Integrating Scientific Knowledge in Mixed Forests
EuMIXFOR Final Conference
COST Action FP 1206

EUMIXFOR
Cost Action

Programme
and Book of Abstract

5–7 October 2016, Prague, Czech Republic

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Forestry and
Game Management
Research Institute

Czech University of Life Sciences Prague
Faculty of Forestry
and Wood Sciences

MINISTRY OF AGRICULTURE
OF THE CZECH REPUBLIC

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of Forestry
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Forestry and Game Management Research Institute
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The conference is organized under the auspices of the Czech Minister of Agriculture Marian Jurečka

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Contents

Foreword

European forests have developed for more than one thousand years under the human influence. Intensity of this coexistence varied in time and space from scattered use of forest products to extensive deforestation, resulting in planned forestry approaches and finally in the concept of sustainable forests management. Nowadays we perceive forest as a base for the sustainable timber production as well as complex system fulfilling many other economic, environmental and social functions. Forests play an essential role in helping to protect climate, on the other hand, they are endangered by the ongoing change of climatic system – e.g. by increased periods of droughts in sensitive regions. It is broadly accepted that appropriate mixture of forest tree species increases not only the biodiversity but can also positively influence vitality and ensure long-term productivity of forests stands. In this respect we highly appreciate the involvement of scientists, forest owners, other stakeholders and general public in the issue of mixed forest, which is represented by the COST EuMIXFOR action.

About one third of the Czech Republic is covered by forests. The majority is represented by highly productive coniferous species – Norway spruce (50.7 %) and Scots pine (16.5 %). When assessing the species biodiversity of national forests, the overall proportion of individual tree species is the major indicator, along with the distribution of forest stand mixtures within individual units of spatial arrangement of forests. The proportion between individual tree species within a unit has been continuously increasing in favour of mixed forest stands and forest stands with prevailing broadleaves. This increasing trend is a result of foresters' permanent efforts to acquire an optimum species composition of forests, a practice that enjoys a long-term support under a goal-oriented national subsidy policy.

I would like to thank all those involved in this valuable effort and wish you continued success.

Marian Jurečka
Minister of Agriculture of the Czech Republic

Mixed forest research matters

Around one fifth of the total forest area in Europe comprises a mixture of broadleaves and conifers, and when species are considered individually 70% or European forests are dominated by two or more species[1]. Globally, forest area is decreasing while planted forest area is increasing[2], however, in Europe the sharing of single-species forest is decreasing at an annual rate of 0.6% in a steady form since 1990[1]. But, what have been the reasons for this tree species diversification in European forests?

Concerns about the loss of biodiversity and the negative consequences for resilience have oriented management to adopt a diversification strategy. But the picture would not be complete if we do not consider that changes in management are preceded by changes in social attitudes towards forests, their products and services.

The interplays between environmental drivers, forestry alternatives and social demands from mixed forests have opened appealing research questions whose answers needed to be addressed: what species mixture is better adpated to current environmental conditons and social demands?, what species composition would cope better with climate change?, are mixtures always more productive than monocultures? What are the drivers of stability in mixed stands?, how do ecosystem processes and functions in mixed forests affect the delivery of ecosystem services?

In 2012, a group of researchers from 16 European countries launched an innitiative to discuss the role of mixed forests in Europe including the analysis of dynamics, adaptive management and social impact of species mixture with the goal of integrating scientific knowledge in the sustainable management of mixed forests. This proposal was funded by COST Association (www.cost.eu) in the form of the FP1206 COST Action EuMIXFOR. On February 2013 the kick-off meeting officialy marked the beginning of the *European network on mixed forests* (www.mixedforests.eu). Today, 31 COST Countries, 6 International Partners and 4 Near Neighbour countries have joined the Action conferring it a unique world-wide perspective. The action and their activities (meetings, training schools and short term scientific missions) will end on February 18th 2017 but the strength of the professional and personal relationships built during the Action will last for many years.

This book comprises the abstracts of one invited talk, 5 keynote speakers, 24 voluntary talks and 32 posters presented in the Final Conference of the FP1206 COST Action held in Prague (Czech Republic) on October, 5th -7th 2016. The conference was structured in three sessions: Mixed forest fuctioning and dynamics; Adaptative Forest Management of mixed forests; and Policy and Social Impact of mixed forests The research results summarized in this book represents the latest findings and research perspectives about mixed forests. I am sure that many of them will be published as research articles and they will contribute to the advancement of forest research in mixed forests. A research that truly matters.

Andrés Bravo-Oviedo
Chair of COST Action FP1206 EuMIXFOR

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[1] Forest Europe (2015). State of European Forests, 312 p. Madrid
[2] FAO (2015). Global Forest Resources Assessment. How are the world's forests changing? 47 p. Rome

Acknowledgments

The success of this Conference has been only possible with the support and hard work of members from the Scientific and Organisation committee and the Local Organizer, **Vít Šrámek**, as well as all participants in the Action, including STSM applicants and hosts, trainees, trainers, Management committee and woking group members. A full list of names can be retrieved from the Action webpage (www.mixedforests.eu).

The Management Committee of the Action thanks the Grant Holder Manager, **Ricardo Ruiz-Peinado**, for his full commitment with the Action. The support and advices from the Scientific and Administrative staff of COST office, **Melae Langbein, Fatima Bouchama, Aranzazu Sánchez, Matthias Kahlenborn and Grabiela Cristea** and INIA, **Mercedes Martínez,** are highly appreciated.

Conference Program

October 4th
Arrival of Participants

October 5th

08:30-09:00 Registration
09:00-09:20 Welcome
09:20-09:40 *Insights from EuMIXFOR* – Andrés Bravo-Oviedo (INIA-CIFOR)
09:40-10:00 *The triplet initiative* – Hans Pretzsch (TUM)
10:00-11:00 *Inaugural talk: Species mixtures: Questions for the Next Generation* – Dan Binkley (Colorado State University)
Coffee Break

TOPIC 1: Mixed Forests Dynamics and Functioning (I)

11:30-12:00 *Tree diversity – forest resistance relationships* – Hervé Jactel
12:00-12:12 *Tree diversity effect on dominant height* – Patrick Vallet
12:12-12:24 *Is tree species diversity or tree species identity the most important driver of European forest soil carbon stocks?* – Lars Vesterdal
12:24-13:36 *Tree size and local neighbourhood affect foliar nutrition in a young forest plantation of beech (Fagus sylvatica) and sycamore maple (Acer pseudoplatanus)* – Hans Nickmans
12:36-12:48 *A neighbourhood analysis of the effects of tree diversity on growth in the BIOTREE experiment* – Charles Nock
12:48-13:00 Discussion
13:00-14:00 Lunch

TOPIC 2: Adaptive Management of Mixed Forests (I)

14:00-14:30 *Adapting forests to climate change: lessons learned from mixed forests* – Ch. Ammer (University of Göttingen)
14:30-14:42 *Site, species, and age influence the extent of overyielding in long-term mixtures experiments in Britain* – Bill Mason
14:42-14:54 *Overyielding of temperate mixed forests occurs in evergreen–deciduous but not in deciduous–deciduous species mixtures over time* – Huicu Lu
14:54-15:06 *Conversion of introduced conifer species to mixed native broadleaved forest – silvicultural tools for low-cost regeneration* – Magnus Löf
15:06-15:18 *Modelling conversion of pure even-aged Norway spruce (Picea abies [L.] Karst.) stands into mixed uneven-aged stands using SIBYLA software: a case study of the Ukrainian Carpathians* – Oksana Pelyukh
15:18-15:30 Discussion
Coffee Break

