ACRP

Interim Report – Activity Report

Program control:
Climate and Energy Fund

Program management:
Kommunalkredit Public Consulting GmbH (KPC)

1 Project Data

Short title	MOTI	
Full title	Comparing MODIS Satellite versus Terrestrial Inventory driven Carbon Estimates for Austrian Forests	
Project number	K10AC1K00050	
Program/Program line	ACRP 3rd Call for Proposals	
Applicant	Institute of Silviculture, BOKU University of Natural Resources and Life Sciences, Vienna.	
Project partners	**We have one Partner:** (i) Centre for Global Change and Sustainability (internal BOKU partner only interested in the results), **and two Subcontractors:** (iii) The Numerical Terradynamic Simulation Group (NTSG) in Missoula Montana, USA, and (iii) The Institute of Forest Inventory of the Forest Research Centre (BFW) in Vienna, Austria.	
Project start and duration	Project start: 01.07.2011	Duration: 30.6.2013
Consecutive number of interim report	Interim report 1	
Reporting period	from 01.07.2011 to 30.06.2012	

Synopsis:

The purpose of this project is to compare Net Primary Productivity (NPP) estimates from MODIS satellite information with productivity estimates derived from the Austrian National Forest Inventory between 2000 and 2009. For this period, overlapping data records are available, thus allowing statistically supportable comparisons to be made. The MODIS driven NPP estimates will come from two sources: (1) the available online database and (2) calculated with the ’offline’ code developed by the NTSG Lab of Prof. Running in Missoula, Montana using Austrian daily climate data and the BFW vegetation distribution map. We are specifically interested in analysing the error structures of each dataset and solving the spatial and temporal difficulties in direct comparisons. Successful resolution of these issues will allow more efficient use of currently collected data.

2 Technical /Scientific Description of the Project

2.1 Project abstract

Carbon dioxide (CO2) is one of the most abundant greenhouse gases, increasing from 278 ppm in pre-industrial times up to 391 ppm in 2010. According to IPCC, this has contributed to temperature increases in many parts of the world. The trend of increasing CO2 as well as temperature is expected to continue. The world's forest and carbon sequestration due to forest management is an important part of the global carbon cycle, and hence is not only of interest to the forest community. Unmanaged forests are assumed as being in an equilibrium state where the same amount of carbon is released due to respiration and decomposition than what is fixed by photosynthesis. By looking at the stadial phases of forests, one can observe carbon uptake during the optimum stage, carbon neutral behaviour in mature stands, and carbon release in the breakdown and regeneration phase. This transition from a carbon sink to a carbon source is an elementary process in ecosystem dynamics. Ensuring a positive carbon balance is done by regular timber harvesting (assuming that the wood is not used for energy generation where the CO2 is released again). Permanent storage of these natural carbon stocks is of growing interest in climate change mitigation.

A core area of climate change research is in carbon monitoring. Focusing on the terrestrial carbon cycle, two contrasting approaches are possible:

1. Top-down: using biophysical principles to derive the productivity of a site,
2. Bottom-up: combining detailed measurements for a site.

In the first approach, satellite-derived information from sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) is used to estimate Net Primary Productivity (NPP). Principles derived from a simplification of a process-based ecosystem model are used to calculate NPP based on surface reflectance. Estimates are provided on a 1 x 1 km grid as annual sums.

In the second method, known as forest inventory, individual trees are measured and biomass functions are applied to calculate the carbon stock. In Austria inventory plots are distributed according to a robust statistical sampling design and re-measured every 5 to 10 years. The two most recent recording periods available for this study were 2000-2002 and 2007-2009, giving 7-year increments not attributed to individual years.

The data recording systems of the two methods differ not only in their principles for deriving carbon, but also in their spatial (1 x 1 km vs. individual trees selected on a given sampling plot) and temporal (annual NPP estimates vs. 7 year periodic mean average development) resolution. For a given forest area, both methods should ideally deliver comparable productivity estimates. Early studies in validating satellite-driven productivity estimates used flux tower measurements which provide information on gas exchange but not productivity. Up until now, there is still no well-established procedure which includes a thorough error assessment utilising forest productivity data derived from National Forest Inventories (e.g. the Austrian NFI).

In this first part of our research covered by this report, we were specifically interested in:

1. Do the different data recording systems produce comparable results
2. Is it possible to harmonise temporal differences between the recording systems i.e. obtain annual estimates from the 7-year inventory-based increment which may then be validly compared with annual NPP estimates from MODIS?
3. Are there any other issues to consider such as forest management, etc.?

