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Book of Abstracts

Edited by

Andrzej M. Jagodziński and Andrzej Węgiel

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Modeling sessile oak stump sprouting for coppice forest in the Czech Republic

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Keywords: sessile oak, coppice, sprouting capacity, logistic regression.

The probability of stump sprouting of sessile oak (*Quercus petraea* (Matt.) Liebl.) one year after harvest was modeled. Seven research plots were established in forest stands with ages of 31 to 97 years, differing site indexes and altitudes ranging from 290 to 410 m above sea level. In each plot, the position (respective to the plot centre), age at the time of harvest, stump surface diameter, and regeneration status (successful or unsuccessful) were determined for every stump. A total of 862 stumps of sessile oak were analyzed. Logistic regression was used to model the probability of stump sprouting. Parent tree age and stump diameter were both negatively correlated with sprouting probability. There was no impact of the site index on sprouting probability. The model with stump diameter as the only predictor was found to be the most suitable using AIC. Comparison of the sessile oak model with similar models used for three North American oak species (*Quercus velutina* Lamb., *Quercus montana* W. and *Quercus alba* L.), showed that the sprouting probability of sessile oak stumps declines more sharply as the stump diameter increases.

The potential of exotic and native species plantations to improve the productivity of degraded forestland in Malaysia

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Keywords: allometric equation, biomass, carbon sink, deforestation, forest plantation.

Deforestation and change to other land use types have contributed to degraded secondary forests or forestland and increases the emission of greenhouse gases which ultimately lead to global climate change. Forest plantation on degraded forestland is regarded as an important approach for carbon sequestration. However, limited information exists on productivity and potential of fast growing exotic and indigenous tree plantations for sequestering CO_2 from the atmosphere through photosynthesis. Therefore, this study aimed to assess the productivity and biomass accumulation along with the potential for sequestering CO_2 of planted exotic and indigenous species on degraded forestland. The present study was conducted at a five-year-old forest plantation of *Khaya ivorensis* and *Hopea*

odorata in Segamat Johore, Malaysia. To evaluate the forest productivity and biomass accumulation of both species, we established plots with a size of 40x30 m in three replications in each stand, followed by measuring height and Diameter at Breast Height (DBH) of all trees in the plots. To develop allometric equations, five representative trees at each stand were chosen for destructive sampling. The growth performance in terms of mean height, DBH, annual increment of height and diameter and basal area of exotic species (*K. ivorensis*) was significantly higher than that of the indigenous species (*H. odorata*). We used the diameter alone as an independent variable to estimate stem volume and biomass production of both species. The stem volume of *K. ivorensis* stands was 43.13 m^3 ha^{-1} and was significantly higher than H. odorata stands (33.66 m^3 ha^{-1}). The results also showed that the *K. ivorensis* and *H. odorata* stands have the potential to absorb CO_2 from the atmosphere which was stored in aboveground biomass with values of 15.90 Mg C ha^{-1} and 13.62 Mg C ha^{-1}, respectively. In addition, the carbon content in root biomass of *H. odorata* stands was higher than that in *K. ivorensis* stands with values of 7.67 Mg C ha^{-1} and 4.58 Mg C ha^{-1}, respectively. The exotic (*K. ivorensis*) and indigenous (*H. odorata*) species which were planted on degraded forestland exhibited different growth rates, biomass production and ability to absorb CO_2 from the atmosphere in each part of the tree. In general, forest productivity and ability to absorb CO_2 from the atmosphere of the exotic species (*K. ivorensis*) was higher than that of the indigenous species (*H. odorata*), indicating that productivity of enrichment planting on degraded forestland was affected by species site suitability. Thus, to sustain high productivity with suitable species selection for carbon sequestration, these factors should be considered for future forest establishment.

Harvesting and transport solutions for economically viable forest energy

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Keywords: forest energy, bioenergy, biomass supply.

Use of wood and wood waste for energy in EU totals 90 Mtoe annually representing almost 50% of all renewables. Currently, the most remarkable biomass suppliers and end-users are the forest industries using the by products such as sawdust, bark and black liquor in energy production. District heating and combined heat and power production are also increasing the use on forest biomass as their feedstock. Several studies indicate that EU's forests could supply about 200 million m^3 (35 Mtoe) residual forest biomass and 100 million m^3 (17 Mtoe) woody biomass from urban areas, fence wood from farms and wood production on set aside land for energy.

Residual forest biomass (harvesting residues, wood from early thinnings and stumpwood) is already utilized in large scale in Sweden and Finland. About 16 million m^3 (2.5 Mtoe) forest biomass for energy production are utilized annually in more than 1,000 heat and power plants in the both countries. The main challenge in EU's forest biomass supply for energy is the mobilization of the existing forest biomass potential in a competitive and sustainable manner. Sustainable and reliable supply of feedstock will be a critical success factor for the long-term competitiveness of biomass-based energy production: Fuel represents typically 60-80% of the total energy production costs of a CHP plant.

Biomass supply chains have to be cost-efficient and sustainable also when supply stretches over very long distances. The manpower needed to run the operations is estimated to be over 40,000 ma-

chine operators in the EU. By now the entrepreneurs running round wood harvesting for industrial purposes have extended their operation to energy biomass supply. In the availability of skilled labor may become a serious bottleneck of supply.

New production and business concepts, where energy and energy carrier production is integrated with other industrial infrastructures show promising paths for resource efficient use of forest biomass. Particularly integration with the forest industrie's production systems is underway. Also traditional CHP sector already builds full scale demonstrations, where biofuel production or cooling of buildings is integrated in the existing services.

It is economic to use same base machines for industrial and energy wood harvesting to reduce investment costs and thus economic risk. Standard single grip harvesters and forwarders dominate energy wood harvesting. In final fellings a single grip harvester cuts the industrial roundwood and places residues in heaps along the strip road. Residues are seasoned several weeks during the summer to reduce the moisture content and drop needles to the site. Subsequently a forwarder is used to transport residues to the roadside landing. Residue piles are covered with paper to reduce the rewetting of the material during the fall and winter season prior to chipping. In early thinnings cutting is mainly done by single grip harvesters, however, in some cases motor-manual felling is also applied. Harvester heads often use the multi stemming technique to process several stems simultaneously. Chipping is done dominantly at roadside landings, where the interactions with truck transport can reduce the productivity. Introduction of large chip trucks with interchangeable large trailers can reduce not only transport but also chipping costs.

The economic viability of biomass based energy, however, has been found to be the weaker link. Forest based bioenergy is competitive against oil in heat and power markets in many parts of the EU. As a result, thousands of heat and CHP plants using forest biomass as their main fuel have been raised across the EU. Replacing coal with biomass is more difficult and requires either taxation of coal or direct subsidies for biomass supply.

Biomass allocation to leaves, stem and roots of chestnut oak seedlings across a light gradient

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Keywords: leaf to root ratio, Hyrcanian forest, growth, adaptation, environmental factor.

Environment can affect allocation patterns of plant biomass. Light is one of the most important environmental factors affecting the relative amount of biomass present in the various organs, which is termed "biomass allocation".

In this research, we examined patterns of biomass allocation across a light gradient for seedlings of five provenances of chestnut oak (*Quercus castaneifolia* C.A.Mey.) from west to east of Hyrcanian forest. Different provenances were collected along a west to east precipitation gradient within the Hyrcanian forest, with annual rainfall ranging from 2045 mm in Pilambra in the west to 488 mm in Loveh in the east, from 49.08°E, 37.58°N to 55°E, 37°N respectively.

Experimental design was executed under controlled conditions at eight different light levels (10, 20, 30, 40, 50, 60, 70 and 100% full light) for five months on one-year-old seedlings of chestnut oak. The experiment was carried out in the greenhouse at the Faculty of Natural Resource and Marine Science of Tarbiat Modares University, which is located within the Hyrcanian forest (36°34′54″N, 52°2′32″E).

After one growing season, we quantified the biomass allocation patterns to leaves, stems and roots. We also calculated leaf to root (L/R) and root to shoot (R/Sh) ratios as two of the major factors dictating plant growth rate and fitness. These ratios are helpful for understanding plant growth strategies in natural ecosystems, and refer to the balance between investment in light intercepting organs vs. water and nutrient organs. To show the functional responses to light, graphs were drawn for the mean values of biomass allocation.

Based on the measurements, the biomass allocation for all the provenances could be ranked as follows: root > stem > leaf. As could be expected, there is a negative correlation between light and leaf allocation, and for root allocation the reverse pattern is found. The L/R ratio was negatively correlated with light. At wet provenances (Pilembera, Kelardasht, Lajim) variation in L/R was strongly correlated with light (coefficient of determination R^2: Pl = 0.76, Kl = 0.76, Lj= 0.82), but at dry provenances (Kordkûy and Loveh) this relationship gradually disappeared (R^2: Kr = 0.17, Lo = 0.31). The relationship between root to shoot (R/Sh) ratio and light was also weak at dry provenances (R^2: Kr = 0.56, Lo =0.25) and became gradually stronger at wet provenances (R^2: Lj = 0.55, Kl = 0.94, Pl = 0.83).

Such relationships indicated that the growth strategies of chestnut oak seedlings are different at dry provenances compared to wet provenances. In dry conditions, the seedlings try to invest more biomass into root mass to facilitate water uptake and to alter their leaf size to prevent overheating. In our experiment, despite similar growth conditions in the greenhouse, different growth strategies in the seedlings from wet and dry provenances may be the result of genetic adaptation to the ecological conditions and precipitation regimes that prevail in native habitats.

Monitoring for changes in biomass of mountain forests

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Keywords: GIS, monitoring, modelling, mountains, informatics.

The project „Establishment of the forest information system including monitoring and evaluation of forest condition for the Sudety Moutains and the Beskidy Zachodnie Mountains" is the largest GIS initiative of this kind related to environmental protection and financed by the State Forests National Forest Holding. The project mainly aims at the monitoring of mountain ecosystems and modelling of the future natural processes that substantially contribute to deforestation.

The changes taking place in the Beskidy Zachodnie and Sudety mountains result from many, often parallel processes. Most of them are interconnected in a system of complex mutual relationships. In order to understand the disastrous occurrences that we are witnessing now, it is necessary to use a comprehensive approach that includes as many parameters as possible and to employ state-of-the-art technologies. One of the most significant indicators of health are the changes that are taking place in the biomass of forest stands.

The achievement of the project objectives will be possible thanks to the application of state-of-the-art data collection methods such as airborne and field based laser scanning and satellite based imaging. Additionally, genetic, dendrochronological, phytopathological and physicochemical studies of soil will be carried out, using the data obtained from over 600 test areas.

As a complement to the planned studies, a spatial information system will be developed and implemented in order to facilitate future operations of field based services and to deliver additional analytical tools for managing departments at the levels of forest inspectorate and regional directorate.

Impact of tree spacing on quantity and quality of merchantable timber biomass in pine (*Pinus sylvestris* L.) stands of the 5th age class

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Keywords: pine, tree spacing, biomass quantity and quality.

A varied intensity of silvicultural treatments, natural tree mortality, insect devastation and fungal infection can eventually lead to different spacing in stands, even on sites of the same quality. In addition, the wider the spacing, the bigger the crown and trunk volume of single trees. The objective of the research was a detailed analysis of tree spacing impact on volume and quality of merchantable timber biomass (over 5 cm under bark). The research was carried out in North-West Poland, Forest District Drawno (Regional Directorate of the State Forests Szczecin) on sites with sandy soil optimal for Scots pine (*Pinus sylvestris* L.).

The total volume of merchantable roundwood biomass was measured on 19 sample plots of 0.5 ha each. These plots were selected in 19 different stands of the 5th age class (81-100 years old). The volume of a single tree was obtained using dbh, height and absolute form factor ($f_{1.3}$). A quality classification of all 6,554 tree trunks was carried out in accordance with the Polish Norm PN-92/D-95017. As a result, different spacing was observed in each sample plot, ranging from 476 to 836 trees per ha. No dependence was observed between the spacing and volume per hectare of merchantable roundwood biomass, which ranged from 135 to 217 m^3 ha^{-1}.

