Validation of PICUS across Europe

MASTER THESIS

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Abstract

This Master thesis faces the objective to validate the ecological model PICUS v 1.5.2 across Europe. The aforementioned model is a hybrid model which combines elements of a gap model (Lexer and Hönninger, 2001) with models of forest management and forest production (Landsberg and Waring, 1997).

To assess the functionality of PICUS v 1.5.2 under a wide range of ecological conditions, it was decided to use two different types of simulation experiments. The first one is the simulation of competitive relationships of tree species in a scenario of potential natural vegetation (PNV). The second one focuses on the estimation of forest productivity.

The simulations are performed on a regular grid of 200km^2 across Europe. The PNV runs extend over a period of 1000 years. The simulations are performed to see the forest development without human influence starting from bare ground. For this task PICUS has available a list with 28 tree species. The outputs are compared with the classification of the European Forest Types, which is provided by the European Environment Agency (EEA), and also with the map of the PNV produced by Bohn et al. (2004).

Simulations of forest productivity are performed from bare ground as well as with forest regeneration process (plantation). The time period of this simulations is 100 years. Comparison between the PICUS outputs and the NPP values estimated from CASA (Pan et al., 2006) using vegetation index from MODIS.

In the PNV experiment between 84% and 93% of the simulated plots could be classified as the correct forest type (EFT) according to EEA. Using the more detailed classification by Bohn et al. the correct classifications is reduced to 18-69%, depending on the forest type.

The simulated NPP estimates explained between 37-45% of the variation in CASA NPP, depending on the scenario setting. There was a general tendency to underestimate NPP by PICUS. The role of site attributes which are highly loaded with uncertainty such as water holding capacity and available Nitrogen for the simulations is discussed.

As result, PICUS generates a representative picture of the PNV when it is compared with the classification made by the EEA. Whereas if we are more interested in a more detailed picture of the potential natural vegetation, PICUS is able to represent consistently the forest types EFT1, EFT2, EFT3, EFT5, EFT6 and EFT7. In our comparison of forest productivity, PICUS is capable as well to simulate consistently forest NPP under a wide range of ecological conditions.

Keywords: modeling, PICUS, PNV, NPP, forest types, dominant tree species, Europe, model validation.

Kurzfassung

Diese Masterarbeit behandelt die Validierung des dynamischen Waldökosystemmodells PICUS v 1.5.2 auf dem kontinentalen Scale Europas.

Um die Funktionalität von PICUS v 1.5.2 in einem weiten ökologischen Kontext zu beurteilen, wurden zwei verschiedene Simulationsexperimente auf einem Raster von 200km^2 über Europa durchgeführt. Ein Simulationsexperiment fokussiert auf die potentiell natürliche Vegetation (PNV) und die Konkurrenzverhältnissen zwischen den Baumarten. Das zweite Experiment fokussiert auf die Biomassenproduktivität.

Die PNV wird als mittlerer Vegetationszustand über 200 Jahre nach erfolgter Simulation beginnennd von einer Kahlfläche (i.e. Sekundärsukzession) definiert. Zu diesem Zweck hat PICUS die 28 Baumarten zur Verfügung. Die Ergebnisse der Simulation wurden mit der Waldtypen-Klassifikation der Europäischen Umweltagentur (EEA), sowie der Karte der potentiell natürlichen Vegetation nach Bohn et al. (2004) verglichen.

Die Simulationder Nettoprimärproduktion (NPP) startet sowohl von einer Kahlfläche (i.e. Naturverjüngung) als auch mit bereits vorhandener Baumverjüngung (Aufforstung) und erstreckt sich über insgesamt 100 Jahre. Die Simulationsergebnisse wurden mit unabhängig nach CASA (MODIS) nach Pan et al. (2006) geschätzten NPP-Werten aus der Literatur verglichen. Im PNV-Experiment konnten zwischen 84% und 93% der Probepunkte dem entsprechendem Europäischem Waldtyp (EFT) der EEA zugeordnet werden. Bei Verwendung der detaillierteren Gliederung von Bohn et al. Sank der Anteil der richtig zugeordneten Fälle auf 18-69%, je nach Waldtyp.

Simulierte NPP-Werte erklärten je nach Szenario zwischen 37 und 45% der Variation in den Vergleichsdaten mit allgemeiner Tendenz zu Unterschätzung. Die Rolle von mit starker Unsicherheit behafteten Bodenattributen (Wasserspeicherkapazität, verfügbarer Stickstoff) für die Simulationsergebnisse wird kritisch diskutiert.

Schlagwörter: Modell, Validierung, PICUS, PNV, NPP, Waldtypen, Baumarten, Europa

Abbreviations and Acronyms

AET	Evapotranspiration	**na**	No applicable
APAR	Photosynthetically Active Radiation Absorbed	**NFI**	National Forest Inventory
AISF	Academy of Forest Science	**NPP**	Net Primary Production
BA	Basal Area	**ns**	No significant
BfN	Bundesamt für Naturschutz	***OMfactor***	Organic Mater factor
CASA	Carnegie, Standford, Ames Approach	**TOPL**	Depth of topsoil
CEC	Cation Exchange Capacity	**SUBL**	Depth of subsoil
CCTAME	Climate Change – Terrestrial Adaptation & Mitigation in Europe	**PNV**	Potential Natural Vegetation
cm	Centimetres	**pH**	Level of acidity
cm^3	Cubic centimetres	**PREC_SUM**	Precipitation sum
CN-ratio	Ratio between carbon and nitrogen	**PREC_SUME**	Summer Precipitation
Corg % top AUT	Percentage of organic content in the topsoil in Austria	**3-PG**	Physiological Principles in Predicting Growth
Corg % top EU	Percentage of organic content in the topsoil in Europe	**REMO**	Regional Model
°C	Degrees Celsius	**$resp_{frost}$**	Frost response
dbh	Diameter at breast height	**$resp_{N}$**	Nitrogen response
EEA	Environmental European Agency	**$resp_{pH}$**	pH-response
EFT	European Forest Type	**$resp_{SMI}$**	Soil Moisture Index response
Eqs.	Equation	**$resp_{temp}$**	Temperature response

EUA	Europäischen Umweltagentur	**resp$_{VPD}$**	Vapour Pressure Deficit response
EU27	European Union of twenty seven countries	**SMI**	Soil Moisture Index
ε	Plant biomass increment	***spp***	Species
FAO	Food and Agriculture Organization of the United Nations	**TEMP_AMPLI**	Temperature amplitude
FWC_SUB	Field water capacity in the subsoil	**TEMP_AVG**	Mean temperature
FWC_TOP	Field water capacity in the topsoil	**UNECE**	Unite Nations Economic Commission for Europe
GDD	Growing Degree Days	**v**	Version
GIS	Geographical Information System	**VPD**	Vapour Pressure Deficit
hd	High	**VS_SUB**	Volume of stones in subsoil
ICP	International Co-operative Program	**VS_TOP**	Volume of stones in topsoil
kg/ha	Kilogram per hectare	**WHC**	Water Holding Capacity
km	Kilometre	**WHCtop**	Water Holding Capacity in the top soil
km²	Square kilometres	**WHCsub**	Water Holding Capacity in the sub soil
kPa	Kilopascal	**WP_TOP**	Wilting point in the topsoil
m	Meter	**WT**	Winter minimum temperatures
MCPFE	Ministerial Conference on the Protection of Forests in Europe	**Wε**	Water stress
mm	Millimetres	**yr.**	Year

MODIS	Moderate-resolution Imaging Spectroradiometer	*	Significant
MPI-M	Max-Planck-Institute für Meteorologie	**	Very significant
N	Nitrogen	***	Highly significant
n	Number of plots		

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1. Introduction

Since the early 70s the technology of gap models has been developed. As one of the earliest works, Botkin et al. (1972) was an inspiration. Thus, the doors were open to new models which simulate growth, reproduction and death of individual trees for small forest patches of around 0.1 ha in size (Lexer and Hönninger, 2001). The popularity of patch models increased considerably due to the linkage to environmental factors such as temperature and soil moisture, providing in this manner valuable tools for decision making related to the issues of global change. However, in the mid 90´s, patch models start to be indicted due to mechanistic deficits, thermal response, derivation of the thermal response and a declining growth at super-optimal temperatures (Lexer and Hönninger, 2001).

The PICUS model has been constantly exposed to several updates, facing the criticism and the weaknesses of former patch models with effective solutions. Lexer and Hönninger presented in 2001 the PICUS v 1.2 as a patch model with 3D spatial structure, as well as the integration of a radiation sub model. PICUS v 1.2 describes the response of European forest trees to temperature and soil moisture. In addition to the characteristics mentioned before, PICUS v 1.2 model the effect of site nutrient status on tree growth by fuzzy logic mechanisms (Lexer et al., 2000). With this innovative patch model presented by Lexer and Hönninger, several weaknesses of patch models presented before PICUS were solved (Lexer and Hönninger, 2001).

In 2005 a new version was presented by Seidl et al. (2005) named as PICUS v 1.3., which couples the structure of PICUS v 1.2 with the production module of the 3-PG (Physiological Principles in Predicting Growth) model. This evolution of the former PICUS v 1.2 combines the simulation of forest dynamics with the 3-PG model based on the concept of radiation use efficiency (Seidl et al., 2005).

2. Objectives

The objective of this study is to assess the functionality of the hybrid model PICUS v 1.5.2 under a wide range of ecological conditions. This assessment will be done by simulating the competitive relationship of tree species in a scenario of potential natural vegetation (PNV), and the simulation of forest productivity.

To achieve these objectives the study evaluated

a. the achievement of the steady state of forest composition (i.e. PNV).
b. simulated forest productivity by comparing it with an independent source.

3. Materials and Methods

3.1 PICUS

The model PICUS v 1.5.2 is a hybrid model which combines functions of a gap model (Lexer and Hönninger, 2001) simulating forest development based on the patch dynamics theory (Watt, 1947; Picket and White, 1985), with models of forest management and forest production (Landsberg and Waring, 1997). PICUS as hybrid model incorporates as well elements of physiology-based forest growth models (Didion et al., 2009), which utilize a spatial framework of 10m x 10m to do the simulations of each tree and calculations of the level light regime for the whole stand. Consider additionally interactions between patches. This model simulates multi-species stands which are structured in different layers and with a realistic response to climate drivers (Seidl et al., 2005).

PICUS v 1.5.2 offers different modules (e.g., Stand initialization/management, Bark beetle module and Rock fall module) as well as a flexible framework allowing a fully interaction between the model operator and PICUS v 1.5.2. It allows the direct communication with sub-models and offers an intuitive 3D graphical interface, plus the analysis of large areas due to an efficient computing time with large and complex databases (Seidl, 2007).

For this work I would like to mention some PICUS environments which are especially relevant to drive the validation. These environments are the temperature, soil moisture index and nutrient supply. A detailed description can be found in Lexer and Hönninger (2001).

Temperature: The temperature regime is represented by the winter minimum temperatures (WT) and the growing degree days (GDD). The input variables of the temperature regime are monthly weather data. The GDD is above a threshold of 5.5°C, calculated from quasi-daily values which are interpolated from monthly means and parameterized using the data of the NFI. The WT is calculated using the coldest month of a year, which is decisive to limit the regeneration of tree species vulnerable to frost (Lexer and Hönninger, 2001).

Soil moisture index: The soil moisture index (SMI) is calculated based on a soil moisture sub model which assumes stable soil conditions controlling the variability of site quality in time with respect to soil properties. Due to similar reasons exposed by Bugmann and Cramer in 1998 arguing about the inconsistencies calculating the evapotranspiration (AET), the moisture sub model used in PICUS is an upgrade version of the moisture model traditionally used in gap models (Lexer and Hönninger, 2001).

Nutrient supply: is represented by available nitrogen. The response of the tree species into five different groups. These groups were parameterized according to literature (Lexer and Hönninger, 2001) and expert knowledge.

3.2 PNV map

The PNV map is the result of a project developed by a total of 31 European countries, as well as the Caucasus region and Eastern Russia (western regions from the Ural Mountains). This project was called "Map of the Natural Vegetation of Europe". The initiative started within the 12th International Botanical Congress in St.

Petersburg during the cold war in 1975 (Bohn et al. 2004). Nowadays this information is available at the website of the BfN.

Bohn et al. (2004) commented in their report "Map of the Natural Vegetation of Europe", that the map offers complete information about PNV to the user. To achieve this type of result, the multidisciplinary and international scientific group had to cope with the different ways of classification and representation of the vegetation, recording and transforming them into a common concept.

The scale of the PNV map is 1:2,500.000 and it is presented in digital form with the software EuroVegMap 2.0 where it can be visualized as a GIS map or as a Google map. Also the user can export the area of interest as a shape file or a Google Earth file. The PNV map is based on two different main types of classifications. The first one is based on phytogeographical zones and regions (e.g. Atlantic, Central Europa, Boreal or Mediterranean). The second classification method is based on climate and site-dependent plant formations (Bohn et al. 2004).

As it is described in "Map of the Natural Vegetation of Europe" by Bohn et al. (2004), the structure and composition of the PNV map were determined on the basis of remaining natural and near-natural ecosystems and their correlation with site-specific conditions. The distribution of characteristics and differences between plants species were treated equally.

The PNV map of Europe provides information about the form, natural variety and spatial distribution of the main vegetation units across Europe. It also shows the location and total extent of areas with similar site qualities and environmental conditions. A unit is defined on this map as a complex of different natural plant communities, which are characteristic for a region or habitat (Bohn et al. 2004).

Bohn et al. (2004) explain the vegetation description on the PNV map in a hierarchically organized system divided in three different levels as it is described below:

First level: The physiognomy classifies the vegetation cover into zonal and azonal formations, and formation complexes as the main structural elements (Figure 3:1).

Second level: Dominant species in the main vegetation layer and their combinations in the middle hierarchical level.

Third level: Combinations of characteristic species and finer floristic differentiation based on geographical and habitat differences at the lowest level (Figure 3:2). This highly detailed description is the level we selected to evaluate the outputs of the PNV simulations with PICUS at small scale.

This hierarchical system has 19 classes and 699 subclasses. The 19 different formations (Table 3:1), of which 14 (A to O) correspond to the macroclimatic zones and latitudinal belt in the mountain ranges across Europe. The remaining five formations (P to U) are characterized mainly by edaphic site factors (Table 3:2) (Bohn et al. 2004).

Table 3:1 List of the different zonal vegetation groups, which are climatically conditioned across Europe and described in the PNV map (Bohn et al. 2004).

	Zonal vegetation (primarily climatically conditioned)
A	Polar deserts and subnival-nival vegetation of high mountains
B	Arctic tundra and alpine vegetation
C	Subarctic, boreal and nemoral-montane open woodlands as well as subalpine and oro-Mediterranean vegetation
D	Mesophytic and hygromesophytic coniferous and mixed broadleaved-coniferous forests
E	Atlantic dwarfs shrub heaths
F	Mesophytic deciduous broadleaved forests and mixed coniferous-broadleaved forests
G	Thermophilous mixed deciduous broadleaved deciduous forests
H	Hygro-thermophilous mixed broadleaved deciduous forests
J	Mediterranean sclerophyllous forest and scrub
K	Xerophytic coniferous forest, woodlands and scrub
L	Forest steppes (meadow steppes alternating with deciduous broadleaved forests) and dry grasslands alternating with xerophytic scrub
M	Steppes
N	Oroxerophytic vegetation (thorn-cushion communities, tomillares, mountain steppes, open scrub)
O	Deserts

Table 3:2 List of the different azonal vegetation groups, which are determined by specific soil properties and water balances across Europe and described in the PNV map (Bohn et al. 2004).

	Azonal vegetation (determined by specific soil properties and water balances)
P	Coastal vegetation and inland halophytic vegetation
R	Tall reed vegetation and tall sedge swamps, aquatic vegetation
S	Mires
T	Swamp and fen forests
U	Vegetation of floodplains, estuaries and freshwater polders and other moist wet sites

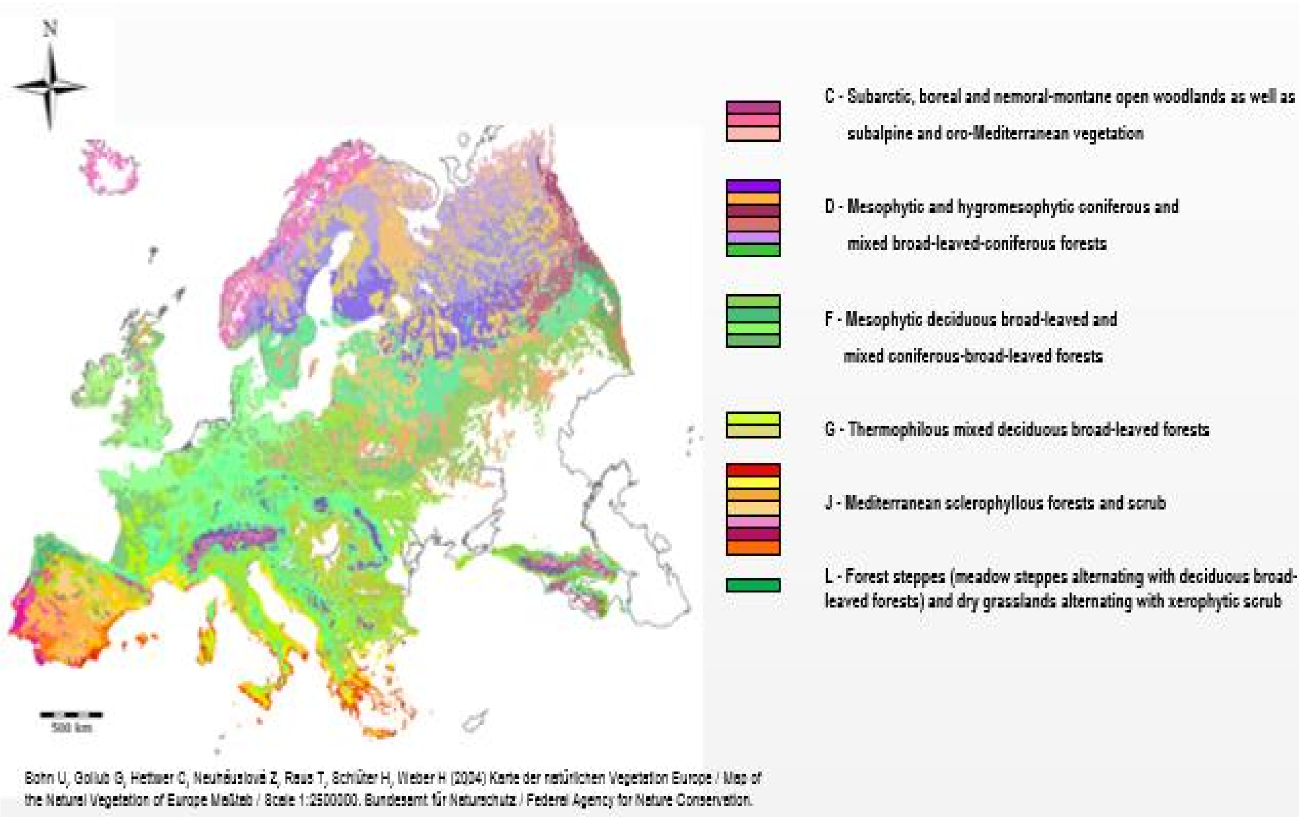

Figure 3:1 Map of the Natural Vegetation of Europe. First level of classification. Scale 1:2500000. Federal Agency for Nature Conservation (Bohn et al 2004).

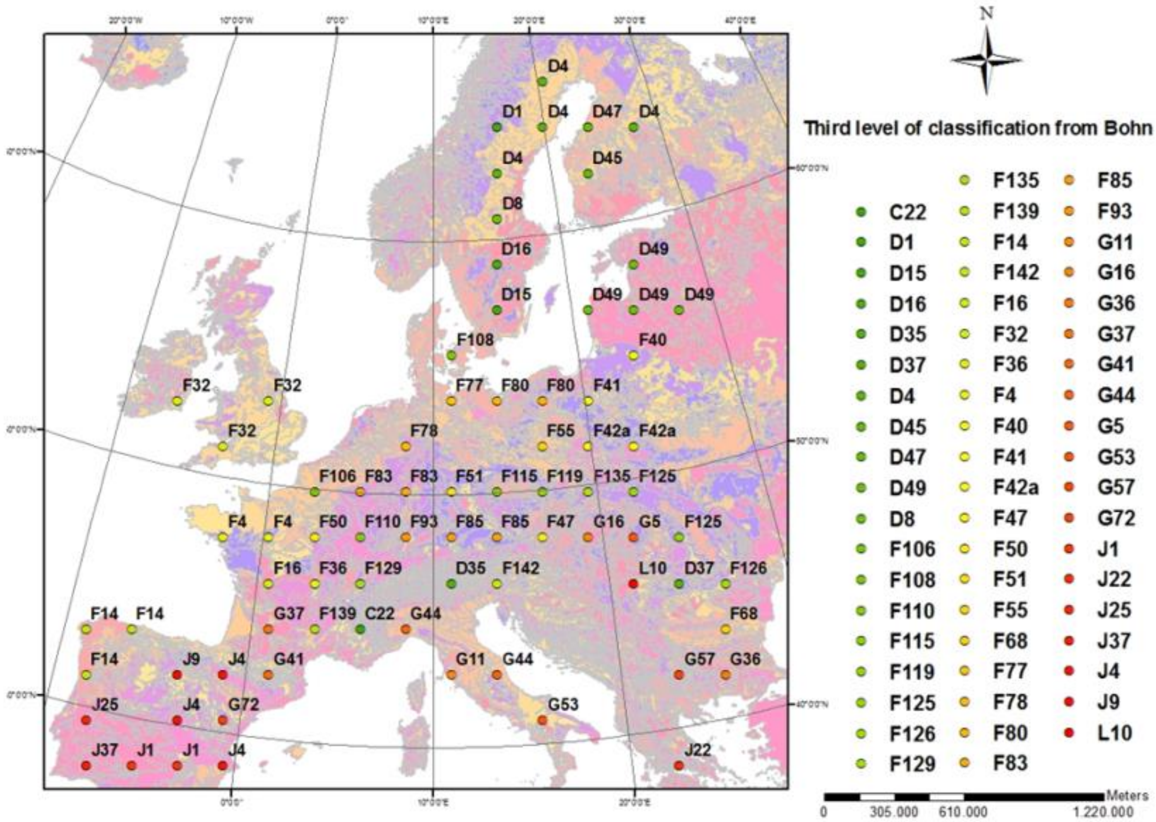

Figure 3:2 Third level of classification of Natural Vegetation distributed across Europe. Density of the grid equal 200km^2. Grid superposed to the Map of the Natural Vegetation of Europe (Bohn et al 2004). Scale 1:220000. See Table 7:2 and 7:22.

3.3 Classification of the EFT's by the EEA

The database generated to classify each forest type is based on the information offered by the output of "Categories and types for sustainable forest management reporting and policy" presented by the European Environment Agency (EEA) in 2006.

This EEA´s technical report shows the result of collaboration between the Italian Academy of Forest Science (AISF) and a group of international experts from several European countries. The results classify the European Forest Types (EFT) in 14 different classes for the first level and 75 different classes for the second level (Barbati et al. 2007). Each European Forest Type is defined by Barbati et al. (2007) as: "A category of forest defined by its composition, and/or site factors (locality), as categorized by each country in a system suitable to its situation". The contribution of Barbati et al. in 2007, provide generalist information and a description of the EFT's, which makes an easy differentiation of each EFT. The next list shows the 14 classes of forest types from the first level which we select to evaluate the outputs of the PNV simulations with PICUS at big scale.

EFT1: Boreal forest.

EFT2: Hemiboreal forest and nemoral coniferous and mixed broadleaved coniferous forest.

EFT3: Alpine coniferous forest.

EFT4: Acidophilus oak and oak-birch forest.

EFT5: Mesophytic deciduous forest.

EFT6: Beech forest.

EFT7: Mountainous beech forest.

EFT8: Thermophilous deciduous forest.

EFT9: Broadleaved evergreen forest.

EFT10: Coniferous forests of Mediterranean, Anatolian and Macaronesian regions.

EFT11: Mire and swamp forest.

EFT12: Floodplain forest.

EFT13: Non riverine alder, birch, or aspen forest.

EFT14: Plantations and self-sown exotic forest.

The work in hand, focuses on those EFT classes which are compatible with the plot grid designed for the project and which PICUS v 1.5.2 is able to simulate. The respective EFT classes are: "Boreal forest", "Hemiboreal forest and nemoral coniferous and mixed broadleaved coniferous forest", "Alpine coniferous forest", "Mesophytic deciduous forest", "Beech forest", "Mountainous beech forest" and "Thermophilous deciduous forest". Next subparagraphs explain each EFT used on this project following the description of Barbati et al. (2007).

3.3.1 Boreal forest

The main drivers which affect forest productivity in the boreal zone are the temperature and length of the growing season. Two conifer species (*Picea abies* and *Pinus sylvestris*) are the dominant species in the boreal forest in the late stage of the succession driven by edaphic conditions. As the early colonists in bare ground and early stages of forest succession, different trees of deciduous species appear (*Betula spp., Populus tremula, Sorbus aucuparia and Salix spp.*)

During the 20th century, most of the boreal forest has been managed as an even-aged forest, favouring conifers instead of deciduous tree species due to economic reasons. The dynamic of boreal forest is regulated under natural conditions by forest fires ignited by lightning and repeated with cyclical frequency. Nowadays, these wildfires are prevented by forest management.

3.3.2 Hemiboreal forest and nemoral coniferous and mixed broadleaved coniferous forest

The main drivers for this type of forest related to productivity are the light regime and the length of the growing season, varying considerably from north to south.

The forest cover is divided in two different categories: latitudinal mixed forests located in between the boreal and nemoral forest zones, and anthropogenic coniferous forest in the nemoral zone.

Hemi-boreal forests are composed by the coexistence between boreal coniferous species and temperate broadleaved tree species like *Betula spp., Populus tremula, Alnus spp. and Sorbus aucuparia*. In scattered patches, with most fertile soils, we can find also other broadleaved deciduous trees as *Quercus robus, Fraxinus excelsior, Ulmus glabra and Tilia cordata*. This forest composition has been altered and reduced by the expansion of hemi-boreal forest by anthropogenic impacts.

3.3.3 Alpine coniferous forest

Climatic and growing variables are similar to the boreal zone, where the temperature and length of the growing season (short growing seasons with cold and harsh climate) are the main drivers to determine productivity. The only differences are the light regime and the length of the day. Forest tree species distribution varies depending on vegetation belts and site conditions (Barbati et al. 2007). The disposition of alpine areas creates different alpine mountain ranges (Figure 3:3). As an example, the mountain ranges through the Alps along a longitudinal section (North to South) are: "Foreland, Front range, Intermediate Range, Central range, Intermediate Range, Front range and Foreland" (Nagy et al. 2003).

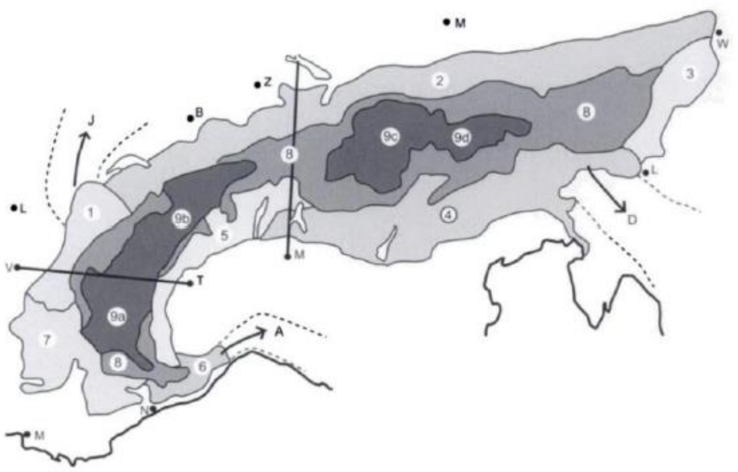

Figure 3:3 Ecological zones in the Alps and biogeographical sectors based on relatedness between the Alps and the peripheral chains: 1-7 Pre-Alps sectors (with a predominance of carbonated rocks, except 3 and 5; 1 Delphino-Jurassian sector of the southern Jura; 2 north-eastern Pre-Alps; 3 Suprapannonian sector; 4 Illyrian and Gardesan-Dolomitic sector extending in to the Dinarid Mountains; 5 Insubrian- Piedmontese sector; 6 Preligurian sector extending into the northern Apennines; 7 High Provençal sector); 8, 9 sectors with a siliceous predominance and a continental climate forming the intra-alpine axis. Around the two poles of continentality (9) are the intermediate Alps, (8) uninterrupted in the eastern Alps but largely fragmented in the western Alps (Ozenda, 1985).

The main conifer species are *Picea abies* and *Pinus sylvestris*. Additionally, *Larix decidua, Pinus cembra, Pinus nigra* and *Pinus mugo* as natural dominant tree species can be found.

The traditional land use pressure produced by pastoral farming practices have modified the landscape and species distribution across alpine areas. In any case, due to the rapidly land abandonment and change of traditional practices to intensive practices, it is observed a remarkable regression of this land use pressure.

In Alpine areas predominate the even-aged management. Only in small areas with species mix (*Picea abies, Fagus sylvatica and Abies alba*) the management is done by selection cutting.

3.3.4 Mesophytic deciduous forest

The canopy of mesophytic deciduous forest is a mixed composition constituted of *Carpinus betulus*, *Quercus petraea*, *Quercus robur*, *Fraxinus spp*., *Acer spp*. and *Tilia cordata*.

Since the mesophytic deciduous forest is associated with fertile soils (mesotrophic and eutrophic soils), most of the original area has been cleared and converted to very productive land. The predominating management across this type of forest is even-aged stands (Barbati et al. 2007).

3.3.5 Beech forest

With a very wide geographic distribution due to the wide climatic and edaphic amplitude as well as its competitive strength, beech forest is present in the lowlands as well as in sub mountainous areas across Europe. The limitations of beech forest are related to low winter temperatures causing either direct damages or too short growing season. It is characterized by the dominance of the forest cover by *Fagus sylvatica* or *Fagus orientalis* in the eastern and southern parts of the Balkan Peninsula. In addition, *Betula pendula* and other mesophytic deciduous species are locally important for this forest formation.

Traditional management as coppice with standards, is still present in rural areas. In any case most of the beech forest is managed as even-aged forest.

3.3.6 Mountainous beech forest

In relation to the mountainous altitudinal belt of the main European mountain ranges, mountainous beech forest is formed by *Fagus sylvatica, Picea abies, Abies alba* and locally *Betula pendula* and mesophytic deciduous species. Where this two coniferous species are as competitive as beech, they also appear as forest building trees (Barbati et al. 2007).

As is described in the technical report of the EEA, the mountainous beech forest has been intensively managed for firewood purposes, in mining areas and in some parts of the Apennines and the Alps. During the 20th century, most of the stands were turned to high forest.

3.3.7 Thermophilous deciduous forest

Appears in the supra-Mediterranean vegetation belt, comparable to the mountainous level of middle European mountains, and is only limited to the north by temperature and to the south by drought.

The forest composition of mixed deciduous and semi-deciduous forest of thermophilous species is directly influenced by climatic conditions. Within this range *Quercus spp.* is the main tree species and *Acer spp., Ostrya spp., Fraxinus spp.* and *Carpinus spp.* are frequently secondary tree species.

Due to the management of this forest type, in most cases natural species disappear because they are not valuable or they have no commercial interest. Traditionally, the silvicultural systems used on thermophilous deciduous forest are coppice, coppice with standards and mixed coppice/high forest (Barbati et al. 2007).

3.4 Map of dominant tree species across Europe

It shows the distribution of 20 tree species groups over Europe within a resolution of 1km grid. The information used by Brus et al. (2012) consist of the ICP-Level-1 plot data collected across Europe (www.icp-forest.org) and the National Forest Inventory (NFI) data of eighteen countries. For each of this data sources, Brus et al. (2012) use two different mapping methods. The first method is a multinominal multiple logistic regression model, used for the ICP data source with a resolution of 16 km grid. In areas not well represented by the ICP it was used the NFI data source mapped by compositional kriging within a resolution of 1km grid. The predictors used by Brus et al. (2012) in the mapping process are a soil map, a biogeographical map and bio indicators from temperature and precipitation. The groups of dominant tree species (Table 3:3) are in intervals from 0 to 1 and sum to 1. To scale the results of dominant tree species proportions, Brus et al. (2012) use a variation of the methodology used by Tröltzsch et al. (2009). This proportions are validated by the Bhattacharyya distance between predicted and observed proportions at 230 plots separated from the calibration, obtaining an estimated overall accuracy of 43%. In areas where the ICP plot data where used, the overall accuracy was 33%. In areas where the NFI plot data were used, the overall accuracy was 57% due to the higher plot data density (Brus et al. 2012).