2.2 Contents and results of the project

The first target was to define a consistent dataset of productivity estimates and explore the difficulties in comparing different data sources. For this the following steps were necessary:

2.2.1 Daymet

First of all, the MODIS algorithm needs daily weather data. Minimum and maximum temperature, precipitation, vapor pressure deficit and incident short wave radiation needed for our plot locations were generated using DAYMET, a climate interpolation model (Thornton et al., 1997) recently adapted and validated for Austrian conditions (Hasenauer et al. 2003, Eastaugh et al. 2010). DAYMET interpolates daily precipitation and minimum and maximum temperatures from surrounding permanent climate stations. Based on these results, missing daily solar radiation and vapor pressure data are calculated according to Thornton et al.(2000). The current version of DAYMET (Petritsch and Hasenauer, 2011) requires longitude, latitude, elevation, slope, aspect and the horizon angle in east and west facing directions for each given plot. The meteorological data for running DAYMET were provided by the Austrian National Weather Center in Vienna and include daily weather records from 250 stations across Austria since 1961. For our analysis we generated daily weather data at a 1 by 1 km grid across the country and for each of our 151 forest locations.

2.2.2 MODIS

The storage system of MODIS data consists of 286 vegetated land tiles including forests. Each tile covers an area of 1200 x 1200 km or 1.44 Million pixels. The MOD17 algorithm provides an 8-day GPP/NPP estimate for each 1 x 1 km pixel. Thus each pixel observation can be easily assigned to a given location on the ground based on given longitudinal and latitudinal values. For our study we will use the improved MODIS NPP product which employs the correction routines for FPAR and LAI as developed by (Zhao et al., 2005). For each of our 151 forest stands we obtained a 3 x 3 km area (nine 1 x 1 km pixels). From these 9 pixels only those were used which were classed as a forest biome in MOD12Q1. For each of these we computed a MOD17 NPP estimate according to three different climate input data sets provided by:

- NASA Global Modeling and Assimilation Offices (GMAO). The data are available for the period 2000 to 2006. MODIS NPP derived from this data set will be referred to as ‘GMAO’.
- The daily climate data set called NCEP_DOE_II: ‘NCEP2’
- Austrian local daily climate data provided by the Austrian National Weather Centre: ‘ZAMG’. These are the DAMET interpolations described in Section 2.2.1.

The difference between the MODIS NPPs driven by GMAO and NCEP2 is that they were generated with different daily climatology drivers and correspondingly modified Biome-Property-Look-UP-Table BPLUT (Zhao et al., 2006). The two data sets are maintained by the Numerical Terra Dynamic Simulation Group (NTSG) while the Austrian local climate data are maintained by the Institute of Silviculture at BOKU.

From 1.1.2000 to 31.12.2004 (5 full years) all 3 variants of MODIS driven NPP estimates were computed. Although the data would be available annually we decided to use the periodic mean annual NPP for the 5 years to have a consistent temporal scaling with the forest growth data.

The MODIS data from the online database was extracted and the offline algorithm of MODIS was applied to 151 permanent inventory plots. The MODIS NPP was calculated with weather data from these three sources

2.2.3 Forest Data

Single tree observations covering the diameter at breast height (dbh) and tree height (h) obtained for this study come from 151 long term research plots across Austria (Figure 1). The majority of the data come from the “Waldboden-Zustandsinventur” (WBZI) – and is comprised of permanent forest plots to monitor stand and soil conditions. These plots have a fixed area size of 0.1 hectare. All plots were established in 1989 and measured every 5 years since. The second data set covers the 15 plots of the International Co-operative Program on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) - Level 2. These permanent plots are 0.25 hectare and were established in 1994, and re-measured in 1999 and 2004.

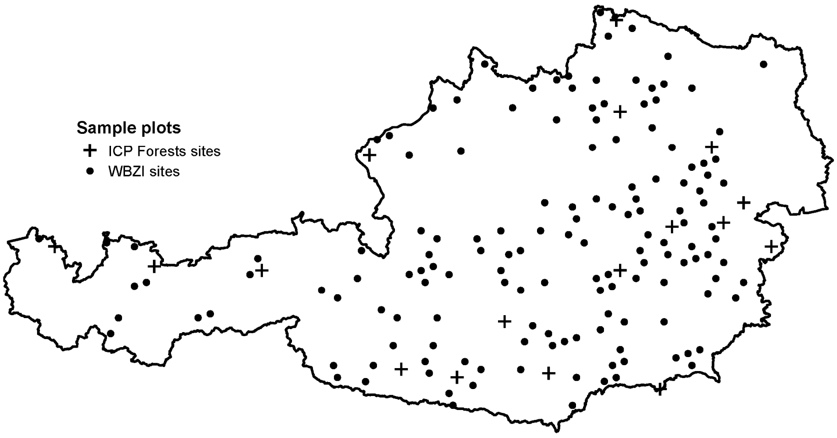

Figure 1: Permanent forest inventory plots (Hasenauer et al., 2012)

From each tree on a given plot the dbh is measured, however only a limited number of tree height observations were available. Thus, height – diameter curves were obtained for deriving missing tree heights. Given the *dbh* and *h*, the corresponding individual tree volume (V) was calculated according to Kennel (1973).