Results showed that over 80% (in volume) of merchantable roundwood biomass quality was timber of the WC0 class. The remaining timber was represented in the following decreasing order: WB0, WA0 (the highest quality class) and WD (the lowest quality class). It was also observed that the narrower the spacing, the smaller the dbh. This suggests that on plots with wider spacing, trees of a bigger volume are higher in number, giving more assortments within the higher thickness class (but the same quality class, e.g. WC0) at a better price. This leads to the conclusion that pine stands should in their final stage be grown with wider spacing in order to achieve better financial results per unit area.

Belowground tree biomass estimation – the case study of Scots pine and silver birch in Poland

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Keywords: root biomass, allometric equations, root-to-shoot ratio, chronosequence.

Belowground parts play an important role in the process of carbon sequestration by trees. Despite this great importance of root biomass, there has been rather limited research aiming to determine amount of carbon stored by roots in Polish forests. The study presented discusses various approaches to the estimation of root biomass. Allometric equations and root-to-shoot ratios were used to assess the belowground biomass of Scots pine (*Pinus sylvestris* L.) and silver birch (*Betula pendula* Roth.) stands. Equations for Scots pine were based on data from sample plots located in western Poland, and for silver birch – from post-agricultural lands in central Poland. A clear dependence of root biomass on the age and size of a tree was observed as well as the influence of habitat fertility and moisture.

30 years searching for forest biomass and carbon sequestering data: the need for statistically valid estimates and accurate forecasting methods

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Keywords: forest modeling, forest inventory, biomass inventory, carbon sequestering, model validation.

In this presentation, I discuss the results of 45 years of research on forest biomass and carbon storage. In the 1980s we conducted the first statistically valid estimates of above ground forest biomass and carbon storage for any large area: the boreal forests and eastern deciduous forests of North America. The method was direct stratified random sampling of forest plots. Resulting mean values are considerably lower than those in wide use and the confidence interval is greater than 20% of the mean. We hope that this method would be used widely, but today we know of few others that provide statistically valid estimates for forested biomes. Beginning in the 1970s, we developed the JABOWA computer model of forest growth, the first successful multi-species model, today in wide use worldwide in more than 50 versions. Working with Michael R. Ngugi, and David Doley, colleagues in Australia, where there is detailed long-term forest monitoring, we have been able to show that an Australian version of the model can account for 88.6% of above ground biomass. The measurement

methods and forecasting methods provide useful, accurate estimates of biomass and carbon storage, and we hope that these will be applied widely so that comparable estimates will be available for the major forest biomes of Earth.

Induced Innovation and Renewable Energy Policies for Bioenergy: An Econometric Analysis

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Keywords: biomass, bioenergy, biofuels, renewable energy policy, innovation.

To address the problem of global warming as well as the insecurity of supply of traditional fossil fuels such as crude oil, a variety of public policies meant to support the development of renewable energy sources have emerged during the decades since the first oil crisis in 1973. One key factor in the development of useful alternatives to fossil fuels is innovation. A continuous improvement of existing technology is necessary to make renewable energy generation feasible as a reliable and cost-competitive substitute for traditional energy sources. The relationship between environmental policies and innovations in renewable energy technologies in general has been the subject of many previous studies (e.g. Brunnermeier and Cohen 2003, Lanjouw and Mody 1996, Noailly and Batrakova 2010, Walz et al. 2008). However, relatively few of these studies have focused on the effect of environmental policies on bioenergy innovation.

The aim of this paper is to test the effect of various climate and renewable energy policies on innovation in bioenergy technologies. Earlier attempts to assess policy-types have focused on wide categories of policies. However, these wide policy categories include a multitude of policy variants, such as price supports, tax credits, and renewable energy mandates, all of which are likely to have different effects on renewable energy innovation. Instead, the approach in this paper is to disentangle and categorize the policies into specific types and areas. By embracing as many countries and policies as possible, a more complete empirical understanding of the actual effects of the policies that have been in use to date can be reached.

We will conduct an econometric study using panel data on patent counts to examine the effect of climate and energy policies on bioenergy innovations. The study uses a cross-country perspective, something that only has been done in a small number of earlier studies on this subject (see Johnstone et al. 2010, Rübbelke and Weiss 2011, and Lundmark and Bäckström 2012). The main benefit of this approach is that it allows an analysis of the effect of a variety of usual policy types on a disaggregated level. The policies investigated here are different types of investment supports, feed-in tariffs and production quotas. The explanatory variables also include a vector of other important determinant variables of patenting activity for bioenergy technologies. Fixed effects are employed to capture unobservable country-specific heterogeneity using a negative binomial model.

We expect to find evidence indicating whether various renewable energy policies have had a significant effect on innovations in bioenergy. In this study, a broad set of explanatory variables provide rigor to the investigation and show whether results obtained earlier are robust. The results will give a better understanding of which measures might be appropriate for an efficient design of public policies and the transition to a biobased economy.

Empirical equations for dry biomass of trees and their components for Scots pine growing in various stocking

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Keywords: Scots pine, biomass, empirical equations, seemingly unrelated regression.

Many studies on tree allometry and biomass allocation omit changes in tree form caused by different stand density. In the study presented we tested two groups of existing equations for the biomass of Scots pine trees and their components. The first group was for typical Scots pine habitats in western Poland, the second one was based on studies performed in various European countries. Measurements from research plots of various stocking levels from the Drawno Forest District were used for validation. The results suggested that stand density may have an influence on biomass allocation into different pools. Thus, the new equations for biomass of trees and their components were elaborated to account for the effect of stocking on biomass allocation. In their preparation the seemingly unrelated regression approach (SUR) was used. This allowed for more accurate biomass assessment of Scots pine trees in western Poland.

The effects of forest fragment size on above ground biomass in a neo-tropical landscape

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Keywords: forest fragmentation, carbon stocks, remote sensing, climate change.

Although only about 14% – 18% of all human Greenhouse Gas Emissions originate from land use change and agriculture, the mitigation of this source alone could help many countries reach emissions goals agreed to in the Kyoto Protocol. Several recent studies have indicated that small forest fragments, remnants of land use change, are unable to maintain large stocks of carbon, due to higher tree mortality caused by edge effects. In the present work, we assess differences in inferred above ground tree biomass (using vegetation indexes as proxies) of small fragments (<50 ha) and large fragments (>300 ha), employing remote sensing techniques in a long-term fragmented forest in Northeast Brazilian Mata Atlântica. Therefore we estimated a linear model of spectral indexes (NDVI and EVI) and above ground biomass using forest inventory data, SPOT and Landsat data. We then evaluated the correlation between the measured biomass in the field and the spectral response. For each fragment we calculated the mode of the pixel values (evaluated in an 8 bit converted NDVI/EVI image, 0-255) and compared the modes of small fragments (<50 hectares) and large fragments (>300 hectares). Our results show that small fragments contained significantly less carbon, as inferred by

the pixel values (mode 215.76±1.15, note that pixel values are dimensionless and range between 0 and 255), than large fragments (222.6±4.72). Our results underpin the importance of including the effect of fragmentation, spatial configuration of forest area and degradation in the carbon balance, in addition to forest area.

Recent trends in incorporating participatory approach models into sustainable management of natural and planted forests

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Keywords: tropical forest, forest management, West Africa.

The days when tropical forests appeared inexhaustible are long past. However, these forests are still invaluable renewable natural resources (RNR) with multiple functions important for the sustenance of livelihood in both developed and developing countires. Therefore, interests in planted forests are growing worldwide, as these forests are expected to complement natural forests with their different functions such as wood production. Thus, there is a need to ensure increased planting rates of these forests. In order to scale up the benefits accruable from the growth of planted forests, concepts encapsulated by sustainable forest management (SFM) have been recommended. However, SFM and other related concepts may not succeed if diverse interests in the management and utilisation of forest resources are not well represented. For instance, in reserving natural forests and setting up of plantations in many West African states, laws and other legal frameworks were enacted that excluded many of the stakeholders, particularly traditional land owners and those living within or at the fringes of these forests and protected areas, whose livelihoods are mainly dependent on these RNR. This led to a series of conflicts and failure of many past projects, whose solutions have been identified to be realisable through appropriate and adequate participatory processes involving these stakeholders. Therefore, this presentation is aimed at evaluating the contributions of various models of participatory approaches at managing RNR, especially forests, showing how these approaches have impacted planted forests, and how some of the challenges encountered were surmounted, with particular reference to Nigeria.

Analysis of the time-consumption and efficiency of basic harvesting operations at the motor-manual technological level

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Keywords: logging efficiency, CO_2 emissions, fuel consumption.

The purpose of the research performed in three forest inspectorates was to define the structure of lumberjacks' working day and to estimate their logging efficiency in reference to the main tree species of the Augustowska Primeval Forest.

The ergonomic aspect of the work was taken into consideration by calculating the lumberjacks' energy expenditure. Also environmental impact – in the form of CO_2 emissions and fuel consumption – has been estimated.

Data collection was conducted through a working day activity study on six final felling areas. During over 43 hours of research, 327 m^3 of timber has been harvested.

Allocation of elements in former farmland afforestation with birch of varying age

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Keywords: secondary succession, afforestation, allocation of elements, chronosequence.

Research on the effect of birch regeneration on changes occurring under its influence in former farmlands included quantitative and qualitative analysis of biomass growing on research plots. Five experimental plots were selected in the Mazovia voivodeship: in Dobieszyn and the Kampinos National Park - 2 plots in each, and in Kozienice - 1 plot. Analysis performed on each plot concerned the chemical composition and amount of biomass in four patches of vegetation, characterised by different ages of birch trees growing there. The vegetation patches were classified according to subsequent age groups: I: 1 - 4 years, II: 5 – 8 years, III: 9 – 12 years and IV: over 12 years. Biomass samples were obtained and weighed, determining in kg dry mass/ha its following elements: roots, stem, bark, branches, assimilation apparatus, litterfall and total biomass of the other (except birch) plants. For all groups mentioned above, the content of the following elements was determined: N, C, S, Ca, K, Mg, Na, P, Mn, Cu, Fe, Zn, Pb, Cd. This allowed for obtaining both the values of concentrations of particular substances and their allocation, in both the organic matter and litterfall. The aim of the analysis of the obtained results is to answer the question whether the allocation of elements changes with the age of birch growing on former farmland.

Determination of biomass, minerals content and depletion of nutrients as a result of different systems of utilisation in clear-cut Scots Pine forests

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Keywords: biomass, Scots pine, nutrients depletion.

This paper presents the biomass of mature clear-cut stands of Scots Pine (*Pinus sylvestris* L.). Data were collected in three 95-year-old stands in the forest district Bolewice (RDLP Szczecin). Fresh and dry weight of biomass was calculated, for whole stand and average tree, separated into stem wood, bark, branches, needles and roots. Mass of trees was 327 Mg/ha, of which 64.6% was stem wood, 5.8% bark, 11.0% branches, 1.9% needles and 16.7% roots. The content of biogenic elements in different parts of the trees was determined using chemical analysis. The highest content of almost all of the elements was found in needles - for nitrogen 1.2107-1.3767% of dry weight, for phosphorus 0.2245-0.2613% dw, for potassium 0.4108-0.5717% dw, for magnesium 0.0540-0.0648% dw and for sodium 0.0247-0.0468% dw. The exception was calcium, for which the highest concentration was found in the bark (0.4608-0.7876% dw). The amount of mineral substances withdrawn from the environment in different systems of utilisation was analysed. The following systems were taken into account: utilisation of stem wood only, stem wood with the bark, all the aboveground parts of the tree and the whole tree. It was found that the traditional harvesting of stem wood with bark was causing mineral loss in the amount of 169.77 kg/ha for nitrogen, 17.10 kg/ha for phosphorus, 35.54 kg/ha for potassium, 165.70 kg/ha for calcium, 22.38 kg/ha for magnesium and 7.74 kg/ha for sodium. Increasing the level of utilisation to all aboveground parts of the tree, resulted in increased nutrient losses ranging from 22% for magnesium to 76% for potassium. Determination of mineral elements in the biomass of the stand and the upper soil layers enabled calculation of the rate of nutrient loss in relation to soil nutrient capital. Depending on the system of utilisation the percentages were: 4-8.2 for N, 6-13.3 for P, 13.1-35.1 for K, 24.3-38.4 for Mg and 80.3-178.4 for Ca.

Current status of woody biomass research in the United States Mid-South

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Keywords: woody biomass, feedstocks, assessments, Mid-South, transportation, willingness to harvest.