Table 3:3 Groups of dominant tree species.

Groups of tree species			
1	*Abies spp*	**11**	*Conifers misc.*
2	*Alnus spp*	**12**	*Pinus misc.*
3	*Betula spp*	**13**	*Quercus misc.*
4	*Carpinus spp*	**14**	*Picea spp*
5	*Castanea spp*	**15**	*Pinus pinaster spp*
6	*Eucalyptus spp*	**16**	*Pinus sylvestris*
7	*Fagus spp*	**17**	*Populus spp*
8	*Fraxinus spp*	**18**	*Pseudotsuga menziesii*
9	*Larix spp*	**19**	*Quercus robur & Quercus petraea*
10	*Broad leaved misc.*	**20**	*Robinia spp*

3.5 CASA estimations of NPP across Europe

The estimations of NPP values used to validate the simulations of productivity performed with PICUS, are obtained from simulations with the CASA model using the vegetation index offered by MODIS. The CASA model (Carnegie, Standford, Ames Approach) provides in a global scale, a monthly estimation of NPP, combining ecological theories, satellite data and site information (Field et al. 1995). This model was developed by Portter et al. (1993) to simulate the optimal metabolic rates of biochemical processes occurred in any of the ecosystems.

As Potter et al. (1993) describes in "Global Net Primary Production: Combining Ecology and Remote Sensing", the estimations of the NPP are equal to the product of the photosynthetically active radiation absorbed annually by green vegetation (APAR) by the efficiency, whereby that radiation is converted to plant biomass increment (ε) for a certain location and time.

For a time period of 1982 to 1995 the model provides the total NPP values which shows the Figure 3:4, using MODIS vegetation index and the climate data mentioned in the paragraph 3.6. It is available with a resolution of 0.25° (28 x 28 km), whereas the current climate has a resolution of 1 km grid. Rammer and Lexer recalculate the values offered by CASA in to kg/ha as it is explained in "CCTAME / Evaluation" (2011) *(Unpublished manuscript)*.

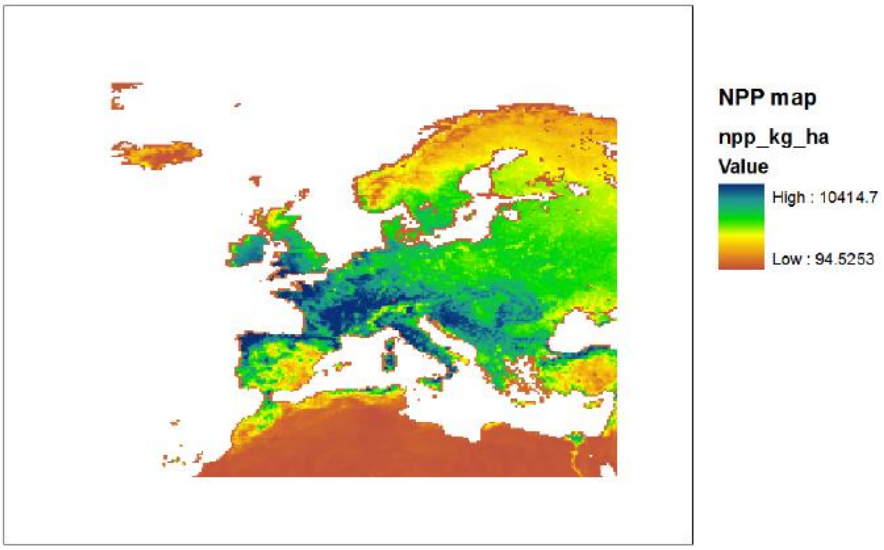

Figure 3:4 Annual NPP values transformed to kg/ha by Rammer and Lexer (2011).

3.6 Climate

The climate data is provided on a regular grid across the EU27. This grid has a resolution of 25 x 25 km and it is composed of 32300 cells (Kindermann et al. 2013). For each pixel the data available are: the mean temperature "TEMP_AVG" (average of monthly mean temperatures over the period (1961-1990) [*°C*]) (Figure 3:5), precipitation sum "PREC_SUM" (yearly sum of precipitation in *mm*), summer precipitation "PREC_SUMME" (precipitation sum *mm* of the month May, June, July, August and September) (Figure 3:6) and temperature amplitude "TEMP_AMPLI" (difference between the warmest and coldest month [*°C*]) (Rammer and Lexer 2011). This climate data is extracted from the Regional Model (REMO), (Jacob et al. 2008). This current climate was used as a starting point for the climate information, developing a database of climate series for the years 2000-3000 sampling by random numbers the REMO climate data for the period 1961-1990.

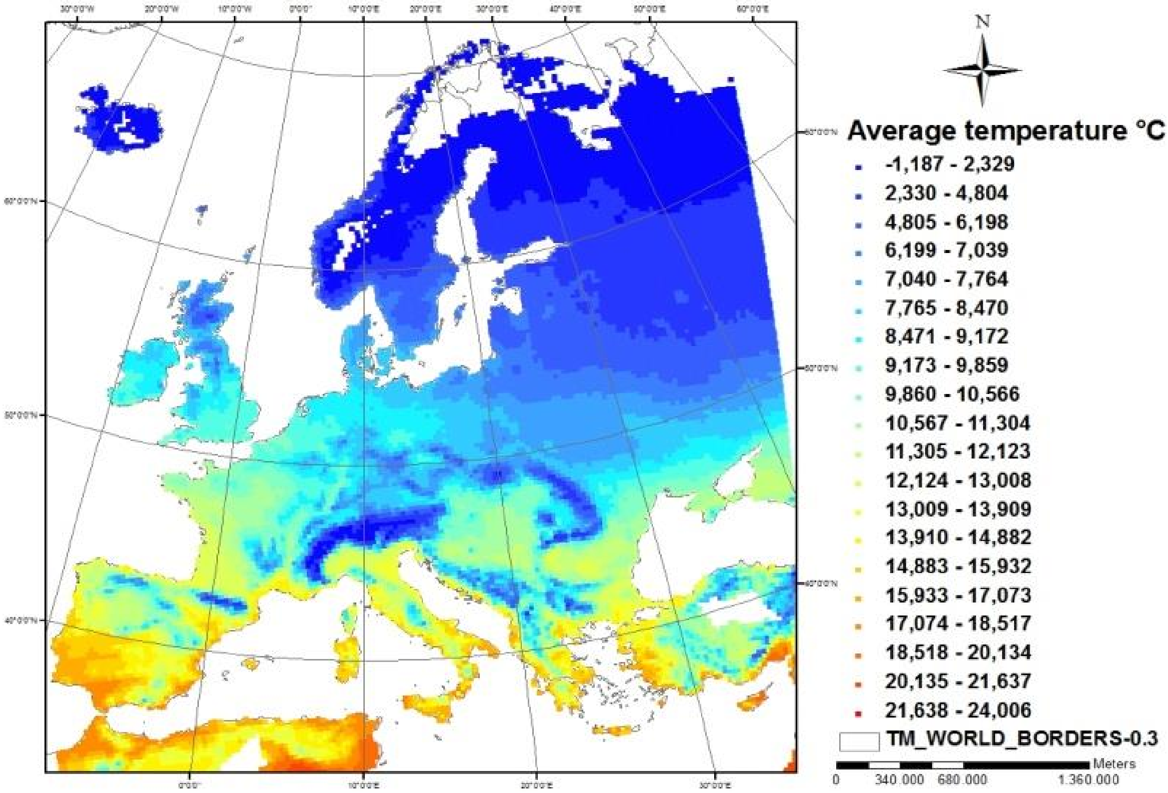

Figure 3:5 Distribution of average temperatures across EU27 (Rammer and Lexer 2010).

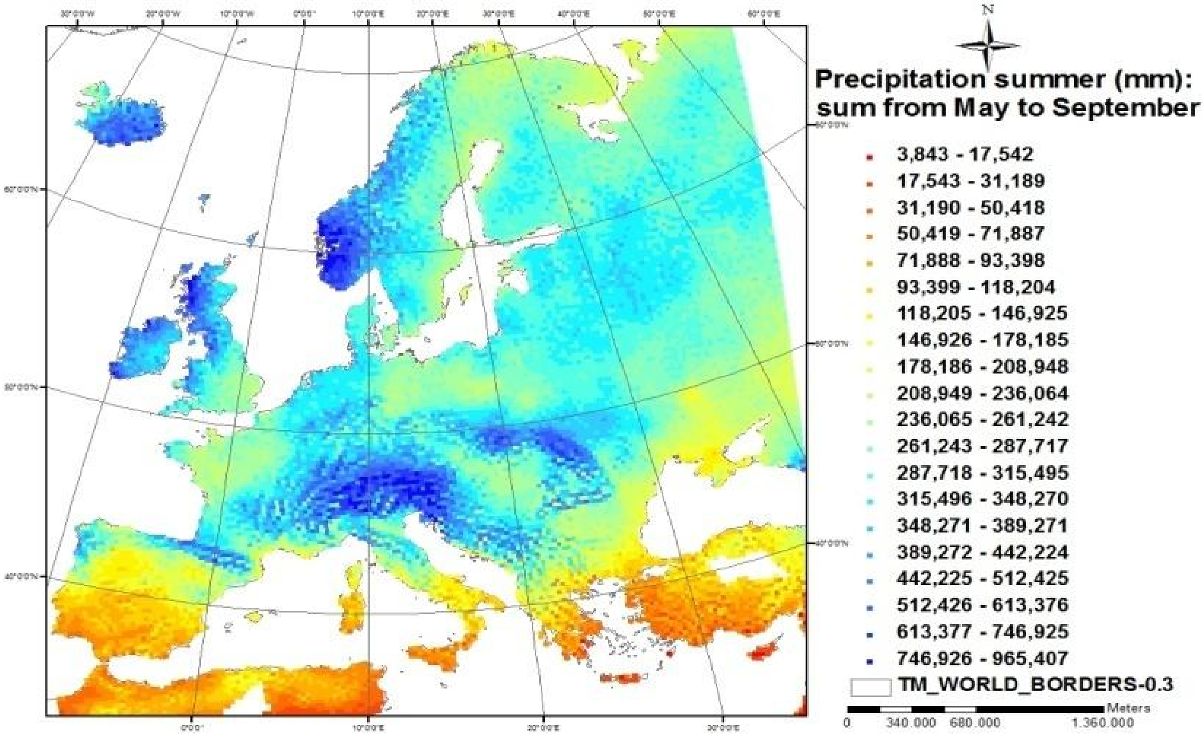

Figure 3:6 Distribution of summer precipitations across EU27 (Rammer and Lexer 2010).

3.7 Soil

Soil information is set by four different components. These components are water holding capacity, the plant available nitrogen, pH and CN-ratio, which defines partially the conditions with which the simulations are performed.

3.7.1 Water holding capacity

The water holding capacity values (WHC) are obtained from Rammer and Lexer (2010) and based on "CCTAME. Climate data processing. Rammer and Lexer, 2010".

Table 3:4 shows the variables used by Rammer and Lexer (2010) to calculate the WHC. The data set developed by Rammer and Lexer (2010) includes a value of organic carbon of 0.01% as a default value.

As the data set misses any values of organic carbon from the sub-soil, and is based on data of the Austrian Forest Soil Survey; Rammer and Lexer (2010) estimates those values and enables the computing of a correction factor which incorporates the effect of organic matter in the sub-soil [*OMfactor*] (Rammer and Lexer 2010).

The values of WHC derived by Rammer and Lexer (2010) were calculated following the Eqs. (3:1) - (3:3) using the parameters provided by Table 8.7-1 (Rammer and Lexer 2010):

$$WHCtop = (FWCtop - WPtop) \cdot TOPL \cdot (1 - VStop) \quad \text{Eq. (3:1)}$$

$$WHCsub = (FWCsub - WPsub) \cdot SUBL \cdot (1 - VSsub) \cdot OMfactor \quad \text{Eq. (3:2)}$$

$$WHCtotal, mm = (WHCtop + WHCsub) \cdot 1000 \quad \text{Eq. (3:3)}$$

For more information it is recommended to read the paper "CCTAME / Data processing - Part II - Water Holding Capacity and Nitrogen." from Rammer and Lexer (2010) as well as "CCTAME. Climate data processing" wrote also by Rammer, Lexer (2010) *(Unpublished manuscripts)*.

Table 3:4 Variables used to calculate the WHC using the data set from CCTAME (Rammer and Lexer 2010).

Name	Description	Remarks
WP_TOP	Wilting point at 15020 kPa in the topsoil [cm³/cm³]	
WP_SUB	Wilting point at 15020 kPa in the subsoil [cm³/cm³]	
FWC_TOP	Field water capacity at 33kPa in the topsoil [cm³/cm³]	
FWC_SUB	Field water capacity at 33kPa in the subsoil [cm³/cm³]	
TOPL	Depth of topsoil [m]	Three classes [0.05, 0.1 and 0.15m]
SUBL	Depth of subsoil [m]	Four classes [0.4, 0.8, 1.2 and 1.5m]
VS_TOP	Volume of stones in topsoil [%]	
VS_SUB	Volume of stones in subsoil [%]	

3.7.2 Nitrogen

Values of Nitrogen required for the simulations are the yearly available Nitrogen. These values are obtained by Rammer and Lexer (2010) multiplying the

Nitrogen pool size by the mineralization rate. The mineralization rate was estimated in order to calculate the N-available based on values of pH, climate information, cation exchange capacity (CEC) and the CN-ratio. Values of Nitrogen content are estimations based on aggregated data of the Austrian Forest Soil Survey, including four different soil depth classes (0-10 cm, 10-20 cm, 20-30 cm, 30-50 cm) for calcareous soils as well as non-calcareous soils. Using the depth of topsoil/sub-soil, the bulk density of topsoil and sub-soil within a maximum depth of 50 cm, as well as the values of Nitrogen content, a total Nitrogen pool is created allowing the calculation of yearly available Nitrogen (Rammer and Lexer 2010) *(Unpublished manuscript)*.

3.7.3 pH of the soil

Rammer and Lexer commented in "CCTAME / Data processing - Part II - Water Holding Capacity and Nitrogen *(Unpublished manuscripts)*" the range of pH which correspond to the soil across EU of CCTAME dataset. In this range of pH values, the pH equal to 4.6 for the topsoil, are used as threshold to develop the dataset. In Figure 3.7.3-1, the lowest values of pH, which are higher than 4.2, represent agricultural land. Those values usually correspond to acidic forest soils (Rammer and Lexer 2010) *(Unpublished manuscript)*.

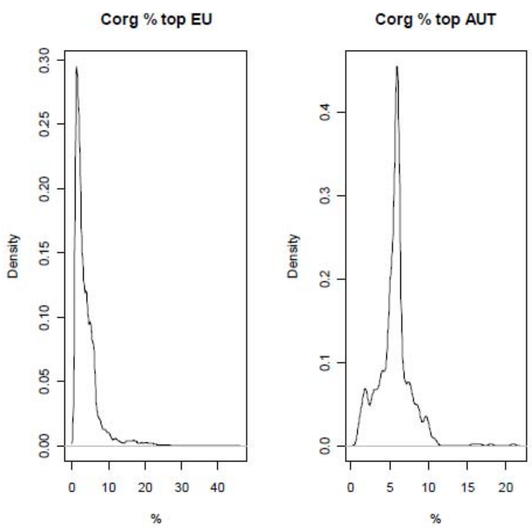

Figure 3:7 Distribution of pH in the dataset (left: top soil pH, right: sub soil pH) (Rammer and Lexer 2010).

3.7.4 *CN-ratio of the soil*

The CN-ratio is calculated dividing the estimated pool size for organic carbon in top soil by the N-pool-size for top soil. Due to the wide variety of data sources, the result of the CN-ratio was narrow. Thereby a CN-ratio > 25 was considered as "high", representing the 24% of soil for EU27 (Rammer and Lexer 2010).

3.8 Study area

More than 35% of Europe are cover by forest (Brus et al., 2012), where 74% of the European forest have been under anthropogenic pressure and the 26% considered as undisturbed remains in Eastern and North European countries (UNECE, MCPFE & FAO., 2007). The diversity of European forests is directly influenced by the strong paleo climate stratification of Europe. Events as glaciations in the Quaternary and geographical barriers (Alps and Pyrenees) have been determinants defining colonization routes and favourable refuge areas, with special regard to thermophilous and temperate species (Ozenda, 1994 and Petit et al., 2002). Therefore, these events together with the remarkable anthropogenic footprint (burning, grazing and forest clearing) with which the European forest cover is mould along the history, are necessary to understand the present geographical distribution and composition of forest communities (Pons, 1984 and Halkka and Lappalainen, 2001).

The study area is the EU 27 with an area of 4319190ha. Located between the latitudes 66° to 38°, with a wide range of forest types going from Subarctic palsa mire complexes in the north of Finland, to hellenic-Aegean meso-Mediterranean holm oak and kermes oak forest in Greece. The very wide study area leads to us very extreme values of WHC, Temperature, Precipitation and Nitrogen (Table 3:5 and Table 7:22 to Table 7:26).

Table 3:5 Climate and soil information of the study area. Values represented in the table are: water holding capacity (WHC), Nitrogen (N), average of all monthly mean temperatures (TEMP AVG), average of summer precipitation from May to September (PREC SUMME).

	Maximum	Minimum
WHC [mm]	266	100
N [kg/ha*yr.]	215	40
TEMP AVG [°C]	16.40	-2.82
PREC SUMME [mm]	648	66

3.9 Study design

3.9.1 PNV

The simulation among competitive relationship of the tree species in a scenario of potential natural vegetation (PNV) has been performed over a 200km² grid across Europe, within a simulation time period of 1000 years. The starting point of the simulation is from bare-ground, where 28 tree species are simulated simultaneously. The climate data necessary for the simulations is based on current climate data series described in the paragraph "3.6 Climate". As the simulations are in a scenario of PNV, operations of forest management are not required. The outputs from PICUS are, as mentioned in earlier publications (Hickler et al., 2012), compared with the PNV map of Europe offered by the BfN and developed by geobotanical expert assessment (Bohn et al., 2003), as well as with the classification of the EFT's developed by the EEA (Barbati et al., 2007). These comparisons are classified as small scale comparison (more detailed) for the comparison with the PNV map, and as big scale comparison (less detailed) for the comparison with the classification of the EFT's.

Originally the 200km² grid across Europe was composed by 103 plots, within which fifty eight subclasses of vegetation are determined (Figure 3.2-2). Due to plots with lack of site information, plots with an altitude over 2000 meters and plots classified as flood plains, exotic plantations, mires or swamps; the number of plots simulated is reduced from 103 to 68 plots. This reduction of plots produce also the reduction in the number of EFT's present in the simulations as well as the number of forest subclasses from the BfN. The new grid with 68 plots classifies fifty one different forest subclasses and seven different EFT's (Table 7:1 and Table 7:2). In this grid, 84 forest tree species are identified by the BfN, sorted in groups by common site factors, geographical distribution, natural accompanying vegetation and identified with the equivalent tree species with which the PICUS simulations are performed (Table 7:3).

3.9.2 NPP

The simulations of forest productivity are performed over the same grid as used for the PNV, within a simulation period of 100 years. Two different starting points are differentiated in this simulation. The first one is from bare ground and the second one is when the regeneration already started, named as plantation. The regeneration parameters are the same for each tree species simulated (Table 7:4). To have a summarized well represented picture of the European forest tree species, eight different tree species were selected for the simulations from the tree species list of PICUS (Table 7:5).

For this simulations the climate data used, is the same as for the simulation of PNV. Operations of forest management are also not required for the simulations of forest productivity. The outputs obtained from the simulations of forest productivity are compared with the NPP estimations across Europe from CASA.

The first four times, the NPP values estimated from the PICUS simulations compared with CASA, are the maximum NPP value from the eight tree species simulated. This comparisons are performed with NPP for the year 50 as well as for the mean of the 100 years simulation.

The map of dominant tree species across Europe, will determine which species values of the NPP simulations must be compared with CASA. The number of tree species selected to simulate the forest productivity is smaller than the number of tree species described in the map of dominant tree species. Therefore, some equivalences between the two lists of tree species were predetermined in order to simplify the study. In the map of dominant tree species, broad leaved misc. represent the average value of NPP from the broad leaved tree species selected in PICUS. *Fagus sylvatica* in PICUS, represent in the map of dominant tree species *Fraxinus spp*, *Fagus spp*, *Castanea spp* and *Alnus spp*.. *Pinus sylvestris* in PICUS represents in the map of dominant tree species *Pseudotsuga menziesii*. The composition of *Quercus robur* and *Quercus petraea* from the map of dominant tree species is equivalent to the average NPP value of *Quercus robur* and *Quercus petraea* from PICUS. This comparisons are performed also with two scenarios and for the year 50 as well as for the 100 years mean.

Due to the extensive study area, the influence of climate, availability of ground water and availability of nutrients is observed. The elements selected to describe these influences are the latitude, WHC and the Nitrogen available. The effects of the confluence of very low values of WHC with very low values of nitrogen, as well as very high values of WHC with very high values of nitrogen were observed.

3.10 Analysis

3.10.1 PNV

In order to analyse the competitive relationship of the tree species in a scenario of potential natural vegetation (PNV), we chose the species composition which is calculated from the basal area for each of the 28 tree species simulated with PICUS. To achieve the steady state of forest composition the last 400 years of the simulation period were used to calculate the species composition.

The information provided by the EEA and the BfN is a very detailed qualitative information. Based on expertise, each EFT description as well as each description of the forest subclasses required, are interpreted to identify the tree species present as dominant, codominant and admixture. The tree species which remain outside of these three categories are classified as "others" with a value for the total of the species share ≤10%. Following this interpretation, the species share calculated from the PNV simulations are summed up reconstructing the stratification of the forest cover on each plot (Table 3:6). It is considered a successful prediction of any of the stratus, when the result of the sum is represented by the Table 3:6. Values <25 % of species share for codominant tree species are also classified as hit when the species share of dominant tree species are >75%.

Table 3:6 Stratification of the forest cover according to the species share composition.

Forest cover stratification	Species share (%)
Dominant	≥50% BA
Codominant	<50% BA to ≥25% BA
Admixture	<25% BA
Others	≤10% BA

To assess the performance of the PNV simulations, the results are displayed in several comparison matrices. With these matrices the simulations are compared with the EEA classification as well as with the BfN classification. The number of correct predictions are in the diagonal axis of the matrix, while the wrong predictions are off of the diagonal.

3.10.2 NPP

In the analysis of forest productivity, we are focused on two different estimated values of NPP. Those values are: maximum NPP and NPP of the present tree species. The comparisons with the NPP estimations from CASA were performed by linear regression, comparing the maximum NPP and the NPP of the present tree species with the NPP estimations from CASA. Values of NPP compared with CASA are obtained from the calculated NPP mean values for the year 50, and from the mean values within the 100 year simulation period.

The influence of climate, availability of ground water, availability of nutrients and sites was analysed by the significance of differences between means for the year 50, as well as for the 100 years' time period utilizing R software. The analysis was performed dividing each influential factor into three different groups. Climate is represented by the latitude and is divided in group A (latitudes ≥35° and <45°), group B (latitudes ≥45° and <55°) and group C (latitudes ≥55° and ≤67°). Availability of water is represented by the WHC and is divided in group A (WHC <110 [mm]), group B (WHC ≥110 [mm] and ≤210 [mm]) and groups C (WHC >210 [mm]). Availability of nutrients is represented by the Nitrogen and is divided in group A (N <50 [kg/ha*yr.]), group B (N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]) and group C (N >100 [kg/ha*yr.]).

Related to the effects of the interaction of very low values of WHC with very low values of nitrogen, as well as very high values of WHC with very high values of nitrogen, two groups are designed and labelled as SITES. This groups are named as group no stress (WHC >210 [mm] and N >100 [kg/ha*yr.]) and stress (WHC <110 [mm] and N <50 [kg/ha*yr.]). The effects are analysed by the significance of differences between NPP means for the year 50, as well as for the 100 years mean NPP between the groups.

The significance of differences between the groups described above is determined with Tukey's test comparing all possible means based on a studentized range distribution (Tukey, 1949). Assuming that the sample size in SITES as well as the variances is different between both groups, the significance of differences between no stress and stress is tested with the Welch's test (Welch, 1947).

4. Results

4.1 PNV

The estimations of Potential Natural Vegetation across Europe are realized with PICUS v 1.5.2. These estimations are achieved through simulations from bare ground, for a time period of a 1000 years. The first part of the PNV results, is represented by the distribution across Europe of tree species, based on the species share calculated with the basal area. The second part shows the number of hit plots as well as the ratio of success per European Forest Type, following the general EFT descriptions of Barbati et al. (2007) and also the detailed EFT descriptions of Bohn et al. (2004).

4.1.1 Distribution of PNV

On 50% of the simulated plots *Fagus sylvatica* is the dominant tree species (Figure 4:1) As described by the Table 7:3 *Fagus sylvatica subsp. moesica* and *Ulmus spp.* are represented by *Fagus sylvatica* in the simulations (Figure 4:1). For this reason, where appears *Fagus sylvatica* after simulations, it can be instead

Fagus sylvatica, *Ulmus spp*. or *Fagus sylvatica subsp. moesica*. The lack of site information, mainly soil information, generates the gaps represented in the distribution of PNV (Figure 4:1).

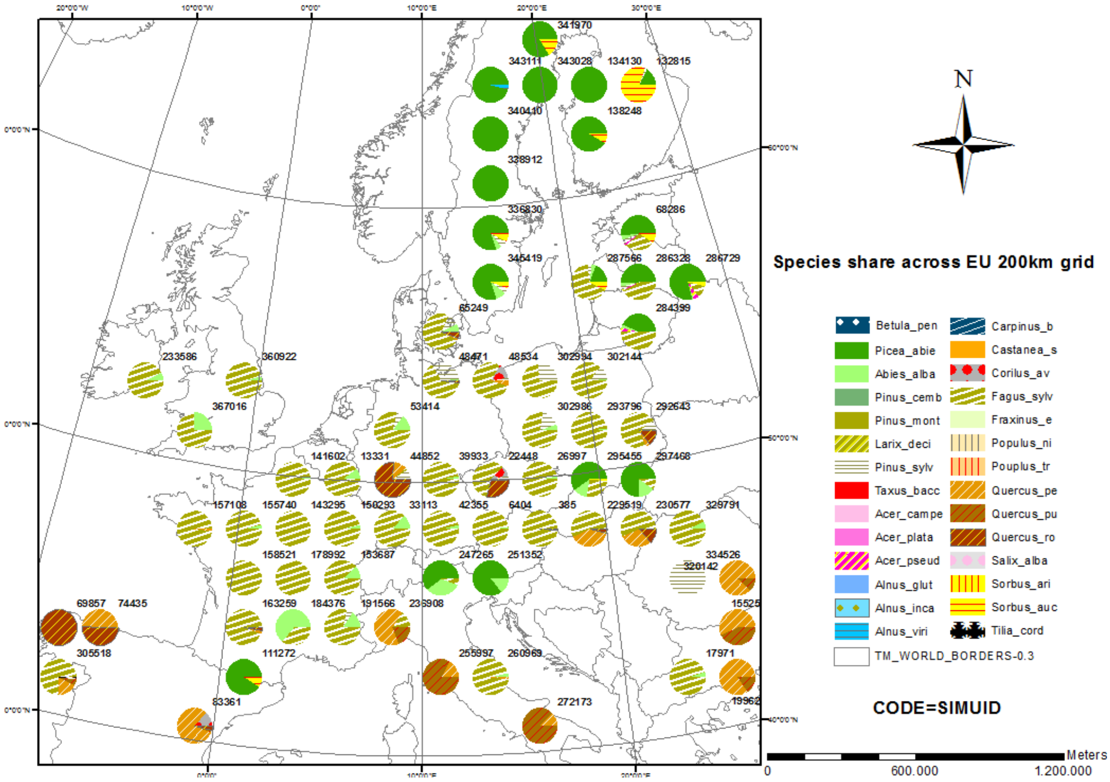

Figure 4:1 PNV distribution across Europe of after simulations with PICUS v 1.5.2 over a 200 km² grid after a time period simulation of 1000 years. Tree species which appears on the legend are described in Table 7:3.

4.1.2 Assessment of PNV simulations versus EFT classification from EEA

At any of the EFTs, the percentage of success is lower than 80% for dominant tree species (Table 4:1) and the overall accuracy remains above 90% (Table 4:3). There are non-remarkable errors across the comparison of PNV simulations versus EFTs classification from EEA, beside one plot classified by the EEA as EFT8 which is simulated by PICUS as EFT3. As it is expected, due to the incorporation of codominant and admixed tree species in the comparison, the percentage of success decreases slightly in EFT7 (Table 4:2).

Table 4:1 ***Assessment*** **of EFTs for dominant tree species. List with short description of the EFT's in Annex 1 (Table 7:1).**

Assessment EFT		EEA classification							N° of Hits	N° of plots	Unclassified	[%] of Hits
		EFT 1	EFT2	EFT3	EFT5	EFT6	EFT7	EFT8				
PICUS	EFT1	**7**	1	0	0	0	0	0	7	8	0	87.50
	EFT2	0	**6**	0	0	0	0	0	6	6	0	100
	EFT3	0	0	**3**	0	0	0	0	3	3	0	100
	EFT5	0	0	0	**19**	0	0	0	19	19	0	100
	EFT6	0	1	1	0	**13**	1	0	13	16	0	81
	EFT7	0	0	0	0	0	**5**	0	5	5	0	100
	EFT8	0	0	1	0	0	0	**10**	10	11	0	91
	Σ	7	8	5	19	13	6	10	**63**	68	0	**93**

Table 4:2 ***Assessment*** **of EFTs for dominant, codominant and admixed tree species. List with short description of the EFT's in Annex 1 (Table 7:1).**

Assessment EFT		EEA classification							N° of Hits	N° of plots	Unclassified	[%] of Hits
		EFT 1	EFT2	EFT3	EFT5	EFT6	EFT7	EFT8				
PICUS	EFT1	**7**	1	0	0	0	0	0	7	8	0	87.50
	EFT2	0	**6**	0	0	0	0	0	6	6	0	100
	EFT3	0	0	**3**	0	0	0	0	3	3	0	100
	EFT5	0	0	0	**19**	0	0	0	19	19	0	100
	EFT6	0	1	1	0	**8**	4	0	8	16	2	50
	EFT7	0	0	0	0	0	**4**	1	4	5	0	80
	EFT8	0	0	1	0	0	0	**10**	10	11	0	91
	Σ	7	8	5	19	8	8	11	**57**	68	2	**84**

Table 4:3 Percentage of accuracy and percentage of misclassification rate of the EFT assessment.

EEA classification	Accuracy [%]	Misclassification Rate [%]
Dominant tree species	93	7
Dominant, codominant and admixed tree species	84	16

4.1.3 Assessment of PNV simulations versus BfN classification from PNV map.

This assessment is much more detailed subdividing the seven EFTs of the EEA classification into 51 different forest types (Table 4:4 to Table 4:13.). Due to this diversification of forest types, the possibility to obtain unrealistic results with the PNV simulations increase. However, the success in the PNV simulations remains very high. Only in the EFT8 the percentage of hits drops dramatically (Table 4:12). The increment of number of errors due to the incorporation of codominant and admixture tree species to the assessment, only affect the simulations of EFT 3 (Table 4:6, Table 4:7 and Table 4:13), indicating the strength of the PNV simulations. The overall accuracy for dominant tree species is 50% (Table 4:13). For dominant, codominant and admixed tree species, the overall accuracy is 41% (Table 4:13).

