGB) for the period 2000 to 2012 and deviations from this for the individual years 2010, 2011 and 2012 is presented in figure 1. On average we calculated an AGB increase of 453 (± 47) t $km^{-2}$ $a^{-1}$. For the whole state we calculated an average increase of 5 829 284 (± 1 188 635) t $km^{-2}$ $a^{-1}$. These values are in good concordance with the data derived from the NFI (see figure 2). Analysis on state level revealed good results ($R^2 = 0.89$).

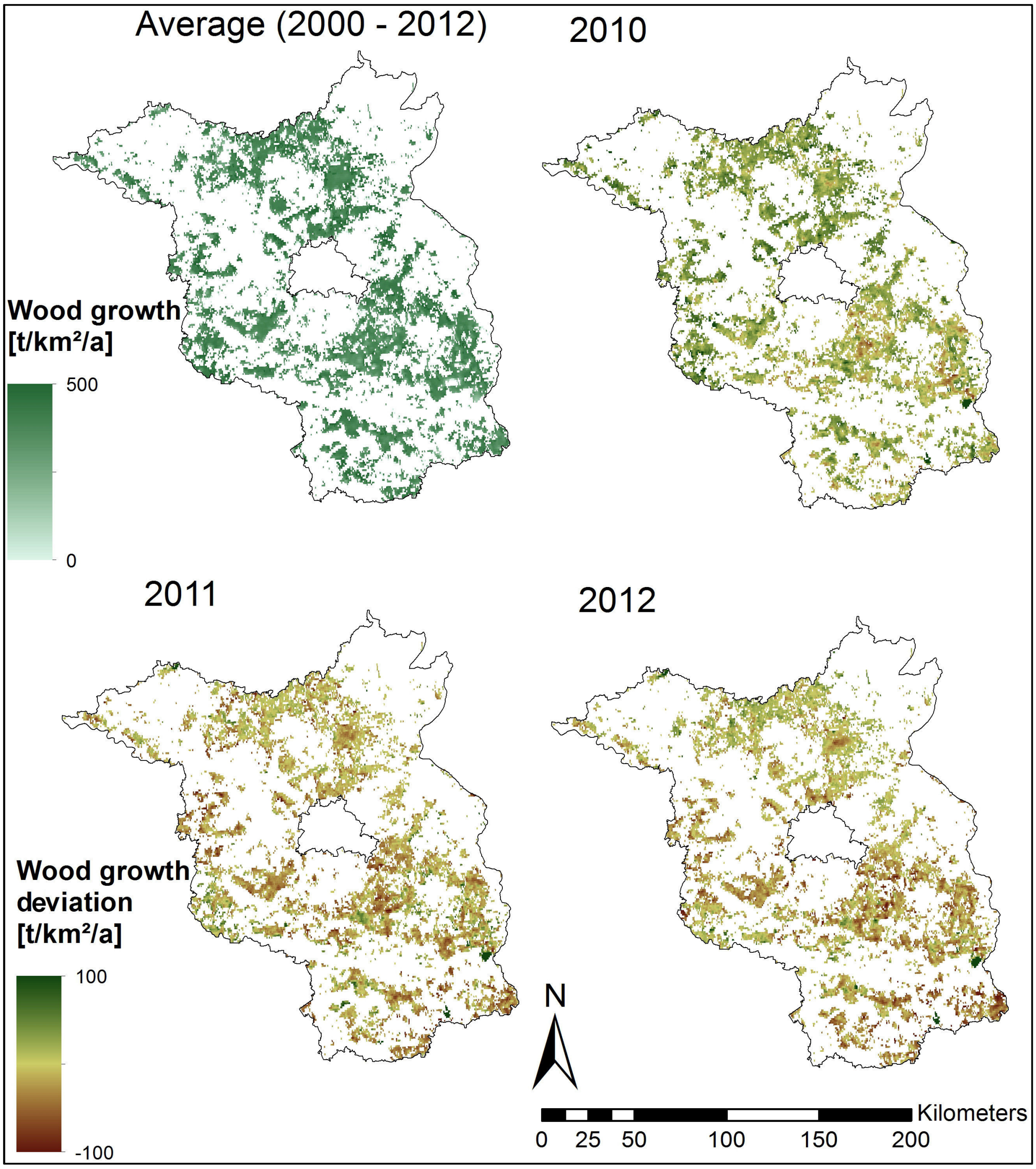


Figure 1: Averaged woody biomass increase (2000-2012) and deviations from average for 2010 - 2012 for Brandenburg's forests. The averaged above ground (woody) biomass increase is represented in green colors. Negative deviations (red) represent areas with less woody biomass increase than the average. Positive deviations (green) represent the opposite. White areas show areas which are not classified as forests in the GLC2000.

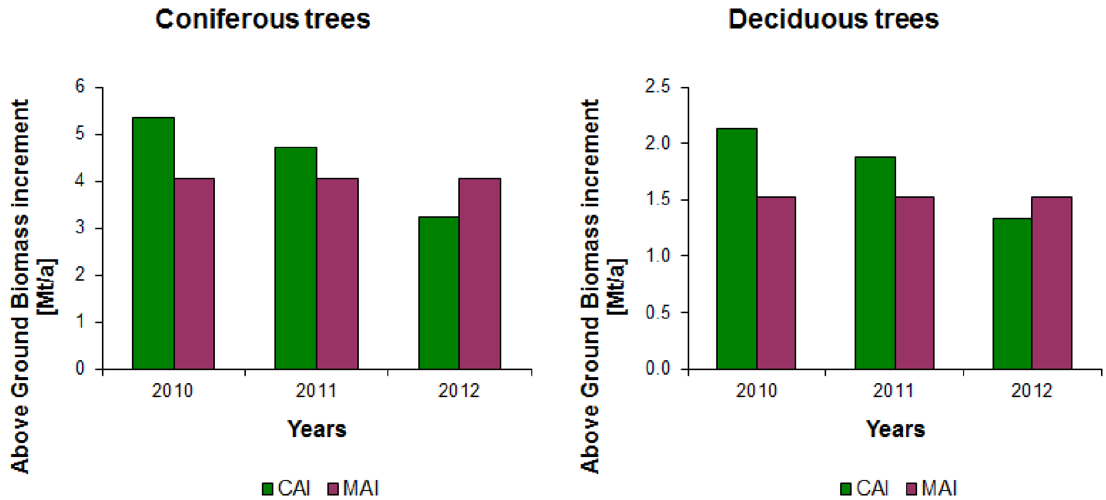

Figure 2: Annual above ground biomass increase calculated with empirical data (MAI) and modelled NPP (CAI) for the period 2010 - 2012 for Brandenburg.

From figure 1 it can clearly be seen that individual years show changes of the CAI up to ± 100 t $km^{-2}$ $y^{-1}$ when compared to the long term average indicating strong feedbacks of the vegetation to the meteorological conditions. Since the data as reported in the NFI only consists of long term averages, and thus cannot represent local variability in the above ground biomass increase, our method can be seen as additional information source to assess forest biomass increase on a regional scale. Secondly, because our results are in good concordance with the empirical data, we believe our method can help monitoring forest biomass development especially in regions where less detailed data is available. In addition, since our approach can easily be adapted to assess biomass increase of other vegetation types, further branches of applications are possible.

## 3. Outlook

In the framework of the ENDORSE project an exploitation exercise of a market expansion was carried out. Aside from the fact that various potential users, coming from research, business and policy, were identified, the portfolio of active users of the service grew. It was identified that not only the initially designed product “above ground biomass increase” is of interest for users, but also further product branches, like “bioenergy potentials”, “irrigation demand” or “net ecosystem exchange of carbon” are requested from the user community. The user community itself is currently placed in Europe and Africa. Since the product branches as described above can be elaborated by applying post-processing algorithms it seems as likely that the product, and thus service portfolio will grow in future.

## 4. Bibliography

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