Stand density affects individual tree dimensions. Thus for characterizing the stand density related variation on our plots, we calculated the following two commonly used competition measures: CCF and SDI.

The Crown Competition Factor (CCF) according to Krajicek et al. (1961) depicts the sum of the species specific potential crown area (PCAi) divided by the area (A) (e.g. the plot area).

$$\boldsymbol{CCF} = \frac{\sum \boldsymbol{PCA_i}}{\boldsymbol{A}} \tag{1}$$

The potential crown area is derived from open grown tree dimensions (Hasenauer, 1997) and defines the crown area of a tree at a given diameter at breast height assuming open grown growing conditions.

As a second index we obtained the Stand Density Index (SDI) according to Reinecke (1933):

$$SDI = N\left(\frac{25}{dg}\right)^{-1.605} \tag{2}$$

Where N is the number of trees per unit area dg is the quadratic mean stand diameter at breast height, 25 provides a reference dg and -1.605 is the slope parameter for the maximum carrying capacity. The index has been proven to be site and age independent and defines an estimate for the carrying capacity of a given forest type (Hasenauer et al., 1994).
The inventory data from the BFW was used to calculate the biomass estimates. The Austrian biomass functions were applied to derive ground based NPP estimates based on repeated tree observations from the plots.

2.2.4 NPP from MODIS

The MODIS algorithm provides annual Gross and Net Primary Production (GPP, NPP) estimates for a 1 x 1 km pixel (Running et al.2004, Zhao and Running 2010). The algorithm calculates GPP as

$$GPP = \varepsilon_{\max} \cdot 0.45 \cdot SWrad \cdot FPAR \cdot f_{VPD} \cdot f_{Tmin} \tag{3}$$

Where ε_{max} is the maximum light use efficiency as it depends on vegetation or biome types, *SWrad* is the short wave solar radiation load at the surface of which 45% (0.45) is photosynthetically active, *FPAR* the fraction of absorbed *PAR* (Photosynthetic Active Radiation), and f_{VPD} and f_{Tmin} which are multipliers between 0 and 1 addressing water stress due to vapor pressure deficit (VPD) and low temperature limits (T_{min}, daily minimum temperature). These values are stored in the Biome Property Type Look Up Tables (BPLUT) and cover 5 forest biome types: (i) ENF – Evergreen Needleleaf Forest, EBF – Evergreen

Broadleaf Forest, DNF – Deciduous Needleleaf forest, DBF – Deciduous Broadleaf Forest, and MF – Mixed Forests. In addition 6 other non forestry biome types are defined but not relevant for this study.

Annual Net Primary Production (NPP) is calculated from GPP by subtracting the autotrophic respiration components (i) maintenance respiration R_m and (ii) growth respiration R_g:

$$NPP = \sum_{i=1}^{365} GPP - R_m - R_g \tag{4}$$

In its original approach the MODIS algorithm calculated the annual growth respiration as a function of annual maximum Leaf Area Index (LAI) obtained from the results of the MOD15 algorithm (Myneni et al. 2002). This resulted in an almost constant R_g since MODIS provides the saturated annual maximum LAI for forests which is unreasonable according to plant physiological principles. Thus, Zhao and Running (2010) modified the approach by assuming growth respiration to be approximately 25% of NPP (Ryan 1991, Cannell and Thornley 2000), resulting in the following equations:

$$NPP = \sum_{i=1}^{365} (GPP - R_m) - 0.25 \cdot NPP \tag{5}$$

Where NPP can be computed as

$$\begin{aligned} NPP &= 0.8 \cdot \sum_{i=1}^{365} (GPP - R_m) && \text{when } \sum_{i=1}^{365} (GPP - R_m) \geq 0 \\ NPP &= 0 && \text{when } \sum_{i=1}^{365} (GPP - R_m) < 0 \end{aligned} \tag{6}$$

Maintenance respiration is the proportion of GPP needed to maintain living organisms. In the MOD17 algorithm three different compartments are distinguished: (i) leaf area, (ii) fine roots and (iii) live wood. The total leaf biomass is computed from the MOD15 product LAI divided by the Specific Leaf Area (SLA, in LAI/kgC). Once the leaf area is known the fine roots and live wood compartments are derived from biome type multipliers.