Table 4:4 *Assessment* of EFT1 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment		BfN classification					N° of Hits	N° of plots	Unclassified	[%] of Hits
EFT1		D4	D45	D47	D1	D8				
PICUS	D4	**3**	0	0	1	0	3	4	0	75
	D45	1	**0**	0	0	0	0	1	0	0
	D47	1	0	**0**	0	0	0	1	0	0
	D1	0	0	0	**1**	0	1	1	0	100
	D8	0	0	0	0	**1**	1	1	0	100
	Σ	5	0	0	7	1	**5**	8	0	**62.50**

Table 4:5 *Assessment* of EFT2 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment		BfN classification			N° of Hits	N° of plots	Unclassified	[%] of Hits
EFT2		D15	D16	D49				
PICUS	D15	**1**	0	0	1	1	0	100
	D16	0	**1**	0	1	1	0	100

	D49	1	2	**0**	0	4	1	0
	Σ	2	3	0	**2**	6	1	**33**

Table 4:6 ***Assessment*** **of EFT3 under the BfN classification for dominant tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).**

Assessment EFT3		BfN classification C22	D35	D37	N° of Hits	N° of plots	Unclassified	[%] of Hits
PICUS	**C22**	**0**	0	0	0	1	1	0
	D35	0	**1**	0	1	1	0	100
	D37	0	0	**1**	1	1	0	100
	Σ	0	1	1	**2**	3	1	**67**

Table 4:7 ***Assessment*** **of EFT3 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).**

Assessment EFT3		BfN classification C22	D35	D37	N° of Hits	N° of plots	Unclassified	[%] of Hits
PICUS	**C22**	**0**	0	0	0	1	1	0
	D35	0	**0**	1	0	1	0	0
	D37	0	0	**1**	1	1	0	100
	Σ	0	0	2	**1**	3	1	**33**

Table 4:8 ***Assessment*** **of EFT5 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).**

Assessment EFT5		BfN classification F14	F16	F32	F36	F4	F40	F41	F42	F47	F50	F51	F55	F68	N° of Hits	N° of plots	Unclassified	[%] of Hits
PICUS	**F14**	**1**	1	0	0	0	0	0	0	0	0	1	0	0	1	3	0	33.33
	F16	0	**0**	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
	F32	0	0	**0**	0	0	0	0	3	0	0	0	0	0	0	3	0	0
	F36	0	0	0	**0**	0	0	0	0	0	0	1	0	0	0	1	0	0

F4	0	0	0	0	**2**	0	0	0	0	0	0	0	0	2	2	0	100
F40	0	0	0	0	0	**1**	0	0	0	0	0	0	0	1	1	0	100
F41	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	1	1	0
F42	0	0	0	0	0	0	0	**2**	0	0	0	0	0	2	2	0	100
F47	0	0	0	0	0	0	0	0	**1**	0	0	0	0	1	1	0	100
F50	0	0	0	0	0	0	0	0	0	**0**	1	0	0	0	1	0	0
F51	0	0	0	0	0	0	0	0	0	0	**1**	0	0	1	1	0	100
F55	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	1	1	0
F68	0	0	0	0	0	0	0	0	0	0	0	0	**1**	1	1	0	100
Σ	1	1	0	0	2	1	0	5	1	0	5	0	1	**9**	19	2	**47**

Table 4:9 Assessment of EFT6 under the BfN classification for dominant tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment		BfN classification												N° of Hits	N° of plots	Unclassified	[%] of Hits
EFT6		F106	F108	F110	F119	F125	F126	F139	F77	F78	F80	F83	F85				
PICUS	**F106**	**1**	0	0	0	0	0	0	0	0	0	0	0	1	1	0	100
	F108	0	**1**	0	0	0	0	0	0	0	0	0	0	1	1	0	100
	F110	0	0	**1**	0	0	0	0	0	0	0	0	0	1	1	0	100
	F119	0	0	0	**1**	0	0	0	0	0	0	0	0	1	1	0	100
	F125	0	0	0	0	**1**	0	0	0	0	0	0	0	1	2	1	50
	F126	0	0	0	0	0	**0**	0	0	0	0	0	0	0	1	1	0
	F139	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	1	0
	F77	0	0	0	0	0	0	0	**1**	0	0	0	0	1	1	0	100
	F78	0	0	0	0	0	0	0	0	**1**	0	0	0	1	1	0	100
	F80	0	0	0	0	0	0	0	0	0	**1**	0	0	1	2	1	50
	F83	0	0	0	0	0	0	0	0	1	0	**1**	0	1	2	0	50
	F85	0	0	0	0	0	0	0	0	0	0	0	**2**	2	2	0	100
	Σ	1	1	1	1	1	0	0	1	2	1	1	2	**11**	16	4	**69**

Table 4:10 Assessment of EFT6 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment		BfN classification												N° of Hits	N° of plots	Unclassified	[%] of Hits
EFT6		F106	F108	F110	F119	F125	F126	F139	F77	F78	F80	F83	F85				
PICUS	F106	**1**	0	0	0	0	0	0	0	0	0	0	0	1	1	0	100
	F108	0	**0**	0	0	0	0	0	0	0	0	0	0	0	1	1	0
	F110	0	0	**1**	0	0	0	0	0	0	0	0	0	1	1	0	100
	F119	0	0	0	**1**	0	0	0	0	0	0	0	0	1	1	0	100
	F125	0	0	0	0	**1**	0	0	0	0	0	0	0	1	2	1	50
	F126	0	0	0	0	0	**0**	0	0	0	0	0	0	0	1	1	0
	F139	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	1	0
	F77	0	0	0	0	0	0	0	**0**	0	0	0	0	0	1	1	0
	F78	0	0	0	0	1	0	0	0	**0**	0	0	0	0	1	0	0
	F80	0	0	0	0	0	0	0	0	0	**0**	0	0	0	2	2	0
	F83	0	0	0	0	1	0	0	0	1	0	**0**	0	0	2	0	0
	F85	0	0	0	0	0	0	0	0	0	0	0	**2**	2	2	0	100
	Σ	1	0	1	1	3	0	0	0	1	0	0	2	**6**	16	7	**37.50**

Table 4:11 *Assessment* of EFT7 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment		BfN classification					N° of Hits	N° of plots	Unclassified	[%] of Hits
EFT7		F115	F129	F135	F142	F93				
PICUS	F115	**0**	0	0	0	0	0	1	1	0
	F129	0	**1**	0	0	0	1	1	0	100
	F135	0	0	**1**	0	0	1	1	0	100
	F142	0	0	0	**0**	0	0	1	1	0
	F93	0	0	0	0	**1**	1	1	0	100
	Σ	0	1	1	0	1	**3**	5	2	**60**

Table 4:12 *Assessment* of EFT8 under the BfN classification for dominant, codominant and admixed tree species. List with short description of the BfN classification in Annex 1 (Table 7:2).

Assessment EFT8		BfN classification										N° of Hits	N° of plots	Unclassified	[%] of Hits
		G11	G16	G36	G37	G41	G44	G5	G53	G57	G72				
PICUS	G11	**1**	0	0	0	0	0	0	0	0	0	1	1	0	100
	G16	0	**0**	0	0	0	0	0	0	0	0	0	1	1	0
	G36	0	1	**0**	0	0	0	0	0	0	0	0	1	0	0
	G37	0	0	0	**0**	0	0	0	0	0	0	0	1	1	0
	G41	0	0	0	0	**0**	0	0	0	0	0	0	1	1	0
	G44	1	0	0	0	0	**0**	0	0	0	0	0	2	1	0
	G5	0	0	0	0	0	0	**0**	0	0	0	0	1	1	0
	G53	0	0	0	0	0	0	0	**1**	0	0	1	1	0	100
	G57	0	0	0	0	0	0	0	0	**0**	0	0	1	1	0
	G72	0	1	0	0	0	0	0	0	0	**0**	0	1	0	0
	Σ	2	2	0	0	0	0	0	1	0	0	**2**	11	6	**18**

Table 4:13 Percentage of accuracy and percentage of misclassification rate of the EFT assessment from BfN classification.

BfN classification	Accuracy [%]	Misclassification Rate [%]
Dominant, codominant and admixed tree species EFT1	62.50	37.50
Dominant, codominant and admixed tree species EFT2	33	67
Dominant tree species EFT3	67	33
Dominant, codominant and admixed tree species EFT3	33	67
Dominant, codominant and admixed tree species EFT5	47	53
Dominant tree species EFT6	69	31
Dominant, codominant and admixed tree species EFT6	37.50	62.50
Dominant, codominant and admixed tree species EFT7	60	40
Dominant, codominant and admixed tree species EFT8	18	82
Total accuracy dominant tree species	50	50
Total accuracy dominant, codominant and admixed tree species	41	59

4.2 NPP

4.2.1 NPP50 Plantation

The productivity simulated with PICUS starting from a plantation (NPP50 Plantation), shows the tendency to underestimate when compared with the productivity values estimated from CASA utilizing the data base of MODIS (NPP-MODIS) (Figure 4:2, Table 7:7). The regression model explains 42% of the variation in the data. The slope coefficient of the regression model (b= 0.7546) indicates that PICUS in general underestimates the NPP values from CASA.

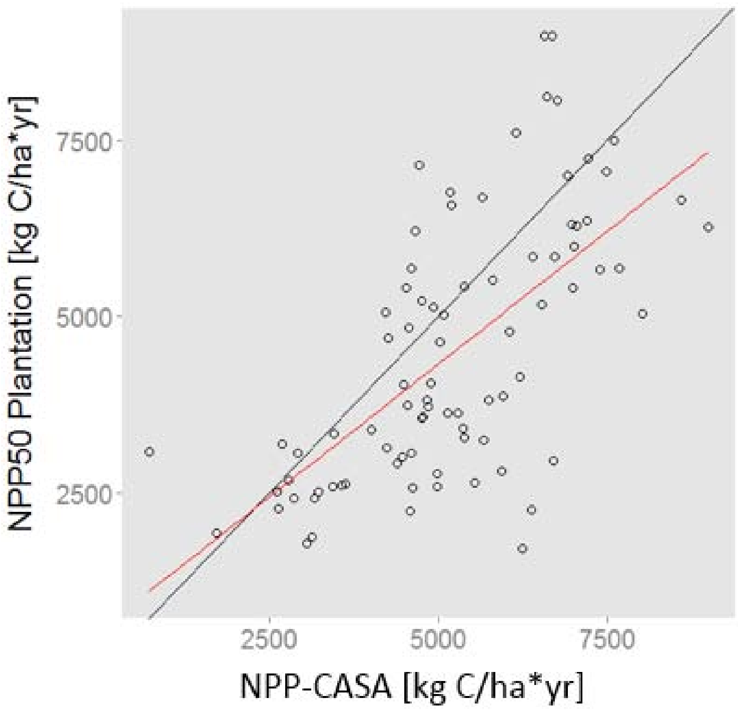

Figure 4:2 Linear regression (red line; R^2 = 0.42) between the simulated net primary production of year 50 (NPP50) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a plantation. n = 84.

Looking into more detail, there are some significant patterns in the estimation of productivity by PICUS depending on site factors across the study area (Figure 4:3 - to Figure 4:6). Latitude levels are no significant factor while there is an overestimation at WHC levels >210mm. At Nitrogen levels <50 kg ha^{-1} yr^{-1} PICUS underestimates NPP50 while at sites with better Nitrogen supply there is no clear tendency to over- or underestimate. Nitrogen, WHC and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:14).

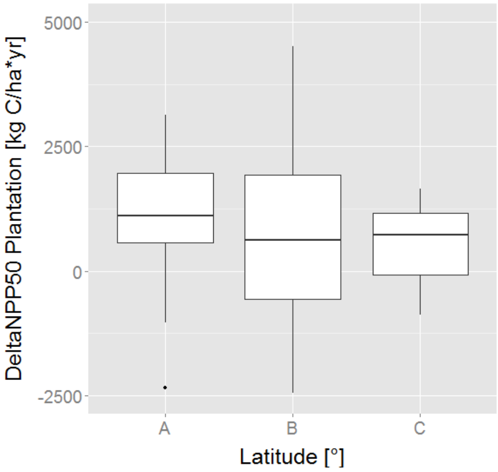

Figure 4:3 Influence of the latitude on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 17, n(B) = 48, n(C) = 19. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Plantation.

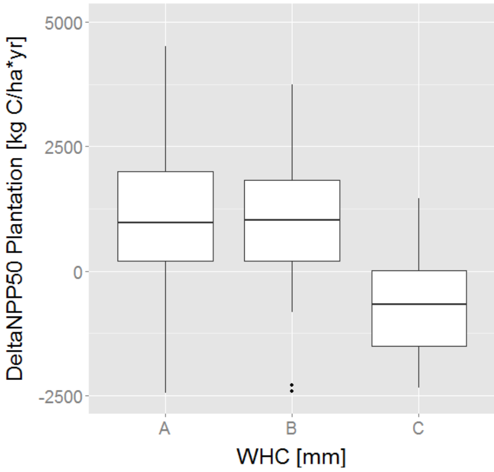

Figure 4:4 Influence of the water holding capacity (WHC) on simulated the net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 23, n(B) = 47, n(C) = 14. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Plantation.

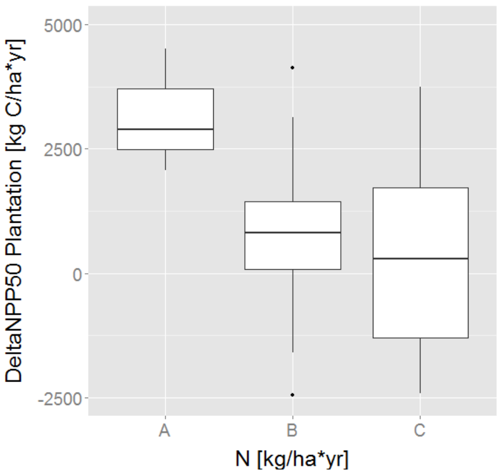

Figure 4:5 Influence of the nitrogen (N) on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 3, n(B) = 60, n(C) = 21. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Plantation.

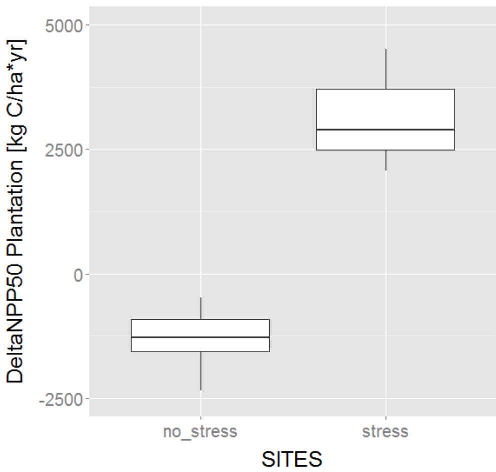

Figure 4:6 Influence of sites with stress and sites without stress on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]. Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. n(no-stress) = 6, n(stress) = 3. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Plantation.

Table 4:14 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Simulations started from a plantation. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 84 (Table 7:6).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	**	ns	**	na
Anova	ns	***	**	na
One-way test	ns	***	ns	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	*	na
A-C	ns	**	**	na
C-B	ns	**	ns	na

4.2.2 NPP100 Plantation

The productivity simulated with PICUS starting from a plantation (NPP100 Plantation), shows the tendency as well to underestimate when compared with the productivity values estimated from CASA (NPP-CASA) (Figure 4:7, Table 7:9). The regression model explains 44% of the variation in the data. The slope coefficient of the regression model (b= 0.7665) indicates that PICUS in general underestimates the NPP values of CASA.

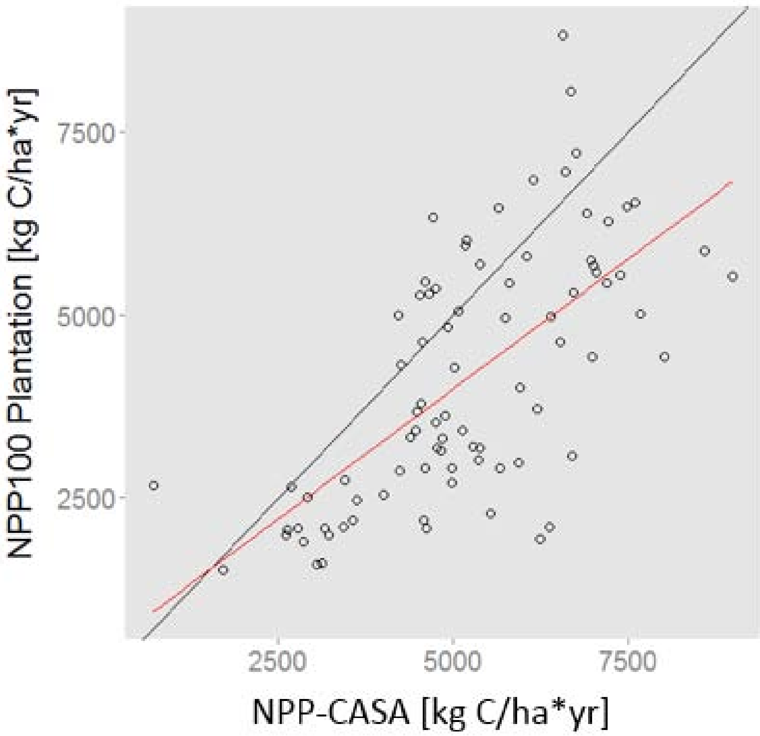

Figure 4:7 Linear regression (red line; R^2 = 0.44) between the simulated net primary production along 100 years (NPP100) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a plantation. n = 84.

There are some significant patterns in the estimation of productivity by PICUS depending on site factors across the study area (Figure 4:8 to Figure 4:11). PICUS has the tendency to underestimate NPP100 depending on latitude levels while there is overestimation at WHC levels >210mm. At Nitrogen levels <50 kg ha^{-1} yr^{-1} PICUS underestimates NPP100 while at sites with Nitrogen levels ≥50 to ≤100 kg ha^{-1} yr^{-1} this tendency is reduced drastically. With the highest Nitrogen supply there is no clear tendency to over- or underestimate. Nitrogen, WHC and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:15).

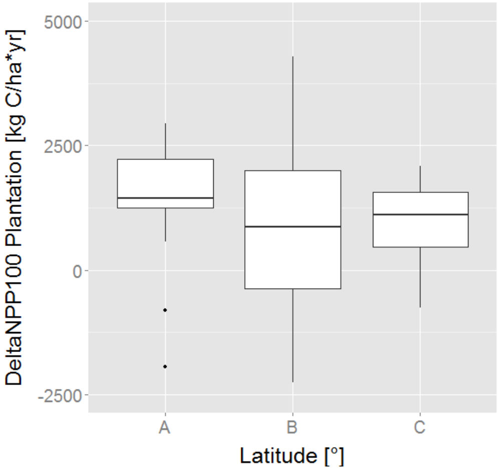

Figure 4:8 Influence of the latitude on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from plantation. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 17, n(B) = 48, n(C) = 19. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Plantation.

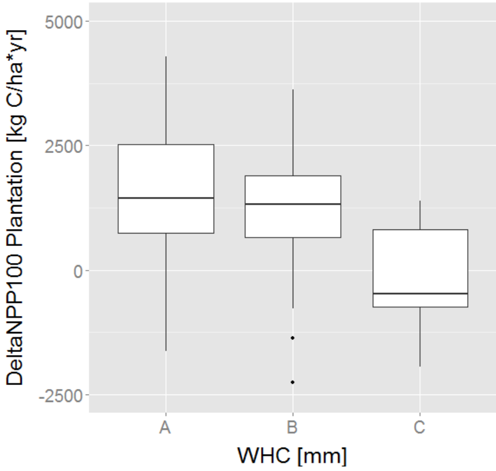

Figure 4:9 Influence of the water holding capacity (WHC) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 23, n(B) = 47, n(C) = 14. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Plantation.

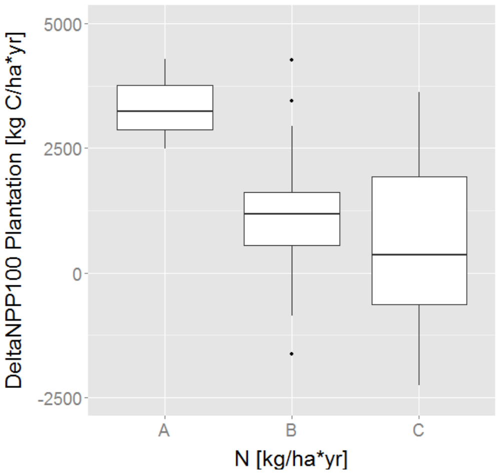

Figure 4:10 Influence of the nitrogen (N) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 3, n(B) = 60, n(C) = 21. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Plantation.

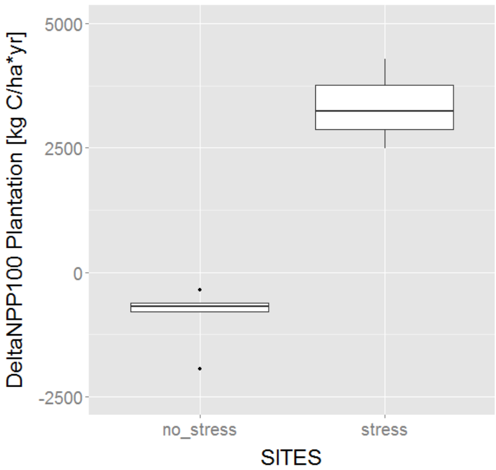

Figure 4:11 Influence of sites with stress and sites without stress on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. n(no-stress) = 6, n(stress) = 3. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Plantation.

Table 4:15 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Simulations started from a plantation. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water**

holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 84 (Table 7:8).

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	**
Levene's test	**	ns	**	na
Anova	ns	***	**	na
One-way test	ns	***	*	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	*	na
A-C	ns	**	**	na
C-B	ns	**	ns	na

4.2.3 NPP50 Bare ground

The results of NPP50 Bare ground demonstrate that overall there is no over-underestimation by simulations of PICUS when compared with productivity values estimated from CASA (NPP-CASA) (Figure 4:12, Table 7:11). The regression model explains 44% of the variation in the data. The slope coefficient of the regression model (b= 0.999) indicates that PICUS in general tends to represent the NPP (CASA) values well.

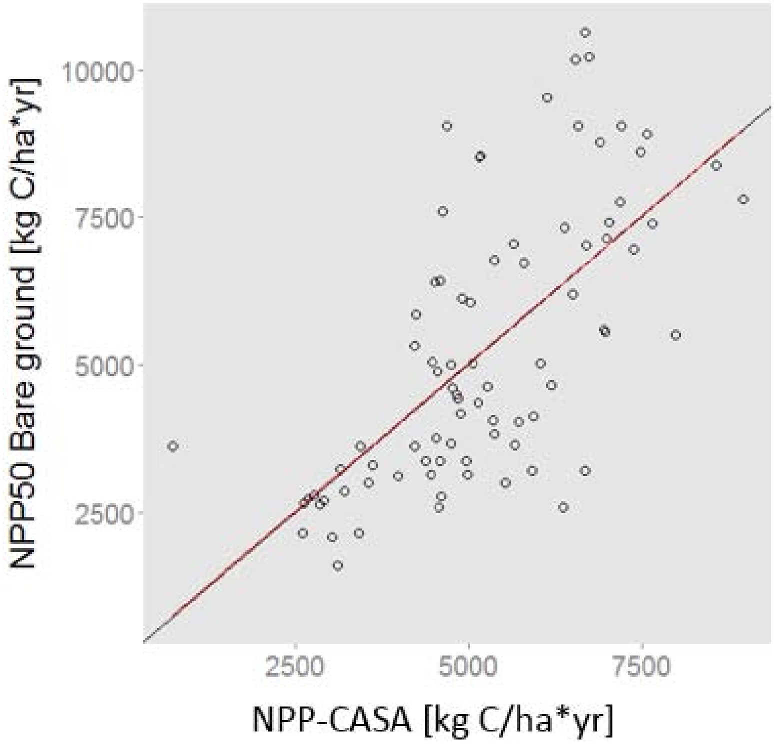

Figure 4:12 Linear regression (red line; R^2 = 0.44) between the simulated net primary production of year fifty (NPP50) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a bare ground scenario. n = 82.

For NPP50 Bare ground there is no clear pattern of general under- or over estimation by PICUS depending on site factors across the study area (Figure 4:13 to Figure 4:16). Depending on latitude levels the PICUS simulations fits well with the values of NPP-CASA, while there is tendency to overestimation by PICUS at WHC levels >210mm. At Nitrogen levels, even though with the Figure 4:15 there is no significant pattern as shown in Table 4:16**.** WHC and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:16).

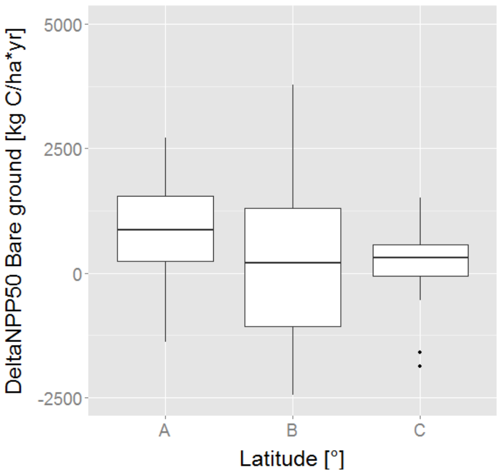

Figure 4:13 Influence of the latitude on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a bare ground. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 17, n(B) = 47, n(C) = 18. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Bare ground.

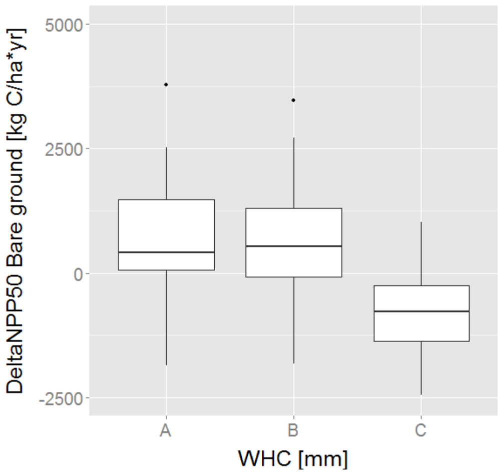

Figure 4:14 Influence of the water holding capacity (WHC) on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a bare ground. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 22, n(B) = 46, n(C) = 14. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Bare ground.

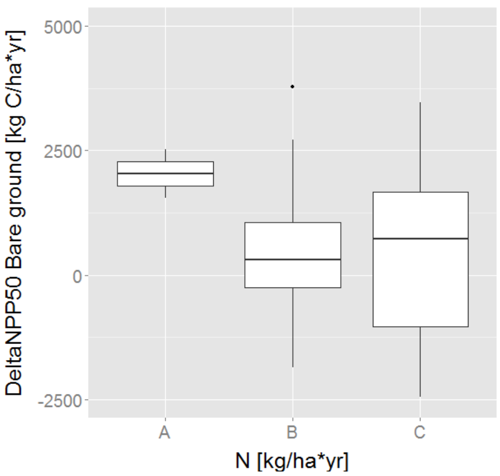

Figure 4:15 Influence of the nitrogen (N) on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a bare ground. Group A: N <50 [kg/ha*yr.]; Group B: N >=50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 2, n(B) = 59, n(C) = 21. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Bare ground.

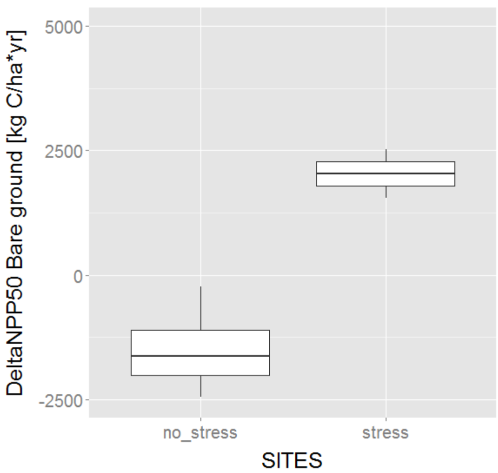

Figure 4:16 Influence of sites with stress and sites without stress on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a bare ground. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. n(no-stress) = 6, n(stress) = 2. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Bare ground.

Table 4:16 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Simulations started from a bare ground. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F)

≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 82 (Table 7:10).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	***	ns	**	na
Anova	ns	**	ns	na
One-way test	ns	**	ns	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	ns	na
A-C	ns	*	ns	na
C-B	ns	**	ns	na

4.2.4 NPP100 Bare ground

For NPP100 Bare ground, there is a clear tendency to the underestimation by PICUS when compared with the estimations from CASA (NPP-CASA) (Figure 4:17, Table 7:13). The regression model explains 45% of the variation in the data. The slope coefficient of the regression model (b= 0.7379) indicates that PICUS in general underestimates the NPP values of CASA.

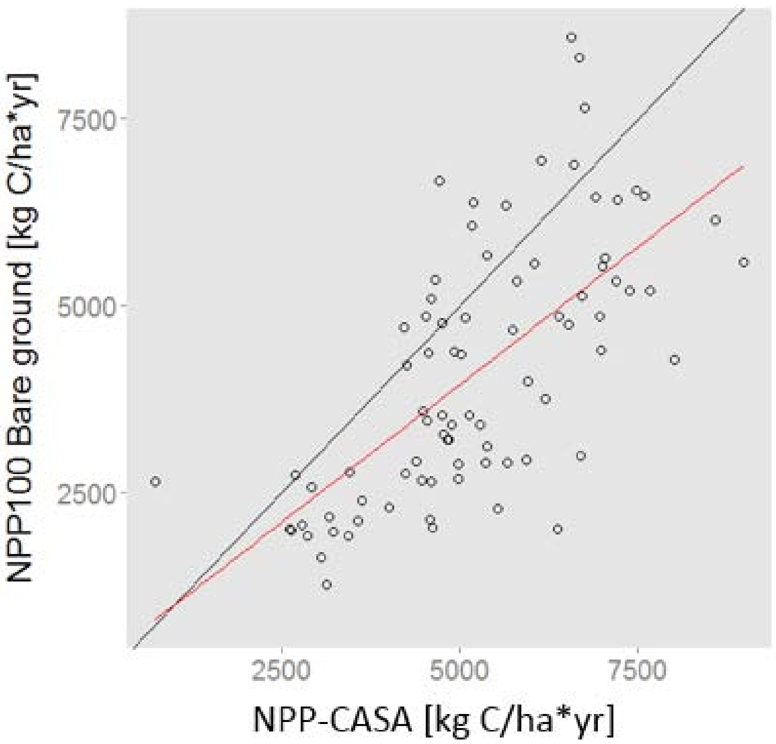

Figure 4:17 Linear regression (red line; R^2 = 0.45) between the simulated net primary production along 100 years (NPP100) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a bare ground. n = 82.

WHC and SITES are significant factors for the differences between NPP from PICUS and from CASA (Figure 4:19, Figure 4:21 and Table 4:17). PICUS NPP100 has the tendency to underestimate depending on latitude levels and Nitrogen levels, while the mean values at WHC levels >210mm represent nearly perfect the NPP-CASA (Figure 4:18, Figure 4:20).

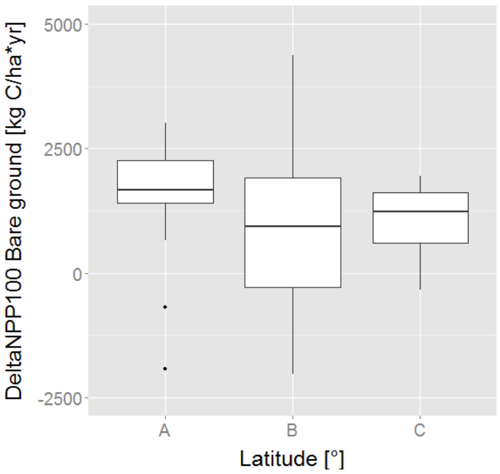

Figure 4:18 Influence of the latitude on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a bare ground. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 17, n(B) = 47, n(C) = 18. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Bare ground.

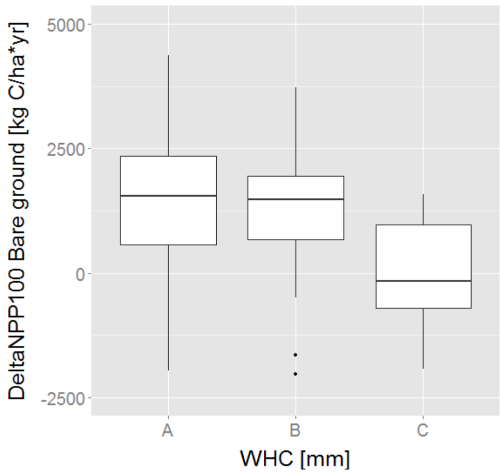

Figure 4:19 Influence of the water holding capacity (WHC) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a bare ground. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group (C) represent plots with WHC >210 [mm]. n(A) = 22, n(B) = 46, n(C) = 14. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Bare ground.