The use of wood to generate or synthetize alternative fuels has been of great interest in many regions of the globe. In the Southern United States, especially the Mid-South, the interest has been justified due to the region's extensive private forestland and need for stimulating the rural economy. State-level resource assessment needs have sparked research interest that has focused on the availability of woody biomass feedstocks. Numerous studies have not only assessed the physical inventories of

woody biomass in the region, but also examined the financial viability of new production systems as well as determined willingness of non-industrial private forests (NIPF) landowners and mill owners to provide feedstock to this emerging energy industry. Another pertinent issue has been the cost of recovering woody biomass from the forest and transporting it to a processing facility. This paper summarizes recent research on this topic pertinent to Mississippi as a representative state of the Mid-South region. Results suggest much research is needed to not only develop better assessments of physical woody biomass inventories, but also understand the needs of NIPF landowners and the dynamics of markets that already exist for mill waste. This understanding will aid policy makers as well as companies interested in developing new processing facilities in the region.

Some retrospective and prospective aspects of growth trends in relation to climate change in France

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Keywords: renewable energy, forest management, climate scenarios.

The governmental and European policy aims at raising the share of energy consumption produced from renewable resources to 20%. Accordingly, the intensification of forest management is promoted. However, successive storms, droughts and heat waves have questioned the classical management of production forests in France (Southwestern namely). In this context, the climate scenarios predictions, which all agree on enhanced drought in Southern Europe from 2050 onwards, adds a new complex interaction for predicting the future of production.

Our objectives were:
- Calibrate and evaluate a new process based model of managed forests using long term data sets (flux, growth and soil data);
- Analyse the potential effect of climate scenarios on productivity, water and carbon cycle in managed forests;
- Investigate the role of forest management on CO_2 flux and in situ carbon balance;
- Identify and quantify interactions between management and environment (soil type, climate);
- Implement the model over France at hourly time resolution according to:
  - A spatial factorial cross-sensitivity analysis (climate x soil x management): spin-up of 5-6 rotations under 4 climates at 86 grid points centered in forest regions;
  - Dynamic projections at 8 x 8 km and from 1970 to 2100.

From these numerical experiments, we conclude that Intensification for biomass production depletes the stand carbon balance (NEE) by forests. We evidenced a strong interactive climate-management effect on primary production and harvest production. The soil carbon is controlled by soil operations intensity and frequency and management effects are magnified in fertile sites but also under drier conditions. Finally, no future for production forests in most part of Southern Europe beyond 2070 could be envisioned according to this scenario (Arpege-A2).

Allometric equations for estimating dipterocarp forest biomass in the tropics of Southeast Asia

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Keywords: carbon stock, tropical forest, biomass expansion factor.

General allometric equations for specific forest types are required for the conversion of forest inventory measurements to local scale estimates of forest carbon stock. To determine the most appropriate predictor variables to produce a forest type-specific allometric equation, we examined Dipterocarp biomass and volume data from tropical forest in Indonesia and Malaysia, Southeast Asia. Predictor variables included diameter at breast height (D), combination of D and height (D2H) and stem volume (V). The data set contained 119 trees, with D ranging from 1.2 cm to 114.6 cm and H ranging from 1.9 m to 59.1 m. Examination of the model residuals of the forest type-specific equation (model A) indicated that using D alone as the predictor variable produced a stable relationship, but the inclusion of H as a second predictor variable increased the performance of the model, both for stem volume and biomass. The biomass expansion factor decreased with increasing D from 1.6 for D less than 10 cm to 1.2 for D more than 40 cm. We have therefore compared our model with two existing general allometric equations for tropical forests resulted that standard error increased consequently with increasing diameter.

Predicting shoot height of coppiced poplars - a comparison between a simple and a mixed effect linear height model

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Keywords: Populus, short rotation coppice, bioenergy.

Poplar (*Populus* sp.) is a fast-growing tree species of increasing interest to establish as short rotation coppice plantations for bioenergy in Sweden (10-15 year cutting cycles). After harvest, most poplar clones produce a large number of self-generated shootings. Volume or biomass models are usually based on total height (TH) and diameter at breast height (DBH). A function to predict shoot heights will therefore be useful. The objective of this study was to investigate if a linear mixed height model can improve height predictions compared to a simple model. Data of fifty shoots with observed DBH and TH in each of five harvested poplar stands in Skåne, South Sweden, was used.

The simple linear model was expressed as $TH = b_0 + b_1 DBH$, with transformation $\log(TH) = b_0 + b_{1*} \log(DBH)$. For calculations of the transformed models, the retransformation equation $TH=\exp(b_0)*DBH^{b1}$ was used. "Site" was the group level (random intercept and "slope") in the mixed effect model. The transformed simple model reduced the absolute bias by 3.2%, but with a small tendency to underestimate height (0.9 dm). However, the main effect was observed when selecting a linear mixed effect model, with absolute bias reduction from 9 dm down to 6 dm, resulting in a remarkable lower span between Min and Max values. A linear mixed model will give a reduction of absolute bias up to almost 30% compared to a simple linear model (Table).

Model		Bias dm	Abs Bias dm	Min	Max	% Abs Bias Improve-ment
Simple /Mixed	NT* /Log T**					
Simple	NT	0	9.4	-47.4	45.9	0 (ref)
Simple	Log T	-0.9	9.1	-48.6	30.7	3.2
Mixed effect	NT	0	6.6	-25.2	30.7	29.8
Mixed effect	Log T	-0.8	6.9	-32.9	24.6	26.6

*No Transformation **Log Transformation

Quantifying the global warming potential of CO_2 emissions from wood fuels

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Keywords: carbon pools, dead organic matter, soil carbon.

Recent studies have introduced the metric GWPbio, an indicator of the potential global warming impact of CO_2 emissions from biofuels. When a time horizon of 100 years was applied, the studies found the GWPbio of bioenergy from slow-growing forests to be significantly lower than the traditionally calculated GWP of CO_2 from fossil fuels. This result means that bioenergy is an attractive energy source from a climate mitigation perspective. The present paper provides an improved method for quantifying GWPbio. The method is based on a model of a forest stand that includes basic dynamics and interactions of the forest's multiple carbon pools, including harvest residues, other dead organic matter and soil carbon. Moreover, the baseline scenario (with no harvest) takes into account that a mature stand will usually continue to capture carbon if not harvested. With these methodological adjustments, the resulting GWPbio estimates are found to be two to three times as high as the estimates of GWPbio found in other studies, and also significantly higher than the GWP of fossil CO_2, when a 100-year time horizon is applied. Hence, the climate impact per unit of CO_2 emitted seems to be even higher for the combustion of slow-growing biomass than for the combustion of fossil carbon in a 100-year time frame.

Effect of initial planting density on standing biomass of pole-stage Scots pine stands

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Keywords: *Pinus sylvestris* L., stand density, unthinned stands, biomass allocation, allometric equations.

The choice of initial stand density and tree spacing is one of the most important decisions taken before establishment of a forest stand of any tree species. Stand density enables foresters to manage and control the processes which occur during stand growth and development. The control of stand density is a crucial tool useful in accomplishing the key aims of forestry – to increase total productivity of forest stands and timber production with the highest technical quality. Results of many studies of economically important species grown at variable stand densities, have allowed us to recognize the influence of initial stand density on standing biomass in managed stands. However, little is known about the influence of stand density on biomass allocation and accumulation in unthinned stands.

The specific objectives of this study were (1) to develop allometric equations for predicting aboveground stand biomass and (2) to determine how above- and belowground biomass vary with initial stand density.

The study was conducted in the Siemianice Experimental Forest (51°14.87'N, 18°06.35'E, elevation 150 m). The stands were established in the spring 1974 where two-year-old Scots pine seedlings were planted in nine different spacings (stand densities varied from 2500 to 20833 trees/ha). From the onset of the experiment no cleanings or thinnings were done and stand density was reduced only as a result of natural mortality. In 2003 we harvested 8-9 trees that represented the range of DBH in each spacing treatment. In total we harvested 74 model trees (aboveground biomass) and divided them into biomass components. All organs were weighed in the field to obtain fresh biomass. Based on water content in samples taken from the model trees we determined their dry biomass. To assess the aboveground standing biomass we developed a set of allometric equations (stand-specific) and used them to calculate tree biomass per stand area. The belowground biomass of Scots pine stands were calculated based on root excavation from soil pits.

We found that initial stand density had a clear effect on natural tree mortality, mean tree DBH and total basal area. The total aboveground biomass ranged from 108 Mg/ha to 127 Mg/ha and was not related with initial stand density. The total belowground biomass ranged from 23 Mg/ha to 54 Mg/ha and decreased with increasing initial stand density. When initial stand density increases the total Scots pine stand biomass decreases.

Dynamics of Spruce and Pine Market Integration in Sweden

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Keywords: spruce and pine sawlogs, spatial price integration, structural break, causality.

The sawmilling industry holds a key role in the Swedish economy. It is the third-largest producer worldwide and largest exporter of sawn timber in Europe. The majority of sawmills are state-owned and the sawn timber which is utilized, consists mainly of Norwegian spruce (whitewood) and Scots pine (redwood). The extent to which the sawn market is integrated is a vital indicator of efficiency and performance of the Swedish economy's pricing system. Market integration can be referred to as the co-movement of price, and more generally, to the smooth transmission of price signals and information across spatially separated markets. In case a market is well integrated, the government can stabilize prices in one key market only and depend on arbitrage to produce the comparable outcome in other markets. With the avoidance of duplication of intervention, price stabilization cost can be reduced significantly. A weak degree of market integration more often than not results in incomplete price transmissions which can arise due to trade and other policies or transaction costs such as poor transport and communication infrastructure. This state of affairs can distort production and marketing decisions which will eventually lead to a misallocation of resources and undermine the potential for economic growth. To evaluate the performance of the spruce and pine market and to assist government interventions, knowledge of the degree of spatial market integration is of utmost relevance.

The paper thus attempts to evaluate the order of market integration in three Swedish regions such as Central, Northern and Southern ones. Quarterly data of delivery prices are employed over the period 1999Q1-2012Q4. Various unit root and cointegration tests have been computed. The variables are found to be integrated of first order and cointegrated, especially after controlling for a structural break. This lends support to the Law of One Price (LOP). However, the effects of structural shocks on forestry are arguably significant and these are controlled while performing a vector error-correction mechanism (VECM)-based Granger-causality test. Bi-directional causality between the Northern and Central markets is uncovered in the short-run. In the long-run, similar causal effect is detected between Northern and Southern markets whilst the Central market emerges as the price leader. Further investigation is carried out using variance decompositions and impulse response functions and these approaches also tend to confirm the existence of a single market well as price interdependence among markets. Aggregation at regional, national or international levels is often unavoidable. Since the market for spruce and pine is integrated, long-run aggregate market analysis is feasible. Moreover, the causality results have shed light on the process of price formation across regions and could be used in forecasting. Since the Central market is acting as the price leader, spruce and pine prices can be used to predict future prices in the Northern and Southern markets. Such knowledge can also be helpful in designing a price stabilization programme whereby policies affecting the Central market will affect other markets and not vice versa. In essence, market integration analysis can assist policy makers in efficient long-term decision making.

Forest Products Exports and Economic Growth: Evidence from Rich Countries

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Keywords: forest product exports, economic growth, panel DOLS.

Forest resources have been a major source for economic development for many states. They provide not only wood, wild foods, medicines, carbon dioxide storage, and landscape beauty, but additionally contribute by stimulating foreign exchange earnings, employment and economic growth. Forests indeed epitomize a productive asset which can be employed as a means for attaining national development goals, including equity, stability, investment and growth. The question of whether there is a causal relationship between forest product exports and economic growth has vital implications for policy-makers in enacting proper development strategies. For instance, the forest industry utilizes mainly renewable materials and manufactures recyclable products. Forestry therefore plays an important role for adhering to climate and environmental norms while designing economic development policies.

The paper attempts to examine the forest product export-led growth hypothesis for 23 rich countries over the period of 1970-2011. Together with several time-series unit root tests, three generations of panel unit root and cointegration tests are applied. Both series are found to be I(1) cointegrated especially after controlling for cross-sectional dependence. A panel causality test is conducted using the least squares with dummy variables bias-corrected. A unidirectional causality from forest product exports to economic growth is found in the short-run and a bi-directional causality is uncovered in the long-run. Moreover using a dynamic OLS, a 1% rise in forest product exports causes a 0.001% rise in economic growth in the long-run for the whole panel.