TOPIC 3: Policy and Social impact of Mixed Forests

15:45-16:15 *Which portfolio mix do forest owners apply in their choice of tree species?* – Jette B. Jacobsen (KU)
16:15-16:27 *Human decision-making in the forests: selecting trees for removal during transformation to uneven-aged forest stand structures* – Lucie Vítková
16:27-16:39 *Mixed forests in Europe: how much is enough?* – Anna Barbati
16:39-16:55 *Economics of even- and uneven-aged mixed species forestry* – Olli Tahvonen
16:55-17:07 *Future research needs on mixed-forests from the perspective of European forest managers* – Lluís Coll
17:07-17:19 *Optimal carbon storage in mixed species uneven-aged forests* – Aino Assmuth
17:19-17:40 Discussion
17:40-19:00 Poster session / Working Groups side meetings

October 6th

TOPIC 3: Mixed Forest Functioning and Dynamics (II)

9:00-10:00	*The production ecology of mixtures: From pattern to process to application* – David I. Forrester (U. Friburg)
10:00-10:12	*Intra-annual growth of Norway spruce and Common beech in pure and mixed stands* – Sonja Vospernik
10:12-10:24	*Interspecific interactions affecting on size structure and growth patterns in mixed pine forest* – José Riofrío
10:24-10:36	*Species proportions by area in mixtures of Scots pine (Pinus sylvestris L.) and European beech (Fagus sylvatica L.)* – Gerald Dirnberger
10:36-10:48	*Effect of ecological factors on intra-annual radial variation cycles in pine-oak Mediterranean mixed forest stands* – Jorge Aldea
Coffee Break	
11:15-11:30	*Development of biomass allocation of Norway spruce (Picea abies (L.) KARST.) trees in unmanaged mixed stands* – Vaclav Hurt
11:30-11:45	*Base cation nutrition patterns of pure Norway spruce (Picea abies L. Karst) and European beech (Fagus sylvatica, L.) forest stands comparing to their mixtures* – Vit Sramek
11:45-12:10	Discussion
12:10-13:00	Poster session / Side meetings
13:00-14:00	Lunch

TOPIC 5: Adaptive Management of Mixed Forests (II)

14:00-14:30	*Relevance of analysing mixing effects at tree and stand level* – Miren del Río (INIA-CIFOR)
14:30-14:42	*Analysing mixture effect on European beech (Fagus sylvatica L.) and Scots pine (Pinus sylvestris L.) from growth models based on NFI data* - Sonia Condés
14:42-14:54	*Stand structural complexity of mixed old-growth and adjacent selection managed forests in the Dinaric Mountains of Bosnia and Herzegovina* – Srdjan Keren et al.
14:54-15:06	*Thinning in young mixed stands with Douglas fir* – Jiri Novak
15:06-15:18	*Number of oak (Quercus robur L.) natural regeneration growing under pine (Pinus silvestris L.) canopy: possibilities for inclusion into the next generation stand* – Maciej Pach
15:18-15:30	*Silviculture of mixed oak stands can be supported by natural succession processes* – Kamil Bielak
15:30-15:45	Discussion
Coffee Break	
16:00-16:30	CONCLUSIONS
17:00-18:30	Poster session / Working Groups side meetings
20:00	Social event

October 7th

8:30-10:00	EuMIXFOR Management Committee Meeting (MC members and MC subtitutes)
10:00-17:00	On-site discussion

Growth of mixed versus mono-specific stands of Scots pine and European beech in Europe. Results of the triplet study

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Abstract

Mixed species stands of Scots pine and European beech are of considerable practical relevance as they combine an economically preferred conifer with an ecologically favoured deciduous species. Both species are complementary as Scots pine is light-demanding, fast-growing, and evergreen, whereas European beech is shade-tolerant, slow-growing and a deciduous species. In order to better understand the effect of mixing on their growth and structure we established along an ecological gradient through Europe 32 triplets consisting of mono-specific Scots pine, European beech, and a mixed-species stand of both species. The trees in the mostly 40-60 year old stands of the triplets were measured regarding stem diameter, tree height, stem position, crown size; furthermore increment cores were taken for retrospectively analyzing tree and stand growth.

Based on this rather unique dataset we found, first, an average overyielding of mixed stands versus monocultures of about 10 % in terms of stand basal area and stem volume growth. Second, we found that the mixing hardly changed the mean stand height and diameter but increased the stand density in terms of tree number, SDI, and standing volume by 10-20 % compared with monocultures. Third, the structural heterogeneity in terms of tree size distribution and Gini coefficient was significant higher in mixed stands. Fourth, the mixing can modify growth allocation at the individual tree level; crown morphology can vary in a wider range and wood density can be lower in mixed species stands. Fifth, we found that the site index and water availability which vary strongly along the gradient had no significant effect on the overyielding. However, the heterogeneity of structure increased with water availability. This suggests that on sites which are well supplied with water and mineral nutrients, overyielding may result from the species complementary in canopy space occupation and light interception, whereas on poor sites the species' complementary may remedy the water and nutrient limitation.

The 32 triplets established within the EuMIXFOR FP 1206 COST action also contribute to standardization of measurement, evaluation, and characterization of mixed-species stands. They may provide a platform for further ecological and economical evaluations and research projects. The data of the triplets will be freely availably soon via a data base publication submitted to Annals of Forest Science.

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Species mixtures: Questions for the next generation

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Key words: mixed forests; landscape; forest growth; experimental templates

Abstract

Mixing species within managed forests changes almost all aspects of forest structure and function, including understory communities, animal habitat, resource use and production. Increased variation in tree sizes within stands could result in a "diversity" penalty. At a scale of landscapes, mixed-species forests will likely develop greater variation as well. The influence of species on forest growth can be assessed from multiple perspectives, including statistical patterns and functional relationships. A variety of new questions need to be examined for future forests across landscapes, covering the basic patterns to be expected in mixed-species forests, the variations around typical patterns, and the factors that drive the variations. These issues will require a new generation of experimental designs to provide experimental templates, at scales that match forestry operations

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Tree diversity - forest resistance relationships

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Keywords: mixed forests, associational resistance, natural disturbances

Abstract

To meet the rising demand for wood products and carbon sequestration while preserving natural forests, more efficient production practices must be adopted in managed forests, hence increasing their net productivity. However compared to crops or grasslands, species composition of forests remains fixed for decades, which may strongly reduce their ability to respond to changing conditions, particularly to the threats posed by climate change. It is therefore critically important to design and manage forests in order to maintain the stability of their productivity over time. Mixed forests are considered one of the main options for adapting to and reducing risks of climate change. Both empirical and modelling studies have revealed greater productivity in mixed than monospecific forests on the long term. However there is no point to design more productive forests if they turn out to be more prone to damage from natural disturbances.