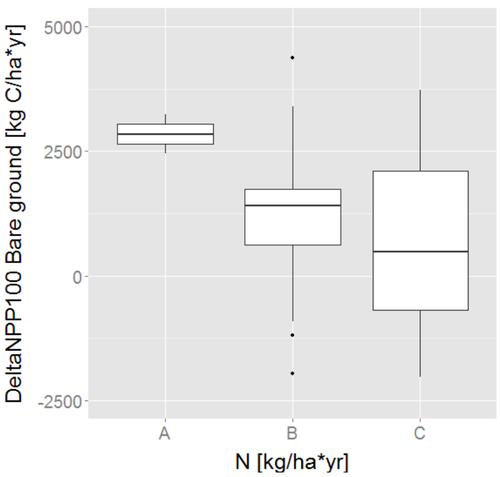

Figure 4:20 Influence of the nitrogen (N) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a bare ground. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 2, n(B) = 59, n(C) = 21. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Bare ground.

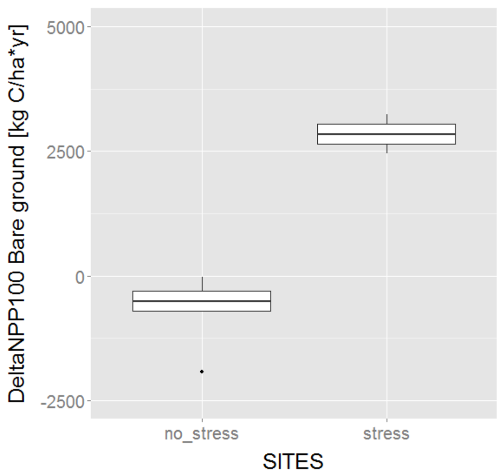

Figure 4:21 Influence of sites with stress and sites without stress on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a bare ground. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]. Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. (no-stress) = 6, (stress) = 2. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Bare ground.

Table 4:17 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Simulations started from a bare ground. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very

significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 82 (Table 7:12).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	**	ns	**	na
Anova	ns	**	ns	na
One-way test	ns	**	ns	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	ns	na
A-C	ns	**	ns	na
C-B	ns	**	ns	na

4.2.5 NPP50 Brus Plantation

PICUS has also a tendency to underestimate the values of NPP50 in a scenario of plantation when compared with the productivity values estimated from CASA (NPP-CASA), using as reference the map of dominant tree species across Europe (Figure 4:22, Table 7:15). The regression model explains 37% of the variation in the data. The slope coefficient of the regression model (b= 0.6143) indicates that PICUS in general underestimates the NPP values of CASA.

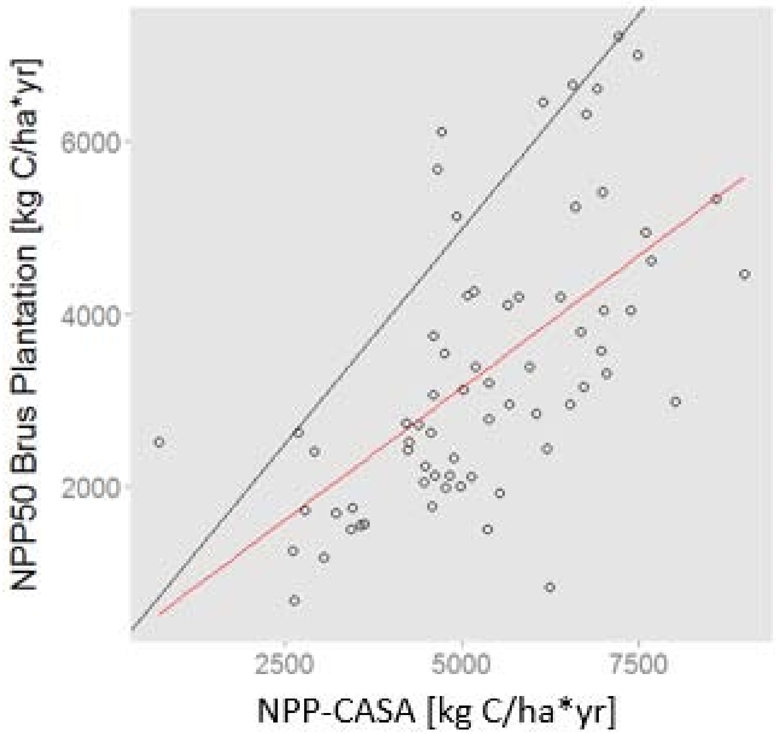

Figure 4:22 Linear regression (red line; R^2 =0.37) between the simulated net primary production of year 50 (NPP50) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a plantation with dominant tree species classified in the map of dominant tree species across Europe. n = 68.

The tendency of PICUS to underestimate the values of NPP-CASA are also reflected in the Figure 4:23 to Figure 4:26, where some significant pattern of NPP estimation depending on site factors across the study area are present. These patterns are at WHC levels of >210mm and at Nitrogen levels of <50 kg ha^{-1} yr^{-1}. WHC and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:18).

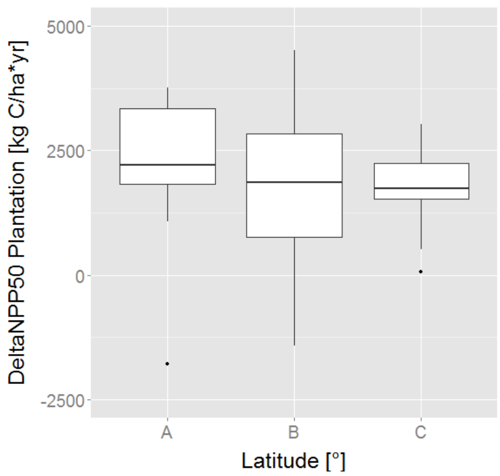

Figure 4:23 Influence of the latitude on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Plantation). Group A: latitudes ≥35° and <45°; Group B: ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 13, n(B) = 41, n(C) = 14. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Brus Plantation.

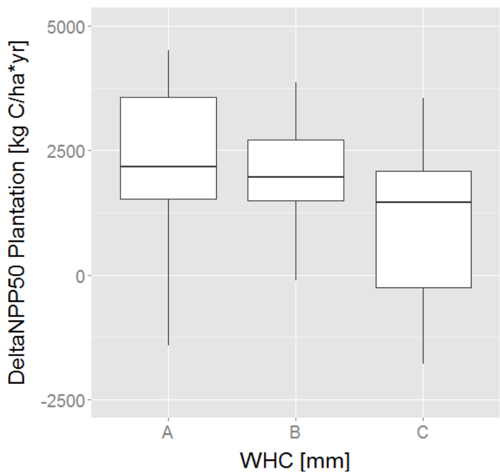

Figure 4:24 Influence of the water holding capacity (WHC) on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Plantation). Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 18, n(B) = 38, n(C) = 12. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Brus Plantation.

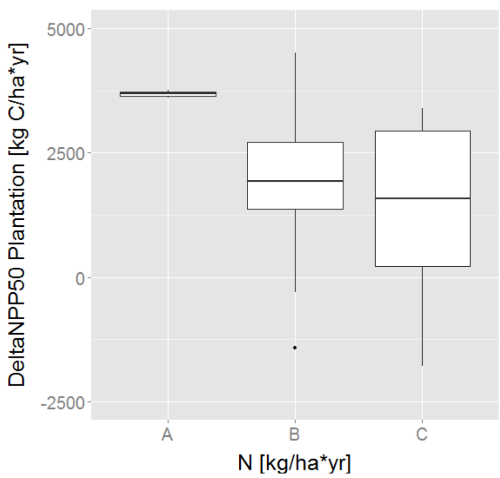

Figure 4:25 Influence of the nitrogen (N) on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 3, n(B) = 49, n(C) = 16. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Brus Plantation.

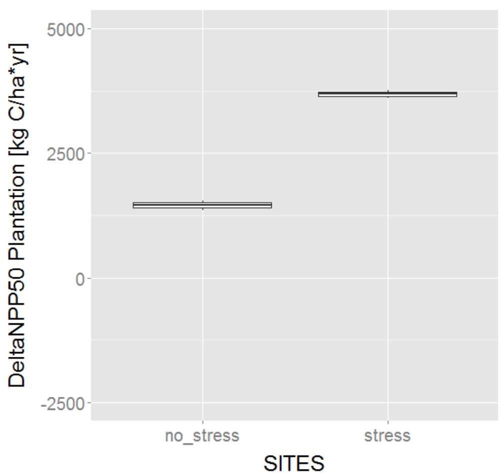

Figure 4:26 Influence of sites with stress and sites without stress on the simulated net primary production values of year 50 across Europe (NPP50). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: represent plots with WHC <110 [mm] and N <50 [kg/ha*yr.]. (no-stress) = 2, (stress) = 3. DeltaNPP50 Plantation = NPP(CASA) - NPP50 Brus Plantation.

Table 4:18 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Simulations started from a plantation. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 68 (Table 7:14).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	*	ns	ns	na
Anova	ns	*	*	na
One-way test	ns	ns	*	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	*	na
A-C	ns	*	**	na
C-B	ns	ns	ns	na

4.2.6 NPP100 Brus Plantation

Under these conditions PICUS tends to underestimate the productivity when compared with values estimated from CASA (NPP-CASA) (Figure 4:27, Table 7:17). The regression model explains 37% of the variation in the data. The slope coefficient of the regression model (b= 0.5830) indicates that PICUS in general underestimates the NPP values of CASA.

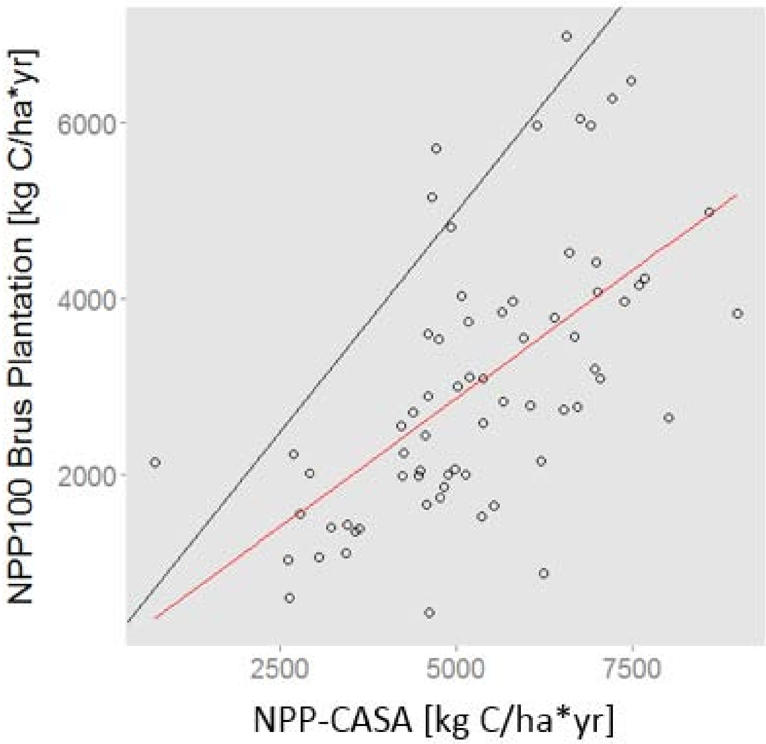

Figure 4:27 Linear regression (red line; R^2 =0.37) between the simulated net primary production along 100 years (NPP100) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a plantation with dominant tree species classified in the map of dominant tree species across Europe. n = 68.

The patterns present in the estimation of productivity by PICUS depending on site factors across the study area, are the same as for DeltaNPP50 Plantation which are described in the paragraph 4.2.5 (Figure 4:28 to Figure 4:31). Nitrogen, WHC and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:19).

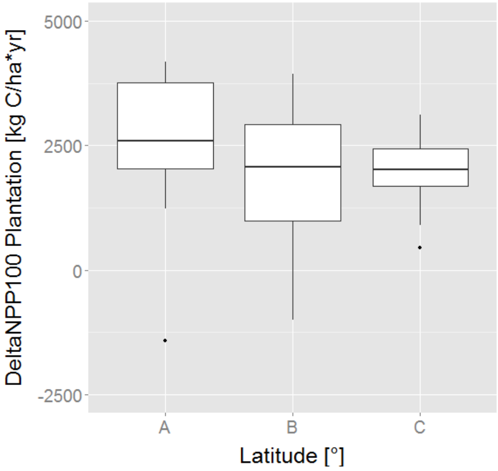

Figure 4:28 Influence of the latitude on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 13, n(B) = 41, n(C) = 14. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Brus Plantation.

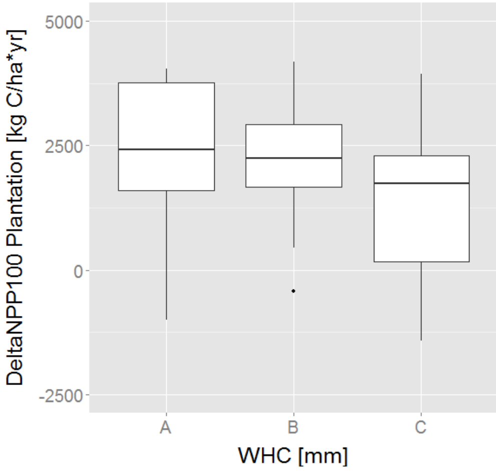

Figure 4:29 Influence of the water holding capacity (WHC) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Plantation). Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 18, n(B) = 38, n(C) = 12. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Brus Plantation.

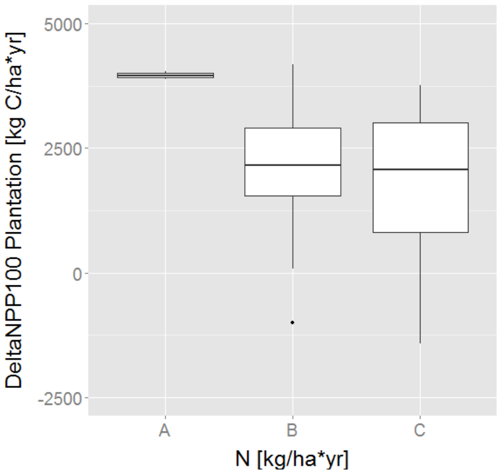

Figure 4:30 Influence of the nitrogen (N) on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Plantation). Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 3, n(B) = 49, n(C) = 16. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Brus Plantation.

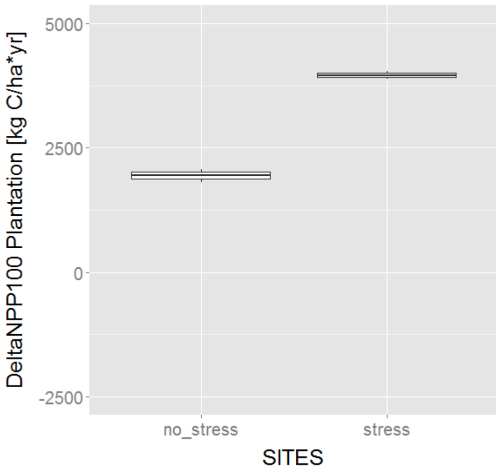

Figure 4:31 Influence of sites with stress and sites without stress on the simulated net primary production values along 100 years across Europe (NPP100). Simulations started from a plantation. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Plantation). Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. (no-stress) = 2, (stress) = 3. DeltaNPP100 Plantation = NPP(CASA) - NPP100 Brus Plantation.

Table 4:19 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Simulations started from a plantation. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 68 (Table 7:16).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	ns	ns	ns	na
Anova	ns	ns	*	na
One-way test	ns	ns	*	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	ns	ns	*	na
A-C	ns	*	*	na
C-B	ns	ns	ns	na

4.2.7 NPP50 Brus Bare ground

Using the tree species specified in the map of dominant tree species across Europe, PICUS tends also to underestimate NPP50 from bare ground when compared with the productivity values estimated from CASA (NPP-CASA) (Figure 4:32, Table 7:19). The regression model explains 43% of the variation in the data. The slope coefficient of the regression model (b= 0.7456) indicates that PICUS in general underestimates the NPP values of CASA.

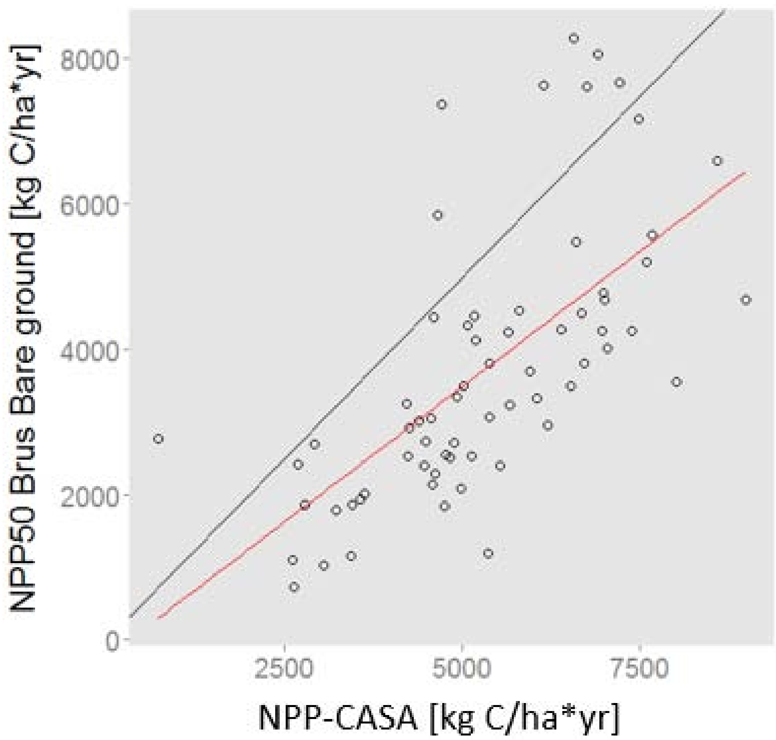

Figure 4:32 Linear regression (red line; R^2 = 0.43) between the simulated net primary production of year 50 (NPP50) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a bare ground with dominant tree species classified in the map of dominant tree species across Europe. n = 66.

Some significant patterns are revealed as important in the estimation of productivity by PICUS depending on site factors across the study area (Figure 4:33 to Figure 4:36). The tendency of PICUS to underestimate NPP50 is directly related to the latitudinal levels, WHC and Nitrogen. At Sites without stress (no-stress) the tendency to over- or underestimate is not clear. Nitrogen and SITES are revealed as significant factors in explaining the difference in NPP from PICUS and from CASA (Table 4:20).

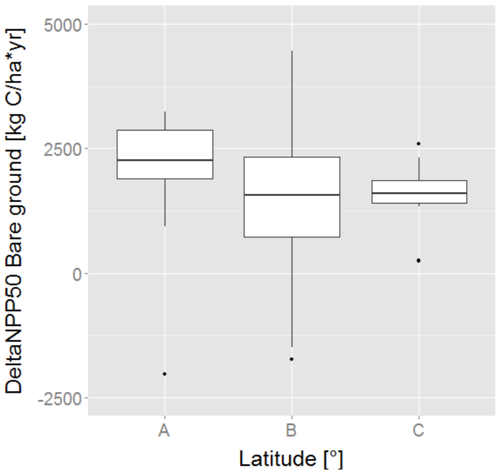

Figure 4:33 Influence of the latitude on the simulated net primary production values of year 50 (NPP50). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 13, n(B) = 40, n(C) = 13. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Brus Bare ground.

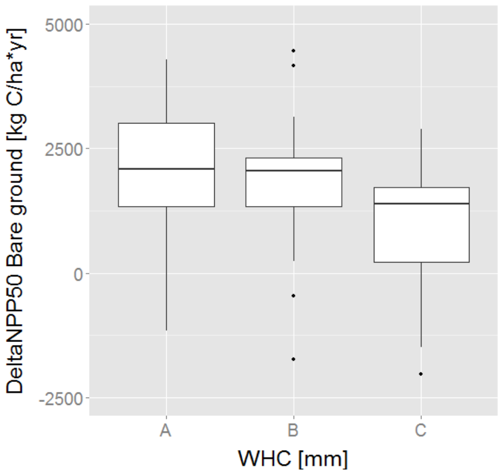

Figure 4:34 Influence of the water holding capacity (WHC) on the simulated net primary production values of year 50 (NPP50). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 17, n(B) = 37, n(C) = 12. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Brus Bare ground.

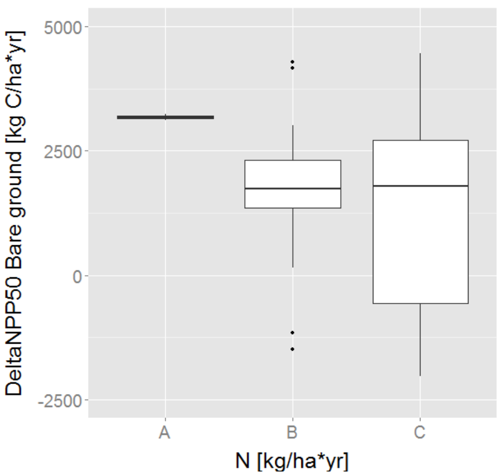

Figure 4:35 Influence of the nitrogen (N) on the simulated net primary production values of year 50 (NPP50). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr.]. n(A) = 2, n(B) = 48, n(C) = 16. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Brus Bare ground.

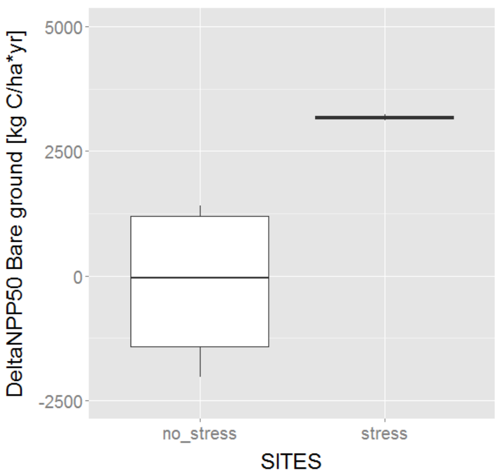

Figure 4:36 Influence of sites with stress and sites without stress on the simulated net primary production values of year 50 (NPP50). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. (no-stress) = 4. (stress) = 2. DeltaNPP50 Bare ground = NPP(CASA) - NPP50 Brus Bare ground.

Table 4:20 Test for differences between categories of site factors for the simulated net primary production in the year 50 (NPP50). Simulations started from a bare ground. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n = 66 (Table 7:18).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	*	ns	*	na
Anova	ns	ns	ns	na
One-way test	ns	ns	***	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	ns	na
A-C	ns	ns	ns	na
C-B	ns	ns	ns	na

4.2.8 NPP100 Brus Bare ground

As indicated by the slope coefficient of the regression model (b= 0.60625), PICUS tends to underestimate generally for this NPP100 when compared with the estimated NPP from CASA (NPP-CASA) (Figure 4:37, Table 7:21). The regression model explains 41% of the variation in the data.

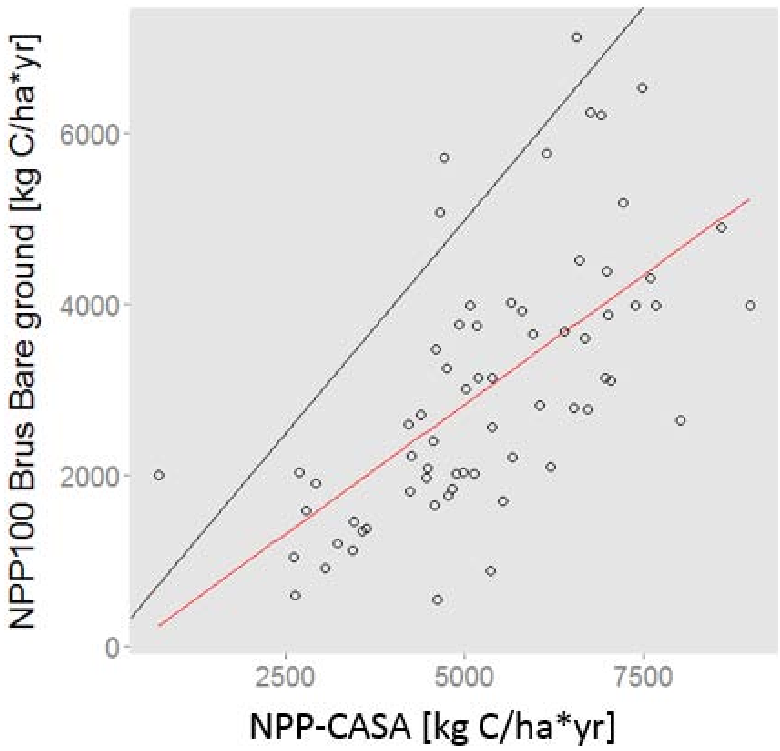

Figure 4:37 Linear regression (red line; $R^2 = 0.41$) between the simulated net primary production along 100 years (NPP100) and the net primary production calculated with CASA using the data base of MODIS and the 1:1 line (black line). The simulations are started from a bare ground with dominant tree species classified in the map of dominant tree species across Europe. n = 66.

Some significant patterns are present in the estimation of productivity by PICUS depending on site factors across the study area (Figure 4:38 to Figure 4:41). PICUS tends to underestimate NPP100 depending on latitudinal levels, WHC, Nitrogen and Sites. This tendency in the other hand is less remarkable at values of Nitrogen ≥50 kg ha^{-1} yr^{-1} and sites without stress conditions (no-stress). SITES are revealed as the significant factor to explain the difference in NPP from PICUS and from CASA (Table 4:21).

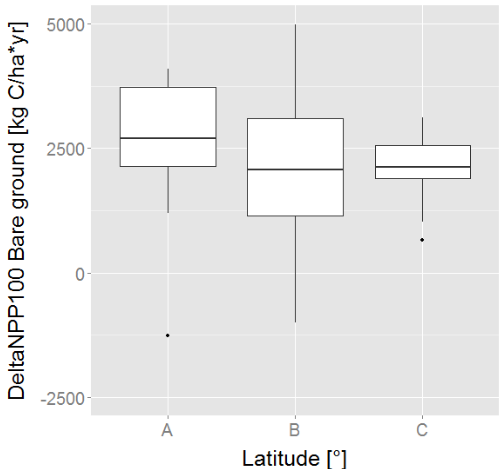

Figure 4:38 Influence of the latitude on the simulated net primary production values along 100 years (NPP100). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: latitudes ≥35° and <45°; Group B: latitudes ≥45° and <55°; Group C: latitudes ≥55° and ≤67°. n(A) = 13, n(B) = 40, n(C) = 13. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Brus Bare ground.

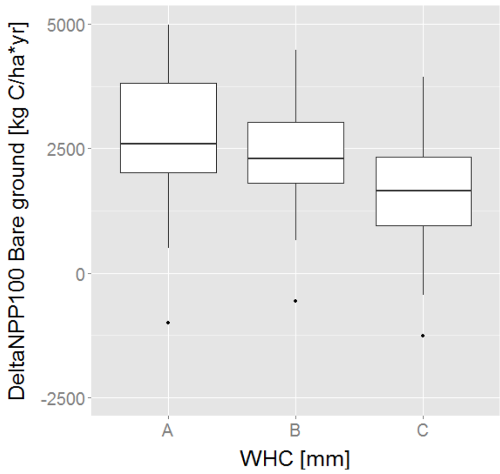

Figure 4:39 Influence of the water holding capacity (WHC) on the simulated net primary production values along 100 years (NPP100). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: WHC <110 [mm]; Group B: WHC ≥110 [mm] and ≤210 [mm]; Group C: WHC >210 [mm]. n(A) = 17, n(B) = 37, n(C) = 12. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Brus Bare ground.

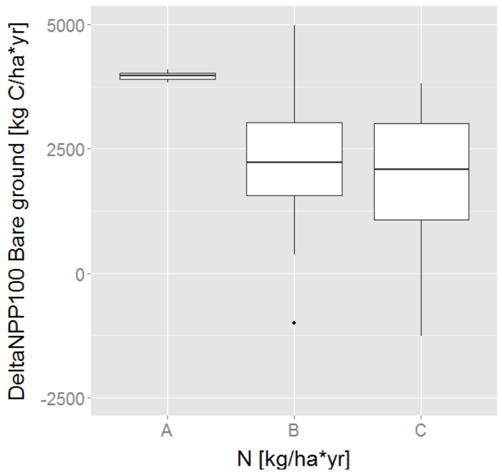

Figure 4:40 Influence of the nitrogen (N) on the simulated net primary production values along 100 years (NPP100). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe. Group A: N <50 [kg/ha*yr.]; Group B: N ≥50 [kg/ha*yr.] and ≤100 [kg/ha*yr.]; Group C: N >100 [kg/ha*yr]. n(A) = 2, n(B) = 48, n(C) = 16. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Brus Bare ground.

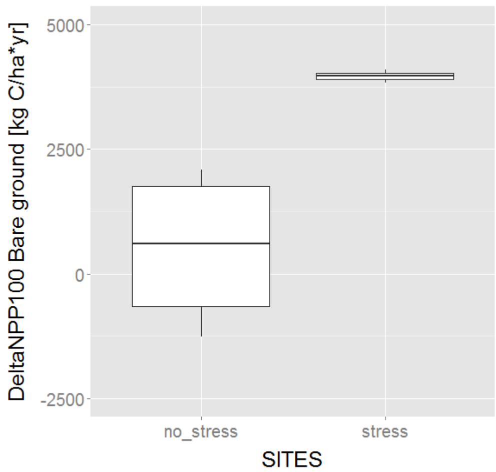

Figure 4:41 Influence of sites with stress and sites without stress on the simulated net primary production values along 100 years (NPP100). Simulations started from a bare ground. The tree species simulated, are the tree species classified in the map of dominant tree species across Europe (Brus Bare ground). Group no stress: WHC >210 [mm] and N >100 [kg/ha*yr.]; Group stress: WHC <110 [mm] and N <50 [kg/ha*yr.]. (no-stress) = 4, (stress) = 2. DeltaNPP100 Bare ground = NPP(CASA) - NPP100 Brus Bare ground.

Table 4:21 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Simulations started from a bare ground. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs. sites without such limitations. n = 66 (Table 7:20).**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	*
Levene's test	ns	ns	ns	na
Anova	ns	ns	ns	na
One-way test	ns	ns	***	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	ns	ns	ns	na
A-C	ns	ns	ns	na
C-B	ns	ns	ns	na

5. Discussion

5.1 PNV

The simulations among competitive relationship of the tree species in a scenario of potential natural vegetation (PNV) are performed without any kind of anthropogenic intervention and from bare ground, simulating in each plot across Europe the same 28 tree species simultaneously omitting migration processes. In these simulations, factors of interspecific competition, climate and site characteristics, are definitive to define the steady state of the forest composition.

In the assessment of PICUS with the EEA classification, the total accuracy of the PNV simulations for the dominant tree species is equal to 93% along the seven forest types tested. For the codominant and admixed tree species, the accuracy of the PNV simulations along the seven forest types tested is equal to 84%. This reduction of accuracy is produced by the inclusion of three different levels of dominance in the forest cover. The EFT6 and EFT7 are affected by this reduction in accuracy, from 81% to 50% and from 100% to 80%, respectively, due to the higher variability of codominant and admixed tree species in relation to the other EFTs simulated. The more general description of the EFTs presented in the EEA classification has a percentage of total accuracy remaining very high in the dominant tree species as well as in the codominant and admixture.

On the other hand, the assessment of PICUS with the BfN classification has much lower percentage of total accuracy (Table 4:13). As is exposed in the assessment with the EEA classification, the results of the assessment with the BfN are influenced by the same factors. In this assessment, the more detailed qualitative information about natural species composition than in the assessment with the EEA classification reduces the total percentage of accuracy.

As has been commented before, interspecific competition, climate, site characteristics and the omission of migration processes define the steady state of the forest composition in each of the European forest type simulated.

5.1.1 EFT1

In the Boreal forest, the mismatches produced in the assessment with the EEA classification and with the BfN classification are justified by site requirements between *Picea abies* and *Pinus sylvestris*, as well as by factors of interspecific competition between *Sorbus aucuparia* and *Pinus sylvestris*. According to Esseen et al. (1997), *Pinus sylvestris* prevails on drier soils, with continental climate and where forest fires are more frequent. On the other hand, *Picea abies* prefers soils rich in nutrients, with oceanic climate and with lower frequency of forest fires. The interspecific competition between *Sorbus aucuparia* and *Pinus sylvestris* reported by Fankhauser (1910), Leder (1996), Prein (1965 and 1995) in the early successional stages, *Sorbus aucuparia* is shown as very shade tolerant during the first years of development. For this period of time, *Sorbus aucuparia* competes with *Pinus sylvestris*, which due to a low density of the *Sorbus* crown can continue its development. Once the *Sorbus aucuparia* achieves the mature stage, it is overtaken by *Pinus sylvestris* due to a higher growing rate of *Pinus sylvestris* and less shade tolerance of *Sorbus aucuparia*.