For maintenance respiration the Q_{10} theory is applied (Ryan, 1991). This approach describes the increase in maintenance respiration for living organs according to a temperature increase of 10°C and provides a maintenance respiration index (MRI) as a function of daily average air temperature (T_{avg}).

$$MRI = Q_{10}^{\left(\frac{T_{avg} - 20}{10}\right)} \tag{7}$$

In the original approach the maintenance respiration expressed by the Q_{10} ratio was assumed to be a constant of 2 for leaves, fine roots and live wood. For leaves Zhao and Running (2010) adopted the temperature–acclimated new Q_{10} equation as proposed by Tjoelker et al. (2001)

$$\boldsymbol{Q}_{10} = 3.22 - 0.046 \cdot \boldsymbol{T}_{\boldsymbol{avg}} \qquad (8)$$

They used “base line maintenance respiration” at 20°C for the three different compartments (i) leaves, (ii) fine roots and (iii) live wood by forest biome.

Important remotely sensed drivers of the MODIS GPP/NPP estimates are FPAR and LAI. LAI is used to calculate the living biomass of the three living organs (i) leaf, (ii) fine root and (iii) live wood. This information is needed for calculating the maintenance respiration by compartment as outlined above (equations (4) to (6)). The input data of FPAR and LAI are a MOD15 product and provide an 8 day composite of maximum FPAR and the corresponding LAI. The MODIS FPAR and LAI are estimated with a canopy radiation transfer model using MODIS surface reflectance from red and near-infrared bands (Myneni et al., 2002). The vegetation types are defined according to the University of Maryland land cover classification system – the Land_Cover_Type_2 data field in the MODIS land cover data product MOD12Q1 (Friedl et al., 2010) and cover 5 forest biome types.

2.2.5 NPP from terrestrial forestry data

The MOD17 algorithm provides an 8 day NPP estimate in carbon gC/m2/year over 1x1 km pixels, while the forest growth data provide volume increment in m3/ha/growth period. A growth period depends on the re-measurement interval and may vary from 5 to 10 years. Thus, the first step is to develop a consistent and comparable data set by deriving NPP estimates from forest growth observations according to the following procedure:

$$NPP = \Delta C_{Forest} + C_{Litter} \qquad (8)$$

where C_{Litter} is the dry carbon content of litter as defined in equation (17), ΔC_{Forest} is the periodic dry carbon increment of the above and below ground biomass for a given forest resulting from repeated plot observation at the end C_{Forest_2} minus the beginning C_{Forest_1} of a given growth period.

$$\Delta \boldsymbol{C}_{\boldsymbol{Forest}} = \boldsymbol{C}_{\boldsymbol{Forest}\_2} - \boldsymbol{C}_{\boldsymbol{Forest}\_1} \qquad (9)$$

The carbon values (C_{Forest_1} and C_{Forest_2}) are the sum of the individual tree carbon estimates derived from repeatedly measured diameter at breast height (dbh) and tree height (h) for a tree at a given plot. The total dry carbon tree estimates C_{Tree} are the result of:

$$\boldsymbol{C_{Tree}} = \boldsymbol{CC} \cdot (\boldsymbol{dsm} + \boldsymbol{dbm} + \boldsymbol{dnm} + \boldsymbol{drm}) \qquad (10)$$

where *CC* is the carbon content, *dsm* is the dry stem mass, *dbm* the dry branch mass, *dnm* the dry needle mass and *drm* the dry root mass.

The dry stem mass (*dsm*) can be calculated from tree volume functions (Kennel, 1973) and conversion factors

$$\boldsymbol{dsm} = \boldsymbol{V} \cdot \boldsymbol{WD} \cdot (1 - \boldsymbol{WC}) \qquad (11)$$

$$\boldsymbol{V} = \left(\frac{\boldsymbol{dbh}}{200}\right)^2 \cdot \boldsymbol{\pi} \cdot \exp(\boldsymbol{a}_1 + \boldsymbol{a}_2 \ln(\boldsymbol{h}) + \boldsymbol{a}_3 \cdot \ln^2(\boldsymbol{h})) \qquad (12)$$

$$\boldsymbol{a_i} = \boldsymbol{c}_{1\boldsymbol{i}} + \boldsymbol{c}_{2\boldsymbol{i}} \cdot \ln(\boldsymbol{dbh}) + \boldsymbol{c}_{3\boldsymbol{i}} \cdot \ln^2(\boldsymbol{dbh})$$

Where *V* is the volume of a given tree, *WD* the wood density and *WC* the water content by tree species, *dbh* is the diameter at breast height and *h* is the tree height. a_i and c_i are the species-specific parameter estimates to calculate tree volume according to the volume function proposed by Kennel (1973).