Here we review the current scientific knowledge about tree species diversity effects on forest health in the broadest sense of the term. Based on comparisons between tree monocultures and mixtures we present the global pattern of tree diversity effects on forest resistance to biotic and abiotic hazards. We show that mixed forests often exhibit associational resistance, i.e. an emerging property of the association of different tree species. The effect of tree species diversity on resistance ranges from weak to strong against hazards ranked in the following order: drought, fire, windstorm, mammal browsers, fungal pathogens and pest insects. A main result is that tree species composition is more important than tree species richness *per se* to explain the resistance of mixed forests. We also discuss about potential mechanisms underlying diversity - resistance relationships, including the insurance hypothesis, niche complementarity and facilitation, resource accessibility and multitrophic interactions. Finally we use the outcomes of our review to suggest knowledge-based solutions for the establishment of more resistant mixed forests through relevant tree species associations.

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Tree diversity effect on dominant height

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Key words: Species mixture, Dominant height, National Forest Inventory, Plant–plant interactions, Temperate forest.

Abstract

For forest ecosystems, studies dealing with diversity-productivity relationships are often based on diameter increment observations. Studying how height growth is affected by species interactions can provide new insights on this issue. We studied the mixture effect on dominant height growth in order to answer two questions. Do species interactions in mixed forest modify the dominant height growth of species? Does the diversity effect on diameter found in previous studies correspond to an effect on allocation of growth between diameter and height, or to actual overyielding?

We used the French National Forest Inventory (NFI) data and a modelling approach to evaluate the mixture effect on dominant height. We included biophysical factors in the models to compare mixed and monospecific stands, all other parameters being equal. We studied five target species – Quercus petraea (Matt.) Liebl., *Fagus sylvatica* L., *Picea abies* (L.) Karst., *Abies alba* Mill., and *Pinus sylvestris* L. – in association with sixteen other species.

Mixture effects on dominant height were weak, though often significant. They were either positive or negative according to species association. We showed that mixture effect on dominant height is driven by species ontogeny and corresponds to a levelling process between species: the taller one limits its growth while the smaller one's growth increases. Furthermore, most of the time, effects on dominant height are in the same direction as those found on diameter, though with a lower magnitude. Our results confirm that tree diversity results in overyielding rather than in a different allocation of volume between the parts of the tree.

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Is tree species diversity or tree species identity the most important driver of European forest soil carbon stocks?

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Key words: soil carbon; tree species diversity; tree species identity; roots; forest type

Abstract

Studies of functional species diversity have reported positive effects for aboveground carbon (C) sequestration, but the question remains whether higher soil C stocks could also result from belowground niche differentiation including more efficient root exploitation of soils. We studied soil C stocks in tree species diversity gradients within the FunDivEurope project to explore biodiversity-ecosystem functioning relationships in six European forest types in Finland, Poland, Germany, Romania, Spain and Italy. In the Polish forest type the sampling was extended to include subsoils.

We found consistent but modest effects of species diversity on total soil C stocks (forest floor and 0-20 cm) across the six European forest types. Carbon stocks in the forest floor alone and in the combined forest floor and mineral soil layers increased with tree species diversity. In contrast, there was a strong effect of species identity (broadleaf vs. conifer) and its interaction with site-related factors. Within the Polish forest type we sampled soils to 40 cm and found that species identity was again the main factor explaining total soil C stock. However, species diversity increased soil C stocks in deeper soil layers (20-40 cm), while species identity influenced C stocks within forest floors. Root biomass increased with diversity in 30-40 cm depth, and a positive relationship between C stocks and root biomass in the 30-40 cm layer suggested that belowground niche complementarity could be a driving mechanism for higher root C input and deeper distribution of C in diverse forests.

We conclude that total C stocks are mainly driven by tree species identity. However, modest positive diversity effects were detected at the European scale, and stronger positive effects on subsoil C stocks in Poland were associated with higher subsoil root biomass. Targeted selection of tree species would be a stronger forest management approach for C sequestration than increasing tree species diversity *per se*.

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Tree size and local neighbourhood affect foliar nutrition in a young forest plantation of beech (*Fagus sylvatica*) and sycamore maple (*Acer pseudoplatanus*)

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Key words: forest nutrition; mixture; neighbourhood

Abstract

Nutrient imbalances, caused by changing environmental conditions or site conditions, can negatively affect forest health and productivity. Species mixing could possibly mitigate these effects by influencing foliar nutrition. We investigated foliar nutrition in a young mixed plantation of beech and sycamore maple, planted along a double gradient of density and species proportion. To disentangle tree size and neighbourhood effects, target trees of both species were selected over the full diameter range within each portion of the double gradient, and neighbourhood was determined in a 3 m radius, by measuring number and basal area of the surrounding trees. Using regression analysis, we investigated whether target tree size (diameter and height) and/or neighbourhood, expressed as local density (total number, basal area), identity (i.e. percentage of non-target species) or diversity (i.e. Shannon diversity index), had a significant effect on foliar nutrition. We observed mostly effects of tree size for both species.

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A neighbourhood analysis of the effects of tree diversity on growth in the BIOTREE experiment

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Key words: tree diversity; tree growth; neighbourhood; tree crown plasticity

Abstract

Manifold global changes are leading to a loss of tree species diversity and the simplification of forest ecosystems worldwide. Whereas decades of research in manipulated herbaceous communities have revealed the important role of complementary resource use in diverse plant assemblages for ecosystem functions such as biomass production, much less research has focused on tree dominated systems, in part due to the greater length of time required for interactions among individuals. An opportunity now exists in a number of experiments to explore the effects of more than a decade of species interactions. Previous research suggests that niche partitioning and complementary resource use occurs in mixed forest types where differences in the functional traits of species lead to a reduction in the strength of interspecific competition relative to intraspecific competition. While such complementary resource use may arise through differences in species fundamental niche, it may also result from realized niche differences arising from intraspecific trait plasticity. Studies have confirmed a role for such plasticity in moderating the strength of competition amongst individuals. In this study, we test for mixture effects on tree growth in 330 focal-tree neighbourhoods ranging in diversity from 1 to 4 species (*F. sylvatica, P. abies, Q. petraea and P. menziesii*) in a tree diversity experiment planted in 2004 in central Germany—BIOTREE. In both 2011 and in 2014 all neighbourhoods were visited and tree height, tree diameter, and tree crown dimensions were measured for all trees on a 3x3 grid, with each neighbourhood consisting of a focal tree with eight neighbours. We test the hypothesis that average stem growth from 2011 to 2014 increased with tree species diversity. In addition, we explore whether differences in growth can be explained by tree crown character displacement in mixtures (measured as the deviation from that in monocultures neighbourhoods).

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Adapting forests to climate change: lessons learned from mixed forests

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Key words: Drought stress, competition, facilitation, stress-gradient hypothesis

Abstract

Climate change implies a new and challenging source of uncertainty for forestry and requires adaptation measures. In the context of silviculture two main approaches have recently been discussed: adapting target tree species composition, and adapting stand density. Creating mixed stands and controlling stand density through thinning are effective adaptation principles, which both may reduce resource competition among trees. Mixed stands composed of species with different functional traits and foraging strategies increase the likelihood of complementary effects because of reduced (intraspecific) competition pressure, and/or facilitation effects. However, complementarity and lower stress levels of the species in mixed stands were not always observed. The contrasting findings may be explained by refining the stress-gradient hypothesis (SGH) according to Maestre (2009) who suggested taking the interacting species and the characteristics of the stress factor (resource versus non-resource) into account. In any case, adaption strategies fostering mixed stands have shown to successfully reduce the degree of drought stress in forest stands. Because the functional traits of the species involved are of crucial importance, species identity seems to be more important than species diversity.