5.1.2 EFT2

The presence of *Fagus sylvatica* in Hemiboreal forest and nemoral coniferous and mixed broadleaved coniferous forest outside of its traditional distribution is justified by Bolte et al. (2007), Groß (1934) and Dreimanis (2004). They to pointed isolated beech populations in Latvia and Lithuania, which were partially overlapping with the distribution area of boreal species. *Fagus sylvatica* is the most competitive tree species in deciduous forests in Central Europe, being delayed in their expansion to the Northern part of Europe due to climatic conditions in the earlier Holocene (dry and warm summers) as well as anthropogenic effects (Bolte et al., 2007; Tinner and Lotter, 2006). The high presence of *Fagus sylvatica* with *Picea abies* on these plots explains the theory of Tinner and Lotter (2006), where the expansion of *Fagus sylvatica* would be much faster and extended than what it is currently. As well, the predominance of *Picea abies* over *Pinus sylvestris* is explained by high levels of silt, clay and WHC explaining the mismatches in the assessment with the BfN classification.

5.1.3 EFT3

The presence of *Fagus sylvatica* at high altitude in the Maritime Alps in the Alpine coniferous forest is reported in the literature by different authors. Tschermak (1929) reported the existence of *Fagus sylvatica* in the Maritime Alps and in Sicilia at an altitude of 2250 meters. As well, Magri et al. (2006) located after a study of paleobotanic and genetic data, the Maritime Alps as one of the origins from where *Fagus sylvatica* started to colonize Europe. Site conditions present on our plots do not represent a major constrain for the development of *Fagus sylvatica* (Ellenberg, 1996; Felbermeier, 1993; Kahn and Pretzsch, 1997; Leuschner et al., 1993; Röhe, 1984; Scamoni, 1989; Tschemark, 1950) and *Abies alba* (Rol, 1937; Rubner, 1953). Therefore, without big limitations from the site conditions, only the existing competition between *Fagus sylvatica* and *Abies alba* is responsible for the dominance of *Fagus sylvatica* over *Abies alba*. As is exposed in earlier works of forest ecology, *Fagus sylvatica* and *Abies alba* were considered as equals in terms of shade tolerance (Ellenberg et al., 1992). More recently, in 2014, Janik et al. describe that the higher shade tolerance of *Fagus sylvatica* in advanced regeneration stages without human intervention favors the dominance of *Fagus* *sylvatica* over *Abies alba*. Meanwhile the development of advanced regeneration stages of *Abies alba* is linked to the presence of gaps in the canopy produced by disturbance agents. Another element which affect the competition between these two trees species which explains the mismatches in this EFT, is the litter produced by *Fagus sylvatica*. This litter produce a negative effect on the regeneration of *Abies alba*, due to a high thickness of the litter layer (Simon et al., 2011) which produce higher surface run-off (Zlatník, 1935 and 1978) and reduce the ventilation resulting in the formation of raw humus. Janik et al. (2014) agree as well that the litter of *Fagus sylvatica* can affect negatively the regeneration of *Abies alba* due to its higher thickness.

5.1.4 EFT5

The mismatches produced in the assessment with the BfN classification simulating the Mesophytic deciduous forest is explained by interspecific competition between beech and oaks, the intraspecific competition between oaks and the affinity to site conditions of fir in the south of the British Isles. As *Quercus petraea* and *Quercus robur* have a similar distribution and growing process, only site requirements driven by the WHC can make the difference between them. Thus, the *Quercus petraea* dominates over *Quercus robur* taking the advantage on drier sites (Burschel and Huss, 1997). According to Bontemps et al. (2012) and Ligot (2013), in the European temperate forest, *Fagus sylvatica* and *Quercus petraea* are the most common late successional native broadleaved tree species. Without human intervention, the competition between these two tree species is based on light requirements. Where *Fagus sylvatica* juveniles have higher shade tolerance, juveniles of *Quercus petraea* have greater light requirements (Petrian et al., 2014). The recruitment limitations of *Quercus petraea* define profoundly the forest composition, structure and forest biodiversity. Without good light conditions, the seedlings of *Quercus petraea* are not capable to compete against *Fagus sylvatica* which needs 15% to 20% less light than *Quercus petraea*. Another factor exposed by Petrian et al. (2014), is the maintained slow growth of *Fagus sylvatica* combined with a low mortality at low light. This facilitates the establishment of *Fagus sylvatica* in detriment to *Quercus petraea* over time. During drought periods mixed forests of *Quercus petraea* and *Fagus sylvatica* grow better than pure stands of *Fagus* *sylvatica*, because the deeper roots of *Quercus petraea* facilitate the access to water compared to the more sallow-rooting *Fagus sylvatica* (Zapater et al., 2011). Rozas (2003) explained that the large reserves of carbohydrates in the cotyledons of *Quercus robur* can facilitate the development of their seedlings in the first year, but with the disadvantage that during the second year it will be fully dependent on light intensity received during the previous-year.

Bolte et al. (2007) classify England as part of the natural distribution of *Fagus sylvatica*, as well as Packham et al. (2012) describe the dominance of *Fagus sylvatica* over *Quercus robur* within his natural range. Only the interespecific competition exposed in the discussion of the EFT3 explains the total dominance of *Fagus sylvatica* across the three plots located on the British Isles. The possible factors which drive the competition between the beech and the oaks are already explained above. On the other hand, the British Isles are not within the natural range of *Abies alba*. After the last glacial period, *Abies alba* started to colonize Europe from his refugia in the Pyrenees, the Apennines and the Balkans (Langer, 1963), but it did not reach the British Isles. The first presence of Silver firs on the British Isles is dated in the 1600s, when it was introduced for the first time (Mason, 2013). The site conditions which define the three plots include the area in the phytogeographical range of *Abies alba*.

In north-eastern Poland, the Masuria region is classified by Bolte et al. (2007) as the overlapping zone between European beech forest and the boreal coniferous forest. The establishment of *Pinus sylvestris* as admixture tree species of *Fagus sylvatica* is defined by the soil texture and the water content. Rubner and Reinhold (1953) identify loamy moraine soils as places where *Fagus sylvatica* dominates the forest composition with admixed *Pinus sylvestris* coinciding with the soil characteristics of the area in the Masuria region as well as in other areas of Poland.

5.1.5 EFT6

The presence of *Pinus sylvestris* in beech forests is already discussed in the EFT5 justifying the simulation results. Scots pine appears as well as admixed tree species in the beech forest, being limited by its light requirements and the negative effect which has the beech litter on its germination. Oak trees are common codominant and admixed tree species in the beech forest, but in places where Scots pine appears usually it takes advantage over the oaks. The Scots pine and the oaks are light demanding tree species, the difference between the pine and the oaks which makes possible a much higher species share of the pine over the oaks, is the faster growth and longer growing period of the pine (Toigo et al., 2015).

Fagus sylvatica has a notable capability of adaptation to drought (Bolte et al., 2007), but in areas of the transition zone with the sub alpine coniferous forest and sandy to sandy loam soils, values of 106mm of WHC are not enough for beech, being dominated by *Picea abies* and accompanied by *Abies alba* as admixed tree species. Dengler (1980-1982) and Hoenisch (1963) include the Baltic coast, as part of the distribution of *Abies alba*. The lower percentage of *Abies alba* and *Pinus sylvestris* when *Fagus sylvatica* is present, is the result of interspecific competition produced by light requirements and the effect of beech litter on the regeneration of other tree species (Trocha et al., 2015). Rubner and Reinhold (1953) mentioned in "*Das natürliche Waldbild Europas als Grundlage für einen Europäischen Waldbau"* the possibility to have *Fagus sylvatica* with admixture of *Pinus sylvestris* in lowland areas under the influence of the Baltic sea. In the same work Rubner and Reinhold comment that under special conditions *Pinus sylvestris* can dominate the forest cover leading to a codominant role of *Fagus sylvatica*. In a scenario as is decrypted by Rubner and Reinhold (1953), we have a beech forest with admixture of Scots pine. The WHC equal to 169mm, N availability equal to 59kg/ha*yr and a soil of sandy loam structure, makes the presence of Scots pine as codominant tree species possible. Ozenda (1994) classified areas of the Baltic coast in Germany and Poland as transitional zone between boreal and temperate forest in Europe, with a mixed forest of *Pinus sylvestris* and *Quercus robur* accompanied by *Quercus petraea* and *Fagus sylvatica*. With the transitional zone made by Ozenda and site characteristics favourable to Scots pine, the dominance of *Pinus sylvestris* with admixtures of *Quercus robur* and *Fagus sylvatica* is justified in the simulations.

5.1.6 EFT7

In the simulations of mountainous beech forest, forest formations composed by dominant coniferous forest with codominant oaks were simulated. They are justified by values of WHC equal to 100mm, dry summer periods due to low precipitation, sandy to sandy loam soil texture and in areas where only coniferous trees are present, the factor of high altitude (1200m) is added to the others mentioned before. Forest cover composed of *Pinus sylvestris* and *Quercus robur* are traditional for thermophilous deciduous forest in the supra-Mediterranean climatic zone. But according to Quézel et al. (2003), the geographical distribution of thermophilous deciduous forest is situated mainly in the Mediterranean region (Climatic zone: supra-Mediterranean), but under specific local microclimate conditions as well as edaphic conditions, it can be found in the Atlantic, Continental and Pannonic regions.

5.1.7 EFT8

The simulations of the PNV in thermophilous deciduous forest has a total accuracy of 91% in the assessment with the EEA classification for dominant, codominant and admixture tree species. While the total accuracy in the assessment with the BfN classification drops to 18.2%. The expected success in the PNV simulations of the EFT8 before the experiment were very low, being materialized in the assessment with the BfN classification. As the tree species simulated are not present or representative in the thermophilous deciduous forest, it was decided to search for similarities between the tree species which represents the EFT8 and the tree species simulated with PICUS (Table 7:3). The species shares obtained from the simulations are extrapolated to the forest compositions of the EFT8, being remarkable effective in the assessment with the EEA classification which is less detailed than the BfN classification. Beside that the tree species simulated do not represent well the EFT8 some of the mismatches produced in the assessment with the EEA classification and the BfN classification are justified as in the other EFTs.

Paleoecological studies demonstrate the important presence of *Picea abies* in the NE of Spain, near to the border with France and Andorra (Suc et al., 1982), explaining the dominant situation of *Picea abies* in front of the other simulated species at the same time and from bare ground, justifying the presence of Picea abies in the area which produces the mismatch in the assessments. The presence of *Quercus petraea* in places where *Quercus pubescens* is expected, is justified by a scenario with a WHC equal to 100mm, with dry summer periods where the precipitation is ≤ 303mm and soil with a sandy to sandy-loam texture, facilitating the development of sessile oak.

In Romania, forest formations of *Quercus robur* with *Quercus pubescens* and *Tilia cordata* are expected to be present. But three different factors affect directly the forest composition and justify the presence of beech accompanied by oaks. These factors are the demand of light, climate and WHC. The high demand of light by the oaks and the continental climate present in the area, favor the development of beech among the oaks (Bolte et al., 2007; López and Camacho, 2006). On the other hand, not very high generous values of WHC in the area equal to 140mm is not the optimum for the development of beech, permitting the presence of the *Quercus petraea* and *Quercus robur* with percentages of species share of 30% and 13.5% respectively. López and Camacho (2006) expose that pedunculate oak has less resistance to colder temperatures than sessile oak. This explains the modest presence in the forest composition of the pedunculate oak with only 13.55% of the species share.

5.2 NPP

Previous estimations of forest productivity across Europe simulated with PICUS showed an underestimation in contrast with the estimations of productivity from CASA which were simulated by Rammer and Lexer in 2011. Therefore, to reduce this underestimation, the maximum NPP simulated per plot was used in the analysis. In parallel, we did also the estimations of forest productivity using the database which offer the map of dominant tree species across Europe developed by Brus et al. in 2012, with which as well underestimated values of forest productivity were obtained.

In CASA as well as in MODIS, the algorithm to calculate the NPP is determined by the increment of biomass present (ε). In both models only one variable reflects general moisture conditions which is associated to different broad biomes or vegetation types. These variables are, the vapour pressure deficit (VPD) in MODIS and the effects of water stress (W_ε) in CASA (Pan et al., 2006 and Potter et al., 1993). The algorithm utilized in PICUS to calculate the NPP, in contrast to CASA, include as well factors which define any scenario at local or regional scales. Thus, the algorithm of PICUS avoid any bias in the estimation of NPP due to general data input which can produce an overestimation of the NPP (Pan et al., 2006), explaining the different of NPP values between PICUS and CASA. In this algorithm, to calculate the NPP, PICUS includes the pH-response ($resp_{pH}$) and Nitrogen response ($resp_{N}$), the monthly soil moisture index response ($resp_{SMI}$), the monthly vapour pressure deficit response ($resp_{VPD}$), and the monthly temperature response ($resp_{temp}$), the monthly frost response ($resp_{frost}$).

The underestimation produced vary between databases (the dominant tree species across Europe and the eight most representative tree species across Europe), time period and simulation starting point. The selection of maximum NPP simulated per plot from the most representative tree species, has reduced the underestimation of productivity consistently in comparison with the database of dominant tree species. At the same time, within the databases we observe as well some differences in the underestimation of productivity. We obtain higher values of NPP for the year 50 than for the 100 years' time period. In the year 50 the underestimations vary as well between starting points, being lower for simulations started from bare ground than from a plantation. In previous studies, it has been studied the relationship between NPP and age, demonstrating that the maximum values of NPP are reached for many species between the years 30 and 50 (Croft et al., 2014; Magnani et al., 2000; Wang et al., 2011). This explains the differences of underestimation between the year 50 and the 100 years' time period. On the other hand, there is no significant difference of underestimation between simulations of both starting points for the 100 years' time period utilizing the maximum NPP as well as utilizing the database of dominant tree species.

5.2.1 Latitude

The values for NPP obtained follow the tendency described by Gillman et al. (2015) as well as by Leith and Whittaker (1975), claiming that there is a negative relationship between NPP values of forest and the latitude. By contrast, the latitude does not influence the underestimation of the NPP between the PICUS simulations and the values simulated with the CASA model across Europe.

5.2.2 WHC

Utilizing the database of MAX NPP, WHC is an influential factor in the underestimation of NPP values, within the plantation and bare ground scenarios for the year 50 and for the 100 year mean. Thus, WHC present significant differences between the groups A and C, as well as between the groups C and B. On the other hand, the influence of WHC on the underestimation of NPP values is only present for the year 50 plantation utilizing the data base of dominant tree species between the groups A and C. For the scenario of bare ground utilizing the data base of dominant tree species, the WHC has no influence on the underestimation of NPP values in the year 50 and in the 100 years' time period.

5.2.3 Nitrogen

The influence of this limiting factor in the underestimation of the NPP values utilizing both data bases is present only for the simulations started from plantation. The significant differences are present between group A and group B, as well as between group A and group C.

5.2.4 Sites

Sites is influential in the underestimation of the NPP across Europe in all of our experiments, increasing the underestimation where values of WHC <110 [mm] and N <50 [kg/ha*yr.] (Babst et al., 2013).

6. Conclusion

The assessed version of PICUS simulating the competitive relationship of the tree species in a scenario of potential natural vegetation across Europe, offers a representative picture of the PNV when it is compared with the classification made by the EEA. Whereas if the interest is in a more detailed picture of the potential natural vegetation, this version of PICUS is able to represent consistently the EFT1, EFT2, EFT3, EFT5, EFT6 and EFT7. Due to part of the representative tree species of the EFT8 were not available in the simulations the EFT8 is not well represented in a detailed scale as in the classification offered by the BfN.

Due to the increasing of complexity in the composition of the forest when the codominant and the admixture tree species are included in the assessment, the model faces a considerable reduction of accuracy in the PNV simulations, especially for the EFT6 and EFT7. This is produced by a higher diversity in the codominant and admixture tree species in relation with the other EFTs simulated.

Despite the mismatches produced in the assessment of the PNV, the simulations can be justified as explained in the discussion, under the starting conditions of bare ground, without anthropogenic pressure and simulating in each plot across Europe the same twenty eight tree species simultaneously omitting migration processes. The mismatches produced in the assessment of the EFT8 simulations are only justified when the tree species present in the description of the EFT8 are included in the tree species simulated by PICUS. Thus, it can be said that the methodology used to replace the tree species missing in the simulations of the EFT8 does not meet the requirements.

In the EFT1, like *Pinus sylvestris* and *Picea abies*, *Sorbus aucuparia* can be dominant in the Boreal forest. Under the conditions with which the simulations are performed, the distribution of *Fagus sylvatica* has been increased, being present as well in the EFT2 and in the EFT3, dominating the forest composition as is argued in the discussion.

Depending on the site conditions alpine coniferous tree species can dominate over *Fagus sylvatica* in the EFT6. The intersection areas between the temperate forests and the boreal forest is where most of the mismatches in the assessment of the EFT6 are located due to the presence of coniferous tree species in this EFT.

Places in the EFT7 where the WHC has values around 100mm are equivalent to the EFT8 according to the results in the simulations.

On the simulations, the distribution of *Picea abies* has been enlarged to the northern parts of the EFT8. Oak tree species are well represented in the EFT8, but due to the lack of parts of the representative tree species of this EFT, this version of PICUS is not capable to simulate well the EFT8.

PICUS is capable to simulate consistently the forest NPP under a wide range of ecological conditions, representing the negative relationship between NPP values of forest and the latitude as well as the response of NPP in forest tree species.

The algorithm utilized in PICUS to calculate the forest NPP produced an underestimation of NPP when compared with the NPP values estimated with CASA which utilize the MODIS approach. This algorithm is very sensible to tree response to WHC and N representing well the fluctuations of NPP values according to variations of climate and site conditions (Lexer and Hönninger, 2001).

7. Annexes

7.1 Annex 1

Table 7:1 List of the EFT's used in the assessment.

EFT	Description
EFT1	Boreal forest
EFT2	Hemiboreal forest and nemoral coniferous and mixed broadleaved coniferous forest
EFT3	Alpine coniferous forest
EFT5	Mesophytic deciduous forest
EFT6	Beech forest
EFT7	Mountainous beech forest
EFT8	Thermophilous deciduous forest

Table 7:2 List of the forest subclasses under the BfN classification.

BfN classification	Description
D4	North European moss-rich spruce forests (*Picea abies*, in the east *P. abies* x *P. obovata*, *P. obovata*) with dwarf shrubs and herbs (*Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Trientalis europaea*, *Hylocomium splendens*, *Pleurozium schreberi*, *Dicranum spp*.)
D45	North European pine forests (Pinus sylvestris), partly with Picea abies, with dwarf shrubs (Vaccinium vitis-idaea, Arctostaphylos uva-ursi), lichens and mosses
D47	North and east European hygrophilous pine forests (*Pinus sylvestris*) with *Betula pubescens*, with dwarf shrubs (*Vaccinium myrtillus*, *Vaccinium uliginosum*, *Ledum palustre*), *Equisetum sylvaticum* and mosses (*Sphagnum angustifolium, Sphagnum russowii)*
D1	North European open moss-rich spruce forests (*Picea abies*, in the east *Picea abies* x *Picea obovata*, *Picea obovata*) with *Pinus sylvestris*, *Betula pubescens*, *Betula pubescens subsp. czerepanovii*, alternating with open pine and spruce forests on half-bog soils and with aapa mires
D8	Scandinavian-east European spruce forests (*Picea abies* in the east *Picea abies* x *Picea obovata*), partly with *Tilia cordata* and *Corylus avellana*, with herbs, dwarf shrubs and mosses (*Oxalis acetosella*, *Melica nutans*, *Vaccinium myrtillus*, *Rhytidiadelphus triquetrus*, locally *Anemone nemorosa*, *Hepatica nobilis*)
D15	Southwest Scandinavian subatlantic spruce forests (*Picea abies*) with *Quercus robur*, with dwarf shrubs and herbs (*Vaccinium myrtillus*, *Oxalis acetosella*, *Melica nutans*, *Viola riviniana*) alternating with raised bogs
D16	Southeast Scandinavian herb-rich spruce forests (*Picea abies*), with *Quercus robur*, partly *Pinus sylvestris*, with *Corylus avellana*, *Melica nutans*, *Convallaria majalis*, *Hepatica nobilis*, *Paris quadrifolia*, partly in combination with wooded mires (*Picea abies*, *Pinus sylvestris*, *Ledum palustre*), in the coastal region and on islands with rocky pine forests (*Pinus sylvestris*) with *Arctostaphylos uva-ursi*

D49	East European psammophytic pine forests (*Pinus sylvestris*) with dwarf shrubs and herbceous plants (*Vaccinium vitis-idaea*, *Rubus saxatilis*, *Calamagrostis epigejos*, *Dianthus arenarius*) with *Pulsatilla patens*, *Festuca ovina*, *Koeleria glauca*, *Thymus serpyllum*, with lichens and mosses
C22	*Pinus uncinata*-forests with *Erica carnea*, *Polygala chamaebuxus*, *Sesleria albicans* on carbonate rocks in the west Alps
D35	Homogyne alpina- and *Adenostyles alliariae*-spruce forests (*Picea abies*) in the Alps, partly alternating with *Pinus mugo*- and *Alnus alnobetula*-scrub
D37	East and South Carpathian spruce forests (*Picea abies*), partly with *Abies alba*, with *Leucanthemum waldsteinii*, *Hieracium rotundatum*
F14	Galician-north *Lusitanian hyperoceanic* pedunculate oak forests (*Quercus robur*, partly *Quercus pyrenaica*, *Quercus suber*) with *Laurus nobilis*, *Viburnum tinus*, *Pyrus cordata*, *Daboecia cantabrica*, *Andryala integrifolia*
F16	Atlantic-subatlantic mixed oak forests (*Quercus robur, Quercus petraea, Sorbus torminalis, Castanea sativa*) with *Ilex aquifolium*, *Teucrium scorodonia, Luzula forsteri* in the Massif Central foreland and in the Lower Dauphiné
F32	Galician-north Lusitanian oak forests (*Quercus robur, Quercus pyrenaica*) with *Betula pubescens subsp. celtiberica, Cytisus striatus, Dryopteris aemula, Anemone trifolia subsp. albida, Omphalodes nitida*
F36	South subatlantic hygrophilous pedunculate oak-hornbeam forests (*Carpinus betulus, Quercus robur*) with *Ornithogalum pyrenaicum*, partly *Pulmonaria montana*, in the southwest with *Pulmonaria affinis, Pulmonaria longifolia*, alternating with acidophilus oak forests (*Quercus robur, Quercus petraea*)
F4	West Armorican oak forests (*Quercus petraea, Quercus robur*) with *Sorbus torminalis, Pyrus cordata, Mespilus germanica, Ruscus aculeatus*
F40	Baltic-Byelorussian-Ukrainian lime-pedunculate oak-hornbeam forests (*Carpinus betulus, Quercus robur, Tilia cordata*) with Picea abies
F41	East Polish-Ukrainian lime-pedunculate oak-hornbeam forests (*Carpinus betulus, Quercus robur, Tilia cordata*) without *Fagus sylvatica, Picea abies*, with *Galium schultesii*
F42	South Polish-pre-Carpathian lime-pedunculate oak-hornbeam forests (*Carpinus betulus, Quercus robur, Tilia cordata*) with *Fagus sylvatica*, with *Carex pilosa, Hepatica nobilis*
F47	Peri-Pannonian pedunculate oak-hornbeam forests (*Carpinus betulus, Quercus robur*) with *Galanthus nivalis, Knautia drymeia*
F50	Subatlantic-Central European sessile oak-hornbeam forests (*Carpinus betulus, Quercus petraea*), partly with *Fagus sylvatica*, mostly with *Galium sylvaticum*, partly *Scilla bifolia*, in the southwest with *Ornithogalum pyrenaicum*
F51	Southwest Central European sessile oak-hornbeam forests (*Carpinus betulus, Quercus petraea, Quercus robur*), alternating with species-rich or species-poor beech forests (*Fagus sylvatica*)
F55	Central European sessile oak-hornbeam forests (*Carpinus betulus, Quercus petraea*), mostly with *Fagus sylvatica*, *with Sorbus torminalis, Carex montana, Hepatica nobilis*
F68	East Moesian-west Pontic mixed sessile oak-hornbeam-silver lime forests (*Tilia tomentosa, Carpinus betulus, Quercus petraea, Quercus dalechampii, Quercus polycarpa*), partly with Carpinus orientalis, with *Nectaroscordum siculum subsp. bulgaricum*
F106	Picard beech forests (*Fagus sylvatica*) with *Hyacinthoides non-scripta, Primula acaulis, Conopodium majus*

F108	South Scandinavian-north Central European *Galium odoratum*- and *Milium effusum*-beech forests (*Fagus sylvatica*), partly with *Fraxinus excelsior*, partly with *Stellaria nemorum subsp. montana, Luzula sylvatica, Polygonatum verticillatum, Ranunculus lanuginosus, Cardamine bulbifera*
F110	Subatlantic-Central European *Melica uniflora*- or *Galium odoratum*- and *Milium effusum*-beech forests (*Fagus sylvatica*), partly with *Galium sylvaticum*
F119	Hercynian-southeast Central European beech forests (*Fagus sylvatica*), partly with *Cardamine enneaphyllos*, with *Cardamine bulbifera*, *Lathyrus vernus*
F125	Pre-Carpathian beech forests (*Fagus sylvatica*), partly with *Carpinus betulus, Abies alba*, with *Cardamine glanduligera, Symphytum tuberosum subsp. angustifolium, partly S. cordatum*
F126	Southeast Carpathian hornbeam-beech forests (*Fagus sylvatica, Carpinus betulus*) with *Melampyrum bihariense*
F139	Calciphilous beech forests (*Fagus sylvatica*) with *Quercus pubescens*, *Buxus sempervirens* and *Acer opalus*, with *Carex alba* in the Causses
F77	(Atlantic-)subatlantic *Deschampsia flexuosa*-(oak-)beech forests (*Fagus sylvatica, Quercus robur, Quercus petraea*) with *Lonicera periclymenum, Maianthemum bifolium, Vaccinium myrtillus*, partly *Ilex aquifolium*
F78	(Atlantic-)subatlantic hygrophilous oak-beech forests (*Fagus sylvatica, Quercus petraea, Quercus robur*) with *Molinia caerulea*
F80	Northeast Central European (sessile oak-)beech forests (*Fagus sylvatica, Quercus petraea*), partly with *Calamagrostis arundinacea*
F83	((Atlantic-)subatlantic Luzula luzuloides-(sessile oak-)beech forests (*Fagus sylvatica, Quercus petraea*) with Ilex aquifolium, *Teucrium scorodonia, Lonicera periclymenum*
F85	Central European *Luzula luzuloides*-(sessile oak-)beech forests (*Fagus sylvatica, Quercus petraea*) with *Carex umbrosa, Calamagrostis arundinacea*, on moist habitats with *Carex brizoides*
F115	Central European *Galium odoratum*-(fir-)beech forests (*Fagus sylvatica, Abies alba*) with *Quercus robur, Quercus petraea*, partly with *Tilia cordata, Tilia platyphyllos*
F129	South subatlantic calciphilous beech and fir-beech forests (*Fagus sylvatica, Abies alba*) with *Lathyrus vernus*, *Asarum europaeum, Cardamine heptaphylla*, locally with *Cephalanthera*- and *Sesleria*-beech forests
F135	Carpathian fir-beech and spruce-fir-beech forests (*Fagus sylvatica, Abies alba, Picea abies*) with *Cardamine glanduligera*, *Symphytum tuberosum subsp. angustifolium,* partly with *S. cordatum, Pulmonaria rubra*
F142	Fir-beech forests (*Fagus sylvatica, Abies alba*), partly with *Picea abies*, with *Anemone trifolia, Lamium orvala, Cardamine enneaphyllos*, *Hacquetia epipactis, Omphalodes verna, Vicia oroboides* in the south(east) Alps and Illyria
F93	Subatlantic *Luzula luzuloides*-fir-beech forests (*Fagus sylvatica, Abies alba*) with *Ilex aquifolium, Prenanthes purpurea*
G11	North Apennine mixed sessile oak-bitter oak forests (*Quercus cerris, Quercus petraea, partly Quercus pubescens*) with *Physospermum cornubiense, Chamaecytisus hirsutus, Anemone trifolia subsp. albida*
G16	Pannonian-pre-Carpathian sessile oak-bitter oak forests (*Quercus cerris, Quercus petraea, Quercus dalechampii*) with *Potentilla alba, Vicia cassubica*
G36	*Thracian* mixed Balkan oak-bitter oak–grey oak forests (*Quercus pedunculiflora, Quercus*

	cerris, Quercus frainetto) with *Carpinus orientalis, Physospermum cornubiense*
G37	Aquitanian mixed downy oak forests (*Quercus pubescens, Quercus petraea, Quercus robur*) with *Rubia peregrina*
G41	Downy oak forests (*Quercus pubescens*) with *Buxus sempervirens, Genista cinerea*, partly *Acer opalus* from the south Pyrenees to the southwest pre-Alps
G44	Ligurian-middle Apennine downy oak forests (*Quercus pubescens*) with *Viola alba subsp. dehnhardtii*
G5	Pannonian mixed sand steppe-oak forests (*Quercus robur, partly Quercus pubescens, Tilia cordata*) with *Convallaria majalis,* partly *Silene coronaria*
G53	South Apennine-Sicilian-east Adriatic mixed downy oak forests (*Quercus virgiliana, Quercus pubescens, partly Quercus congesta*) with *Carpinus orientalis, Fraxinus ornus*, with *Anemone apennina, Cyclamen hederifolium*
G57	Albanian-Macedonian-Greek mixed Oriental hornbeam-downy oak forests (*Quercus pubescens, Quercus virgiliana, Carpinus orientalis*) with *Symphytum ottomanum*, partly with *Phillyrea latifolia, Quercus coccifera, Asparagus acutifolius*
G72	Northeast Iberian supra-Mediterranean *Quercus faginea-forests* with *Viola willkommi*

Table 7:3 Grouping tree species classified by the PNV map and simulated by PICUS.