For calculating the dry branch (*dbm*) and dry needle mass (*dnm*), we selected the relationships proposed by Hochbichler et al. (2006):

$$\boldsymbol{dbm}[\boldsymbol{dnm}] = \boldsymbol{e}^{\boldsymbol{b}_0 + \boldsymbol{b}_1 \cdot \ln(\boldsymbol{dbh}) + \boldsymbol{b}_2 \cdot \ln(\boldsymbol{h})} \qquad (13)$$

dbm and *dnm* follow the same relationships as a function of the diameter at breast height (*dbh*) and tree height (*h*). The species-specific parameters for calculating the dry branch and dry needle mass are given in Hochbichler et al. (2006). The leaf mass for deciduous trees is set to zero.

Finally the total dry fine and course root mass (drm) by tree species are calculated for
(i) Norway spruce and all other needle trees (Wirth et al., 2004):

$$\boldsymbol{drm} = 1.0406 \cdot \boldsymbol{e}^{-8.35049 + 4.56828 \cdot \ln(\boldsymbol{dbh}) - 0.33006 \cdot \ln^2(\boldsymbol{dbh}) + 0.28074 \cdot \ln(\boldsymbol{age})} \qquad (14)$$

(ii) Scots pine:

$$\boldsymbol{drm} = 0.038872 \cdot \boldsymbol{dbh}^{2.066783} \qquad (15)$$

(iii) Common beech and all other broad leaf trees (Li et al., 2003):

$$\boldsymbol{drm} = 1.576 \cdot (\boldsymbol{dsm} + \boldsymbol{dbm})^{0.615} \tag{16}$$

(iv) Oak spp.:

$$\boldsymbol{drm} = 1.0517 \cdot \boldsymbol{e}^{-3.97478 + 2.52317 \cdot \ln(\boldsymbol{dbh})} \tag{17}$$

dbh is the diameter at breast height, *dsm* the dry stem mass derived according to equations (11) and (12) and *dbm* the dry branch mass according to equation (13).
The last compartment for estimating NPP from forest growth data (see equation 8) is the carbon content of litterfall (C_{Litter}). We selected the relationship proposed by Liu et al. (2004):

$$\ln(C_{Litter}) = 2.296 + 0.741 \cdot \ln(T) + 0.214 \cdot \ln(P) \tag{18}$$

Where C_{Litter} is the carbon content of the litter in (g/m2/year), T is the mean annual temperature (°C), and P the mean annual precipitation (mm).

2.2.6 NPP from Biome-BGC

As a diagnostic tool for analyzing possible discrepancies in NPP estimates derived from MOD17 vs. ground based forest data we use the biogeochemical-mechanistic model BIOME-BGC. The model operates on a daily time step and simulates the cycle of energy, water, carbon and nitrogen within a given ecosystem. The model requires meteorological input data, such as daily minimum and maximum temperature, incident solar radiation, vapor pressure deficit and precipitation. Aspect, elevation, nitrogen deposition and fixation and physical soil properties are needed to calculate a wide range of daily ecosystem attributes. These include: canopy interception, evaporation, transpiration, soil evaporation, outflow, water potential and water content, LAI, stomatal conductance, assimilation of sunlight, shaded canopy fractions, growth and maintenance respiration, GPP, NPP, allocation, litter-fall, decomposition, mineralization, denitrification, leaching and volatile nitrogen losses. In the model, the carbon allocated to the leaves is multiplied by the specific leaf area (m^2 leaf area per kg leaf carbon) to calculate leaf area index (LAI, m^2 leaf area per m^2 ground area). LAI controls canopy radiation absorption, water interception, photosynthesis, and litter inputs to detrital pools. Net primary production (NPP) is based on gross primary production (GPP), calculated with the Farquhar photosynthesis routine (Farquhar et al., 1980), minus the autotrophic respiration. The autotrophic respiration includes the maintenance respiration and is calculated as a function of tissue nitrogen concentration (Ryan, 1991). Growth respiration is a function of the amount of carbon allocated to the different plant compartments (leaf, root and stem). The remaining NPP is partitioned to the leaves, fine and coarse roots and stems as a function of fixed allocation patterns.

Recent model improvements include species-specific parameters for all major tree species in Europe (Pietsch et al., 2005) and an improved self-initialization or model spin-up routine (Pietsch and Hasenauer, 2006).

2.2.7 Comparison of different NPP estimates

Considering Figure 2 and Figure 3, the ground based NPP estimates (Austrian Biomass Functions (ABF) + Terrestrial litter fall (REG) = 480 gC/m2/year) are lower than the MODIS driven NPP estimates regardless of the daily climate data set used (ZAMG=640 gC/m2/year, NCEP2=718 gC/m2/year, and GMAO=666 gC/m2/year). To explore these differences we run BIOME-BGC as a diagnostic tool for all our 151 sites. The model has been applied in two previous studies using the same forest data set to (i) validate a species specific version of the model (Pietsch et al., 2005) and to (ii) introduce a simple management routine which allows us to address potential density related management impacts on the flux dynamics (Petritsch et al., 2007). Therefore we know that the model produces unbiased and consistent estimates for these forest stands.