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Site, species, and age influence the extent of overyielding in long-term mixtures experiments in Britain

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Key words: Mixtures; overyielding; long-term experiments; functional traits

Abstract

Between 1954 and 1964 a series of 22 long-term mixture experiments was established on afforestation sites throughout Britain. The experiments involved two or more species and had a common design involving three replicates of pure plots of each species and of all possible two species mixtures in a 1:1 proportion. Plot size was generally 0.2 ha and the experiments used an alternative chequerboard layout in the mixed plots to ensure that the mixture survived into the stem exclusion phase. This design would be considered as a 'replacement' series in all treatments were planted at a constant spacing. By 2010, about 50 per cent of these experiments had survived representing six conifer (*Pinus contorta*, *P. sylvestris*, *Larix kaempferi*, *Picea abies*, *P. sitchensis*, and *Tsuga heterophylla*) and three broadleaved (*Alnus glutinosa*, *Betula pendula*, and *Quercus petraea*) species. Previous analyses of results from three individual experiments have shown a range of productivity responses in the mixtures ranging from transgressive overyielding to no overyielding depending upon site quality and species combinations (Mason & Connolly, 2014; Mason & Connolly 2016). This paper provides the first comprehensive overview of results from the whole series, showing that overyielding is more likely to occur on less fertile sites with species of different functional traits (e.g. light demanding and shade tolerant), and that positive interactions appear to diminish with increasing age. We develop the general principles provided by these results and combine them with existing site classifications and knowledge of species ecophysiology to identify species mixtures that could be favoured in British forestry to sustain delivery of ecosystem services in a changing climate.

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Overyielding of temperate mixed forests occurs in evergreen–deciduous but not in deciduous–deciduous species mixtures over time

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Key words: mixed stand, monoculture, niche complementarity, productivity, stand development

Abstract

Recent studies show that mixed species forests sometimes have higher productivity than monospecific forests (also referred to as overyielding). Yet, results for temperate forests are ambiguous, possibly because of confounding effects of local site conditions, thinning and forest age. In line with the niche complementarity hypothesis, we expect stronger overyielding for forests with species differing in both leaf phenology (evergreen or deciduous) and shade tolerance. We also hypothesize that overyielding will decrease over time because of decreasing resource availability. We compared 4 two-species mixtures with their corresponding monocultures from long-term field measurements in the Netherlands. Overyielding was observed in 2 of the 4 mixtures: for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)–common beech (*Fagus sylvatica* L.) mixtures relative to Douglas-fir (35.3%) and common beech (36%) monocultures, and for Scots pine (*Pinus sylvestris* L.)–common oak (*Quercus robur* L.) mixtures relative to Scots pine (17.9%) and common oak monocultures (26.6%) on average. Furthermore, overyielding was relatively constant for the two mixtures through stand development. This result was robust after accounting for confounding effects of thinning and site productivity, where thinning had no effect and site productivity contributed independently to productivity. No significant overyielding effects were observed for the two deciduous mixed stands, i.e. common oak–common beech, and common oak–silver birch (*Betula pendula* Roth). Mixing tree species in temperate forests resulted in overyielding for evergreen–deciduous but not for deciduous–deciduous species mixtures. This indicates that leaf phenology contributes to overyielding effects. Overyielding was higher in the Douglas-fir–common beech mixtures than the Scots pine–common oak mixtures, which coincides with a stronger contrast in shade tolerance between Douglas-fir and common beech and thus stronger complementarity. Our results support the complementarity hypothesis and imply that such mechanisms are maintained with stand development. It therefore appears that mixing evergreen with deciduous species with contrasting shade tolerance is a valid management strategy for increasing diversity and productivity of temperate forests.

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Conversion of introduced conifer species to mixed native broadleaved forest – silvicultural tools for low-cost regeneration

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Key words: hardwoods; rehabilitation; restoration

Abstract

A large proportion of the original temperate deciduous forest in Europe has been lost to other land uses. Agricultural needs was a dominating factor at first, but later and due to industrial needs of fast growing timber - introduced conifer species (e.g. *Picea abies* L Karst) were planted at sites once dominated by broadleaves over large areas. Although many times economically attractive for the forest owner, these conifer plantations are vulnerable to various disturbances and therefore, they have an associated economic risk. In addition, concerns for biodiversity, environmental services, adaptation to climate change and the ecological instability of such stands drives the conversion towards mixed stands including native broadleaves. Our research reports the influence on the early performance (establishment, survival and growth) of regeneration in relation to proximity to other mixed broadleaved stands, fencing and mechanical site preparation treatment. In our experiment the regeneration consists of planted beech (*Fagus sylvatica* L.) seedlings and naturally regenerated plants of other tree species (both broadleaves and conifers). We hope our conclusions will stimulate the development of new management guidelines for cost-efficient restoration of mixed native broadleaved forests in southern Sweden and elsewhere.The aim with this presentation is also to examine results of other studies from Europe on conversion practices. In addition, we want to discuss the effects of conifer conversion on various environmental services.

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Modelling conversion of pure even-aged Norway spruce (*Picea abies* [L.] Karst.) stands into mixed uneven-aged stands using SIBYLA software: case study of the Ukrainian Carpathians

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Key words: conversion; pure and mixed stands; SIBYLA model.

Abstract

We analysed different strategies for conversion of pure even-aged Norway spruce stands to mixed uneven-aged ones. The conversion regime was modeled by the growth simulator SIBYLA. We calibrated model to minimize the differences between simulated and observed values. Tree diameter and height data from the yield tables, developed for Ukrainian Carpathians, were used for the calibration. For adapting the increment functions in the model to real condition, eight site factors, which reflect nutritional, water and temperature conditions, were adjusted. The initial data for the simulation were gathered using forest inventory database of the State Enterprise „Rakhiv forestry", Transcarpathian region, Ukraine. We modeled four different conversion strategies with application of various alternatives of selective thinning and target diameter harvest. These strategies, differing in the number and size of harvested stems (target diameter harvest), were compared with each other. A simulation-run had the duration of 80 years and was divided into 8 periods of 10 years. Analysis of the simulation showed negative correlation between stands volume and the Jaehne and Dohrenbusch index of diversity. Application of only two conversion strategies allows us to obtain desired tree species composition with sufficient height and diameter diversity. These strategies had a bit higher direct costs for stands thinning comparing with the other two. The results showed that for the older stand with the low stand density (0.5), the application of sole selective thinning was the only rational way to obtain the target trees species composition with different horizontal and vertical structures. However, for the younger stand with a higher stand density (0.7), there was a need to combine target diameter harvest with an intensive selective thinning in the initial periods of conversion process to initiate the establishment of sufficient and stable new generation - the main factor of success of the conversion. Achievement of the best horizontal and vertical diversity, described by the indexes of species and structural diversity, depended on intensity of conversion regime.