These findings have significant implications for policymakers in assisting them to make projections and implementing natural resource and forest policies. Bi-directional causality is found, implying a virtuous circle between forest product exports and economic growth. Natural resource conservation policies with regard to forest products can inhibit economic growth. Forest products exports are found to have a positive impact on GDP in the long-run which emphasizes the key role of the forest industry in driving economic growth for the rich economies. It is therefore imperative for the rich economies to sustain their forest areas and support their forestry.

Tree species identification and estimation of wood biomass at the forest stand level using multi-temporal RapidEye Data

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Keywords: wood biomass estimation, tree species identification, RapidEye, multi-temporal, Maximum Likelihood Classification, Pomerania.

Above-ground woody biomass is central information for many stakeholders like foresty or agricultural companies, environmental organisations, institutions and decision-makers. Within the framework of "Forseen POMERANIA", a German-Polish EU INTERREG IVa project, started in 2011, remote sensing data from Euroregion POMERANIA shall be used to derive such information and provide it in a publicly accessible biomass information system. The objective of this study is to estimate overall wood biomass in the study area as well as other relevant forest parameters, for example the tree species composition. In order to achive this, remote sensing data of different scales (marcro-, meso-, microscale) are connected to terrestrial datasets. Primarily, the focus is on the multispectral satellite system RapidEye. The RapidEye satellite system has a comparatively high spatial (5 m), spectral (5 bands) and temporal resolution (1 day), which allows estimation of tree species and wood biomass at the forest stand level.

The approach is based on sampling and allows the direct combination of data with measurement units such as forest inventory plot data and multi-temporal satellite remote sensing data. In addition to the RapidEye data, forest inventory data and a forest management database ("Datenspeicher Wald 2") were used as terrestrial references. By linking up the terrestrial reference data and RapidEye data, several classification maps for timber stocks and tree species are produced. The applied classification method is the traditional pixel-based Maximum Likelihood Method.

For tree species classification, a mono-temporal as well as a multi-temporal approach were used. As a result of the mono-temporal approach 5 different tree species (classes) could be distinguished with sufficient accuracy. The overall accuracy of all classes was found to be 81.3% for an area of about 4500 km^2. For the multi-temporal approach which considered significant phenological stages, eight tree species could be distinguished with sufficient accuracy. The overall accuracy was still 60.4% for an area of 1500 km^2.

As results for the estimation of wood biomass, two categorical growing stock maps with four timber stock classes and three tree classes for the dominating species pine, beech and oak were derived. The first growing stock map produced for an area of 625 km^2 (single RapidEye scene) has an overall accuracy of 75.4%. In the second growing stock map covering a larger area of 4500 km^2 (using 18 mosaiced RapidEye scenes), overall accuracy was reduced to 54.2%.

The final objective was the determination of growing stock at the stand polygon level. The result is an accurate and detailed growing stock map, which contains information on growing stock per hectare (m^3/ha) and absolute growing stock (m^3) for each stand polygon. The values are given in tabular form and can be added to forest inventory or management databases. Therefore it was possible to determine the growing stock of approximately 12,000 stand polygons by satellite remote sensing. The validation of the growing stock map showed a mean deviation of 23% per stand polygon and growing stock (m^3/ha).

Based on a comparison of different terrestrial and remote sensing methods for wood biomass estimation, recommendations on their practical applications are provided. The results of this project, especially maps, are provided to stakeholders and practicioners through web-based geoservices.

Forest management strategies responding to increasing demand for energy wood in five European countries

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Keywords: forest biomass, energy wood, forest management, stakeholder interviews.

Wood from forests is one of the resources pointed out by the EU for achievement of a Europe-wide 20% share of renewable energy by the year 2020. Due to different forest resources and management practices, the contribution of forest-based energy to achievement of the national renewable energy targets will vary from country to country. This study aims at investigating and analyzing forest management strategies responding to increasing demands for the use of energy wood in Finland, Germany, Norway, Slovenia and Spain. The study is based on analysis of published national reports and on interviews of experts and stakeholders. It was found that in all five countries, energy wood provision is currently largely considered as a side objective of timber production goals. In the future, energy wood production may strengthen its position as a priority forest management goal, depending on the weight that will be assigned to the forests' climate change miti-

gation function, relative to other benefits provided by forests in the respective countries. Forest management activities like choice of tree species, planting density, thinning intensities and type of harvesting methods are likely to be influenced and develop differently in the various countries included in the analysis.

Assessment of above ground biomass and macroelement contents – Establishing single tree allometric equations for oak in northeast German lowlands

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Keywords: randomized branch sampling, macronutrients, above ground biomass, oak, allometric equation.

Soil nutrient balances are of major importance for the productivity of ecosystems. The utilization of products obtained from them, i.e. harvesting of renewable raw materials like herbaceous or woody biomass, leads to differing degrees of nutrient removal. Due to the discussion on more efficient ways of using forest biomass, especially full tree logging and harvesting of wood residues, there is growing interest in measuring nutrient removals. The present work aims to establish allometric equations for the oak species *Quercus petraea*, to estimate its above ground biomass and macroelement contents. To take into account the uneven distribution of macroelements within the tree, the compartments leaves (1), twigs (2), branches (3), stemwood (4) and dead branches (5) were considered seperately. Special attention has been given to cover a large range of tree dimensions from 8 cm to 40 cm DBH and 7.1 m to 30.7 m height. The 10 selected oaks were sampled by applying the Randomized Branch Sampling (RBS) method. In total, 117 samples were analysed for C, N and water content. 50 of these samples were additionally analysed for their Ca, K, Mg, P and S contents. The resulting estimation models for above ground biomass and macroelement contents use DBH and height as input variables.

Determination of the aboveground biomass of Scots pine (*Pinus sylvestris* L.) with use of airborne and terrestrial laser scanning

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Keywords: airborne laser scanning, terrestrial laser scanning, forest biomass, ForseenPOMERANIA.

Research plots were established on the Drawno Forest District (north-western Poland) in 60 Scots pine stands (*Pinus sylvestris* L.) that represent 3 age groups (3rd, 4th and 5th age class) with varying tree density (from ca 400 up to more than 900 trees per hectare). For 10 of these sample plots, 10 model trees were chosen that represent the range of DBH variation (including height of trees). Model trees were scanned by terrestrial laser scanner and precise 3D models were created. Then the model trees were felled and biomass was estimated for each fraction. In addition, a high resolution terrestrial laser scan was made in the middle of each research plot. The point clouds obtained were processed with tScan software that allows automatic calculation of basic biometric parameters (eg. diameter at any height, height and volume of trees) and quality-dimensional classification.

An aerial laser scan of the entire Drawno Forest District was also made with resolution of 4 points per square meter and, for some chosen areas, with resolution of 16-25 points per square meter. GPS and a total station were used to measure coordinates of sample plot corners and location of model trees. These data were used for the selection of a point cloud of airborne laser scans that represent research plots and model trees. Point clouds were analysed using TIFFS software, with automatic filtration of point clouds to DTM, DSM and nDSM (OHM). Segmentation of tree crowns was conducted to automatically determine basic parameters such as: number of trees, area of crown projection, coordinates of crown top, radius of crown, volume of crown and height of tree. Analyses of model tree point clouds, describing height of the base of crown and length of crown, were manually done in FUSION software. These extracted parameters of model trees, combined with measured biomass of every fraction of model trees, were used to construct mathematical models that allowed estimation of the biomass of every tree from aerial laser scanning. This also allowed estimation of forest biomass at the stand and landscape scales.

The work presented was created as part of the international project: "Development of trans-border decision support system for remote and model assessment of forest dendromass in Pomerania Region" (acronym: ForseenPOMERANIA) co-financed by the European Union in Operational Programme Objective 3, Cross-Border Programme for Territorial Co-operation 2007-2013 Mecklenburg-Western Pomerania, Brandenburg and Poland (Region Zachodniopomorskie) (Interreg IVA).

Influence of airborne LiDAR data with different resolutions on the estimation of forest stand and single tree parameters

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Keywords: airborne laser scanning, lidar, spatial resolution.

Airborne laser scanning as a tool to record forest structure is becoming more and more popular. It is possible to produce digital terrain and surface models with a high spatial resolution and extract vegetation height by differentiating both models. Depending on the requirements, different forestry parameters at the stand and single tree levels, can be provided to the local managers. For example, it is possible to estimate stand and single tree height or merchantable wood volume. In the current study three lidar data sets with approximately 1, 8 and 25 points/m^2 were used to illustrate the influence of the resolution on the accuracy of height estimation. The study area is located in the northeast of Germany near Eberswalde and has a size of 60 km^2. To verify the lidar data a forest stock inventory was carried out at the same time. For this purpose an inventory raster of 400 by 500 m was used to install sample plots with a radius of 12 m. The DBH and positions of all trees greater than 7 cm were measured. Additionally the heights of selected trees were recorded. Thus it was possible to calculate stand values for validation purposes.

Assessment of allometric equations for estimating aboveground tree biomass in Indonesian tropical forests

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Keywords: allometry, aboveground biomass, carbon accounting, climate change, tropical forest.

A capability for biomass accounting is required to assess the condition of forest ecosystem, to understand the dynamics of organic matter cycling in the forest, and to predict carbon sequestration and potential impacts resulting from climate change and land use change. The accuracy of biomass estimates can be improved by applying allometric equations which relate biomass with easily measured variables. In this study, we examined species- and site-specific allometric equations to predict aboveground tree biomass developed for several tree species and ecosystem types in Indonesia. There was a high variation of tree biomass estimates among forest ecosystem types. A variety in tree biomass estimates was also found within ecosystem type and individual species among sites. The reliability of biomass estimates will increase with an increase in level of site specificity of allometric equations used to convert site-level forest inventory data into biomass. Application of the

species- and site-specific allometric equations should enable more accurate estimates of biomass and carbon sequestration in Indonesian forests. These results will support the national carbon accounting system necessary in the development of REDD+ strategies for climate change mitigation and will encourage transparency and consistency in the estimation of greenhouse gas emissions for the land-based sector.

Estimating tree biomass in the miombo woodlands and associated land use systems in Kasungu, Malawi

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Keywords: allometric equations, biomass estimates, carbon stocks, species diversity, Southern Africa.

There is growing demand for information on biomass estimates of trees inside and outside forest boundaries because of their contribution to climate change mitigation. Allometric equations which relate easy-to-measure tree parameters with tree mass have been proposed for rapid assessments of aboveground tree biomass (AGB) and these can be used without cutting down trees. Although universal scaling relationships exist, the variation in tree characteristics among ecological conditions requires that appropriate equations be developed at a local scale to enhance their accuracy. This study evaluated the appropriateness of published biomass equations developed in the miombo countries for estimating tree biomass in Malawi. The generalized biomass equation selected was used to estimate AGB of trees inventoried at Kasungu. At the 53 locations covering 19 farms and 34 woodlands, 508 trees were inventoried over a surveyed area of 4.8 ha. A total of 49 species were documented across the study site, indicating a rich species diversity (Shannon diversity index, H' = 3.4). Tree density in the plots ranged from 11 to 1367 individuals ha^{-1} with a mean of 101 (median 55) trees ha^{-1}. Plot basal area varied from <1 to 3.7 m^2 ha^{-1}, with a mean of 0.3 (SD 0.6) m^2 ha^{-1}. While large trees (diameter at breast height, D>20 cm) hold most of the biomass (47%), such trees were scarce in the landscape (1% of the total tree population). Biomass estimates in plots ranged from <1 to over 25 Mg ha^{-1}, with a mean of 1.2 (SE 0.5) Mg ha^{-1}. Representative landscape AGB totaled 57 Mg (11.3 Mg ha-1). The top three species in terms of biomass were Mangifera indica, Eucalyptus spp. and Uapaca kirkiana, which when combined contributed to 54.8% of the total AGB. Woody biomass was disproportionally distributed across the landscape, with relatively high biomass (>5 Mg ha^{-1}) in some farmed plots, and low or no biomass in woodlands and transition plots. These low biomass plots areas are mainly farmed areas and woodlands with an earlier high level of disturbance, and shrub land with low biomass trees. This study provides a useful benchmark for the miombo woodlands and associated farming areas against which future estimates can be compared, and sets a baseline for calculating changes in carbon stocks over time, especially in areas experiencing noticeable loss of woody cover through clearing for agriculture and harvesting for fuel wood.