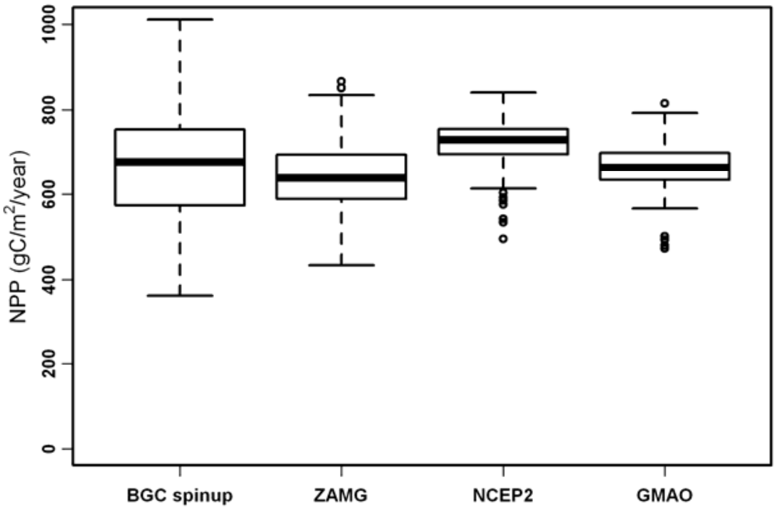

Figure 2: Example for a continuous 11-year average MODIS 1 by 1 km Net Primary Productivity (NPP) estimation for 2000 through 2010 across Austria (Hasenauer et al., 2012).

We started with a self-initialization procedure or ‘spin-up run’ to enable model applications for locations where no observations of initial conditions are available. For this study we applied the latest version of the self-initialization process (Pietsch and Hasenauer, 2006). During self-initialization, a set of climate records is used repeatedly to run the model until each model output converges towards a steady state. The steady state reached at the end of self-initialization is interpreted as the “temporally averaged state of an undisturbed ecosystem for a region large enough to encompass all its natural development stages” (Law et al., 2001). This situation may be seen as a regional productivity potential of fully stocked forest stands. For the self-initialization run, we used pre-industrial carbon dioxide concentration (280ppm) and nitrogen deposition (0.0001 kg/m2; Holland et al., 1999) rates. Since 1765 we increased the CO2 concentration and nitrogen deposition to current levels, as given in Eastaugh et al. (2011). This resulted in the model initialization prior to the actual simulation run for each plot. The median (665 gC/m2/year) and the first and third quartiles of the resulting spin-up computations for our 151 research plot is given in Figure 2.

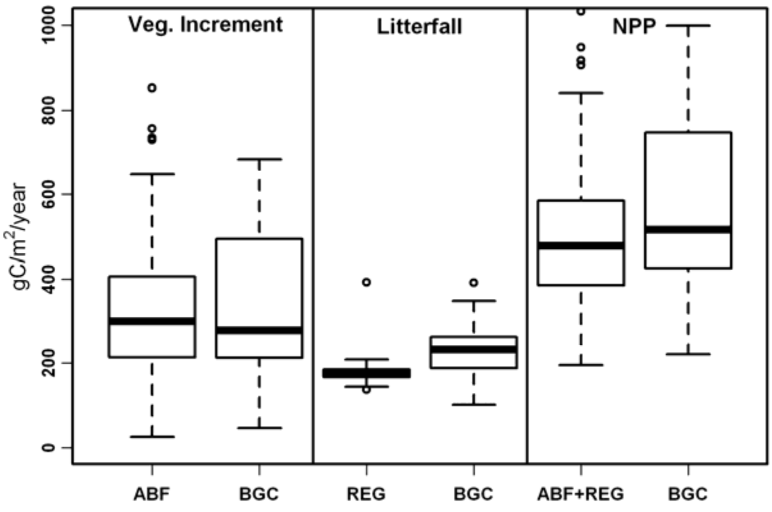

Figure 3: Comparison of the dry carbon vegetation Increment (Veg. Increment), Litterfall and total Net primary Production (NPP) calculated with the Austrian Biomass functions (ABF) versus simulated BIOME-BGC (BGC) (Hasenauer et al., 2012).

For each stand in our study species composition, current stand age and information regarding the thinning intensity is available. Thus, the actual simulations start with an assumed planting or regeneration according to stand age. Species specific differences in growth response due to thinning are considered using the available parameter sets for common beech and low- and high-elevation Norway spruce. Stem carbon predictions are converted into bole volume and used for comparisons with observed data according to species specific conversion factors. The conversion factors incorporated the bole fraction of aboveground timber, timber water and carbon content and timber density. For further details we refer to Pietsch et al. (2005).