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Which portfolio mix to apply – a case study of Danish forestry and Danish foresters

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Key words: portfolio; mixed species; economics; risk; price

Abstract

Mixing tree species in a forest is a well-known way for forest owners to diversify management and reduce their vulnerability to species specific risk, e.g. related to price (and thereby demand) uncertainty, windthrow and pests. From society´s perspective there are additional benefits from mixing species as recreationists prefer mixed forests and since protection services of forests depend on their stability at the landscape level. Therefore the question arises, which species mix forest owners actually apply and how this agrees with quantifiable uncertainties related to price? In this paper we apply a simple portfolio approach and analyse price uncertainty based on a 100-year price series from Denmark for three main species: Norway spruce, beech and oak. First we analyse the price variation and conclude that a vector autoregressive model of order 1 is appropriate. Based on this we estimate efficient frontiers for portfolios for different regions in Denmark. First we compare the results obtained for different return criteria – annual return for a Normal forest, soil expectation value and expectation value for a Normal forest. We find large differences depending on which criteria are being used. Next we show that the initial price level determines the shape of the efficient frontier, and that this has therefore changed considerably over the years. Consequently, optimal portfolios change quite fast and this questions the potential of the approach for long term investments. Finally we compare species mixes along the efficient frontier with actual mixes – at a regional level and at a forest property level.

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Human decision-making in the forests: selecting trees for removal during transformation to uneven-aged forest stand structures

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Key words: agreement; continuous cover forestry; experts; novices; training.

Abstract

Various methods for successful forest management are applied worldwide. However, such methods have to be carefully carried out to achieve desired species composition and stand structure. Marking trees for removal (or retention) is a crucial pre-requisite for successful forest management as inappropriate choice of trees for removal or retention may cause changes to the forest environment that may be hard to reverse. This study explored how different levels of expertise in managing forest ecosystems affect the way professional foresters approach the task of selecting trees for removal before and after receiving specific training in method used to initiate transformation to more diverse forests (species and stand structures) in Ireland.

The results of this research showed that the study participants (forestry professionals) with varying levels of expertise responded differently when provided with the same task. Prior to training, when presented with the task to mark trees for removal without being provided any specific instructions, the study participants with a higher level of expertise in such tasks applied the method they were most familiar with. When trained in a specific method used during transformation management, participants with less expertise successfully and more accurately applied this method, while those with more expertise did not. The level of agreement as to the choice of trees for removal was generally low. It was, however, highest prior to the training and declined most after training among those with a higher level of expertise.

Prior knowledge and experience in managing forest environments affected how participants approached the task; the longer an individual applies a task in a particular way, the harder it is to change this routine to a new approach. This is crucial information suggesting that if novel approaches to forest management are to be successfully implemented, more effort should be made to convince experts about the specific techniques.

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Mixed forests in Europe: how much is enough?

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Key words: forest statistics, tree species mixtures, tree species richness, European Forest Types

Abstract

Reducing the share of single-species stands by promoting the establishment of tree species mixtures is recognized as a means to support large variety of forest species, but also a strategic opportunity to stabilize forest productivity and to increase forest stand resilience.

However, there are natural constraints in Europe that need to be taken into account when targeting forest management towards species mixtures. At high latitudes, altitudes, or under certain ecological limiting conditions single-species, mainly coniferous, forests naturally dominate. Mixed forest stands are, instead, naturally more frequent in mesophytic or thermophilous deciduous broadleaved forests or in riparian forest communities.

The main goal of this contribution is to quantify the current share of mixed vs. pure forest stands in Europe across ecologically distinct groups of forest communities, as categorized by the 14 categories of the European Forest Types classification.

The assessment is based on basal area information processed from ground plot data from about 2600 sampling units, gathered in the framework of the EU project Biosoil and covering 19 EU Countries.

Basal area information has been processed to provide reliable statistics of the following variables by European Forest Types: i) proportion of plots by number of tree species (minimum basal area threshold >5% of total basal area of the plot); ii) proportion of pure vs mixed forest stands (threshold for mixed forest: 2 or more species which accounts for more than 15% of total basal area of the plot); iii) proportion of the most widespread mixed forest types in Europe.

The rationale of this exercise is not to question if the share of mixed species stands is enough or only 70% of what should be natural. Rather, it is to provide a snapshot at EU level, that could be useful as baseline to evaluate progress made by sustainable forest management in establishing species mixtures, taking into account the ecological constraints associated to different European Forest Types.

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Economics of even- and uneven-aged mixed species forestry

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Key words: forest economics, mixed forests, even-aged forestry, uneven-aged forestry, optimal conversion, optimal thinning

Abstract

Boreal planted and semi-natural forests are typically managed applying artificial regeneration, understory cleaning, thinning from below and clearcuts. This has led to even-aged stands that are dominated by Norway spruce *(Picea abies)* or Scots pine *(Pinus sylvestris).* Emerging interest to emphasize biodiversity, social and cultural values of forests and the expected increasing risks related to climate change has awaken an interest for mixed even- and uneven-aged forests in all Nordic countries.

This study applies generalized interdisciplinary economic-ecological model for optimizing the sustainable management of mixed-species boreal forests. The model includes natural and artificial regeneration, transition matrix specification for mixed species stands and detailed economic descriptions of harvesting costs and timber revenues over time. The model is general in the sense that in addition to optimized timing and type of thinning it solves the economically optimal choice between optimized finite rotation period and optimal continuous cover forestry. Additionally the model is suitable to optimize conversion from even-aged monocultures toward heterogeneous mixed stands. The model is solved by dynamic mixed nonlinear programming and applied to Norway spruce and birch *(Betula pendula)* and Norway spruce, birch and Scots pine mixed stands. The results suggest that when continuous cover forestry is economically preferable the long run optimal steady state is dominated by Norway spruce. With moderate interest rates and average site productivity the fraction of birch is about 20% but the fraction of Scots pine remains low. When the stand is regenerated for Norway spruce or Scots pine but natural regeneration of birch after clearcut is high, the model solves a specific optimal solution to manage a mixed species even-aged stand. Adding preferences to species diversity into the objective function produces mixed uneven-aged stands with more equal fractions of different species. This causes rather low economic losses suggesting that increasing species heterogeneity may be a suitable strategy to prepare for the risks of climate change.

Interdisciplinary economic-ecological research for mixed forests is scarce and the model and results for mixed species even-and uneven-aged forestry presented in this study have not been presented at the same level of generality in any earlier studies.

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Future research needs on mixed-forests from the perspective of European forest managers

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Key words: mixed-forests; research gaps; participatory process; priority settings; forest managers

Abstract

In any scientific discipline, the identification of knowledge gaps is essential for designing relevant and innovative research projects. In the particular case of applied sciences, such as forestry, the generation of new knowledge must go hand in hand with the implementation of adequate strategies to transfer this novel information to the end-users (e.g. forest managers). If this is not properly done, it could happen than the gaps in knowledge perceived by the practitioners do not coincide with the ones recognized by the researchers. This may lead to the development of research projects that are considered by the users to not respond to their needs thus impairing the implementation of evidence-based decisions.