Application of a Regional Biomass Model to estimate forest biomass in the POMERANIA region

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Keywords: biomass, remote sensing, regional biomass model, net primary production, PAR.

Information on the current and future productivity of forests is important for a wide range of stakeholders. Within the scope of the project "ForseenPOMERANIA", one objective was the development of a model capable of estimating above-ground woody biomass production in the Pomerania region spanning about 38,000 km^2 from northeastern Germany to northwestern Poland. This model should not only assess the current status but also produce reliable information on future system behavior under changing environmental conditions.

To meet these demands, ForseenPOMERANIA commissioned DELPHI IMM GmbH to develop a model framework for forest biomass estimation based on data from various remote sensing sources. The "Regional Biomass Model" (RBM) compiled by Richters (2005) was chosen as the conceptual basis which should be adapted to the specific needs and data in the Pomerania region. The RBM estimates Net Primary Productivity (NPP) for different vegetation types based on photosynthetically active radiation (PAR) and ecosystem information summarized in a conversion factor ε. NPP thus depends on (i) the ratio between the amount of PAR absorbed by plants and total PAR, and (ii) the conversion factor which expresses the biophysical ability of an ecosystem to produce organic dry matter from a given unit of energy input. The presentation will give an introduction to the steps necessary to quantify the factors which modify PAR and explain the sub-models necessary for including the influence of soil, temperature, and water availability on the conversion factor ε. Remote sensing products used for deriving required input data and relevant estimation routines to estimate missing values will be presented. Regional data on forest types, standing volume, and age as compiled in forestry data bases are used as corrective information and for model evaluation. Finally, preliminary results of the application of the modified RBM to the Pomerania region will be shown.

Understanding Blue Carbon: Precision and Accuracy of Methodology Used in Estimating Below-Ground Biomass In Mangrove Forests

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Key words: REDD+, mangroves, root biomass, methodology, allometry.

The increasing pressure of global warming and climate change issues has led to equally increased interest in the carbon sequestration potential of mangroves. Large carbon stocks in mangrove forests are an incentive for the inclusion of mangroves in carbon market schemes under the Reducing Emissions from Deforestation and forest Degradation (REDD+) program. Precise measurement of carbon still proves to be a problem in mangrove forestry with no standardized methodology to estimate below-ground biomass, which contributes about half of the vegetative carbon sequestered by the forests. The present study aimed at testing the precision and accuracy of three commonly used techniques viz. coring, excavation and trench sampling of *Ceriops tagal* (Perr.) C.B. Robinson trees and *Avicennia marina* (Forsks) Vierh. seedlings. The data generated were subjected to allometric scaling based on fractal law and pipe model theory. The coring method yielded a mean of 19.1±10.4 t ha^{-1} while trench sampling gave slightly lower values of 16.9±13.6 t ha^{-1}. The excavation method gave significant relationships between above-ground and below-ground biomass for *C. tagal* (R^2=0.95) trees and *A. marina* seedlings (R^2=0.83), with most of the tree biomass allocated to the roots. The top 40 cm depth contained 85% of total root biomass using the coring method and 78% of total biomass for the trench method. We observed decreasing trends of root biomass radiating from the tree base with increasing depth, confirming the assumption of a radially rapidly decreasing distribution of roots around the tree base. The coring method showed a stronger relationship with the excavation method (R^2=0.95). There was however no significant difference between the trench and coring methods (p=>0.05). Testing pipe model theory predictions gave positive and significant results for the different diameter variables used and different plant components. Testing fractal law predictions, however, showed deviations from predicted values in scaling of the different plant components, indicating species-specific effects of mangroves. These deviations also seemed to differ across ages. This study was a step towards improving the quantification of sequestered carbon so as to ensure equity in future payments of carbon credits.

Biomass of Tree Layer and Regeneration in Xerothermic Oak Ecosystem (SCI "Zapadna Stara Planina i Predbalkan", Bulgaria)

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Keywords: biomass, tree layer, oak forest.

Xerothermic oak ecosystems are a part of the autochthonic vegetation of Bulgaria. The xerothermic oak vegetation has significant environmental, economic and social importance in Bulgaria. These facts underlie the announcement of xerothermic oak forests as protected and also as an endangered habitat (Biological Diversity Act, Annex 1; The Red Data Book of the Republic of Bulgaria, vol. 3). The forest ecosystem studied, *Quercus frainetto-Quercus cerris* belongs to habitat G1.768 Moesio-Danubian termophilous oak forest (EUNIS) or habitat 91M0 Pannonian-Balkanic turkey oak-sessile oak forests (Natura 2000).

The underground and aboveground biomass of the tree layer and young tree saplings and regeneration in a representative *Quercus frainetto-Quercus cerris* ecosystem from SCI "Zapadna Stara Planina i Predbalkan" was determined. The study was conducted in a semi-stationary sampling plot located in the investigated forest area. The classical methods for studying biomass (Rodin and Bazilevich 1968, Lyubenova 2009) were used. The biomass structure of the model trees was determined by the weight ratio of the fractions – leaves, annual branches, perennial branches, wood, bark and roots of different mean diameter. The grade of regeneration of the forest ecosystem was also determined. The data for biomass of each fraction was compared to the others. The data obtained in this study was also compared to the results of previous studies and the values in classical scales. The ecological status of the forest ecosystem studied and its functional efficiency was discussed based on the results obtained, the data for health status of xerothermic oak vegetation in SCI "Zapadna Stara Planina i Predbalkan" and climate data for the region.

Results of the research carried out are important for forest monitoring, for further utilization of oak communities and for preservation of xerothermic oak ecosystems in areas protected by Nature 2000 in Bulgaria. They can also be incorporated into the existing forest ecosystems database.

Inter and intra specific variation of carbon sequestration in mangroves

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Keywords: RNA: DNA ratio, carbon sequestration, NOx uptake, Sundarban.

Mangroves dominate the majority of the world's tropical and subtropical coastline, forming 15 million hectares of forest worldwide and accounting for 0.7% of the tropical forest area that provides habitat for rich biodiversity. It is highly productive, fixing and storing significant amounts of carbon. Although mangrove ecosystems are rich in carbon, they are, paradoxically, often nutrient poor. The objective of this study was to find how mangrove maintains high productivity in spite of the nutrient poor status of the sediment. Seasonal variations of carbon sequestration in different mangrove species were studied in relation to the cellular nutrient content, sediment nutrient concentration along with RNA/DNA ratio as a growth indicator in the Sundarban mangrove ecosystem. Results showed a positive correlation between carbon sequestration and RNA: DNA ratios. RNA: DNA ratios were higher in the rapidly growing mangroves *A. marina* and *A. alba* than *A. rotundifolia* and *B. gymnorrhiza* with lower C: N and C: P ratios. Inter-specific variations in carbon sequestration were associated with N enrichment, but intra-specific differences showed more P enrichment relative to N. Mangroves maintain high productivity through nutrient conservation and leaf uptake of atmospheric NOx supplemented the limited supply of sediment nitrogen.

Long term monitoring of carbon stocks and fluxes of a mixed deciduous forest in East Germany

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Keywords: carbon stocks, soil respiration, tree growth, tree water use, net ecosystem carbon exchange.

Long term observational data of ecosystem stocks and fluxes are required to understand the present state and predict future behavior of the carbon cycle as well as to calculate regional greenhouse gas emission budgets. Deciduous forests are particularly vulnerable to warming and drought associated with climate change, with the consequent C cycle perturbations. As part of the European monitoring network ICOS and the German long-term research project TERENO, we established an experimental station for long-term measurements in a protected area of a mixed deciduous forest (Hohes Holz, 51.88215 N, 11.334407 E) close to Magdeburg, Germany.

Biomass production, carbon (C) and nitrogen (N) storage and allocation are monitored periodically through field measurements of the different forest biomass components (i.e., stem growth with band dendrometers; foliar production and litterfall with litter traps and digital photography; understory biomass with LAI-2000, digital photography and harvesting) and soil C and N analyses. Changes in soil CO2 fluxes due to environmental conditions (temperature, moisture), litterfall decay and bio-

mass production are also monitored at hourly and seasonal time scales. In addition, tree water use of different species and age classes and, therefore, its influence on biomass production is investigated by simultaneous measurements of tree transpiration and water storage with sap flow sensors and high sensitive dendrometers.

Canopy LAI resulted very high in the stand, so light availability was limited for the understory vegetation, which showed a negative spatial correlation with the canopy distribution. The annual litterfall inputs to the soil were 169.8±4.5 g m^{-2} of C and 3.7±0.1 g m^{-2} of N, whereas the biomass production of annual grasses and understory vegetation was 15.2±2.9 g m^{-2} of C and 1.0±0.2 g m^{-2} of N. Seasonal soil respiration in the stand ranged between 0.41±0.1 and 5.9±0.6 µmol of CO_2 m^{-2} s^{-1}. Daily and seasonal oscillations were mainly driven by soil temperature and the occurrence of rain events, whereas the spatial variability was determined by litterfall inputs and understory productivity. These data will be complemented by Eddy Covariance measurements of net ecosystem production and ecosystem water balance.

Forest Biomass for bioenergy: opportunities and constraints for governance context

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Keywords: bioenergy, forest biomass sustainability, carbon policy and accounting.

In recent years, increased use of forest biomass for energy purposes, predominantly spurred by policy incentives for reduction of fossil fuel use and greenhouse gas emissions as well as by efforts from the forestry sector to diversify products and increase value from the forests, has again brought much attention to this issue (Lamers et al. 2013).

The globe has approximately 13,200 Mha of land, of which around 1,600 Mha is used for cropping[1]. The IPCC special report on renewable energy[2] estimates that 780 Mha of land are available for bioenergy production without irrigation worldwide, mostly consisting of unprotected grassland and woodland found in Africa (35%), Latin America (21%), North America (16%) and Europe (14%), having the potential to deliver bioenergy amounting to more than 4000 Mtoe.

In national greenhouse gas inventories the LULUCF sector has a positive and significant impact on the EU's greenhouse gas emissions. The sector removes the equivalent of 9% of greenhouse gases emitted in other parts of the economy (COM(2012) 595 final). An international agreement on revised accounting rules for LULUCF for the second commitment period under the Kyoto Protocol post 2012 was achieved at the 17th Conference of the Parties to the UNFCCC ("COP17") in Durban in December 2011. In particular accounting for forest management activities, including harvested wood products, will be mandatory and definitions for natural disturbances and "wetland drainage and rewetting" have been established COM(2012) 595 final).

Directive 2009/28/EC on the promotion of the use of energy from renewable sources (the "Renewable Energy Directive") established mandatory targets to be achieved by 2020 for a 20% overall share

[1] WWF/Ecofys 2011 - The Energy Report, available here: http://www.ecofys.com/com/publications/The Energy-Report-Ecofys.htm.
[2] Available at http://srren.ipcc-wg3.de/report.

of renewable energy in the EU and a 10% share for renewable energy in the transport sector. At the same time, an amendment was adopted to Directive 98/70/EC1 ("the Fuel Quality Directive") which introduced a mandatory target to achieve by 2020 a 6% reduction in the greenhouse gas intensity of fuels used in road transport (http://ec.europa.eu/).

According to the Economist of 6 April 2013, which source of renewable energy is most important to the European Union? Solar power, perhaps? (Europe has three-quarters of the world's total installed capacity of solar photovoltaic energy.) Or wind? (Germany trebled its wind-power capacity in the past decade.) The answer is neither. By far the largest so-called renewable fuel used in Europe is wood. In its various forms, from sticks to pellets to sawdust, wood (or to use its fashionable name, biomass) accounts for about half of Europe's renewable-energy consumption. Unlike new solar or wind farms, power stations are already linked to the grid. Moreover, wood energy is not intermittent as is that produced from the sun and the wind: it does not require backup power at night, or on calm days. The EU wants to get 20% of its energy from renewable sources by 2020; it would miss this target by a country mile if it relied on solar and wind alone.