Grouping tree list PNV map and PICUS						
SHORT NAME MAP	**SHORT NAME**	**LATIN NAME**	**SHORT NAME**	**LATIN NAME**	**GERMAN NAME**	**ENGLISH NAME**
Abies_alba	ABIALB	*Abies alba*	ABIALB	*Abies alba*	Tanne	Silver Fir
Acer_campe	ACECAM	*Acer campestre*	ACECAM	*Acer campestre*	Feldahorn	Field Maple
			ACEMON	*Acer monspessulamun*	Französische Ahorn	Montpellier Maple
Acer_plata	ACEPLA	*Acer platanoides*	ACEPLA	*Acer platanoides*	Spitzahorn	Norway Maple
Acer_pseud	ACEPSE	*Acer pseudoplatanus*	ACEPSE	*Acer pseudoplatanus*	Bergahorn	Sycamore Maple
Alnus_glut	ALNGLU	*Alnus glutinosa*	ALNGLU	*Alnus glutinosa*	Schwarzerle	Black Alder
Alnus_inca	ALNINC	*Alnus incana*	ALNINC	*Alnus incana*	Weißerle	Grey Alder
Alnus_viri	ALNVIR	*Alnus viridis*	ALNVIR	*Alnus viridis*	Gruenerle	Green Alder
Betula_pen	BETPEN	*Betula pendula*	BETPEN	*Betula pendula*	Birke	Silver Birch

			BETPUB	*Betula pubescens*	Moorbirke	White Birch
			BETPUBcz	*Betula pubescens subsp. Czerepanovii*	Fjellbirke	Mountain Birch
Carpinus_b	CARBET	*Carpinus betulus*	CARBET	*Carpinus betulus*	Hainbuche	European Hornbeam
			CARORI	*Carpinus orientalis*	Orientalische Hainbuche	Oriental Hornbeam
Castanea_s	CASSAT	*Castanea sativa*	CASSAT	*Castanea sativa*	Edelkastanie	Sweet Chestnut
Corilus_av	CORAVE	*Corylus avellana*	CORAVE	*Corylus avellana*	Hasel	Common Hazel
Fagus_sylv	FAGSYL	*Fagus sylvatica*	FAGSYL	*Fagus sylvatica*	Buche	Common Beech
			FAGSYLmo	*Fagus sylvatica subsp. moesiaca*	Rotbuche	Crimean Beech
			ULMMIN	*Ulmus minor*	Feldulme	Field Elm
			ULMsp	*Ulmus sp*	Ulmen	Elm
			ULMGLA	*Ulmus glabra*	Bergulme	Wych Elm
Fraxinus_e	FRAEXC	*Fraxinus excelsior*	FRAEXC	*Fraxinus excelsior*	Esche	Common Ash
			PRUAVI	*Prunus avium*	Vogelkirsche	Wild Cherry
			FRAEXCco	*Fraxinus excelsior subsp. Coriariifoliain*	Esche	Common Ash
			PLAORI	*Platanus orientalis*	Morgenländische Platane	Oriental Plane
			FRAANG	*Fraxinus angustifolia*	Schmalblättrige Esche	Narrow-leafed Ash
			FRAANGda	*Fraxinus angustifolia subsp. Danubialis*	Schmalblättrige Esche	Narrow-leafed Ash
Larix_deci	LARDEC	*Larix decidua*	LARDEC	*Larix decidua*	Laerche	Larch
Picea_abie	PICABI	*Picea*	PICABI	*Picea*	Fichte	Norway Spruce

		abies		*abies*		
			PICOBO	*Picea obovata*	Sibirische Fichte	Siberian Spruce
Pinus_cemb	PINCEM	*Pinus cembra*	PINCEM	*Pinus cembra*	Zirbe	Swiss Pine
Pinus_mont	PINMON	*Pinus montana*	PINMON	*Pinus montana or uncinata (Pinus mugo)*	Latsche	Mountain Pine
Pinus_sylv	PINSYL	*Pinus sylvestris*	PINSYL	*Pinus sylvestris*	Kiefer	Scots Pine
			PINBRU	*Pinus brutia*	Brutische Kiefer	Brutia Pine
			PINHAL	*Pinus halepensis*	Aleppo Kiefer	Aleppo Pine
			PINNIG	*Pinus nigra*	Schwarzkiefer	European Black Pine
Populus_ni	POPNIG	*Populus nigra*	POPNIG	*Populus nigra*	Schwarzpappel	Black Poplar
			POPALB	*Populus alba*	Silberpappel	White Poplar
			POPCAN	*Populus x canescens*	Graupappel	Grey Poplar
Pouplus_tr	POPTRE	*Populus tremula*	POPTRE	*Populus tremula*	Aspe	Common Aspen
Quercus_pe	QUEPET	*Quercus petraea*	QUEPET	*Quercus petraea*	Traubeniche	Sessile Oak
Quercus_pu	QUEPUB	*Quercus pubescens*	QUEPUB	*Quercus pubescens*	Flaumeiche	Downy Oak
			ACEOPA	*Acer opalus*	Schneeballahorn	Italian Maple
			ACEOPAob	*Acer opalus subsp. obtusatum*	Neapolitanischerahorn	Bosnian Maple
			CELAUS	*Celtis australis*	Europaeische Zügelbaum	Honeyberry
			OSTCAR	*Ostrya carpinifolia*	Gemeine Hopfenbuche	Hop Hornbeam
			QUERCER	*Quercus cerris*	Zerreiche	Turkey Oak
			FRAORN	*Fraxinus ornus*	Manna Esche	Manna Ash

			QUECON	*Quercus congesta*		
			QUEVIR	*Quercus virginiana*	Lebenseiche	Southern live Oak
			ACETAT	*Acer tataricum*	Tatarischer Steppenahorn	Tatarian Maple
			QUEDAL	*Quercus dalechampii*	Dalechamp-Eiche	Dalechamp´s oak
			QUECOC	*Quercus coccifera*	Kermeseiche	Kermes Oak
			ARBUNE	*Arbutus unedo*	Westlicher Erdbeerbaum	Strawberry Tree
			ARBAND	*Arbutus andrachne*	Östlicher Erdbeerbaum	Greek Strawberry Tree
			QUEILE	*Quercus ilex*	Steineiche	Holm Oak
			LAUNOB	*Laurus nobilis*	Echter Lorbeer	Bay Laurel
			QUEILEro	*Quercus ilex subsp. rotundifolia*	Steineiche	Holm Oak
			QUEFRA	*Quercus frainetto*	Ungarische Eiche	Hungarian Oak
			QUESUB	*Quercus suber*	Korkeiche	Cork Oak
			QUEROB	*Quercus robur*	Stieleiche	Englisch Oak
			MALSYL	*Malus sylvestris*	Holzapfel	European crab apple
			QUEPED	*Quercus pedunculiflora*	Stieleiche	Englisch Oak
Quercus_ro	QUEROB	*Quercus robur*	QUEPYR	*Quercus pyrenaica*	Pyrenäeneiche	Pyrenean Oak
			QUEFAG	*Quercus faginea*	Portugiesische Eiche	Portuguese Oak
			QUEFAGbr	*Quercus faginea subsp. Broteroi*	Portugiesische Eiche	Portuguese Oak
			ULMLAE	*Ulmus laevis*	Flatterulme	European White Elm
Salix_alba	SALALB	*Salix alba*	SALALB	*Salix alba*	Silberweide	White Willow

			PRUPAD	*Prunus padus*	Gewöhnliche Traubenkirsche	Bird Cherry
			SALCAP	*Salix caprea*	Salweide	Goat Willow
			SALPEN	*Salix pentandra*	Lorbeerweide	Bay Willow
			SALATR	*Salix atrocinerea*	Grauweide	Grey Willow
			SALVIM	*Salix viminalis*	Korbweide	Osier
			SALFRA	*Salix fragilis*	Bruchweide	Crack Willow
Sorbus_ari	SORARI	*Sorbus aria*	SORARI	*Sorbus aria*	Mehlbeere	Whitebeam
			PYRPYR	*Pyrus pyraster*	Wildbirne	European Wild Pear
			PYRBOU	*Pyrus bourgaeana*	Birnen	Iberian Pear
Sorbus_auc	SORAUC	*Sorbus aucuparia*	SORAUC	*Sorbus aucuparia*	Eberesche	Rowan
			SORDOM	*Sorbus domestica*	Speierling	Service Tree
			SORTOR	*Sorbus torminalis*	Elsbeere	Wild Service Tree
Taxus_bacc	TAXBAC	*Taxus baccata*	TAXBAC	*Taxus baccata*	Europaeische Eibe	Yew
			TILCOR	*Tilia cordata*	Winterlinde	Small leaved Lime
Tilia_cord	TILCOR	*Tilia cordata*	TILPLA	*Tilia platyphyllos*	Sommerlinde	Large leaved Lime
			TILTOM	*Tilia tomentosa*	Silberlinde	Silver Lime

Table 7:4 Parameters of regeneration in the plantation mode.

Density [n/ha]	dbh [cm]	hd [cm]
2000	1.5-2.5	100

Table 7:5 Tree species selected for the simulations of the forest productivity.

Tree species	
Abies alba	*Fagus sylvatica*
Picea abies	*Quercus robur*
Larix decidua	*Quercus petraea*
Pinus sylvestris	*Quercus pubescens*

7.2 Annex 2

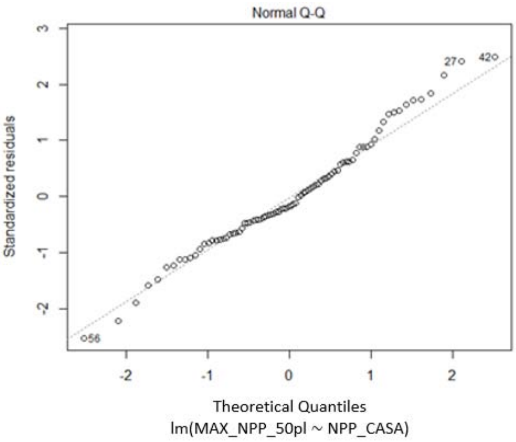

Figure 7:1 Normal distribution of the standardized residuals of the NPP50 Plantation related to the NPP from CASA.

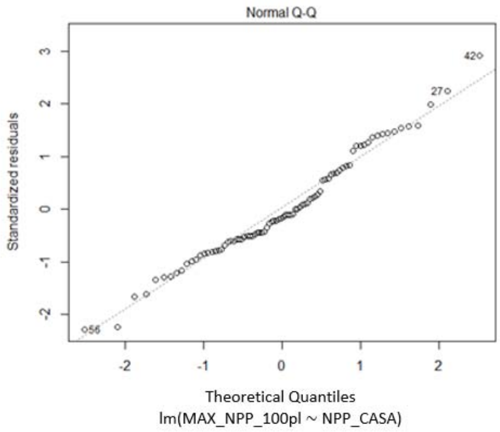

Figure 7:2 Normal distribution of the standardized residuals of the NPP100 Plantation related to the NPP from CASA.

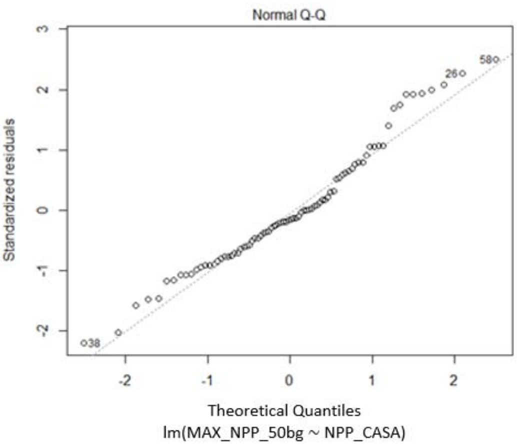

Figure 7:3 Normal distribution of the standardized residuals of the NPP50 Bare ground related to the NPP from CASA.

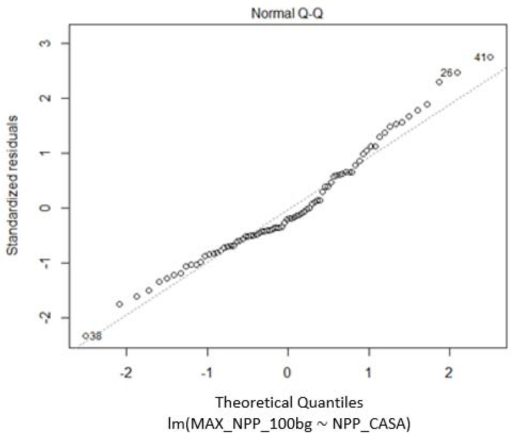

Figure 7:4 Normal distribution of the standardized residuals of the NPP100 Bare ground related to the NPP from CASA.

7.3 Annex 3

Table 7:6 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Linear regression between NPP50 Plantation and NPP-CASA. Simulations started from a plantation. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=84.**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	0.0154
Levene's test	0.0027	0.3064	0.004	na
Anova	0.446	0.0008	0.0046	na
One-way test	0.2777	0.0003	0.0505	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	0.478	0.9767	0.0104	na
A-C	0.525	0.002	0.0028	na
C-B	0.988	0.0011	0.3535	na

Table 7:7 Regression model NPP50 Plantation = a+b*NPP-CASA. n=84.

Estimates			Significance
a	=	553.89	p=0.30
b	=	0.7546	p= 2.51e-11
R^2	=	0.421	
Pr(>F)	=	2.513e-11	

Table 7:8 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Linear regression between NPP100 Plantation and NPP-CASA. Simulations started from a plantation. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=84.**

Test	Site factors			
	Latitude	WHC	Nitrogen	Sites

	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	0.0066
Levene's test	0.006	0.1923	0.0056	na
Anova	0.3	0.0008	0.004	na
One-way test	0.2777	0.0002	0.01921	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	0.291	0.7318	0.0108	na
A-C	0.469	0.001	0.0026	na
C-B	0.997	0.002	0.2971	na

Table 7:9 Regression model NPP100 Plantation = a+b*NPP-CASA. n=84.

Estimates			Significance
a	=	436.91	p=0.37
b	=	0.7665	p= 8e-12
R^2	=	0.4365	
Pr(>F)	=	8.003e-12	

Table 7:10 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Linear regression between NPP50 Bare ground and NPP-CASA. Simulations started from a bare ground. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=82.**

Test	Site factors			
	Latitude	**WHC**	**Nitrogen**	**Sites**
	Pr(>F)	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**
Welch' test	na	na	na	0.0107
Levene's test	0.00024	0.3803	0.004	na
Anova	0.0641	0.002	0.0959	na
One-way test	0.0534	0.0014	0.0669	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	0.0544	0.6452	0.235	na

A-C	0.6342	0.0297	0.103	na
C-B	0.4994	0.0013	0.347	na

Table 7:11 Regression model NPP50 Bare ground = a+b*NPP-CASA. n=82.

Estimates			Significance
a	=	27.92	p=0.967
b	=	0.999	p= 7.71e-12
R^2	=	0.4451	
Pr(>F)	=	7.711e-12	

Table 7:12 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Linear regression between NPP100 Bare ground and NPP-CASA. Simulations started from a bare ground. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=82.**

Test	Site factors			
	Latitude	**WHC**	**Nitrogen**	**Sites**
	Pr(>F)	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**
Welch' test	na	na	na	0.0162
Levene's test	0.0063	0.264	0.0054	na
Anova	0.186	0.0038	0.0789	na
One-way test	0.1371	0.0018	0.0633	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	0.165	0.9984	0.1769	na
A-C	0.438	0.0099	0.0772	na
C-B	0.954	0.004	0.3727	na

Table 7:13 Regression model NPP100 Bare ground = a+b*NPP-CASA. n=82.

Estimates			Significance
a	=	254.8400	p=0.612
b	=	0.7379	p=7.1e-12

R^2	=	0.4462
Pr(>F)	=	7.104e-12

7.4 Annex 4

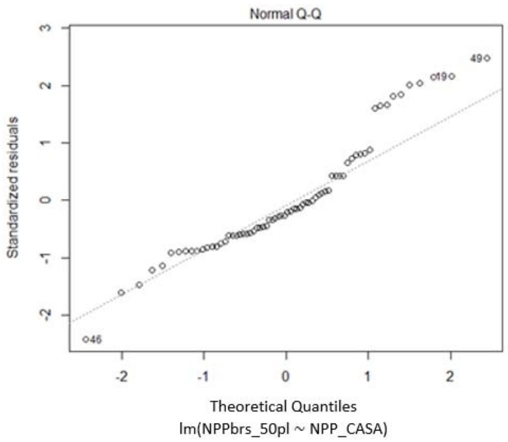

Figure 7:5 Normal distribution of the standardized residuals of the NPP50 Plantation related to the NPP from CASA. Tree species simulated classified in the map of dominant tree species across Europe.

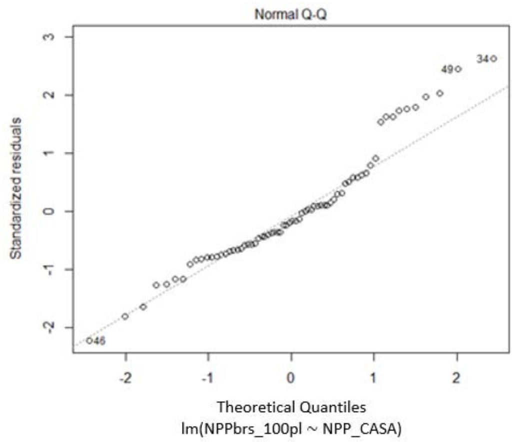

Figure 7:6 Normal distribution of the standardized residuals of the NPP100 Plantation related to the NPP from CASA. Tree species simulated classified in the map of dominant tree species across Europe.

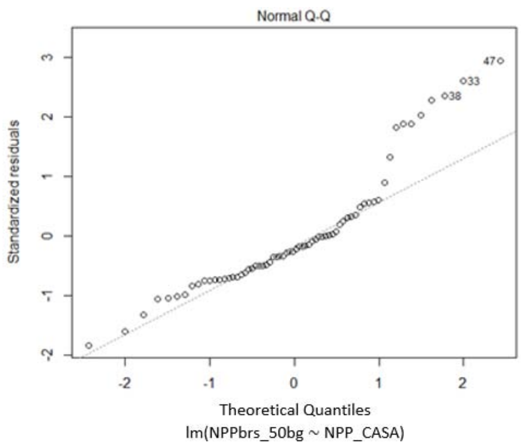

Figure 7:7 Normal distribution of the standardized residuals of the NPP50 Bare ground related to the NPP from CASA. Tree species simulated classified in the map of dominant tree species across Europe.

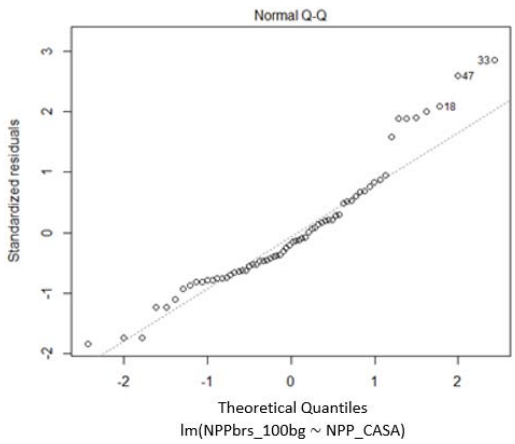

Figure 7:8 Normal distribution of the standardized residuals of the NPP100 Bare ground related to the NPP from CASA. Tree species simulated classified in the map of dominant tree species across Europe.

7.5 Annex 5

Table 7:14 Test for differences between categories of site factors for the simulated net primary production in year 50 (NPP50). Linear regression between NPP50 Brus Plantation and NPP-CASA. Simulations started from a plantation. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=68.**

TEST	Site factors			
	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	Pr(>F)	Pr(>F)	Pr(>F)
Welch' test	na	na	na	0.0364
Levene's test	0.05	0.0535	0.0595	na
Anova	0.646	0.0318	0.0124	na
One-way test	0.539	0.1022	0.0305	na
Post-hoc Tukey	Pr(>F)	Pr(>F)	Pr(>F)	na
A-B	0.710	0.6212	0.0123	na
A-C	0.667	0.0268	0.0087	na
C-B	0.961	0.0818	0.7997	na

Table 7:15 Regression model NPP50 Brus Plantation = a+b*NPP-CASA. n=68.

Estimates			Significance
a	=	72.16	p=3.55e-08
b	=	0.6143	p= 0.895
R^2	=	0.3711	
Pr(>F)	=	3.546e-08	

Table 7:16 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Linear regression between NPP100 Brus Plantation and NPP-CASA. Simulations started from a plantation. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=68.**

TEST	Site factors

	Latitude	WHC	Nitrogen	Sites
	Pr(>F)	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**
Welch' test	na	na	na	0.0262
Levene's test	0.0625	0.0842	0.1063	na
Anova	0.489	0.0537	0.0172	na
One-way test	0.3737	0.1489	0.0149	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	0.566	0.5066	0.0170	na
A-C	0.517	0.0418	0.0122	na
C-B	0.940	0.1706	0.8108	na

Table 7:17 Regression model NPP100 Brus Plantation = a+b*NPP-CASA. n=68.

Estimates			Significance
a	=	-44.8757	p=0.932
b	=	0.5830	p= 4.58e-08
R^2	=	0.3663	
Pr(>F)	=	4.585e-08	

Table 7:18 Test for differences between categories of site factors for the simulated net primary production in the year 50 (NPP50). Linear regression between NPP50 Brus Bare ground and NPP-CASA. Simulations started from a bare ground. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=66.**

TEST	Site factors			
	Latitude	**WHC**	**Nitrogen**	**Sites**
	Pr(>F)	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**
Welch' test	na	na	na	0.0289
Levene's test	0.0315	0.1629	0.023	na
Anova	0.266	0.152	0.196	na
One-way test	0.22	0.2007	6.9e-09	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na

A-B	0.234	0.902	0.286	na
A-C	0.591	0.345	0.170	na
C-B	0.938	0.128	0.619	na

Table 7:19 Regression model NPP50 Brus Bare ground = a+b*NPP-CASA. n=66.

Estimates			Significance
a	=	-235.73	p=0.695
b	=	0.7456	p= 2.66e-09
R^2	=	0.4274	
Pr(>F)	=	2.661e-09	

Table 7:20 Test for differences between categories of site factors for the simulated net primary production along 100 years (NPP100). Linear regression between NPP100 Brus Bare ground and NPP-CASA. Simulations started from a bare ground. Tree species simulated are defined in the map of dominant tree species across Europe. na = not applicable, ns = not significant (Pr(>F) ≤ 0.05), significant * (Pr(>F) ≤0.01 & >0.05), very significant ** (Pr(>F) ≤0.001 & >0.01), highly significant * (PF(>F) ≤0 & >0.001). WHC = water holding capacity, SITES = water and nutrient limited sites vs sites without such limitations. n=66.**

TEST	Site factors			
	Latitude	**WHC**	**Nitrogen**	**Sites**
	Pr(>F)	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**
Welch' test	na	na	na	0.0217
Levene's test	0.1238	0.2306	0.0979	na
Anova	0.42	0.114	0.157	na
One-way test	0.3692	0.1987	2.253e-05	na
Post-hoc Tukey	**Pr(>F)**	**Pr(>F)**	**Pr(>F)**	na
A-B	0.442	0.911	0.183	na
A-C	0.520	0.124	0.123	na
C-B	0.986	0.149	0.750	na

Table 7:21 Regression model NPP100 Brus Bare ground = a+b*NPP-CASA. n=66.

Estimates	Significance

a	=	-198.58110	p=0.696
b	=	0.60625	p= 7.83e-09
R^2	=	0.4081	
Pr(>F)	=	7.825e-09	

7.6 Annex 6

Table 7:22 Study area information of the PNV. Values represented in the table are: water holding capacity (WHC), Nitrogen available (N AVILABL), average of all monthly mean temperatures (TEMP AVG), average of summer precipitation from May to September (PREC SUMME), CN RATIO, elevation (ELEV), pH (PH TOP), Third level of PNV classification (CODE PNV) and classification of the EFT (EFT ID).

POINT X	POINT Y	SIMU ID	LAT	PREC SUM [mm]	PREC SUMME [mm]	TEMP AMPLI [°C]	TEMP AVG [°C]	WHC [mm]	N AVAILABL [kg/ha*yr.]	CN RATIO	ELEV [m]	PH TOP	CODE PNV	EFT ID
4800500	4800500	341970	66	463,64	226,46	27,69	0,13	174,41	55,50	73,08	166	4,58	D4	1
5000500	4400500	138248	62	601,80	299,16	23,87	2,86	102,92	61,31	58,85	140	4,65	D45	1
4600500	4400500	340410	63	515,91	270,81	22,93	2,12	174,92	55,94	60,38	429	4,59	D4	1
5200500	4600500	132815	63	580,08	314,80	27,12	2,05	101,69	62,08	46,92	141	4,63	D4	1
5000500	4600500	134130	64	503,53	263,61	24,71	2,17	167,26	69,67	70,77	52	5,18	D47	1
4800500	4600500	343028	64	522,45	251,17	23,98	1,54	175,31	58,04	33,85	238	4,59	D4	1
4600500	4600500	343111	64	595,99	311,52	23,29	1,09	175,43	56,39	53,46	391	4,60	D1	1
4600500	4200500	338912	61	613,11	319,38	23,22	3,49	179,24	61,03	15,38	344	4,65	D8	1
5400500	3800500	286729	56	579,30	294,05	22,71	5,24	199,74	81,91	24,23	181	5,80	D49	2
5200500	3800500	286328	57	601,78	313,22	21,47	6,25	217,07	103,10	18,46	24	5,58	D49	2
5000500	3800500	287566	57	672,64	294,14	21,39	5,58	135,80	81,68	41,54	26	4,95	D49	2
4600500	3800500	345419	57	700,56	325,08	18,75	5,85	173,87	56,06	59,23	162	4,60	D15	2
5200500	4000500	68286	58	650,33	321,67	22,70	5,45	139,85	82,84	32,31	50	4,66	D49	2
4600500	4000500	336830	59	630,46	319,74	20,50	5,74	175,99	57,05	45,00	81	4,63	D16	2
5200500	3600500	284399	55	581,20	304,11	21,33	6,38	219,90	74,04	10,77	99	5,92	F40	5
4400500	3600500	65249	56	510,00	246,50	16,36	8,22	191,43	64,61	6,84	35	6,26	F108	6
4800500	3400500	302994	53	457,97	250,11	19,22	7,46	217,28	71,98	12,00	104	5,74	F80	6
5000500	3400500	302144	53	527,24	293,31	20,19	6,76	162,86	71,07	26,31	190	4,77	F41	5
4600500	3400500	48534	54	488,21	246,41	17,75	8,29	153,77	68,49	32,31	12	4,65	F80	6
4400500	3400500	48471	54	595,95	276,66	16,43	8,44	169,63	59,32	31,92	56	5,92	F77	6
3600500	3400500	360922	53	597,51	263,24	12,71	9,18	217,81	109,59	9,23	50	5,98	F32	5
3200500	3400500	233586	53	910,17	350,19	10,21	9,57	114,55	109,13	16,15	89	5,25	F32	5
5000500	3200500	293796	52	512,51	296,98	19,96	7,71	203,81	77,39	11,15	184	5,63	F42	5
5200500	3200500	292643	51	438,89	245,81	21,08	7,54	251,08	75,79	10,38	209	5,98	F42	5
4800500	3200500	302986	52	504,84	281,49	18,97	8,32	217,28	71,98	12,00	121	5,74	F55	5
4200500	3200500	53414	52	727,24	309,36	15,65	9,36	151,60	73,32	21,69	86	4,68	F78	6
3400500	3200500	367016	51	671,77	262,77	12,07	9,56	200,52	63,78	9,09	231	6,12	F32	5
5200500	3000500	297468	49	725,18	407,02	19,50	6,36	106,45	81,59	17,08	375	4,68	F125	6
5000500	3000500	295455	50	806,70	450,51	18,39	5,84	100,00	87,26	13,46	503	4,70	F135	7

4800500	3000500	26997	50	623,65	368,13	19,32	7,19	100,00	80,06	19,23	512	4,66	F119	6
4600500	3000500	22448	50	516,77	295,32	18,57	8,52	100,08	47,75	22,27	384	6,05	F115	7
4400500	3000500	39933	50	675,69	325,20	18,01	7,68	156,77	102,09	11,54	361	5,74	F51	5
4200500	3000500	44852	50	580,63	253,62	17,34	9,53	109,02	53,37	19,23	231	5,92	F83	6
4000500	3000500	13331	50	868,36	348,55	15,14	7,88	206,91	58,15	19,62	471	5,21	F83	6
3800500	3000500	141602	50	709,07	292,90	14,10	9,78	265,92	65,63	7,37	108	6,26	F106	6
5400500	2800500	329791	47	761,74	442,89	21,53	8,38	206,00	102,48	11,92	513	4,75	F125	6
5200500	2800500	230577	48	508,62	270,98	22,14	9,99	138,63	71,90	20,91	148	6,12	G5	8
5000500	2800500	229519	48	445,89	220,58	21,09	9,80	204,56	117,63	8,46	184	4,77	G16	8
4800500	2800500	385	48	574,70	292,23	19,98	10,30	155,11	85,85	6,82	187	6,26	F47	5
4600500	2800500	6404	48	671,50	358,89	18,37	8,68	169,40	62,43	3,85	352	5,86	F85	6
4400500	2800500	42355	48	818,59	450,55	18,10	7,96	214,10	64,50	8,95	478	6,26	F85	6
4200500	2800500	33113	48	952,77	434,27	16,83	7,70	100,00	84,44	21,92	437	4,60	F93	7
4000500	2800500	150293	48	867,45	357,45	16,45	9,00	160,71	95,03	19,55	379	6,26	F110	6
3600500	2800500	155740	48	633,15	235,95	14,57	11,04	255,64	67,42	12,73	104	6,19	F4	5
3800500	2800500	143295	48	602,55	254,73	15,61	10,98	260,51	115,43	8,31	128	5,86	F50	5
3400500	2800500	157108	48	713,49	228,33	12,50	11,72	132,99	110,03	7,69	31	5,00	F4	5
5600500	2600500	320142	45	407,11	218,55	23,15	9,76	199,00	106,13	13,85	209	5,98	F126	6
5400500	2600500	334526	46	476,88	251,46	20,08	4,15	100,00	40,35	21,54	1343	4,58	D37	3
4600500	2600500	251352	46	987,23	491,35	18,25	5,45	100,00	102,76	15,38	1198	5,86	F142	7
4400500	2600500	247265	47	1139,54	648,06	18,49	6,29	100,00	73,85	19,23	1902	4,62	D35	3
3800500	2600500	178992	46	721,75	361,30	15,88	10,32	105,36	85,74	12,00	260	4,62	F36	5
4000500	2600500	153687	46	1151,95	470,83	16,84	7,18	100,00	77,11	16,54	852	5,98	F129	7
3600500	2600500	158521	46	822,12	299,37	14,91	11,48	213,69	74,43	10,38	162	5,58	F16	5
5600500	2400500	15525	43	399,96	173,03	22,82	11,81	197,78	102,27	10,00	194	6,26	F68	5
4000500	2400500	191566	45	1081,28	395,01	16,89	8,00	100,00	67,62	11,36	1930	6,05	C22	3
4200500	2400500	236908	45	891,41	337,11	18,55	13,25	100,00	113,50	5,00	243	4,87	G44	8
3800500	2400500	184376	45	1057,47	423,14	15,70	7,18	100,00	92,77	14,62	886	5,63	F139	6
3600500	2400500	163259	44	696,33	273,16	15,61	12,11	126,65	91,29	6,32	187	6,26	G37	8
3000500	2400500	74435	43	746,50	196,03	13,02	12,60	150,00	63,31	26,92	478	4,58	F14	5
2800500	2400500	69857	43	1035,38	240,29	9,61	12,60	100,00	46,24	13,08	391	4,57	F14	5
5600500	2200500	19962	42	527,33	170,84	20,99	11,46	150,73	97,98	11,92	423	4,63	G36	8
5400500	2200500	17971	42	724,68	316,43	21,08	9,61	226,92	111,38	12,69	536	5,52	G57	8
4400500	2200500	255997	43	730,72	210,88	15,89	14,45	100,00	115,93	6,54	173	4,68	G11	8
4600500	2200500	260969	43	694,70	252,98	16,77	9,79	181,26	111,83	10,00	456	5,86	G44	8
3600500	2200500	111272	43	1052,20	455,70	15,91	5,04	100,00	39,80	25,00	994	4,60	G41	8
2800500	2200500	305518	41	1384,52	268,82	12,87	13,80	100,00	112,73	5,77	186	4,60	F14	5
4800500	2000500	272173	41	586,91	157,39	16,64	14,39	100,00	126,10	3,85	554	5,80	G53	8
3400500	2000500	83361	41	584,72	212,14	17,22	10,10	112,59	60,33	13,16	1258	6,26	G72	8

Table 7:23 Study area information of the NPP Plantation (NPP50 and NPP100). Values represented in the table are: water holding capacity (WHC), Nitrogen available (N AVILABL), average of all monthly mean temperatures (TEMP AVG), average of summer precipitation from May to September (PREC SUMME), CN RATIO, elevation (ELEV), pH (PH TOP), dominant tree species for the year 50 (species NPP50 Plantation) and dominant tree species for the 100 years time period (Species NPP100 Plantation).