Here, we present the results of a participatory approach aimed at identifying the main questions related to mixed-forest management and dynamics that, from the perspective of European forest managers, require further attention from the research community. This exercise was conducted under the frame of the COST Action FP1206 EuMIXFOR and counted on the participation of wide representation of European countries within this network. The following methodology was used: First, a representative per country was identified and asked to collect research questions from forest managers about mixed-forests of its country of origin. Fifteen countries participated to this task and provided a total of 289 questions. All those questions were then classified in broad topics (e.g. timber production, species interactions…), merged (when similar) and rephrased if needed. This process resulted in the definition of 30 questions covering most of the interrogations originally received. This reduced number of questions were ranked by order of importance through an online prioritization survey completed by 209 forest managers (from different working environments) from 22 European countries. Finally, the highest ranked questions were used to structure a revision of the state of the art in relation to them and to address future research challenges in mixed-forest science. We consider the use of such participatory exercises involving suppliers and users of knowledge to be of critical importance for the design of credible and high-impact research initiatives.

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Optimal carbon storage in mixed species uneven-aged forests

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Key words: carbon sequestration; multi-species; continuous cover forestry; optimal harvesting; dynamic optimization

Abstract

This study analyses economically optimal carbon storage in boreal uneven-aged mixed species forests. Our subject is motivated by recent ecological research that underlines the importance of heterogeneous age, size and species structure for maintaining forest resilience under disturbances caused by climate change. We optimize the management of size-structured stands for the co-production of timber and carbon storage services, using road-side timber prices and empirically estimated variable harvesting cost functions. In addition to carbon storage in the stand, we consider carbon both stored in and released from sawlog and pulpwood products. The ecological model applied in the study is a transition matrix model with empirically estimated Scandinavian growth functions for Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula pendula Roth* and *B. pubescens* Ehrh.). The optimization problem is solved in its general dynamic form using gradient-based interior point methods. Assuming 2% interest rate and no social value for carbon storage, the optimal steady state is a mixed species stand where Norway spruce accounts for 80% of stand volume. Increasing the value of carbon storage to €20 tCO2-1 and €40 tCO2-1 increases the predominance of spruce. Given 4% interest rate, the optimal steady state without considering carbon storage is a low-density mixed species stand, and including the value of carbon storage increases optimal stand density while maintaining the species composition unchanged. With the studied carbon prices and interest rates, timber revenues at steady state increase when carbon storage is valued. We show that considerable carbon storage is maintained not only in the stand but also in timber products.

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The production ecology of mixtures: From pattern to process to application

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Abstract

Mixed-species forests are often proposed as a way to increase the level of various ecosystem services, including productivity, compared with monocultures. However, while mixtures may often be superior to monocultures, there are also many examples where they are not, so there needs to be a way to determine when and where mixtures are likely to be better or worse than monocultures at providing any given ecosystem service. Despite the many studies that have been published about mixture – monoculture comparisons it can be very difficult know how those results can be transferred from the journal articles to a specific forest with its unique set of silvicultural objectives, climatic and edaphic conditions. It is perhaps not surprising that the vast majority of the world's plantations are monospecific.

The aim this project was to find an approach that could be developed and used to determine species combinations and silvicultural treatments for specific sites and species. Firstly, a framework was developed to explain the spatial and temporal changes in mixing effects that have been reported in the literature; complementarity increases as the availability of resource "X" declines (or climatic condition "X" becomes harsher) if the species interactions improve the availability, uptake or use efficiency of resource "X" (or interactions improve climatic condition "X"). This framework based around the production ecology equation, which is useful when determining which processes and interactions are occurring in a mixture and how strongly they influence productivity; just because a process is occurring faster in a mixture does not mean it has a significant effect on growth complementarity.

While this framework is useful for designing experiments and interpreting their results, it is a considerable simplification of reality and cannot easily be applied by foresters to a specific site and species composition. This is because multiple types of interactions usually occur simultaneously in mixtures (e.g. nitrogen fixation, increased light absorption, and increased water-use efficiency) and so different resource availability-complementarity patterns can occur for a given pair of species, depending on the prevailing climatic and edaphic conditions as well as the developmental stage, stand density, etc. This complexity cannot be depicted using the simple framework described above.

In contrast, this complexity can be summarized using forest growth models. While many forest growth models have been developed, and some have even been applied to mixtures, it is very rare that the predicted mixing effects are compared with actual measurements of the mixing effects. Therefore the last part of this study involved a modification of the forest growth model 3-PG so that it could be applied to mixed-species forests and to examine silvicultural treatments that influence stand density, such as thinning. 3-PG is widely used as a routine management tool for *monospecific* plantations and forests and this study shows that it could potentially be used when managing and designing mixed-species stands as well.

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Intra-annual growth of Norway spruce and Common beech in pure and mixed stands

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Abstract

The cumulative growth of single trees is influenced by several factors, among them tree species, age, site (position, climate, soil) and inter-tree competition. Those factors likewise determine the inter-annual growth pattern. Whereas drought limits growth at lower elevation sites, temperature acts limiting at higher elevations. Diameter increment is modelled by means of high-resolution dendrometer data from sample plots in Kreisbach, Austria. To examine which effect species mixture has on increment, dendrometer were installed at trees in monospecific stands as well as in a mixed species stand. The study was thus established as a triplet design consisting of a pure Norway spruce stand, a pure European stand and a third stand having mixture proportions of the latter both species. In 2013 20 band dendrometers were installed hourly recording the change in stem circumference. 4 dendrometers were placed in the pure Norway spruce stand, 8 in the mixed stand and 8 in the pure European beech stand. In each stand dendrometers were installed on dominant, intermediate and suppressed trees defined by the percentile of the diameter distribution (90^{th}, 50^{th}, 10^{th}).

Diameter increment during the growing season was modelled using a logistic growth curve in a non-linear hierarchical mixed logistic model framework. The asymptote parameter thereby indicates the maximum growth attainable in year, the inflection point of the curve is where half of the asymptotic growth is attained, and the scale parameter represents the distance on the x-axis between this inflection point and the point where the response is about 0.73. All three parameters differ significantly by year, the asymptote parameter also differs by dominance, species and mixture.

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Interspecific interactions affecting on size structure and growth patterns in mixed pine forest

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Key words: growth partitioning**,** size-structure, *Pinus pinaster*, *Pinus sylvestris,* admixture effect

Abstract:

A plausible comparison between mixed stands with neighboring pure stands allows detecting any positive or negative mixing effects. However, interspecific interactions and net effects could vary depending of the level analyzed (from stand to tree-level) due to emerging properties. This work try to understand the differences between admixture effect patterns at tree-level from those observed at the stand level in mixed pine forest of Scots pine (*Pinus sylvestris*) and Maritime pine (*Pinus pinaster*) in in the Iberian and Central Range of Spain. Previous analysis at regional scale revealed that the main driver limiting basal area growth in these mixtures is light competition, so, tree size and its growth may be used as a proxy for light interception. Inventory data and dendrochronology growth series from cores extracted from 12 triplets of pure and mixed stands were used in the analysis. We use size distribution, as well size-structure dynamics in terms of growth rate to reveal the reaction at tree level for trees of different sizes and show how mixing modifies the hierarchy between trees, in order to link findings at individual tree and stand level. We used the individual tree volume as size dimension to compare the tree size distribution of mixed stands with pure stands. For analyzing any differences of the size distribution, the mean ratio and standard error of the main tree size distributions traits (e.g. tree number, tree volume, skewness, kurtosis, and Gini coefficients) between mixed stands and pure stands were calculated for each species and whole stand to test whether species mixing alters the scale (tree number, SDI), location (mean tree dimension), or shape (skewness, kurtosis, Gini coefficients) of the distribution of size and tree growth partitioning. This work improve our understanding of emerging properties in mixed stands, proper scaling and for tracing mixing effects from the individual tree to the size distribution and stand level.