As to the aspect of sustainability, the issues of main concern are biodiversity conservation and carbon neutrality (Muys et al. 2013). Increased wood mobilization might offer opportunities for biodiversity conservation, with additional benefits in terms of fire prevention and climate change resilience, especially in southern regions. Concerning the carbon neutrality issue there was agreement that carbon balances for subsidized energy use of forest biomass should always be positive, when evaluated over sufficiently large time-and-space windows, and including the land use and the product phases of the life cycle. Concerning the sustainable yield question, intensive extraction of harvest residues and tree stumps can lead to nutrient depletion in the long term, but this risk needs site-specific consideration (Gobin et al 2011).

Forest bio-energy development holds good opportunities to mobilize the production potential of european forests, and to contribute to a more climate friendly, bio-based economy. However, this development also holds risks, such as the possible competition for feedstock with the traditional forest industry (EFI NEWS – Bart Muys-EFIMED). But current increment rates of European forests are 50% above the harvesting rates (Forest Europe 2011). So the challenge today is rather how to mobilize this forest biomass, which will essentially depend on trends in prices and market opportunities (Muys et al. 2013).

Quantifying biomass allocation patterns in Scots pine (*Pinus sylvestris* L.)

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Keywords: height and diameter growth, allometric coefficient, cluster analysis, forest development stages.

Scots pine is one of the most widely distributed species throughout Europe, occurring in the boreal forest as well as on relatively dry sites of the Mediterranean regions. In this context, it is of interest to study the influence of climatic factors, forest management and tree interactions on the biomass

allocation patterns of this species. The objective of this ongoing work is to develop a methodology to quantify the allocation principles in terms of height and diameter growth of Scots pine based on the allometric coefficient. We have used the observed allocation patterns to establish a typology for identifying exposure to different environmental factors and developmental stages. Cluster analyses were applied for developing this typology. We have studied annual height and diameter increment data from stem analyses of 55 dominant Scots pine trees from Järvselja and Vastseliina Forest in Estonia. Our results indicate significant growth and allocation patterns in response to environmental factors and developmental stages.

Measurement and assessment methods of forest aboveground biomass: A literature review and the challenges ahead

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Keywords: empirical, semi-empirical & theoretic models of tree aboveground biomass assessment, tree, stand and regional scales.

The measurement and assessment of tree, stand and regional aboveground biomass (bole, branches, and foliage), M, are required for evaluating bio-energy as well as bio-geochemicals such as carbon contained in biomass. The development and use of allometric equations is the standard methodology for the estimation of tree, plot, and regional aboveground biomass. Meta-analysis datasets classify empirical equations in loglinear (82.6%), nonlinear (12.0%), seemingly unrelated linear (3.9%) and seemingly unrelated nonlinear (1.5%) regression. A reported theoretical model requires further refinement before it can be recommended as an M assessment methodology. Flexible semi-empirical models based on shape-dimensional analysis and assuming a constant exponent value are being tested for single and complex forests with compatible tree M assessments. Diameter at breast height & at the bole base, canopy height & area and wood specific gravity are independent variables that individually or in combination explain M with deviations larger than 20% of the mean tree value.

At the plot or stand scale, biomass stocks remain poorly evaluated. The conventional methodology that expands tree M to forest stands is a grid of inventory plots with allometric equations fitting tree data. Uncertainties of more than one order of magnitude are identified by applying different off site allometric models. Tree or plot M can be interpolated at larger spatial scales by a variety of field measurements, environmental gradients and remote sensing techniques; such regional M assessments may have uncertainties larger than two orders of magnitude.

The combination of modern conventional allometric models with semi-empirical and theoretical methods improves tree and plot M evaluations. The interpolation of updated tree or plot M evaluations coupled with a variety of field techniques, environmental gradient approaches and remote sensing techniques must reduce biomass stock uncertainty at regional scales.

Evaluation of aboveground biomass of black alder

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Keywords: black alder, aboveground biomass, allocation.

The study presents results of investigation of the amount and structure of aboveground dry biomass components (wood and bark of stem, the branches, the leaves) for alder trees (*Alnus glutinosa* (L.) Gaertn.).

The empirical data was collected in 56 stands of black alder ranging in age from 6 to 96 years, growing in the Sandomierska Valley situated in south-eastern Poland. The research material was the result of direct measurements of biomass, performed on 168 sample trees. Tree diameter at breast height ranged from 2.8 to 46.6 cm, whereas height ranged from 4.2 to 33.5 m.

The average total aboveground biomass of sample trees was 304.3±20.3 kg. Among 10-year age classes it varied from 4.4±0.6 kg (youngest age class Ia) to 689.8±67.1 kg (oldest age class Va). Variability of tree biomass for all sampled trees was 86.7%, whereas within age classes it varied between 23.4% and 76.5%. The dominant component in the aboveground biomass was stem wood. Its share ranged from 52.8±1.9% for the youngest trees to 79.8%±0.6% for the oldest ones. The average share of bark was 11.6±0.1% and wasn't related to age of trees. The share of branches was on average 10.9±0.4%, while within the individual age classes it varied from 22.4±1.6% (age class Ia) to 8.4±0.6% (age class Va). The smallest part of the aboveground biomass of trees, which strongly depends on the age of the trees, was the fraction of leaves. For the youngest trees the share of leaves was on average 13.1±0.7% while for the oldest ones it was 1.1±0.1%. For each biomass component distinguished, an empirical equation was developed that describes its relationship to tree age.

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Environmental and genetic drivers of biomass allocation in woody plants

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In order to model forest biomass it is necessary to understand physiological, environmental and genetic factors affecting plant growth and allocation patterns to leaves, stems, roots and reproductive organs. It is also important to explore the role of other factors, such as plant size, density (competition), origin, treatments may affect biomass partitioning to these pools. The knowledge of biomass allocation is also crucial in predicting, modeling and accounting for local, regional and global scale carbon (C) partitioning. It is likely that insufficient knowledge in carbon storage and partitioning are responsible for discrepancies for the accuracy C fluxes.

We tested potential genetic component in biomass partitioning in several experiments with altitudinal Norway spruce (*Picea abies* (L.)H.Karst) and latitudinal Scots pine (*Pinus sylvestris* L.) populations. In all cases slow growing provenances originated from colder environments exhibited extensive fine roots production and significantly higher proportional dry mass partitioning to roots. It is likely that in cold temperature conditions, larger fraction of plant biomass is allocated to roots as a result of selection, phenotypic plasticity and restricted by photoperiod shorter aboveground growing season length. In such conditions larger root system is needed to compensate for low nutrient concentration, cycling rate and restricted soil solution movement.

It is less known whether forest biomass allocation in foliage, stems and roots varies systematically across temperature and precipitation gradients. In order to test this pattern we assembled a large dataset (with data from more than 6,300 stands in 61 countries) to test how biomass distributions in standing pools is affected by belowground resource limitation (low temperature and aridity). We determined that the root mass fraction is greater, and foliage smaller in colder climatic conditions - from ca. 27% at mean annual temperature (MAT) of -10 °C to less than 20% °C when MAT > 20 °C. Contrary to our initial assumptions allocation to foliage and roots was unrelated to aridity. Our findings can be useful for assessing for C sequestration and differences among climatic zones and in changing climatic conditions.

Target diameter models for black locust (*Robinia pseudoacacia* L.) growing on semi arid and arid zone afforestation in Turkey (Konya-Karapinar case study)

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Keywords: black locust, mass production, soil conservation, drought, afforestation.

The drought fundamentally influencing tree growth, creating unfavourable conditions in Central and East Anatolia of Turkey in recent years, has led to the more extensive use of Black Locust (*Robinia pseudoacacia* L.) in semi arid and arid zone afforestation. An intensive integrated research and development project has been carried out on the growth, primarily of black locust, on droughty soil conditions. The research revealed several factors influencing growth in afforested areas. The study presents a new, tending operation, growing space and target diameter model suitable for mass production and soil conservation. The simplicity of these practice harmony models may foster mass production, and development of management and soil conservation strategies for black locust afforestation areas in the Konya-Karapınar semi arid and arid zone in Turkey.

Tropical montane rainforests, a productivity and carbon cycle analysis

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Keywords: tropical montane rainforest, vegetation modeling, carbon balance.

Tropical montane rainforests (TMF) have received less scientific attention compared to tropical lowland forests, and scientific knowledge of forest dynamics and carbon exchange of these forests is still limited. However, they play an important role in the global carbon cycle. In this context, dynamic and process-based forest models offer useful tools to improve our understanding of forest dynamics and to evaluate the sensitivity of TMFs to changes of environmental factors. In this study we apply the process-based forest gap model FORMIND to a montane forest in South Ecuador.

The objective of this study is to investigate how carbon fluxes and pools (deadwood and soil) in tropical montane forests are affected by changes in evapotranspiration. Finally, we compare the productivity data (gross primary production and net primary production (GPP and NPP)) to existing measurements in other TMFs.

Our results show that compared to other tropical montane forests, we predict NPP quite well while underestimating soil respiration rates which influence net ecosystem carbon exchange. Our results for forest productivity for the Ecuadorian site are well within the ranges of other tropical montane forests.

Process based forest models are a promising tool for simulating detailed forest carbon cycles, which is particularly helpful in the absence of eddy covariance data.

Security of forest fuel supply versus uncertainty due to risks associated with climate change

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Keywords: climate change, bark beetle infestations, natural disturbances.

The future behavior and condition of forest ecosystems will be affected more and more by uncertainty, and research on methods including uncertainty in forest-planning models is of increasing relevance. The supply of forest fuel is connected with several specific risks, which are seldom considered explicitly in wood procurement planning. For Central Europe, storms and bark beetle infestations are the most significant causes of forest damage and have a massive impact on security of wood supply. The effects of climate change are assumed to be causing more frequent and intensive

storms, or a decreasing number of storms with an increased strength of the most severe ones. However, both assessments result in increased forest damage. Massive bark beetle outbreaks tend to follow storm damage, as there is plenty of breeding material available. Climate change is initiating a warmer and drier climate in Central Europe, with more severe droughts affecting progressively larger areas. Hence, bark beetle infestations could increase, especially in secondary spruce forests, in turn leading to a considerable increase of damaged wood volume.

Additionally, in Austria security of forest fuel supply is threatened by recent trends like restrictions on import, new raw material competitors (Wood Plastic Composites and Biomass to Liquid), or rising roundwood demand in yet exporting neighbor countries. Actually, providing wood turns out to be increasingly crucial and cost intensive, primarily because of the lacking inland supply. At the moment imports are filling the gap, but due to previously mentioned trends, future imports might be reduced.

In order to assess risks and their mid and long-term impacts on forest fuel supply a System Dynamics model of the Austrian wood supply was developed that includes a stochastic simulation (Monte Carlo simulation) of the main risk agents for Austrian forests, namely storms and bark beetle infestations. The model examines future annual cut for Austrian forests and evaluates wood supply security under different scenario assumptions. Following the physical wood supply from the standing tree to industry, the model integrates decisions of the forest owner, for example the decision to harvest a certain amount of wood (planned harvest) or the decision on the proportion of sawlogs, pulpwood and fuelwood (bucking). Planned and salvage harvest are separately calculated for two ownership categories (small-scale forests of less than 200 ha and forest enterprises) and two silvicultural measures (thinning and final cut). At the roundwood market, clearing of each period's supply and demand of roundwood assortments takes place under the premise of competition and substitution. Oversupply stays in the forest and if assortments have to be stored longer than one period, material deteriorates and wood quality properties change constantly. For each period, stochastic forest damage due to storm and bark beetle infestation is included by randomly sampling a value from a distribution function that best fits the cumulative risk-frequency curve for storm damage time series data resp. for bark beetle damage time series data. Exogenous variables are provided by linking with other econometric system dynamic models (FOHOW, EFSOS II). Forecast of global economy (e.g. GDP) and European forest based industry production and prices of forest based industry products are based on preliminary results of the European Forest Sector Outlook Study (EFSOS II: IPCC scenario A1). Changes in Austrian forest based industry production and Austrian wood price changes were provided by a System Dynamics Model of the Austrian Forest Sector (FOHOW).