2.2.8 Forest management impacts

Figure 3 reveals consistent computations for our plots using the Austrian Biomass Functions (ABF) and – after addressing forest management impacts – for the BIOME-BGC simulations. However it is also evident that the ground based NPP predictions in Figure 3 are substantially lower than all MODIS NPP computations (Figure 2). Depending on the climate data source the differences in the medians vary from 160 gC/m²/year (ZAMG vs. ABF) to 238.4 gC/m²/year (NCEP2 vs. ABF). This suggests that stand management may play an important role and this requires further analysis.

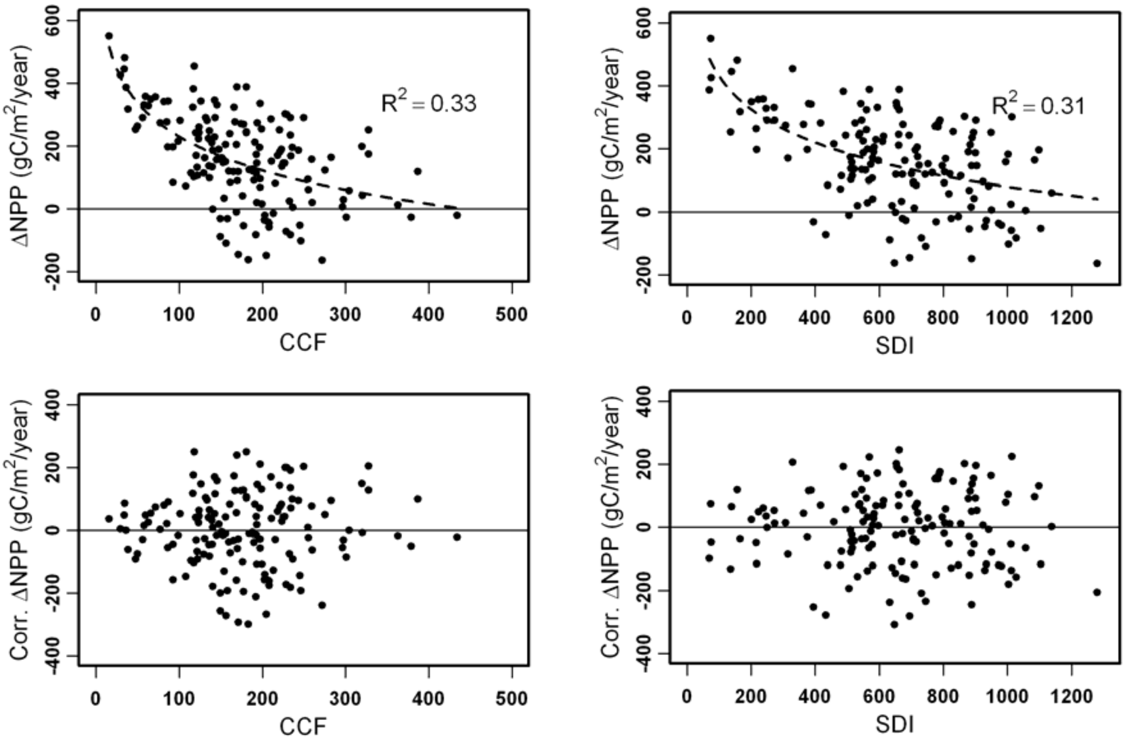

Figure 4: Trend in the differences (*ΔNPP*) between MODIS Net Primary Production (NPP) estimates using local Austrian weather data (ZAMG) minus NPP derived with the Austrian Biomass functions (ABF) vs. Crown Competition Factor (*CCF*) and vs. Stand Density Index (*SDI*). CCF and SDI are stand density measures calculated for each of our 151 permanent forest stands. The two lower graphs give the differences between MODIS versus terrestrial NPP estimates after applying the correction for competition effects (*Corr. ΔNPP*) as given by the trend lines.