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Species proportions by area in mixtures of Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.)

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Key words: *Pinus sylvestris*; *Fagus sylvatica*; proportion by area; mixture proportion; potential density

Abstract

Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.) cover plenty of the forest stands in Europe. Mixtures of European beech and Scots pine are very common all over European countries, but scarcely investigated.

Here we studied the basic knowledge of species composition for these mixtures and its definition as proportion by area. Therefore mixed and monospecific stands on 25 triplets across Europe from North to South (Lithuania to Spain) and East to West (Bulgaria to Belgium) were established and used to compare several methods to estimate species proportion.

There are two main approaches for estimating the species proportion by area. 1st the stand level approach which refers to the potential densities of the species in monospecific stands, and 2nd the tree level approach which gives the species proportions by crown projection area or leaf area.

Ideally, the best methods would be those where the species proportion from the stand level approach does not differ from the tree level approach.

Finally, we found that the stand level approach with potential density estimated from the relative stand density dependent on the Martonne index agrees best with the tree level approach based on individual tree leaf area.

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Effect of ecological factors on intra-annual radial variation cycles in pine-oak Mediterranean mixed forest stands

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Key words: automatic dendrometers; radial increment; seasonal cycle; daily cycles: climate change

Abstract

Radial variation analysis allows us to determine tree responses to weather, thus enabling to predict possible consequences to forest stands from the forecasted climate change scenario. In this study, seasonal and daily cycles of radial variation of pine-oak mixed stands (*Pinus pinaster* Ait. and *Quercus pyrenaica* Willd.) were analyzed in different contrasting climatic conditions at two sites located in central Spain. High resolution measurements of radial variation were recorded by automatic dendrometers installed in three trees for each species and site. Weather effects were monitored over three climatically contrasting years (2012–2014) with an extreme drought event in 2012. The daily radial cycle variation was divided into expansion, contraction and increment phases. Moreover, seasonal cycle was divided into five periods: winter dormancy, spring growth, pre-summer contraction, summer quiescence and autumn expansion. Amplitude and duration of seasonal and daily radial variation phases were calculated and correlated with weather and physiological variables. Intra-annual radial variation was mainly determined by species-specific water tree status and physiological response to the atmospheric environment.

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Development of biomass allocation of Norway spruce (*Picea abies* (L.) KARST.) trees in unmanaged mixed stands

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Key words: mixture, natural development, Norway spruce, biomass/production, tree species composition

Abstract

Norway spruce is the most frequently endangered species in forest stands throughout Europe. In 2014, it made up more than 50 % of species composition in the Czech Republic. Current problems concern mainly monocultures or stands, where the dominant species is Norway spruce. The attention of foresters is therefore concentrated primarily on growth in mixed stands, where its vitality is greater. This paper introduces results gained from 4 mixed stands containing various percentages of *Picea abies* (L.), which have been left to grow freely since the 1960s in the uplands, at an altitude of 400-to-470 m (Lang's Rain Factor: 75; Palmer Z-index: 35 %; 1-Month SPI: 3 months). These stands came to be as a result of combined regeneration in the mid 1930s and 1940s. In that time, the stands (all but Klepačov) were characterized as neglected, excessively thick and richly mixed young growth to a small-pole stage. It was discovered that during the 1950s, without any thinning activity, the amount of spruce increased in all cases but one. The amount of spruce, in terms of above-ground biomass, from the beginning of the measurement till the end, changed from 2 % to 3 % (Olomučany), 28 % to 26 % (Klepačov), 77 % to 50 % (Hrubá jedle), 56 % to 7 % (Smrk). The current level and above-level status of spruce in the mixed stands of Hrubá jedle, Klepačov and Olomučany and its state of health and development in recent years indicate that the assessed forest ecosystems at the given sites are, at the age from 76 to 89 years, stabilized and fulfil all their functions. All stands, except for the Smrk and Klepačov sites, are fully stocked. The results indicate natural dying of spruce where its place is being taken up by species which had been disseminated or mixed in from the past. Throughout the past 50 years, the supply of Norway spruce in the Smrk area has dropped by 65 %. In the other areas, it has grown from 3.8 to 8.0 times (Hrubá jedle 3.8 times, Klepačov 7.2 times and Olomučany 8.0 times).

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Base cation nutrition patterns of pure Norway spruce (*Picea* abies L. Karst) and European beech (*Fagus sylvatica*, L.) forest stands comparing to their mixtures

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Key words: mixed stands; E. beech, N. spruce, tree nutrition, base cations

Abstract

Seven triplets of pure E. beech stands, pure N. spruce stands and their mixtures were established in the broader extent of environmental conditions (altitude 480 – 1020 m a.s.l., yearly mean temperature 4°C – 7°C, annual precipitation 500 – 1200 mm) within the Czech Republic. Soil sampling to depth of 80 cm and foliage chemical analyses were made according to the ICP-Forest methodology. Various patterns of base cations (BC) concentration were found in forest soils. There was no difference between pure and mixed plots at highest elevation where the base saturation is extremely low (< 10%) at all studied sites as a result of naturally poor bedrock and long-term acidification. Second group of plots on less extreme sites exhibit higher contents of BC in deeper horizon (40 – 80 cm) in beech stands but evenly pure soils in spruce and mixed stands. Plots on most favourable soils showed decreasing trend of BC concentrations in beech > mixed > spruce stands which was pronounced mainly in deeper soil. Foliar nutrition did not reflect the soil condition precisely. General trend of higher foliage nutrient content on richer soils was detected for Ca but not for K or Mg. Positive relation of spruce foliar Mg to the upper soil (0 – 20 cm) Mg content was found for pure Norway spruce stands but not for mixtures, where Mg nutrition was significantly higher. Spruce foliage Zn concentration was higher in mixture comparing to the pure stands; Ca and K were higher in mixtures in the case of triplets in most acidic condition. Beech leaves in pure stand exhibit higher concentration of Zn, Ca and K suggesting that the mixed stand condition are more beneficial for nutrition of N. spruce than of E. beech. On the base of obtained results we assume that the interference of tree species with historical atmospheric deposition load was more important driver for current forest nutrition than their nutrient uptake or different procedures of forest management.

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Relevance of analysing mixing effects at different levels

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Key words: species interactions, tree level, size distribution, stand level

Abstract

As consequence of the increasing interest on mixed forests due to their potential benefits, the effect of tree species diversity on productivity, stability and provision of ecosystem services became a hot research topic during last years. Accordingly, the number of studies on specific mixtures increased significantly providing a first scientific basis for mixed forests management. However, more knowledge is needed to develop general theories and rules and to support suitably forest management.

Mixing effects on forest growth and yield, stability and provision of ecosystem services show a great variability as they depend on species composition, site conditions, stand ontogeny, and density. In order to explain this variability at stand level we need to focus on a higher level of resolution, i.e. tree level. However, up-scaling from tree level results to stand level might be problematic depending on the available information. Species interactions can modify the main processes in forest dynamic, i.e. ingrowth, growth and mortality, thus resulting in different stand structure which might be considered when up-scaling to stand level (size distribution, spatial species distribution pattern, height-diameter functions, etc). Observed stand level mixing effects may be compatible with findings at tree level, whereas we should test that when up-scaling from tree to stand level emerging properties fit to stand level results.