The simulation is period-based, meaning that within one simulation iteration covering the time frame from 2010 to 2030, the stochastic values are generated separately for each period. The length of the period is one quarter of a year. Monte Carlo simulation could be restricted to 50 iterations, since standard deviation of average cut was then within a confidence interval of 95%.

Simulation results provide insights on probabilistic future wood supply security for sawlogs, pulpwood and energy wood. If Austria reaches the bioenergy targets of the National Renewable Energy Action Plan 2010 (base scenario), the wood based bioenergy share in 2020 would be 200 PJ and Austrian wood based bioenergy plants will face an unsecure supply of fuelwood with frequent undersupply situations. The climate change scenario assumes an increase in natural disturbances due to climate change impacts leading to a higher amount of salvage wood. Nevertheless, a counter-intuitive effect was observed. Even though salvaged wood volumes were clearly increasing, the supply situation worsened for all roundwood assortments and supply security decreased, since wood harvest was markedly reduced after damaged forest sites had been harvested.

An allometric model for improved estimation of carbon stocks in tropical mangrove forest

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Keywords: allometry, carbon stock, mangrove, India.

Mangroves compose 15 million hectares of forest worldwide, accounting for 0.7% of tropical forest area. It is highly productive, fixing and storing significant amounts of carbon. This study reports a general allometric model developed on the basis of observed above and below ground biomass, diameter at breast height, density and tree height, in the Sundarban mangrove forest at the land-ocean boundary of the Bay of Bengal, India. Variables for above ground biomass are in decreasing order of importance, breast height diameter (d), height (H) and wood density (ρ). Excellent agreement was obtained between the model and observed values ($r^2 = 0.994$, $p<0.001$). Results show that the live biomass in terms of forest biomass (AGB+BGB) and sediment held different carbon stocks (53.20±2.87 Mg C ha^{-1} versus 18.52±2.77 Mg C ha^{-1}) and increased by 18.89 and 5.94 Mg C ha^{-1} respectively, between 2009 and 2011. Sundarbans mangrove (4264 km^2), acting as a sink for atmospheric CO_2 sequesters 2.79 Tg C annually. The study found that carbon stocks were lower in the tropical mangrove forest than in the terrestrial tropical forest and also their annual increase exhibited faster turn over than the terrestrial forest. This allometric model could be used for the estimation of carbon stocks and annual increments in mangrove forests worldwide.

Below-ground biomass production and allometric relationships of eucalyptus coppice plantation in the highlands of Madagascar

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Keywords: short rotation, carbon sequestration, *Eucalyptus robusta*.

Short rotations of Eucalyptus plantations under a coppice regime are extensively managed for wood production in Madagascar. Nevertheless, little is known about their biomass production and partitioning and their potential in terms of carbon sequestration. Although above-ground biomass (AGB) can be estimated based on established allometric relations, below-ground (BGB) estimates are much

less common. Allometric equations were developed to estimate biomass of these plantations, mainly for the root components. Data from 9 *Eucalyptus robusta* stands (47-87 years of plantation age, 3-5 years of coppice-shoot age) were collected and analyzed. Dry weight of AGB components (leaves, branches and stems) were estimated as a function of basal area of all shoots per stump and dry weight for BGB components (mainly stump, coarse root (CR) and medium root (MR)) were estimated as a function of stump circumference. Biomass was then computed using allometric equations from stand inventory data. Stand biomass ranged from 102 to 130 Mg ha^{-1} with more than 77% contained in the BGB components; mainly in the stump and the CR. Equations herein could be applied to other Eucalyptus plantations with similar stand density and growing conditions, but more investigation is needed to understand biomass production and partitioning over time.

Linking eddy covariance data to a forest gap model: functional relationships and calibration

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Keywords: individual-based forest gap model, growth modeling, FORMIND, eddy covariance, carbon fluxes.

Forest gap-models simulate tree increments and carbon fluxes on large time scales to predict forest succession processes. The eddy-covariance method (EC) on the other hand, measures the net carbon exchange (NEE) between the atmosphere and biosphere for an ecosystem in half-hourly time steps. In our study, we use the measured EC data to evaluate the descriptions of processes used in the individual-based, forest gap model FORMIND. Our main objective is the optimization of parameters (e.g. water use efficiency) and the handling of functional relationships (e.g. light response curve, temperature reduction curve) that are commonly used in individual-based forest gap models.

FORMIND is applied on the Norwegian spruce monocultural forest at Wetzstein, Thuringian Forest, Germany, for the years 2003-2008. Inventory data allow a precise initialization of the model site. The FORMIND model uses functional relationships (e.g. gross primary production vs. temperature or photosynthetic active radiation) on an individual level, whereas the EC method measures ecophysiological responses at the ecosystem level. However, we assume that in homogeneous stands as in our study, functional relationships for both methods are comparable. The model is calibrated and cross-validated. In order to test the accuracy of the water module of our model, special attention is drawn to dry periods (e.g. the drought in 2003).

Results show that the functional relationships used in the FORMIND model are similar to those observed in the EC measurements. The temperature reduction curve is well reflected in the EC data and can be used for calibration of the model. The response of the water module to dry periods looks promising. Only the light response curve shows some functional deficits. With the results of our study, the model is calibrated against NEE. Carbon fluxes measured with the EC method and modeled with FORMIND are now well comparable, even under disturbances.

A stochastic algorithm for reconstructing tree height growth with stem analysis data

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Keywords: height growth models, mixed-effects models, growth rates, site productivity.

Tree growth is very important for understanding forest dynamics and forest management planning. Among the alternatives for measuring tree growth, stem analysis, a destructive technique that involves cutting trees, yields detailed information on each tree through time, such as diameter, taper, and total height. Several algorithms have been proposed to adjust the section-height-age information from stem analysis to obtain the real time series data of tree height. Here, we present a stochastic algorithm for reconstructing height-age data pairs from stem analysis data. We use stem analysis data from two deciduous broadleaves tree species (*Nothofagus alpina* and *N. obliqua*), an evergreen tree species (*N. dombeyi*) growing in the southern hemisphere, and a conifer (Douglas-fir) growing in the northern hemisphere for our analysis. We reconstruct pairs of height-age data for each species by the widely used Carmean algorithm and the one proposed here. For each species, we fit the Bertalanffy growth model using both data. A mixed-effects model strategy was used for fitting this non-linear model. Comparisons between the models generated from the two types of data consider confidence intervals of the estimated parameters, as well as a regression-based equivalence test within a non-parametric bootstrapping framework. Results showed that fitted height growth models obtained from these two algorithms are equivalent from a statistical point of view. However, the proposed algorithm is simpler than the Carmean one and most likely more accurate as well, and therefore we propose its use.

Simultaneous fit of biomass-component equations: statistical analysis and practical implications

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Keywords: biomass modelling, regression techniques, statistical inference.

Accurate quantification of tree biomass is key for estimating and understanding fiber production and carbon sequestration by trees, however, tree biomass is also influenced by several factors affecting tree growth. Given the highly intensive set of measurements needed for measuring tree biomass (*w*), we are forced to build statistical relationships between *w* and predictor variables that are easily recorded, e.g., tree diameter (*d*). Modelling of tree biomass components (i.e., stem, branches, and

foliage) has traditionally been carried out by fitting a set of independent equations for each component (and even for total biomass). However, this does not take into account that independent predictions for those components will not produce a total biomass prediction that is consistent with predictions given by a model for total biomass. This problem is known as the property of additivity. Here, we present a statistical analysis for ensuring the property of additivity among the components of tree biomass and total tree biomass for a dataset of *Nothofagus* species in southern Chile. Using a set of base-models for each biomass-component, we compare the statistical inference and the model performance of the following statistical strategies: seemingly unrelated regression (SUR), two-stage least squares (2SLS), weighted two-stage least squares (W2SLS), and three-stage least squares (3SLS). Comparisons among the strategies focused on the estimated covariance matrix of the residuals, and its implications for statistical inference. We also explore the difference in predictions at the stand level for all the modeling strategies.

Positioning of the role of remote sensing – radar for estimating forest biomass in the tropical environmental

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Keywords: biomass modeling, forest inventory, radar data, tropical forest, Eucalyptus stand.

Remote sensing - radar has been used for analysis of forest mapping and biomass estimates in the Brazilian territory. Two examples of SAR attributes for modeling of aboveground biomass of forest stands are presented: (1) the use of full-polarimetric attributes of PALSAR/ALOS for modeling in Amazonian tropical forest, considering the influence of the geomorphometric aspects on this radar response, (2) the use of polarimetric and interferometric airborne data (X_{HH} and full-polarimetric of P-band) for modeling in *Eucalyptus* sp. stands. In both cases, we first realized an analysis of forest structure variability through polarimetric signatures. Multivariate regression was used to integrate variables from polarimetric and/or interferometric radar attributes and field inventory. Considering the terrain aspects where the tropical forest is located, the most significant variables for biomass modeling were the Volumetric Scattering of Freeman-Durden target decomposition, Anisotropy, Relief Elevation, Slope, first and third Helicity components of the Touzi model. For the *Eucalyptus* biomass model, the Interferometry Height and Canopy Scattering Index variables were significant. A set of independent data from field inventory were generated for validation of each model, which indicated an error of ~12% to estimate the biomass, showing the importance of SAR attributes, focusing on models of natural and planted forest stock density.

Governing the expansion of short rotation coppices – a matter of infrastructure and personal attitude

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Keywords: agent-based modeling, bioenergy, policy instruments, decision making, investment theory.

Realizing the German transformation of the energy system to more decentralized forms of renewable energy supply ("Energiewende") in a sustainable way comes with multiple challenges. The identification and implementation of renewable energy pathways are of paramount importance here.

In this context, short rotation coppices (SRC) are a promising option to produce bioenergy. Despite general approval, the expansion of forest plantations is only gradually proceeding in Germany. While many studies investigate physiological aspects, ecological impacts and the economic efficiency of SRC, it remains an open question how to overcome existing restraints of land users. In our study, we examine the expansion of short rotation forestry given an institutional framework by explicitly modeling the decision-making process of land users.

We developed an agent-based ecological-economic model of land use change which enables us to focus on the distinctive features of choices between annual crops and perennial SRC. The latter investment decision is characterized by high uncertainty concerning yields and wood price development during the long cultivation period. The decisions are influenced by available infrastructures and policy instruments, the biophysical heterogeneity of the landscape. and last but not least, the personal risk attitude and time preferences of the land user.

Systemic analysis of the model under different relevant framework conditions, e.g. regional wood demand and access to infrastructures, provides insights on the appropriateness of existing policy instruments. Further, it serves as a tool to test and design innovative instruments. Our goal is to gain a mechanistic understanding of barriers to the expansion of SRC and to suggest governance options to overcome these.

Biomass Production and Carbon Storage Potential of Some Important Temperate Forest Types of Garhwal Himalaya

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Keywords: biomass expansion factor, growing stock, standing biomass.

The Growing Stock Volume Density (GSVD), Total standing Biomass Density (TBD) and Total Carbon Density (TCD) were assessed for fifteen temperate forests types situated between 1500 and 3000 m asl in Garhwal Himalaya. Five sample plots of 0.1 ha each were randomly laid out in each forest type (Total 5x15 =75 plots) to estimate the GSVD (by using appropriate volume tables and volume equations), which was then converted to live tree biomass (TBD = AGBD+BGBD) using various Biomass Expansion Factors (BEFs).The TCD was then calculated for each forest type by multiplying the TBD by appropriate carbon percentage for various species of respective forest types. The GSVD values for different forest types oscillated between 121.30 m^3/ha (for Moist Mixed Deciduous Forest) to 518.20 m^3/ha (for *Cedrus deodara* forest). Similarly, the lowest TBD value (271.34 ton/ha) was recorded for *Alnus nepalensis* forest and highest (651.70 ton/ha) for *Cedrus deodara* forest. However, the TCD values of the selected forest types ranged between 134.67 ton C/ha (*Alnus nepalensis* forest) to 299.78 ton C/ha (*Cedrus deodara* forest). It was observed that conifer-dominated forest types had higher biomass and carbon stocks than the broadleaved-dominated forest types, henceforth it is recommended that at higher altitudes the plantation silviculture of conifer-dominated forests should be encouraged as they have long rotation periods and thereby reduce Global Carbon emissions.