POINT X	POINT Y	SIMU ID	LAT	PREC SUM [mm]	PREC SUMME [mm]	TEMP AMPLI [°C]	TEMP AVG [°C]	WHC [mm]	N AVAILABL [kg/ha*yr.]	CN RATIO	ELEV [m]	PH TOP	Species NPP50 Plantation	Species NPP100 Plantation
5000500	4800500	135306	66	515,10	241,69	27,16	1,16	103,4715	60,65	183,08	22,00	4,59	Larix decidua	Larix decidua
4800500	4800500	341970	66	463,64	226,46	27,69	0,13	174,4125	55,50	73,08	166,00	4,58	Larix decidua	Larix decidua
4600500	4800500	343596	66	705,71	337,50	23,87	-2,82	175,3985	58,27	31,92	952,00	4,58	Larix decidua	Larix decidua
5000500	4400500	138248	62	601,80	299,16	23,87	2,86	102,9155	61,31	58,85	140,00	4,65	Larix decidua	Larix decidua
4600500	4400500	340410	63	515,91	270,81	22,93	2,12	174,9225	55,94	60,38	429,00	4,59	Larix decidua	Larix decidua
5200500	4600500	132815	63	580,08	314,80	27,12	2,05	101,6922	62,08	46,92	141,00	4,63	Larix decidua	Larix decidua
5000500	4600500	134130	64	503,53	263,61	24,71	2,17	167,2585	69,67	70,77	52,00	5,18	Larix decidua	Larix decidua
4800500	4600500	343028	64	522,45	251,17	23,98	1,54	175,3135	58,04	33,85	238,00	4,59	Larix decidua	Larix decidua
4600500	4600500	343111	64	595,99	311,52	23,29	1,09	175,4325	56,39	53,46	391,00	4,60	Larix decidua	Larix decidua
5000500	4200500	138106	60	621,16	285,74	22,72	4,92	100,0000	79,90	3,85	17,00	4,66	Larix decidua	Larix decidua
4600500	4200500	338912	61	613,11	319,38	23,22	3,49	179,2405	61,03	15,38	344,00	4,65	Larix decidua	Larix decidua
5400500	3800500	286729	56	579,30	294,05	22,71	5,24	199,7367	81,91	24,23	181,00	5,80	Fagus sylvatica	Fagus sylvatica
5200500	3800500	286328	57	601,78	313,22	21,47	6,25	217,0733	103,10	18,46	24,00	5,58	Fagus sylvatica	Fagus sylvatica
5000500	3800500	287566	57	672,64	294,14	21,39	5,58	135,8019	81,68	41,54	26,00	4,95	Larix decidua	Larix decidua
4600500	3800500	345419	57	700,56	325,08	18,75	5,85	173,8685	56,06	59,23	162,00	4,60	Larix decidua	Larix decidua
5200500	4000500	68286	58	650,33	321,67	22,70	5,45	139,8526	82,84	32,31	50,00	4,66	Fagus sylvatica	Fagus sylvatica
4600500	4000500	336830	59	630,46	319,74	20,50	5,74	175,9850	57,05	45,00	81,00	4,63	Larix decidua	Larix decidua
5200500	3600500	284399	55	581,20	304,11	21,33	6,38	219,9044	74,04	10,77	99,00	5,92	Fagus sylvatica	Fagus sylvatica
4400500	3600500	65249	56	510	246,5	16,36	8,22	191,4288	64,61	6,84	35,00	6,26	Fagus sylvatica	Fagus sylvatica
5200500	3400500	298715	53	540,15	291,67	21,26	6,68	137,1851	82,20	37,31	152,00	4,77	Fagus sylvatica	Fagus sylvatica
4800500	3400500	302994	53	457,97	250,11	19,22	7,46	217,2827	71,98	12,00	104,00	5,74	Fagus sylvatica	Fagus sylvatica
5000500	3400500	302144	53	527,24	293,31	20,19	6,76	162,8562	71,07	26,31	190,00	4,77	Fagus sylvatica	Fagus sylvatica
4600500	3400500	48534	54	488,21	246,41	17,75	8,29	153,7704	68,49	32,31	12,00	4,65	Quercus petraea	Fagus sylvatica
4400500	3400500	48471	54	595,95	276,66	16,43	8,44	169,6330	59,32	31,92	56,00	5,92	Larix decidua	Fagus sylvatica
3600500	3400500	360922	53	597,51	263,24	12,71	9,18	217,8096	109,59	9,23	50,00	5,98	Larix decidua	Larix decidua
3200500	3400500	233586	53	910,17	350,19	10,21	9,57	114,5497	109,13	16,15	89,00	5,25	Larix decidua	Abies alba
3000500	3400500	234827	52	1322,54	497,77	9,71	9,33	185,7642	214,79	20,77	144,00	5,04	Abies alba	Abies alba
5000500	3200500	293796	52	512,51	296,98	19,96	7,71	203,8087	77,39	11,15	184,00	5,63	Fagus sylvatica	Fagus sylvatica
5200500	3200500	292643	51	438,89	245,81	21,08	7,54	251,0822	75,79	10,38	209,00	5,98	Quercus petraea	Fagus sylvatica
4800500	3200500	302986	52	504,84	281,49	18,97	8,32	217,2827	71,98	12,00	121,00	5,74	Fagus sylvatica	Fagus sylvatica
4400500	3200500	61616	52	636,21	302,58	17,22	8,72	116,0024	64,02	8,31	104,00	5,80	Fagus sylvatica	Fagus sylvatica
4200500	3200500	53414	52	727,24	309,36	15,65	9,36	151,5952	73,32	21,69	86,00	4,68	Fagus sylvatica	Fagus sylvatica
4000500	3200500	288623	51	671,77	262,77	12,07	9,56	122,8020	118,32	6,54	4,00	5,86	Fagus sylvatica	Fagus sylvatica
5200500	3000500	297468	49	725,18	407,02	19,50	6,36	106,4510	81,59	17,08	375,00	4,68	Fagus sylvatica	Fagus sylvatica
5000500	3000500	295455	50	806,70	450,51	18,39	5,84	100,0000	87,26	13,46	503,00	4,70	Larix decidua	Larix decidua
4800500	3000500	26997	50	623,65	368,13	19,32	7,19	100,0000	80,06	19,23	512,00	4,66	Fagus sylvatica	Fagus sylvatica
4600500	3000500	22448	50	516,77	295,32	18,57	8,52	100,0836	47,75	22,27	384,00	6,05	Quercus petraea	Quercus petraea
4400500	3000500	39933	50	675,69	325,20	18,01	7,68	156,7669	102,09	11,54	361,00	5,74	Abies alba	Fagus sylvatica
4200500	3000500	44852	50	580,63	253,62	17,34	9,53	109,0172	53,37	19,23	231,00	5,92	Quercus petraea	Quercus petraea
4000500	3000500	13331	50	868,36	348,55	15,14	7,88	206,9114	58,15	19,62	471,00	5,21	Larix decidua	Larix decidua

3800500	3000500	141602	50	709,07	292,90	14,10	9,78	265,9164	65,63	7,37	108,00	6,26	Larix decidua	Larix decidua
5400500	2800500	329791	47	761,74	442,89	21,53	8,38	205,9998	102,48	11,92	513,00	4,75	Fagus sylvatica	Fagus sylvatica
5600500	2800500	316104	47	471,11	279,62	23,24	8,98	252,4935	111,38	12,69	212,00	5,98	Fagus sylvatica	Fagus sylvatica
5200500	2800500	230577	48	508,62	270,98	22,14	9,99	138,6333	71,90	20,91	148,00	6,12	Fagus sylvatica	Fagus sylvatica
5000500	2800500	229519	48	445,89	220,58	21,09	9,80	204,5646	117,63	8,46	184,00	4,77	Quercus petraea	Fagus sylvatica
4800500	2800500	385	48	574,70	292,23	19,98	10,30	155,1112	85,85	6,82	187,00	6,26	Fagus sylvatica	Fagus sylvatica
4600500	2800500	6404	48	671,50	358,89	18,37	8,68	169,3992	62,43	3,85	352,00	5,86	Fagus sylvatica	Fagus sylvatica
4400500	2800500	42355	48	818,59	450,55	18,10	7,96	214,0994	64,50	8,95	478,00	6,26	Larix decidua	Larix decidua
4200500	2800500	33113	48	952,77	434,27	16,83	7,70	100,0000	84,44	21,92	437,00	4,60	Larix decidua	Larix decidua
4000500	2800500	150293	48	867,45	357,45	16,45	9,00	160,7111	95,03	19,55	379,00	6,26	Abies alba	Fagus sylvatica
3600500	2800500	155740	48	633,15	235,95	14,57	11,04	255,6382	67,42	12,73	104,00	6,19	Fagus sylvatica	Fagus sylvatica
3800500	2800500	143295	48	602,55	254,73	15,61	10,98	260,5125	115,43	8,31	128,00	5,86	Fagus sylvatica	Fagus sylvatica
3400500	2800500	157108	48	713,49	228,33	12,50	11,72	132,9871	110,03	7,69	31,00	5,00	Fagus sylvatica	Fagus sylvatica
5600500	2600500	320142	45	407,11	218,55	23,15	9,76	199,0041	106,13	13,85	209,00	5,98	Quercus pubescens	Quercus petraea
5800500	2600500	318435	45	401,69	176,66	22,43	11,21	224,3661	109,15	13,38	50,00	5,43	Quercus petraea	Quercus petraea
5400500	2600500	334526	46	476,88	251,46	20,08	4,15	100,0000	40,35	21,54	1343,00	4,58	Larix decidua	Larix decidua
5200500	2600500	325299	46	502,94	266,01	21,38	10,95	188,7855	92,12	10,00	113,00	6,19	Quercus petraea	Fagus sylvatica
5000500	2600500	230886	46	552,60	283,46	21,26	10,69	203,2898	100,27	12,73	99,00	6,19	Fagus sylvatica	Fagus sylvatica
4600500	2600500	251352	46	987,23	491,35	18,25	5,45	100,0000	102,76	15,38	1198,00	5,86	Larix decidua	Larix decidua
4400500	2600500	247265	47	1139,54	648,06	18,49	6,29	100,0000	73,85	19,23	1902,00	4,62	Larix decidua	Larix decidua
3800500	2600500	178992	46	721,75	361,30	15,88	10,32	105,3580	85,74	12,00	260,00	4,62	Larix decidua	Fagus sylvatica
4000500	2600500	153687	46	1151,95	470,83	16,84	7,18	100,0000	77,11	16,54	852,00	5,98	Larix decidua	Larix decidua
3600500	2600500	158521	46	822,12	299,37	14,91	11,48	213,6921	74,43	10,38	162,00	5,58	Fagus sylvatica	Fagus sylvatica
5600500	2400500	15525	43	399,96	173,03	22,82	11,81	197,7846	102,27	10,00	194,00	6,26	Quercus petraea	Quercus petraea
4400500	2400500	251777	45	620,74	228,33	21,32	13,18	167,9494	58,59	5,26	13,00	6,19	Quercus petraea	Quercus petraea
4000500	2400500	191566	45	1081,28	395,01	16,89	8,00	100,0000	67,62	11,36	1930,00	6,05	Larix decidua	Larix decidua
4200500	2400500	236908	45	891,41	337,11	18,55	13,25	100,0000	113,50	5,00	243,00	4,87	Fagus sylvatica	Fagus sylvatica
3800500	2400500	184376	45	1057,47	423,14	15,70	7,18	100,0000	92,77	14,62	886,00	5,63	Larix decidua	Larix decidua
3600500	2400500	163259	44	696,33	273,16	15,61	12,11	126,6466	91,29	6,32	187,00	6,26	Fagus sylvatica	Fagus sylvatica
5600500	2200500	19962	42	527,33	170,84	20,99	11,46	150,7264	97,98	11,92	423,00	4,63	Quercus petraea	Quercus petraea
5400500	2200500	17971	42	724,68	316,43	21,08	9,61	226,9183	111,38	12,69	536,00	5,52	Fagus sylvatica	Fagus sylvatica
4600500	2200500	260969	43	694,70	252,98	16,77	9,79	181,2588	111,83	10,00	456,00	5,86	Fagus sylvatica	Fagus sylvatica
3600500	2200500	111272	43	1052,20	455,70	15,91	5,04	100,0000	39,80	25,00	994,00	4,60	Larix decidua	Larix decidua
3400500	2200500	84105	42	582,12	229,45	17,18	12,98	114,9841	56,46	7,27	530,00	6,26	Quercus petraea	Quercus petraea
3200500	2200500	90230	42	563,42	180,65	16,66	10,05	111,5146	65,12	6,84	896,00	6,26	Quercus petraea	Quercus petraea
2800500	2200500	305518	41	1384,52	268,82	12,87	13,80	100,0000	112,73	5,77	186,00	4,60	Fagus sylvatica	Fagus sylvatica
4800500	2000500	272173	41	586,91	157,39	16,64	14,39	100,0000	126,10	3,85	554,00	5,80	Quercus pubescens	Quercus petraea
3400500	2000500	83361	41	584,72	212,14	17,22	10,10	112,5946	60,33	13,16	1258,00	6,26	Quercus petraea	Quercus petraea
3200500	2000500	89059	40	384,57	100,00	18,54	13,64	199,4734	62,14	8,18	700,00	6,26	Quercus petraea	Quercus petraea
2800500	2000500	313548	39	812,59	146,34	14,84	15,34	100,0000	84,72	3,85	265,00	4,65	Quercus pubescens	Quercus petraea
3400500	1800500	117442	39	375,56	118,80	15,46	13,95	100,0000	68,51	9,09	886,00	6,26	Quercus pubescens	Quercus pubescens
3000500	1800500	121994	38	566,95	74,62	18,74	15,40	121,5787	75,41	5,38	700,00	5,98	Quercus pubescens	Quercus pubescens
3200500	1800500	127896	38	435,69	100,13	19,59	13,33	117,1838	64,79	4,55	718,00	6,05	Quercus petraea	Quercus petraea
2800500	1800500	122669	38	517,03	65,77	15,12	16,40	121,1827	76,95	3,85	206,00	5,98	Quercus pubescens	Quercus pubescens

Table 7:24 Study area information of the NPP Bare ground (NPP50 and NPP100). Values represented in the table are: water holding capacity (WHC), Nitrogen available (N AVILABL), average of all monthly mean temperatures (TEMP AVG), average of summer precipitation from May to September (PREC SUMME), CN RATIO, elevation (ELEV), pH (PH TOP), dominant tree species for the year 50 (species NPP50 Bare ground) and dominant tree species for the 100 years time period (Species NPP100 Bare ground).

POINT X	POINT Y	SIMU ID	LAT	PREC SUM [mm]	PREC SUMME [mm]	TEMP AMPLI [°C]	TEMP AVG [°C]	WHC [mm]	N AVAILABL [kg/ha*yr.]	CN RATIO	ELEV [m]	PH TOP	Species NPP50 Bare ground	Species NPP100 Bare ground
5000500	4800500	135306	66	515,10	241,69	27,16	1,16	103,4715	60,65	183,08	22,00	4,59	Larix decidua	Larix decidua
4800500	4800500	341970	66	463,64	226,46	27,69	0,13	174,4125	55,50	73,08	166,00	4,58	Larix decidua	Larix decidua
5000500	4400500	138248	62	601,80	299,16	23,87	2,86	102,9155	61,31	58,85	140,00	4,65	Larix decidua	Larix decidua
4600500	4400500	340410	63	515,91	270,81	22,93	2,12	174,9225	55,94	60,38	429,00	4,59	Larix decidua	Larix decidua
5200500	4600500	132815	63	580,08	314,80	27,12	2,05	101,6922	62,08	46,92	141,00	4,63	Larix decidua	Larix decidua
5000500	4600500	134130	64	503,53	263,61	24,71	2,17	167,2585	69,67	70,77	52,00	5,18	Larix decidua	Larix decidua
4800500	4600500	343028	64	522,45	251,17	23,98	1,54	175,3135	58,04	33,85	238,00	4,59	Larix decidua	Larix decidua
4600500	4600500	343111	64	595,99	311,52	23,29	1,09	175,4325	56,39	53,46	391,00	4,60	Larix decidua	Larix decidua
5000500	4200500	138106	60	621,16	285,74	22,72	4,92	100,0000	79,90	3,85	17,00	4,66	Larix decidua	Larix decidua
4600500	4200500	338912	61	613,11	319,38	23,22	3,49	179,2405	61,03	15,38	344,00	4,65	Larix decidua	Larix decidua
5400500	3800500	286729	56	579,30	294,05	22,71	5,24	199,7367	81,91	24,23	181,00	5,80	Larix decidua	Larix decidua
5200500	3800500	286328	57	601,78	313,22	21,47	6,25	217,0733	103,10	18,46	24,00	5,58	Larix decidua	Larix decidua
5000500	3800500	287566	57	672,64	294,14	21,39	5,58	135,8019	81,68	41,54	26,00	4,95	Larix decidua	Larix decidua
4600500	3800500	345419	57	700,56	325,08	18,75	5,85	173,8685	56,06	59,23	162,00	4,60	Larix decidua	Larix decidua
5200500	4000500	68286	58	650,33	321,67	22,70	5,45	139,8526	82,84	32,31	50,00	4,66	Larix decidua	Larix decidua
4600500	4000500	336830	59	630,46	319,74	20,50	5,74	175,9850	57,05	45,00	81,00	4,63	Larix decidua	Larix decidua
5200500	3600500	284399	55	581,20	304,11	21,33	6,38	219,9044	74,04	10,77	99,00	5,92	Larix decidua	Larix decidua
4400500	3600500	65249	56	510	246,5	16,36	8,22	191,4288	64,61	6,84	35,00	6,26	Larix decidua	Fagus sylvatica
5200500	3400500	298715	53	540,15	291,67	21,26	6,68	137,1851	82,20	37,31	152,00	4,77	Quercus pubescens	Quercus petraea
4800500	3400500	302994	53	457,97	250,11	19,22	7,46	217,2827	71,98	12,00	104,00	5,74	Larix decidua	Fagus sylvatica
5000500	3400500	302144	53	527,24	293,31	20,19	6,76	162,8562	71,07	26,31	190,00	4,77	Larix decidua	Fagus sylvatica
4600500	3400500	48534	54	488,21	246,41	17,75	8,29	153,7704	68,49	32,31	12,00	4,65	Quercus pubescens	Quercus petraea
4400500	3400500	48471	54	595,95	276,66	16,43	8,44	169,6330	59,32	31,92	56,00	5,92	Larix decidua	Fagus sylvatica
3600500	3400500	360922	53	597,51	263,24	12,71	9,18	217,8096	109,59	9,23	50,00	5,98	Larix decidua	Larix decidua
3200500	3400500	233586	53	910,17	350,19	10,21	9,57	114,5497	109,13	16,15	89,00	5,25	Abies alba	Larix decidua
3000500	3400500	234827	52	1322,54	497,77	9,71	9,33	185,7642	214,79	20,77	144,00	5,04	Abies alba	Abies alba
5000500	3200500	293796	52	512,51	296,98	19,96	7,71	203,8087	77,39	11,15	184,00	5,63	Fagus sylvatica	Fagus sylvatica
5200500	3200500	292643	51	438,89	245,81	21,08	7,54	251,0822	75,79	10,38	209,00	5,98	Quercus pubescens	Quercus petraea
4800500	3200500	302986	52	504,84	281,49	18,97	8,32	217,2827	71,98	12,00	121,00	5,74	Fagus sylvatica	Fagus sylvatica
4400500	3200500	61616	52	636,21	302,58	17,22	8,72	116,0024	64,02	8,31	104,00	5,80	Larix decidua	Fagus sylvatica
4200500	3200500	53414	52	727,24	309,36	15,65	9,36	151,5952	73,32	21,69	86,00	4,68	Larix decidua	Fagus sylvatica
4000500	3200500	288623	51	671,77	262,77	12,07	9,56	122,8020	118,32	6,54	4,00	5,86	Larix decidua	Fagus sylvatica
5200500	3000500	297468	49	725,18	407,02	19,50	6,36	106,4510	81,59	17,08	375,00	4,68	Larix decidua	Larix decidua
5000500	3000500	295455	50	806,70	450,51	18,39	5,84	100,0000	87,26	13,46	503,00	4,70	Larix decidua	Larix decidua
4800500	3000500	26997	50	623,65	368,13	19,32	7,19	100,0000	80,06	19,23	512,00	4,66	Larix decidua	Fagus sylvatica
4600500	3000500	22448	50	516,77	295,32	18,57	8,52	100,0836	47,75	22,27	384,00	6,05	Quercus petraea	Quercus petraea
4400500	3000500	39933	50	675,69	325,20	18,01	7,68	156,7669	102,09	11,54	361,00	5,74	Larix decidua	Fagus sylvatica
4200500	3000500	44852	50	580,63	253,62	17,34	9,53	109,0172	53,37	19,23	231,00	5,92	Quercus petraea	Quercus petraea
4000500	3000500	13331	50	868,36	348,55	15,14	7,88	206,9114	58,15	19,62	471,00	5,21	Larix decidua	Larix decidua
3800500	3000500	141602	50	709,07	292,90	14,10	9,78	265,9164	65,63	7,37	108,00	6,26	Larix decidua	Larix decidua

5400500	2800500	329791	47	761,74	442,89	21,53	8,38	205,9998	102,48	11,92	513,00	4,75	Larix decidua	Fagus sylvatica
5600500	2800500	316104	47	471,11	279,62	23,24	8,98	252,4935	111,38	12,69	212,00	5,98	Fagus sylvatica	Fagus sylvatica
5200500	2800500	230577	48	508,62	270,98	22,14	9,99	138,6333	71,90	20,91	148,00	6,12	Quercus pubescens	Quercus petraea
5000500	2800500	229519	48	445,89	220,58	21,09	9,80	204,5646	117,63	8,46	184,00	4,77	Quercus pubescens	Quercus petraea
4800500	2800500	385	48	574,70	292,23	19,98	10,30	155,1112	85,85	6,82	187,00	6,26	Fagus sylvatica	Fagus sylvatica
4600500	2800500	6404	48	671,50	358,89	18,37	8,68	169,3992	62,43	3,85	352,00	5,86	Larix decidua	Fagus sylvatica
4400500	2800500	42355	48	818,59	450,55	18,10	7,96	214,0994	64,50	8,95	478,00	6,26	Larix decidua	Larix decidua
4200500	2800500	33113	48	952,77	434,27	16,83	7,70	100,0000	84,44	21,92	437,00	4,60	Larix decidua	Larix decidua
4000500	2800500	150293	48	867,45	357,45	16,45	9,00	160,7111	95,03	19,55	379,00	6,26	Larix decidua	Fagus sylvatica
3600500	2800500	155740	48	633,15	235,95	14,57	11,04	255,6382	67,42	12,73	104,00	6,19	Larix decidua	Fagus sylvatica
3800500	2800500	143295	48	602,55	254,73	15,61	10,98	260,5125	115,43	8,31	128,00	5,86	Larix decidua	Fagus sylvatica
3400500	2800500	157108	48	713,49	228,33	12,50	11,72	132,9871	110,03	7,69	31,00	5,00	Fagus sylvatica	Fagus sylvatica
5600500	2600500	320142	45	407,11	218,55	23,15	9,76	199,0041	106,13	13,85	209,00	5,98	Quercus pubescens	Quercus petraea
5800500	2600500	318435	45	401,69	176,66	22,43	11,21	224,3661	109,15	13,38	50,00	5,43	Quercus pubescens	Quercus pubescens
5200500	2600500	325299	46	502,94	266,01	21,38	10,95	188,7855	92,12	10,00	113,00	6,19	Fagus sylvatica	Fagus sylvatica
5000500	2600500	230886	46	552,60	283,46	21,26	10,69	203,2898	100,27	12,73	99,00	6,19	Fagus sylvatica	Fagus sylvatica
4600500	2600500	251352	46	987,23	491,35	18,25	5,45	100,0000	102,76	15,38	1198,00	5,86	Larix decidua	Larix decidua
4400500	2600500	247265	47	1139,54	648,06	18,49	6,29	100,0000	73,85	19,23	1902,00	4,62	Larix decidua	Larix decidua
3800500	2600500	178992	46	721,75	361,30	15,88	10,32	105,3580	85,74	12,00	260,00	4,62	Larix decidua	Larix decidua
4000500	2600500	153687	46	1151,95	470,83	16,84	7,18	100,0000	77,11	16,54	852,00	5,98	Larix decidua	Larix decidua
3600500	2600500	158521	46	822,12	299,37	14,91	11,48	213,6921	74,43	10,38	162,00	5,58	Larix decidua	Fagus sylvatica
5600500	2400500	15525	43	399,96	173,03	22,82	11,81	197,7846	102,27	10,00	194,00	6,26	Quercus pubescens	Quercus pubescens
4400500	2400500	251777	45	620,74	228,33	21,32	13,18	167,9494	58,59	5,26	13,00	6,19	Quercus pubescens	Quercus petraea
4000500	2400500	191566	45	1081,28	395,01	16,89	8,00	100,0000	67,62	11,36	1930,00	6,05	Larix decidua	Larix decidua
4200500	2400500	236908	45	891,41	337,11	18,55	13,25	100,0000	113,50	5,00	243,00	4,87	Fagus sylvatica	Quercus petraea
3800500	2400500	184376	45	1057,47	423,14	15,70	7,18	100,0000	92,77	14,62	886,00	5,63	Larix decidua	Larix decidua
3600500	2400500	163259	44	696,33	273,16	15,61	12,11	126,6466	91,29	6,32	187,00	6,26	Larix decidua	Fagus sylvatica
5600500	2200500	19962	42	527,33	170,84	20,99	11,46	150,7264	97,98	11,92	423,00	4,63	Quercus petraea	Quercus petraea
5400500	2200500	17971	42	724,68	316,43	21,08	9,61	226,9183	111,38	12,69	536,00	5,52	Larix decidua	Fagus sylvatica
4600500	2200500	260969	43	694,70	252,98	16,77	9,79	181,2588	111,83	10,00	456,00	5,86	Larix decidua	Fagus sylvatica
3600500	2200500	111272	43	1052,20	455,70	15,91	5,04	100,0000	39,80	25,00	994,00	4,60	Larix decidua	Larix decidua
3400500	2200500	84105	42	582,12	229,45	17,18	12,98	114,9841	56,46	7,27	530,00	6,26	Quercus petraea	Quercus petraea
3200500	2200500	90230	42	563,42	180,65	16,66	10,05	111,5146	65,12	6,84	896,00	6,26	Quercus petraea	Quercus petraea
2800500	2200500	305518	41	1384,52	268,82	12,87	13,80	100,0000	112,73	5,77	186,00	4,60	Quercus petraea	Fagus sylvatica
4800500	2000500	272173	41	586,91	157,39	16,64	14,39	100,0000	126,10	3,85	554,00	5,80	Quercus pubescens	Quercus pubescens
3400500	2000500	83361	41	584,72	212,14	17,22	10,10	112,5946	60,33	13,16	1258,00	6,26	Quercus petraea	Quercus petraea
3200500	2000500	89059	40	384,57	100,00	18,54	13,64	199,4734	62,14	8,18	700,00	6,26	Quercus pubescens	Quercus petraea
2800500	2000500	313548	39	812,59	146,34	14,84	15,34	100,0000	84,72	3,85	265,00	4,65	Quercus pubescens	Quercus petraea
3400500	1800500	117442	39	375,56	118,80	15,46	13,95	100,0000	68,51	9,09	886,00	6,26	Quercus pubescens	Quercus pubescens
3000500	1800500	121994	38	566,95	74,62	18,74	15,40	121,5787	75,41	5,38	700,00	5,98	Quercus pubescens	Quercus pubescens
3200500	1800500	127896	38	435,69	100,13	19,59	13,33	117,1838	64,79	4,55	718,00	6,05	Quercus pubescens	Quercus pubescens
2800500	1800500	122669	38	517,03	65,77	15,12	16,40	121,1827	76,95	3,85	206,00	5,98	Quercus pubescens	Quercus pubescens

Table 7:25 Study area information of the NPP Plantation with the map of domiant tree species (NPP50 and NPP100). Values represented in the table are: water holding capacity (WHC), Nitrogen available (N AVILABL), average of all monthly mean temperatures (TEMP AVG),

average of summer precipitation from May to September (PREC SUMME), CN RATIO, elevation (ELEV), pH (PH TOP), dominant tree species for the year 50 and dominant tree species for the 100 years time period (Dominant species Plantation).

POINT X	POINT Y	SIMU ID	LAT	PREC SUM [mm]	PREC SUMME [mm]	TEMP AMPLI [°C]	TEMP AVG [°C]	WHC [mm]	N AVAILABL [kg/ha*yr.]	CN RATIO	ELEV [m]	PH TOP	Dominant species Plantation
4800500	4800500	341970	66	463,64	226,46	27,69	0,13	174,4125	55,50	73,08	166,00	4,58	Pinus sylvestris
5000500	4400500	138248	62	601,80	299,16	23,87	2,86	102,9155	61,31	58,85	140,00	4,65	Pinus sylvestris
4600500	4400500	340410	63	515,91	270,81	22,93	2,12	174,9225	55,94	60,38	429,00	4,59	Pinus sylvestris
5200500	4600500	132815	63	580,08	314,80	27,12	2,05	101,6922	62,08	46,92	141,00	4,63	Picea spp
5000500	4600500	134130	64	503,53	263,61	24,71	2,17	167,2585	69,67	70,77	52,00	5,18	Pinus sylvestris
4800500	4600500	343028	64	522,45	251,17	23,98	1,54	175,3135	58,04	33,85	238,00	4,59	Picea spp
4600500	4600500	343111	64	595,99	311,52	23,29	1,09	175,4325	56,39	53,46	391,00	4,60	Picea spp
4600500	4200500	338912	61	613,11	319,38	23,22	3,49	179,2405	61,03	15,38	344,00	4,65	Pinus sylvestris
5400500	3800500	286729	56	579,30	294,05	22,71	5,24	199,7367	81,91	24,23	181,00	5,80	Pinus sylvestris
5000500	3800500	287566	57	672,64	294,14	21,39	5,58	135,8019	81,68	41,54	26,00	4,95	Pinus sylvestris
4600500	4000500	336830	59	630,46	319,74	20,50	5,74	175,9850	57,05	45,00	81,00	4,63	Pinus sylvestris
5200500	3600500	284399	55	581,20	304,11	21,33	6,38	219,9044	74,04	10,77	99,00	5,92	Alnus spp
4400500	3600500	65249	56	510	246,5	16,36	8,22	191,4288	64,61	6,84	35,00	6,26	Fagus spp
5200500	3400500	298715	53	540,15	291,67	21,26	6,68	137,1851	82,20	37,31	152,00	4,77	Pinus sylvestris
4800500	3400500	302994	53	457,97	250,11	19,22	7,46	217,2827	71,98	12,00	104,00	5,74	Pinus sylvestris
4600500	3400500	48534	54	488,21	246,41	17,75	8,29	153,7704	68,49	32,31	12,00	4,65	Pinus sylvestris
4400500	3400500	48471	54	595,95	276,66	16,43	8,44	169,6330	59,32	31,92	56,00	5,92	Picea spp
3600500	3400500	360922	53	597,51	263,24	12,71	9,18	217,8096	109,59	9,23	50,00	5,98	Fraixinus spp
3200500	3400500	233586	53	910,17	350,19	10,21	9,57	114,5497	109,13	16,15	89,00	5,25	Abies spp
3000500	3400500	234827	52	1322,54	497,77	9,71	9,33	185,7642	214,79	20,77	144,00	5,04	Pseudotsuga menziesii
5000500	3200500	293796	52	512,51	296,98	19,96	7,71	203,8087	77,39	11,15	184,00	5,63	Pinus sylvestris
5200500	3200500	292643	51	438,89	245,81	21,08	7,54	251,0822	75,79	10,38	209,00	5,98	Qercus robur & Quercus petraea
4800500	3200500	302986	52	504,84	281,49	18,97	8,32	217,2827	71,98	12,00	121,00	5,74	Pinus sylvestris
4400500	3200500	61616	52	636,21	302,58	17,22	8,72	116,0024	64,02	8,31	104,00	5,80	Qercus robur & Quercus petraea
4200500	3200500	53414	52	727,24	309,36	15,65	9,36	151,5952	73,32	21,69	86,00	4,68	Qercus robur & Quercus petraea
5200500	3000500	297468	49	725,18	407,02	19,50	6,36	106,4510	81,59	17,08	375,00	4,68	Pinus sylvestris
5000500	3000500	295455	50	806,70	450,51	18,39	5,84	100,0000	87,26	13,46	503,00	4,70	Pinus sylvestris
4800500	3000500	26997	50	623,65	368,13	19,32	7,19	100,0000	80,06	19,23	512,00	4,66	Picea spp
4600500	3000500	22448	50	516,77	295,32	18,57	8,52	100,0836	47,75	22,27	384,00	6,05	Pinus sylvestris
4400500	3000500	39933	50	675,69	325,20	18,01	7,68	156,7669	102,09	11,54	361,00	5,74	Broad leaved misc
4000500	3000500	13331	50	868,36	348,55	15,14	7,88	206,9114	58,15	19,62	471,00	5,21	Picea spp
3800500	3000500	141602	50	709,07	292,90	14,10	9,78	265,9164	65,63	7,37	108,00	6,26	Qercus robur & Quercus petraea
5400500	2800500	329791	47	761,74	442,89	21,53	8,38	205,9998	102,48	11,92	513,00	4,75	Picea spp
5200500	2800500	230577	48	508,62	270,98	22,14	9,99	138,6333	71,90	20,91	148,00	6,12	Alnus spp
5000500	2800500	229519	48	445,89	220,58	21,09	9,80	204,5646	117,63	8,46	184,00	4,77	Qercus robur & Quercus petraea
4800500	2800500	385	48	574,70	292,23	19,98	10,30	155,1112	85,85	6,82	187,00	6,26	Broad leaved misc
4600500	2800500	6404	48	671,50	358,89	18,37	8,68	169,3992	62,43	3,85	352,00	5,86	Picea spp
4400500	2800500	42355	48	818,59	450,55	18,10	7,96	214,0994	64,50	8,95	478,00	6,26	Picea spp
4200500	2800500	33113	48	952,77	434,27	16,83	7,70	100,0000	84,44	21,92	437,00	4,60	Abies spp
4000500	2800500	150293	48	867,45	357,45	16,45	9,00	160,7111	95,03	19,55	379,00	6,26	Fagus spp
3600500	2800500	155740	48	633,15	235,95	14,57	11,04	255,6382	67,42	12,73	104,00	6,19	Pinus pinaster spp
3800500	2800500	143295	48	602,55	254,73	15,61	10,98	260,5125	115,43	8,31	128,00	5,86	Qercus robur & Quercus petraea

3400500	2800500	157108	48	713,49	228,33	12,50	11,72	132,9871	110,03	7,69	31,00	5,00	Pinus pinaster spp
5800500	2600500	318435	45	401,69	176,66	22,43	11,21	224,3661	109,15	13,38	50,00	5,43	Qercus robur & Quercus petraea
5400500	2600500	334526	46	476,88	251,46	20,08	4,15	100,0000	40,35	21,54	1343,00	4,58	Fagus spp
4600500	2600500	251352	46	987,23	491,35	18,25	5,45	203,2898	100,27	15,38	1198,00	5,86	Picea spp
4400500	2600500	247265	47	1139,54	648,06	18,49	6,29	100,0000	73,85	19,23	1902,00	4,62	Picea spp
3800500	2600500	178992	46	721,75	361,30	15,88	10,32	105,3580	85,74	12,00	260,00	4,62	Qercus robur & Quercus petraea
4000500	2600500	153687	46	1151,95	470,83	16,84	7,18	100,0000	77,11	16,54	852,00	5,98	Picea spp
3600500	2600500	158521	46	822,12	299,37	14,91	11,48	213,6921	74,43	10,38	162,00	5,58	Qercus robur & Quercus petraea
4000500	2400500	191566	45	1081,28	395,01	16,89	8,00	100,0000	67,62	11,36	1930,00	6,05	Pinus sylvestris
4200500	2400500	236908	45	891,41	337,11	18,55	13,25	100,0000	113,50	5,00	243,00	4,87	Castanea spp
3800500	2400500	184376	45	1057,47	423,14	15,70	7,18	100,0000	92,77	14,62	886,00	5,63	Pinus sylvestris
3600500	2400500	163259	44	696,33	273,16	15,61	12,11	126,6466	91,29	6,32	187,00	6,26	Qercus robur & Quercus petraea
5600500	2200500	19962	42	527,33	170,84	20,99	11,46	150,7264	97,98	11,92	423,00	4,63	Qercus robur & Quercus petraea
5400500	2200500	17971	42	724,68	316,43	21,08	9,61	226,9183	111,38	12,69	536,00	5,52	Qercus robur & Quercus petraea
4600500	2200500	260969	43	694,70	252,98	16,77	9,79	181,2588	111,83	10,00	456,00	5,86	Qercus robur & Quercus petraea
3600500	2200500	111272	43	1052,20	455,70	15,91	5,04	100,0000	39,80	25,00	994,00	4,60	Pinus sylvestris
3400500	2200500	84105	42	582,12	229,45	17,18	12,98	114,9841	56,46	7,27	530,00	6,26	Pinus sylvestris
3200500	2200500	90230	42	563,42	180,65	16,66	10,05	111,5146	65,12	6,84	896,00	6,26	Conifers misc
2800500	2200500	305518	41	1384,52	268,82	12,87	13,80	100,0000	112,73	5,77	186,00	4,60	Pinus pinaster spp
4800500	2000500	272173	41	586,91	157,39	16,64	14,39	100,0000	126,10	3,85	554,00	5,80	Quercus misc
3400500	2000500	83361	41	584,72	212,14	17,22	10,10	112,5946	60,33	13,16	1258,00	6,26	Conifers misc
3200500	2000500	89059	40	384,57	100,00	18,54	13,64	199,4734	62,14	8,18	700,00	6,26	Quercus misc
3000500	1800500	121994	38	566,95	74,62	18,74	15,40	117,1838	64,79	5,38	700,00	5,98	Quercus misc
3200500	1800500	127896	38	435,69	100,13	19,59	13,33	121,1827	76,95	4,55	718,00	6,05	Quercus misc

Table 7:26 Study area information of the NPP Bare ground with the map of domiant tree species (NPP50 and NPP100). Values represented in the table are: water holding capacity (WHC), Nitrogen available (N AVILABL), average of all monthly mean temperatures (TEMP AVG), average of summer precipitation from May to September (PREC SUMME), CN RATIO, elevation (ELEV), pH (PH TOP), dominant tree species for the year 50 and dominant tree species for the 100 years time period (Dominant species Bare ground).