From our terrestrial forest plots it is evident that they have experienced very substantial differences in management as expressed by the large variation in CCF and SDI (not shown here). It also suggests that most of the plots do not represent a fully stocked forest stand, a common situation in managed forest ecosystems. Because management alters stand density it will also change the ground based NPP estimates because of its impact on dbh and h development for the remaining trees on our plots. To investigate these effects we calculated the difference between MODIS NPP estimates using the local climate data and the ground based NPP computations (ZAMG minus ABF) and plotted the results versus two common stand density measures - CCF and SDI. **Fehler! Verweisquelle konnte nicht gefunden werden.** gives the differences in NPP (ΔNPP) versus the Crown Competition Factor (CCF) and the Stand Density Index (SDI) plus the corresponding nonlinear trend lines. For both of the two selected competition indices a significant (CCF R^2=0.33 tn=151;α=.005 =4.4*; and SDI R^2=0.31 tn=151;α=0,05=4.5*) density related bias is evident. With increasing density (increasing CCF as well as SDI) these differences approach zero according to the following nonlinear trend lines:

$$\text{CCF:} \qquad \Delta \boldsymbol{NPP} = 946.9 - 155.5 \cdot \ln(\boldsymbol{CCF}) \tag{16}$$

SDI: $$\Delta \boldsymbol{NPP} = 1135.8 - 152.9 \cdot \ln(\boldsymbol{SDI}) \tag{17}$$

All the details are presented in Hasenauer et al. (2012).

2.3 Description of dissemination and publication measures

Three main results can be presented:

1. A four month Sabbatical of Prof. Hasenauer in Missoula Montana working with Prof. Steve Running the developer of the MODIS data set used in this study. (June to September 2011)

2. A first scientific publication in Forest Ecology and Management – the leading forestry journal within the forestry sector:

> Hasenauer, H., Petritsch, R., Zhao, M., Boisvenue, C. and Running, S.W., 2012. Reconciling satellite with ground data to estimate forest productivity at national scales. Forest Ecology and Management, 276: 196-208.

3. A lectures and publication at the Austrian KLIMATAG in June 2011 entitled

> ***“Kohlenstoffschätzungen für Waldgebiete“***

3 Presentation of Costs

Please note the following: Payment of the installment due, based on the volume of support committed in the contract and on information provided in the corresponding report, does not mean that the expenses submitted are accepted as eligible. The eligibility of expenses is established after completion of the project through a detailed review of project costs by KPC. The last installment is paid out after approval of the final report and the final statement of expenses and subsequent adoption by the support management department of KPC.

3.1 Table of costs for the reporting period

The following table provides an aggregated overview of the costs incurred by the applicant and the project partners in the reporting period, broken down by staff costs, capital expenditure, travel expenses, administrative and material expenses, and third-party costs.

So far we received 81.712 at the beginning of the project and ask for the second
Payment of 40.800 Euro for the second year.

Cost category	**Eligible total costs according to contract**	**Cumulative costs of the reporting period** Total costs for the consortium*	**Applicant** Costs in the reporting period from – to	**Partner 1** Costs in the reporting period from - to	**Partner 2** Costs in the reporting period from - to
Staff costs	68981,111	68981,111	68981,111		
Capital expenditure					
Travel expenses	3375,70	3375,70	3375,70		
Administrative and material expenses					
Third-party costs					
Total	72356,891	72356,81	72356,81		

* Sum total of costs incurred / cost category of the applicant and all partners

3.2 Statement of costs in the reporting period

The costs incurred in the reporting period must be stated for each partner and/or each set of activities according to the underlying application.

3.3 Cost reclassification

Presentation and motivation of cost reclassifications, if any (between partners and/or cost categories) during the reporting period.

Not relevant

4 Outlook

The **foreseeable developments and priorities of the project in the next reporting period**, as well as any changes in time and cost schedules to be expected beyond that time frame, are to be described in this section.

We are exactly in the time schedule, no changes to the plan. One of the interesting and unexpected findings is the importance of the forest inventory data recording system (permanent plot versus angle count sampling method) and its impact on the terrestrial carbon estimates. The method strongly derives the accuracy of the resulting predictions and this has to be elaborated in detail to guarantee reliable estimates.

Our next working steps may be summarized as follows (see also the proposal)

1. Further develop and enhance our understanding in deriving forest management impact on the carbon balance of our forests (two papers related to this topic are currently in review)

2. Obtaining all the Austrian forest inventory data (not just the 151 permanent plots) and redoing the analysis

3. We are currently obtaining a second national forest inventory data set (from Norway) to further test our findings and investigate the impact of different recording systems (fixed area plot – see Norway versus angle count sampling – see Austria) on the resulting terrestrial carbon prediction and related error structure.

4.1 Time schedule

Please describe the sequence of activities planned for the coming reporting period. Indicate any changes in the future work and time schedule and adjust the original work and time schedule accordingly.

No changes are needed.

4.2 Planed Cost schedule

Please describe the costs and/or groups of cost items to be incurred in the coming reporting period.

1. Payment of our partners according to the plan
2. Own staff costs of about 50.000 Euro

5 Signature

I herewith confirm that the report in its entirety has been accepted by the project partners.

Wien, am 7. 11. 2012

Place, date

Signature of the applicant (coordinator)

Please note: the signature has to be scanned in and inserted into the document.

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