Efficiency of growing energy crops in Polissya region

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Keywords: Ukrainian Polissya, bioenergy, biomass, willow.

Ukrainian Polissya comprises a densely forested marshy plain. It has a temperate continental climate with warm humid summers and relatively mild, cloudy winters. The soils of Polissya are unproductive in terms of agriculture. Almost 120,000 hectares of agricultural lands in the Rivne region are not used today. However, this region is ideal for growing energy crops. Research areas for growing energy crops such as willow and poplar have been created in the Volyn (2007) and Rivne regions (2011).

Willow is one of the most profitable crops for biomass production, since 1 ton of energy willow replaces the 1.12 tons of straw, 460 kg of fossil coal, 800 kg of brown coal, 0.37 tons of fuel oil, or 510 m3 of natural gas. The cost of 1 ha of energy willow is about 1650-1900 EUR. The willow grows sufficiently fast, reducing the need for replanting to only once every 20 years. The first harvest takes place

in the third year of cultivation with a yield of 21 tons per ha per year. The development of bioenergy will reduce carbon emissions into the atmosphere. Results of energy crops showed that the development of bioenergy in Polissya has a great future.

The problem of withdrawal of chemical elements by utilisation of Scots pine (*Pinus sylvestris* L.) biomass

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Keywords: Scots pine, forest utilisation, chemical elements.

The utilisation of Scots pine stands in Poland is limited to timber assortments cut from the stem. Usually, along with timber, the bark is also removed from forest. Tops, branches, needles, cones and roots remain in the forest environment. Currently, due to increasing demand for biomass, especially for energy production, the possibilities of utilisation of other than stemwood parts of the tree are being assessed. The problem arising is, however, depletion of the forest environment by withdrawal of chemical elements. This is particularly important for Scots pine stands, that grow mostly on poor soils. The aim of the study was to determine chemical composition of different tree parts, as well as to model utilisation systems and their influence on mineral withdrawal from the forest environment.

In the Drawno forest district (north-west Poland), 20 sample plots were chosen in even-aged, 91 to 100 year old, pine stands. Plots size was 0.5 ha. On the plot area 15 model trees were chosen, that represented all the variety of dimensions. Model trees were cut down, measured, divided into parts and weighted. Dry mass was established in the laboratory. From each model tree, 9 samples were taken: thick wood and its bark, thin wood and its bark, dead branches, thick branches, thin branches, needles and cones. Samples were dried at 60 °C, crushed, mineralised in HNO3 and, via an ICP-OES, device, content of the following minerals was determined: K, Ca, Mg, P, Fe, Mn, Cu, Zn, Al and Ni. Without mineralisation, by using a LECO TruMac CNS device, the content of C, N and S was determined.

The content of chemical elements in different parts of the tree was calculated for all model trees and extended to whole sample areas. The results enabled modeling of different utilisation strategies to asses their impact on the forest environment.

Definition of forest biomass in Rivne region

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Keywords: agricultural lands, biomass, forest resources.

The area covered with forests in Rivne region is 729.3 thousand ha or 36.4% of the whole teritory. Most forests are located in the northern part of region. Also, in the northern part, agricultural lands are not completely used, which creates opportunities for cultivation of energy crops.

The volume of wood pulp produced, which can be used for energy purposes, is 60 thousand m^3 annually. The calorific value of 60 thousand m3 of biomass can replace up to 15 million cubic meters of natural gas. The average price of powdered biomass delivered to the warehouse is 220 UAH (25-30 USD). The annual economic effect of implementation of this project is 27 million UAH (more than 3 million USD).

Inter-annual variability in rainfall and biomass in a dry forest tree: evidence from Dendrochronology

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Keywords: tropical forests, tree rings, climate change.

Tropical forests are known to have distinct dry seasons, and seasonality in rainfall with variable degree of seasonality. Local climatic factors have been shown to affect growth of tropical dry forest trees. In a large part of the tropics El-Nino related variability in climate could potentially result in negative growth.

Tree rings produced as a result of annual growth is the best proxy to measure the influence of climate on growth. Several studies have established relationships between annual rainfall and growth by examining tree rings. We are presenting dynamics in growth and rate of assimilation of biomass in peninsular India based on the growth rings of Teak (*Tectona grandis*, L.f.). The dendro-climatic potential of teak is well established. We have exploited the growth response of trees to inter-annual monsoon variability to understand growth and biomass accumulation. We analyzed changes in biomass and related that to rainfall received. Implications of climate change are discussed.

Biomass Availability and Characterization in Trento Region

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Keywords: biomass, biofuels, bioeconomy, cellulose, lignin.

In the Italian Province of Trento, 63% of land area is wooded. The main source of biomass is represented by wood logs and residues, which account for 85%. Another 7% comes from agriculture and the remaining 8% comes from cleaning of the riverbeds. A large portion of biomass is still underused; only 10% of total available resources were converted into energy in 2010. To increase this share, a greater importance on local biomass resources for energy may come from wood waste streams, agricultural wastes, municipal solid wastes and manufacturing wastes.

Two fundamental aspects related to increasing biomass use are: (1) to enlarge and improve the basic knowledge on biomass availability, composition and properties; (2) to apply this knowledge for the most advanced and environmentally safe utilization.
These may have potential industrial implications in the field of technologies and processes for electrical and thermal energy generation, for future advanced and sustainable processing of biomass to biofuels and chemical feedstock.

To exploit the maximum potential of a bio-based economy, biomass can provide food, materials, chemicals and/or energy. For energetic purposes, using various transformation processes such as combustion, gasification, fermentation, liquefaction, and pyrolysis, biomass can be transformed into fuels, heat and/or electricity. These conversion methods use chemical, thermal and/or biological processes.

Each biomass resource has different physical and chemical characteristics in terms of calorific value, moisture and ash content, etc. that require appropriate conversion technologies for efficient utilization in energy production. The transformation route depends on the biomass characteristics. Therefore, an important step in the conversion systems is the evaluation of biomass availability and its energetic, physical and chemical characteristics. These properties characterize and determine biomass quality, potential applications and environmental problems related to its use as a fuel.

For all these purposes, biomass could be characterized knowing its:
(1) chemical composition (cellulose, lignin, hemicelluloses, extractives and inorganic content);
(2) chemical characteristics (carbon, hydrogen, oxygen, nitrogen, sulfur, and other elements content);
(3) physical parameters (density, moisture);
(4) proximate analysis data (fixed carbon, volatile compounds and ash content);
(5) energetic parameters (higher heat value - HHV, lower heat value - LHV).

Finally, to use biomass wisely and thoughtfully we need to have basic knowledge of its composition and structure and its basic properties. Chemical studies of biomass and its components may provide decisive factors not only for its applicability, but also for the economic practicability and environmental security of many processes involving biomass.

Soil enzyme activities in response to long-term organic matter manipulation in a temperate oak forest

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Keywords: detritus, decomposition, DIRT, litter manipulation, β-glucosidase, polyphenoloxidase.

Enzymes are considered to be a key soil component catalyzing important transformations related to decomposition and nutrient turnover, and their activity in soil can be used as a measure of soil health. Our study is a part of the Síkfőkút DIRT (Detritus Input and Removal Treatments) Project in a temperate deciduous forest in northern Hungary. DIRT treatments include doubling of leaf litter and woody debris inputs as well as removal of litter and trenching to prevent root inputs. Our objective was to examine soil polyphenoloxidase and β-glucosidase activities and to determine the effects of detrital manipulations on these dynamics after 10 years. Polyphenoloxidase activity was higher in soil by detritus removal treatments in the first years. Decomposition of fine roots affected polyphenoloxidase activity in the early years. β-Glucosidase activity differed significantly only in root removal treatments in the first years. After ten years we found that the litter additions did not affect enzyme activities, but removal of roots caused more significant decreases in enzyme activities. We conclude that plant-induced changes to soil enzyme activities are driven primarily by readily available, labile carbon provided by root turnover and root exudation rather than by aboveground detrital inputs.

Aboveground biomass allocation in pine trees occupying different biosocial positions

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Keywords: pine, biomass allocation, biosocial position.

The aim of this study was an assessment of the impact of tree biosocial position on the biomass of aboveground components of Scots pine (*Pinus sylvestris* L.).

Sixty-three representative sample trees (21 trees for each Kraft class I, II and III), were selected and harvested in homogeneous pine stands of the Chrzanów Forest District (southern Poland). The sample trees were separated into the following parts: stem, dead branches, living branches and shoots with needles and cones. The fresh weight of all above components was measured directly in the field. Fresh biomass of stem bark, stem wood, needles, cones and shoots were calculated on the basis of the share of these fractions in the representative samples. The dry weight of all components was calculated by multiplying the fresh weight by the ratio of dry and fresh biomass, obtained from the samples collected.

The results showed that average value of important tree biometric characteristics, along with the dry biomass of components differed substantially, according to biosocial position of trees. Stem wood was the dominant part of tree biomass, averaging 73.2% for class I and II and 76.9% for class III. The biomass of living branches was on average 10.7%, 8.4% and 6.4% for Kraft classes I, II and III, respectively. Bark was the next largest component, ranging from 5.6% to 7.8% among biosocial classes. The share of such fractions as stem wood, stem bark, living branches and shoots also differed among biosocial classes. The models developed, describing relationships between the branches and stem biomass, as well as branches and needles, indicated that trees of the same stem or needle biomass differed in biomass of branches, depending on their biosocial position in the stand.

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Aboveground biomass of Scots pine stands in western Poland

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Keywords: Biomass Expansion Factor, BEF, allometric equations, Scots pine, stand biomass.

The Drawno Forest district was chosen as a research area to demonstrate the possibility of large scale Scots pine forest biomass estimation. To account for probable differences in biomass allocation caused by different stand densities, biomass was estimated by cutting and weighting model trees representative of various stocking classes. The allometric equations were applied for biomass calculations using tree dbh and height as predictors. Based on those equations the biomass expansion factors were elaborated and used to calculate biomass of Scots pine stands for the study area. The formulas enable determination of stand biomass based on stand merchantable volume. Stand biomasses were calculated using data taken from the State Forestry database (SILP). The differences in biomass allocation between various stocking classes were tested.

RENO: A Computerized Decision Support System for the Economic Optimization of Forest Biomass Processing and Transport

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Keywords: optimization, simulation, economics, forest biomass, renewable energy.

A computerized model is presented to support operational decisions related to forest biomass recovery operations for energy purposes. In forest biomass operations there are several different types of technologies for comminution and transportation configurations. Among all available options, an important task for the analyst is to select the most cost-effective processing and transportation options given particular road characteristics and landing access in relation to the residue pile location. The Residue Evaluation and Network Optimization (RENO) software identifies the most cost effective combination of machines and methods to perform forest biomass processing and transportation operations. A solution procedure uses mixed-integer programming and deterministic discrete-event simulation to optimize the operations. The problem is solved as a directed network in which residue piles are source nodes and the biomass is transported through different arcs in the network that represent different processing and transportation options. RENO has special graphical user interface that allows the analyst to load spatial data (vector) with the residue pile location and road access. The spatial information allows the program to calculate cost as a function of the residue pile location and road characteristics (i.e. truck turn-around and turn-out spaces). The model is specially designed for operations in steep terrain. An ant colony heuristic is also implemented in the model for users who do not have linear programming solvers.

Biomass dynamics in silver birch stands on post-agricultural lands in Poland

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Keywords: secondary succession, afforestation, growth model, chronosequence.

As a result of socio-economic changes in Central and Eastern Europe there are many rural areas with abandoned farms. Frequently these areas are in places of rapid secondary succession of forest pioneer tree species, including primarily birch. The scale of this phenomenon is large in many regions; however, the precise dimension and ecological and economic consequences of this phenomenon are still unknown. The dry biomass of silver birch trees and the biomass of the individual tree components was determined in young successional stands of silver birch (*Betula pendula* Roth.) in central Poland. All the stands investigated originated from natural regeneration that started after the abandonment of farms. No silvicultural treatments had been performed at the time the sample material was collected. The total biomass of trees was estimated as the sum of all the tree components using the seemingly unrelated regression approach. Additionally, the biomass of litter fall and other non-woody plants was assessed. Due to the lack of data from remeasured plots, biomass dynamics was assessed for stands in various ages growing in similar conditions, i.e. forming artificial growth series (chronosequences).