POINT X	POINT Y	SIMU ID	LAT	PREC SUM [mm]	PREC SUMME [mm]	TEMP AMPLI [°C]	TEMP AVG [°C]	WHC [mm]	N AVAILABL [kg/ha*yr.]	CN RATIO	ELEV [m]	PH TOP	Dominant species Bare ground
4800500	4800500	341970	66	463,64	226,46	27,69	0,13	174,4125	55,50	73,08	166,00	4,58	Pinus sylvestris
5000500	4400500	138248	62	601,80	299,16	23,87	2,86	102,9155	61,31	58,85	140,00	4,65	Pinus sylvestris
4600500	4400500	340410	63	515,91	270,81	22,93	2,12	174,9225	55,94	60,38	429,00	4,59	Pinus sylvestris
5200500	4600500	132815	63	580,08	314,80	27,12	2,05	101,6922	62,08	46,92	141,00	4,63	Picea spp
5000500	4600500	134130	64	503,53	263,61	24,71	2,17	167,2585	69,67	70,77	52,00	5,18	Pinus sylvestris
4800500	4600500	343028	64	522,45	251,17	23,98	1,54	175,3135	58,04	33,85	238,00	4,59	Picea spp
4600500	4600500	343111	64	595,99	311,52	23,29	1,09	175,4325	56,39	53,46	391,00	4,60	Picea spp
4600500	4200500	338912	61	613,11	319,38	23,22	3,49	179,2405	61,03	15,38	344,00	4,65	Pinus sylvestris
5400500	3800500	286729	56	579,30	294,05	22,71	5,24	199,7367	81,91	24,23	181,00	5,80	Pinus sylvestris
5000500	3800500	287566	57	672,64	294,14	21,39	5,58	135,8019	81,68	41,54	26,00	4,95	Pinus sylvestris
5200500	4000500	68286	58	650,33	321,67	22,70	5,45	139,8526	82,84	32,31	50,00	4,66	Pinus sylvestris
4600500	4000500	336830	59	630,46	319,74	20,50	5,74	175,9850	57,05	45,00	81,00	4,63	Pinus sylvestris
5200500	3600500	284399	55	581,20	304,11	21,33	6,38	219,9044	74,04	10,77	99,00	5,92	Alnus spp
5200500	3400500	298715	53	540,15	291,67	21,26	6,68	137,1851	82,20	37,31	152,00	4,77	Pinus sylvestris

4800500	3400500	302994	53	457,97	250,11	19,22	7,46	217,2827	71,98	12,00	104,00	5,74	Pinus sylvestris
4600500	3400500	48534	54	488,21	246,41	17,75	8,29	153,7704	68,49	32,31	12,00	4,65	Pinus sylvestris
4400500	3400500	48471	54	595,95	276,66	16,43	8,44	169,6330	59,32	31,92	56,00	5,92	Picea spp
3600500	3400500	360922	53	597,51	263,24	12,71	9,18	217,8096	109,59	9,23	50,00	5,98	Fraixinus spp
3200500	3400500	233586	53	910,17	350,19	10,21	9,57	114,5497	109,13	16,15	89,00	5,25	Abies spp
3000500	3400500	234827	52	1322,54	497,77	9,71	9,33	185,7642	214,79	20,77	144,00	5,04	Pseudotsuga menziesii
5000500	3200500	293796	52	512,51	296,98	19,96	7,71	203,8087	77,39	11,15	184,00	5,63	Pinus sylvestris
5200500	3200500	292643	51	438,89	245,81	21,08	7,54	251,0822	75,79	10,38	209,00	5,98	Qercus robur & Quercus petraea
4800500	3200500	302986	52	504,84	281,49	18,97	8,32	217,2827	71,98	12,00	121,00	5,74	Pinus sylvestris
4400500	3200500	61616	52	636,21	302,58	17,22	8,72	116,0024	64,02	8,31	104,00	5,80	Qercus robur & Quercus petraea
4200500	3200500	53414	52	727,24	309,36	15,65	9,36	151,5952	73,32	21,69	86,00	4,68	Qercus robur & Quercus petraea
5200500	3000500	297468	49	725,18	407,02	19,50	6,36	106,4510	81,59	17,08	375,00	4,68	Pinus sylvestris
5000500	3000500	295455	50	806,70	450,51	18,39	5,84	100,0000	87,26	13,46	503,00	4,70	Pinus sylvestris
4800500	3000500	26997	50	623,65	368,13	19,32	7,19	100,0000	80,06	19,23	512,00	4,66	Picea spp
4600500	3000500	22448	50	516,77	295,32	18,57	8,52	100,0836	47,75	22,27	384,00	6,05	Pinus sylvestris
4400500	3000500	39933	50	675,69	325,20	18,01	7,68	156,7669	102,09	11,54	361,00	5,74	Broad leaved misc
4000500	3000500	13331	50	868,36	348,55	15,14	7,88	206,9114	58,15	19,62	471,00	5,21	Picea spp
3800500	3000500	141602	50	709,07	292,90	14,10	9,78	265,9164	65,63	7,37	108,00	6,26	Qercus robur & Quercus petraea
5400500	2800500	329791	47	761,74	442,89	21,53	8,38	205,9998	102,48	11,92	513,00	4,75	Picea spp
5200500	2800500	230577	48	508,62	270,98	22,14	9,99	138,6333	71,90	20,91	148,00	6,12	Alnus spp
5000500	2800500	229519	48	445,89	220,58	21,09	9,80	204,5646	117,63	8,46	184,00	4,77	Qercus robur & Quercus petraea
4800500	2800500	385	48	574,70	292,23	19,98	10,30	155,1112	85,85	6,82	187,00	6,26	Broad leaved misc
4600500	2800500	6404	48	671,50	358,89	18,37	8,68	169,3992	62,43	3,85	352,00	5,86	Picea spp
4400500	2800500	42355	48	818,59	450,55	18,10	7,96	214,0994	64,50	8,95	478,00	6,26	Picea spp
4200500	2800500	33113	48	952,77	434,27	16,83	7,70	100,0000	84,44	21,92	437,00	4,60	Abies spp
4000500	2800500	150293	48	867,45	357,45	16,45	9,00	160,7111	95,03	19,55	379,00	6,26	Fagus spp
3600500	2800500	155740	48	633,15	235,95	14,57	11,04	255,6382	67,42	12,73	104,00	6,19	Pinus pinaster spp
3800500	2800500	143295	48	602,55	254,73	15,61	10,98	260,5125	115,43	8,31	128,00	5,86	Qercus robur & Quercus petraea
3400500	2800500	157108	48	713,49	228,33	12,50	11,72	132,9871	110,03	7,69	31,00	5,00	Pinus pinaster spp
5800500	2600500	318435	45	401,69	176,66	22,43	11,21	224,3661	109,15	13,38	50,00	5,43	Qercus robur & Quercus petraea
5000500	2600500	230886	46	552,60	283,46	21,26	10,69	203,2898	100,27	12,73	99,00	6,19	Pinus sylvestris
4600500	2600500	251352	46	987,23	491,35	18,25	5,45	100,0000	**102,76**	15,38	1198,00	5,86	Picea spp
4400500	2600500	247265	47	1139,54	648,06	18,49	6,29	100,0000	73,85	19,23	1902,00	4,62	Picea spp
3800500	2600500	178992	46	721,75	361,30	15,88	10,32	105,3580	85,74	12,00	260,00	4,62	Qercus robur & Quercus petraea
4000500	2600500	153687	46	1151,95	470,83	16,84	7,18	100,0000	77,11	16,54	852,00	5,98	Picea spp
3600500	2600500	158521	46	822,12	299,37	14,91	11,48	213,6921	74,43	10,38	162,00	5,58	Qercus robur & Quercus petraea
4000500	2400500	191566	45	1081,28	395,01	16,89	8,00	100,0000	67,62	11,36	1930,00	6,05	Pinus sylvestris
4200500	2400500	236908	45	891,41	337,11	18,55	13,25	100,0000	113,50	5,00	243,00	4,87	Castanea spp
3800500	2400500	184376	45	1057,47	423,14	15,70	7,18	100,0000	92,77	14,62	886,00	5,63	Pinus sylvestris
3600500	2400500	163259	44	696,33	273,16	15,61	12,11	126,6466	91,29	6,32	187,00	6,26	Qercus robur & Quercus petraea
5600500	2200500	19962	42	527,33	170,84	20,99	11,46	150,7264	97,98	11,92	423,00	4,63	Qercus robur & Quercus petraea
5400500	2200500	17971	42	724,68	316,43	21,08	9,61	226,9183	111,38	12,69	536,00	5,52	Qercus robur & Quercus petraea
4600500	2200500	260969	43	694,70	252,98	16,77	9,79	181,2588	111,83	10,00	456,00	5,86	Qercus robur & Quercus petraea
3600500	2200500	111272	43	1052,20	455,70	15,91	5,04	100,0000	39,80	25,00	994,00	4,60	Pinus sylvestris
3400500	2200500	84105	42	582,12	229,45	17,18	12,98	114,9841	56,46	7,27	530,00	6,26	Pinus sylvestris
3200500	2200500	90230	42	563,42	180,65	16,66	10,05	111,5146	65,12	6,84	896,00	6,26	Conifers misc
2800500	2200500	305518	41	1384,52	268,82	12,87	13,80	100,0000	112,73	5,77	186,00	4,60	Pinus pinaster spp

4800500	2000500	272173	41	586,91	157,39	16,64	14,39	100,0000	126,10	3,85	554,00	5,80	Quercus misc
3400500	2000500	83361	41	584,72	212,14	17,22	10,10	112,5946	60,33	13,16	1258,00	6,26	Conifers misc
3200500	2000500	89059	40	384,57	100,00	18,54	13,64	199,4734	62,14	8,18	700,00	6,26	Quercus misc
3000500	1800500	121994	38	566,95	74,62	18,74	15,40	121,5787	75,41	5,38	700,00	5,98	Quercus misc
3200500	1800500	127896	38	435,69	100,13	19,59	13,33	117,1838	64,79	4,55	718,00	6,05	Quercus misc

8. References

Babst F., Pouler B., Trouet V., Tan K., Neuwirth B., Wilson R., Marco C., Grabner M., Tegel W., Levanic T., Panayotov M., Urbinati C., Bouriaud O., Ciais P., Frank D., (2013). Site- and species-specific responses of forest growth to climate across the European continent. Global Ecology and Biogeography. 22: 706 - 717.

Barbati A., Corona P., Marchetti M., (2007). European forest types / Categories and types for sustainable forest management reporting and policy / EEA Technical report No 9/2006 / European Environment Agency.

Bohn U., Gollub G., Hettwer C., Neuhäuslová Z., Raus T., Schlüter H., Weber H., (2004). Karte der natürlichen Vegetation Europe / Map of the Natural Vegetation of Europe Maßtab / Scale 1:2500000. Bundesamt für Naturschutz / Federal Agency for Nature Conservation.

Bolte A., Czajkowski T., Kompa T., (2007). The north-eastern distribution range of European beech - A review. Forestry. 80 (4): 413 - 429.

Bontemps J.D., Hervé J.C., Duplat P., Dhôte J.F., (2012). Shifts in the height-related competitiveness of tree species following recent climate warming and implications for the tree community composition: the case of common beech and sessile oak as predominant broadleaved species in Europe. Oikos. 121: 1287 - 1299.

Botkin D.B., Janak J.F., Walis J.R., (1972). Some ecological consequences of a computer model of forest growth. J. Ecol. 60: 849 - 872.

Brus D.J., Hengeveld G.M., Walvoort D.J.J., Goedhart P.W., Heidema A.H., Nabuurs G.J., Gunia K., (2012). Statistical mapping of tree species over Europe. European Journal of Forest Research. 131 (1): 145 - 147.

Bugmann H., Cramer W., (1998). Improving the behavior of forest gap models along drought gradients. For. Ecol. Manage. 103: 247 - 263.

Burschel P., Huss J., (1997). Grundriß des Waldbaus. 2. Aufl. Parey Verlag, Berlin.

Croft H., Chen J.M., Noland T.L., (2014). Stand age effects on Boreal forest physiology using a long time-series of satellite data. Forest Ecology and Management. 328: 202 - 208.

Dengler A., (1980-1982). Waldbau auf ökologischer Grundlage, 5. Aufl., bearbeitet von röhrig E., Verlag Parey, Hamburg.

Derimanis A., (2004). Europäische Wurzeln der Forstwirtschaft in Lettland. AFZ/Der Wald. 59 (10): 514 - 515.

Didion M., Kupferschmid A., Lexer M.J., Rammer W., Seidl R., Bugmann H., (2009). Potentials and limitations of using large-scale forest inventory data for evaluating forest succession models. Ecological Modelling. 220 (2): 133 - 147.

Esseen P-A, Ehnström B., Ericson L, Sjöberg K., (1997). Boreal forest. Ecol. Bull. 46: 16 - 47.

Ellenberg H., (1996). Vegetation Mitteleuropas mit den Alpen in Ökologischer, dynamischer und historischer Sicht. Ulmer, Stuttgart.

Ellenberg H., Mayer R., Schauermann J., (1986). Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer Sicht. Ulmer. Stuttgart.

Ellenberg H., Weber H., Düll R., Wirth V., Werner W., Paulißen D., (1992). Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica. 18.

Felbermeier B., (1993). Der Einfluß von Klimaänderungen auf die Areale von Baumarten: Methodenstudie und regionale Abschätzung für Rotbuche (*Fagus sylvatica L.*) in Bayern. Forstliche Forschungsbereichte München. 134. München.

Field C.B., Randerson J.T., Malmström C.M., (1995). Global Net Primary Production: Combining Ecology and Remote Sensing. Elsevier Science Inc. REMOTE SENS. ENVIRON. ENVIRON. 51: 74 - 88.

Fankhauser F., (1910). Zur Kenntnis des Vogelbeerbaumes. Schweiz. Z. Forstwes. 61: 1 - 6, 42 - 52, 116 - 120.

Gillman L. N., Wright S. D., Cusens J., McBride P. D., Malhi Y., Whittaker R. J., (2015). Latitude, productivity and species richness. 24: 107 - 117.

Groß H., (1934). Die Rotbuche in Ostpreußen. Z. Forst Jagdweis. 66 (12): 622 - 651.

Gunia S., Due J.E., Kramer W., (1972): Die Weisstanne (*Abies alba Mill.*) im Nordosten ihres natürlichen Verbreitungsgebietes. Forstarchiv. 43: 84 - 91.

Halkka A., Lappalainen I., (2001). Insight into Europe's Forest Protection. WWF Report. Gland: World Wide Fund For Nature (formerly World Wildlife Fund).

Hickler T., Vohland K., Feehan J., Miller P.A., Smith B., Costa L., Giesecke T., Fronzek S., Carter T.R., Cramer W., Kühn I., Sykes M.T., (2012). Projecting the future distribution of European potential natural vegetation zones with a generalized, tree species-based dynamic vegetation model. Global Ecology and Biogeography. 21 (1): 50 - 63.

Hofmann A., (1974). Dalle Madonie alle Alpi Giulie attraverso le faggete italiane. Not. Fitosoc. 9: 3 - 14.

Hoenisch, U., (1963). Die Weisstanne ausserhalb ihres natürlichen Verbreitungsgebietes in Westeuropa. Diss. Ludwig-Maximilian-Universität, München.

Jacob D., Göttel H., Kotlarski S., Lorenz P., Sieck K., (2008). Climate Change / Klimaauswirkungen und Anpassung in Deutschland - Phas 1: Erstellung regionaler Klimaszenarien für Deutzland / Max-Planck-Institut für Meteorologie (MPI-M), Hamburg / ISSN: 1862 - 4359.

Janík D., Dušan A, Libor H., Král K., Šamonil P.U., Vrška T., (2014). Tree spatial patterns of *Abies alba* and *Fagus sylvatica* in the Western Carpathians over 30 years. Eur J Forest Res. 133: 1015 - 1028.

Kahn M., Pretzsch H., (1997). Das Wuchsmodell SILVA-Parametrisierung der Version 2.1 für Rein- und Misch- bestände aus Fichte und Buche. Allg. Forst- u. J-Ztg. 168: 115 - 123.

Kindermann G.E., Schörghuber S., Linkosalo T., Sanchez A., Rammer W., Seidl R., Lexer M.J., (2013). Potential stocks and increments of woody biomass in the European Union under different management and climate scenarios. Carbon Balance and Management. 8 (1): 2.

Landsberg J.J., Waring R.H., (1997). A generalized model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance and partitioning. For. Ecol. Manage. 95: 209 - 228.

Langer H., (1963). Einwanderung und Ausbreitung der Weisstanne in Süddeutchland. Forstwiss. Cbl. 82: 33 - 52.

Lexer M.J., Hönninger K., (2001). A modified 3D-patch model for spatially explicit simulation of vegetation composition in heterogeneous landscapes. For. Ecol. Manage. 144: 43 - 65.

Leder B., (1996). Die Bedeutung der Vogelbeere bei Sekundärsukzession im Eggegebirge. AFZ/Der Wald 51: 997 - 999.

Leith H. & Whittaker R.H., (1975). Primary productivity of the biosphere. Springer-Verlag, New York.

Leuschner C., Rode M., Heinken T., (1993). Gibt es eine Nährstoffmangel-Grenze der Buche im nordwsetdeutschen Flachland?. Flora. 188: 239 - 249.

Lexer M.J., Hönninger K., Vacik H., (2000). Modeling the effect of forest site conditions on the ecophysiological suitability of tree species. Comput. electron. Agric. 27: 393 - 399.

Lexer M.J., Seidl R., Schörhuber S., Kindermann G., Mäkkelä A., Mäkipää R., Linkosalo T., Gracia C., Sanchez A., Sabate S., Keenan T., (2010). CCTAME / Catalogue of potential management practices for adaptation and mitigation covering different biogeographic regions. Operationalization of management practices for simulation in the continental scale modeling framework (*Unpublished manuscript*).

Ligot G., Balandier P., Fayole A., Lejeune P., Claessens H., (2013). Height competition between *Quercus petraea* and Fagus sylvatica natural regeneration in mixed and uneven-aged stands. Forest Ecol. Manage. 304: 391 - 398.

López J., Camacho C., (2006). Characterization and phytoclimatic potentialities of *Quercus petraea (Matt.) Liebl*. and *Quercus robur L*. forests in Spain. Invest Agrar.: Sist. Recir. For. 15 (3): 277 - 295.

Magnani F., Mencuccini M., Grace J., (2000). Age-related decline in stand productivity: the role of structural acclimation under hydraulic constraints. Plant, Cell and Environment. 23 (3): 251 - 263.

Mason W., (2013). The role of true fir species in the silviculture of British forests: past, present and future. Forestry Faculty. 12 (3): 15 - 26

Mayer H., (1984). Wälder Europas. Stuttgart-New York: Gustav Fischer.

Magri D., Vendramin G.G., Comps B., Dupanloup I., Geburek T., Gömöry D., (2006). Anew scenario for the Quaternary history of European beech populations: paleobatanical evidence and genetic consequences. New Phytol. 171: 199 - 221.

Nagy L., Grabherr G., Körner Ch., Thompson D.B.A., (2003). Alpine Biodiversity in Europe.

Ozenda P., (1985). La végétation de la chaîne alpine dams léspace montagnerd européen.

Ozenda P., (1994). Végétation du Continent Européen. Lausanne: Delachaux it Niestlé.

Packham J., Thomas P.A., Atkinson M.D., Degen T., (2012). Biological Flora of the British Isles: Fagus sylvatica. Journal of Ecology. 100 (6): 1557 - 1608.

Pan Y., Birdsey R., Hom J., McCullough K., Clark K., (2006). Improved estimates of net primary productivity from MODIS satellite data at regional and local scales. Ecological Applications. 16 (1): 125 - 132.

Petit R.J., Brewer s., Bordacs S., Burge K., Cheddadi R., Coart E., Cottrellg J., Csaikle U.M., van Dam B., Deans J.D., Espinel S., Fineschi S., Finkeldey R., Glaz I., Goicoechea P.G., Jensen J.S., König A.O., Lowe A.J., Madsen S.F., Mátyás G., Munro R.C., PopescuF., Slade D., Tabbener H., de Vries S.G.M., Ziegenhangen B., de Beaulieu J., Kremer A., (2002). Identification of refugia and post-glacial colonization routes of European white oaks based on chloroplast DNA and fossil evidence. Foreco. 156: 49 - 74.

Petritan I.O., Marzano R., Petritan A.M., Lingua E., (2014). Overstory succession in a mixed *Quercus petraea-Fagus sylvatica* old growth forest revealed through the spatial pattern of competition and mortality. Forest Ecol. Manage. 326: 9 - 17.

Pickett S.T.A., White P.S., (1985). The ecology of natural disturbance and patch dynamics. Academic Press, London. 472.

Portter C.S., Randerson J.T., Field C.B., Matson P.A., Vitousek P.M., Mooney H.A., Klooster S.A., (1993). Terrestrial ecosystem production: a process model based on global satellite and surface data. Global Biogeochem Cycles. 7: 811 - 841.

Pons A., (1984). Les changements de la vegetation de la region méditerranéenne durant le Pliocène et le Quaternaire en ralation avec l'historie du climat e de l'action de l'homme. Webbia. 38: 427 - 434.

Prien S., (1965). Waldbauliche und holzkundliche Eigenschaften der Eberesche (*Sorbur aucuparia L.*). Dissertation Techn. Univ. Dresden, Sektion Forstwirtschaft, Thardant.

Prien S., (1995). Struktur, waldbauliche Eigenschaften und waldbauliche Behandlung von Ebereschenvorwäldern, in: LÖBF (Hrsg.): Weichlaubhölzer und Sukzessionsdynamik in der naturnahen Waldwirtschaft. Schriftenr. Landesanst. Ökologie, Bodenordung und Forsten Nordrhein-Westfalen. 4: 45 - 59.

Quézel P., Médail F., (2003). Ècologie et biogéographie des frêsts du bassin mediterranéen. Paris: Elsevier.

Rammer W., Lexer M.J., (2011). CCTAME / Climate data processing (*Unpublished manuscript*).

Rammer W., Lexer M.J., (2011). CCTAME / Evaluation (*Unpublished manuscript*).

Rammer W., Lexer M.J., (2010). CCTAME / Data processing - Part II - Water Holding Capacity and Nitrogen (*Unpublished manuscript*).

Rivas-Martinez S., (1968). Estudio fitosociológico de los bosques y matorrales pirenaicos del piso subalpino. Barcelona: Publ. Del Inst. De biología aplicada. 44.

Rozas V., (2003). Regeneration patterns, dendroecology, and forest-use history in an old-growth beech-oak lowland forest in Northern Spain. Forest Ecol. Manage. 182: 175 - 194.

Rol R., (1937). Etudes sur la répartition des essences forestières en France. Contribution à l´etude de la répartition du Sapin (Abies alba Mill.). Ann. l'Ecole Nationale des Eaux et Forets. Tome VI. Berger-Levrault, Nancy.

Röhe P., (1984). Untersuchen über das Wachstum der Buche in Baden-Württemberg. Selbstverlag des Landesforstverwaltung Baden-Wüttemberg, Diss. Freiburg.

Rozas V., (2003). Regeneration patterns, dendroecology, and forest-use history in an old-growth beech-oak lowland forest in Northern Spain. Forest Ecol. Manage. 182: 175 - 194.

Rubner K., (1953). Die planzengeographischen Grundlagen des Waldbaus. 4. Aufl., Neumann-Verlag, Radebeul und Berlin.

Rubner K., and Reinhold F., (1953). Das natürliche Waldbild Europas als Grundlage für einen Europäischen Waldbau. Parey, Hamburg-Berlin, Germany. 288.

Scamoni A., (1989). Eine selten Kombination von Baumarten: Alnus glutinosa (L.) Gaertn. - *Fagus sylvatica L.*. Flora. 183: 97 - 102.

Seidl R., (2007). Model-based analysis of sustainable forest management under climate change with particular consideration of bark beetle disturbances.

Seidl R., Baier P., Rammer W., Schopf A., Lexer M.J., (2007). Modeling tree mortality by bark beetle infestation in Norway spruce forests. Ecological Modeling. 206: 383 - 399.

Seidl R., Lexer M.J., Jäger D., Hönninger K., (2005). Evaluating the accuracy and generality of a hybrid patch model. Tree Phys. 25: 939 - 951.

Seidl R., Rammer W., Jäger D., Currie W.S., Lexer M.J., (2007). Assessing trade-offs between carbon sequestration and timber production within a framework of multi-purpose forestry in Austria. For. Ecol. Manage. 248: 64 - 79.

Seidl R., Rammer W., Lexer M.J., (2006). PICUS documentation (*Unpublished manuscript*). www.wabo.boku.ac.at/picus.html

Simon A., Gratzer G., Sieghardt M., (2011). The influence of wind throw micro sites on tree regeneration and establishment in an old growth mountain forest. Forest Ecol Manage. 262: 1289 - 1297

Suc J.P., Cravatte J., (1982). Étude palynologique du Pliocène de Catalogne (nord-est de l'Espagne) - Paléobiologie continentale. 13 (1): 1 - 31.

Tinner W., Lotter A.F., (2006). Holocene expansion of *Fagus sylvatica* and *Abies alba* in Central Europe: where are we after eight decades of debate? Quat. Sci. Rev. 25: 526 - 549.

Toigo M., Vallet P., Tuilleras V., Lebourgeois F., Rozenberg P., Perret S., Courbaud B., Perot T., (2015). Species mixture increases the effect of drought on tree ring density, but not on ring with, in *Quercus petraea-Pinus sylvestris* stands. Forest. Ecol. Manage. 345: 73 - 82.

Trocha L., Weiser E., Robakowski P., (2015). Interactive effects of juvenile defoliation, light conditions, and interespecific competition on growth and ectomycorrhizal colonization of *Fagus sylvatica* and *Pinus sylvestris* seedlings.

Tröltzsch K., Van Brusselen J., Schuck A., (2009). Spatial occurrence of major tree species groups in Europe derived from multiple data sources. Forest. Ecol. Manage. 257 (1): 294 - 302.

Tschermak L., (1929). Die Verbreitung der Rotbuche in Österreich. Frick. Wien.

Tschermak L., (1950). Waldbau auf pflanzengeographischökologischer Grundlage. Springer. Wien.

Tukey J.W., (1949), Comparing Individual Means in the Analysis of Variance. Biometrics. 5 (2): 99 - 114.

UNECE; MCPFE & FAO, (2007): State of Europe's Forest 2007 ─ The MCPFE report on sustainable forest management in Europe. Warsaw, Poland, Ministerial Conference on the Protection of Forests in Europe (MCPFE) Liaison Unit.

Pan Y., Birdsey R., Hom J., McCullough K., Clark K., (2006). Improved estimates of net primary productivity from MODIS satellite data at regional and local scales. Ecological Applications. 16 (1): 125 - 132.

Wang S., Zhou L., Chen J., Ju W., Feng X., Wu W., (2011). Relationships between net primary productivity and stand age for several forest types and their influence on China´s carbon balance. Journal of Environmental Management. 92 (6): 1651 - 1662.

Watt A.S., (1947). Pattern and processes in the plant community. The Journal of Ecol. 35 (1/2): 1 - 22.

Welch B.L. (1947). The generalization of Student's problem when several different population variances are involved. Biometrika. 34 (1/2): 28 - 35.

Whittaker R.H., (1975). Communities and ecosystems. Macmillan, New York, USA.

Zapater M., Hossann C., Bréda N., Bréchet C., Bonal D., Granier A., (2011). Evidence of hydraulic lift in a young beech and oak mixed forest using ^{18}O soil water labeling. Trees. 25: 885 - 894.

Zlatník A., (1935). Vývoj a složení přirozenných lesů na Podkarpatské Rusi a jejich vztah ke stanovišti. Sborník výzkumného ústavu zemědělského. 127: 67 - 206.

Zlatník A., (1978). Lesnická fytocenologie. Státní zemědělské nakladatelství, Praha.