Therefore when analysing the effect of species mixing it is very important to cover different levels of organization, not only for a better understanding of the processes, but also for modelling and forest practice. Most of the studies focus on one level and the different levels are often studied under different conditions (site, stand age and density), so we need to integrate the different levels in a common site. The complexity of mixed forest dynamic requires overarching studies covering different spatio-temporal scales that allow us to understand the responses to all the influencing factors and to develop general theories.

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Analysing mixture effect on European beech (*Fagus sylvatica*, L.) and Scots pine (*Pinus sylvestris L.*) from growth models based on NFI data

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Key words: Reineke's maximum density line; Martonne; mixing proportions; yield level; mixture effect

Abstract

Introduction: National Forest Inventories (NFI) have been used frequently to study mixing effect by developing growth models. However, the use of NFI data presents advantages and disadvantages when comparing with empirical data. So, the main problem of NFI data is the difficulty to find plots in matching site conditions, i.e. to identify triplets of plots in mixtures and pure stands of studied species. This lack of control makes models developed from this data often criticized. However, in the other hand, the NFIs have one important advantage which is to consist of systematic sample plots distributed throughout the complete range of forest types in each country which cover a wide range of environmental conditions. Therefore, if models based on NFI data were really properly validated, NFI data would open great perspectives.

Data: For this study data from 4 countries NFIs (Austria, France, Spain and Poland) and 2 regional inventories (Bavaria in Germany and Catalonia in Spain) were used. The data consisted of a set of sample plots located in pure stands of Scots pine or European beech as well as in mixtures of both species. For each sample plot, each country provided with stand variables (basal area, density, dominant height...) by species and total, volumes and basal area increments, and some other variables related to site (slope, aspect, annual precipitation and mean temperature). Data summary showed that plots were distributed along a wide gradient of aridity conditions according Martonne index.

Methodology: Two different analyses were done using this data set. In a first step, plots located in pure stands were used to estimate maximum stand density relationships (MSDR) for Scots pine and European beech. Non linear quantile regression was applied to estimate MSDR along the Martonne gradient. The results obtained were then used to calculate relative stand density indices for the all the sample plots as well as species proportions in plots located in mixed stands. Finally, linear mixed models for basal area increment were developed for both species using pure and mixed plots. These models were analysed and their results compared with those obtained from the experimental sample plots in tripletsr pure and mixed stands of same species recorded in the EuMIXFOR transect study.

Results: For both pine and beech species, it has been found a clear relationship between maximum densities and climate conditions, in particular with the Martonne aridity index. The more humid the site conditions the higher the maximum densities for both species, but the pattern of this variation was different. Consequently, these relationships have to be taken into account when estimating relative densities and species proportions along a wide gradient of humidity. Moreover, the analysis of growth models showed a positive effect of pine mixture in beech basal area growth, being this positive effect found along the studied humidity's gradient. On the other hand, the effect of beech in pine basal area growth was slightly negative or non significant, and this effect depended on Martonne index. In general, species mixture resulted in a total overyielding, but its degree was related with the stage of development of each species.

Conclusions: National Forest Inventories represent a large data source distributed through a wide range of forest conditions being of great interest for studying mixture effects at large scales. These data, when used properly, provide similar results as those obtained from triplets.

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Stand structural complexity of mixed old-growth and adjacent selection managed forests in the Dinaric Mountains of Bosnia and Herzegovina

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Key words: mixed old-growth forests, selection managed forests, stand structure, species diversity

Abstract

Old-growth forests (OGF) are often considered to be the most reliable references for sustainable nature-based forest management. However, due to the fact that very few OGF are left in Europe, the comparisons between OGF and managed forests (MF) were rarely possible. Besides, contradictory conclusions may be drawn from studying the structures of European OGF, at least in mountainous regions; namely some researchers point out that selection phase develops only temporary in such forests due to biomass accumulation, while others suggest that selection and other similar equilibrium structures prevail. If the latter is the case, then the argument that OGF should serve as natural references for selection management would be fairly strong. Simultaneously, managed mixed selection forests are thought of as the most "natural" type of MF, and thus, similar to large extent to OGF. The concerns have been raised, however, whether selection system provides conditions favorable enough for maintenance of biodiversity. Since nature-based silviculture should follow natural processes and not exclude any species from their natural range, in this study we compared two mixed mountainous OGF Janj and Lom, and neighboring MF on the same site (*PiceoAbietiFagetum illyricum*), which were managed with a selection (plenter) system for more than a century in the Dinaric Mountains of Bosnia and Herzegovina. The comparisons involved a range of structural and compositional characteristics. The differences were found regarding attributes such as tree density, mean diameter, veteran trees and coarse woody debris (CWD), whereas the results for species mixtures were variable. Despite high values of growing stock, dbh distributions in both MF and OGF had shapes that are considered to provide certain demographic equilibrium. Species occurrence matrices further indicated significant domination of European beech (*Fagus sylvatica* L.) young trees over silver fir (*Abies alba* Mill.) and Norway spruce (*Picea abies* L. Karst) in OGF. Nevertheless, the study highlights the crucial role of silvicultural measures which potentially may provide targeted long-term coexistence of broadleaved and coniferous tree species within the Bosnian Dinaric Mountains.

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Thinning in young mixed stands with Douglas fir

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Key words: silviculture, thinning, basal area, quotient of slenderness

Abstract

In Europe, Douglas fir (DF) is an introduced tree species that has great potential for use in mixed stands. Consequently, mixtures with domestic tree species, e.g. Norway spruce, European beech, Scots pine, etc., were planted in the Czech Republic over last decades. These young stands are in the phase of the first thinning now and forest managers usually do not have an experience with adequate techniques. Therefore, three experimental thinning series were established in 2010-2011 in 17-25-year-old mixed stands. One of them is localized in Eastern Bohemia on *Fageto - Quercetum acidophilum* site (DF, pine and spruce from natural regeneration) and two more series were established in Southern Bohemia on *Querceto - Fagetum acidophilum* site (DF, spruce and fir from planting). Effect of the first thinning on growth and development of observed species after 3-5 growing seasons was analysed.

First results showed that diameter increment of all species increased after thinning. Higher differences between thinned and control plots was found in younger (17-year-old) mixtures. Periodic (5-year) basal area of whole mixture increased on control plot by 56% while on thinned plot by 128%. Basal area of DF in this mixture increased by 11% on control plot and 54% on thinned plot. Results showed that in mentioned site and stand age, local species (mainly Scots pine) grew better than DF. On the other hand, DF was supported by thinning more efficiently.

In older series (age of 25 years before thinning), we confirmed the effect of thinning on basal area too. In case of whole mixture, 3-year basal area increased by 9-11% of initial values on control plots compared to 20-23% on thinned plots. While increment of DF was 13-14% of initial values on control plots compared to 15-18% on thinned plots. Consequently the effect of thinning in older stands from artificial regeneration was lower. Local species and DF responded to thinning similarly with slightly positive shift in case of DF.

On the base of our results, we recommend the proper first thinning in young mixtures with DF. This silvicultural measure has positive effect not only on vitality of DF, but also on vitality of other admixed species, i.e. for sustainability of mixture in the future.

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Number of oak (*Quercus robur* L.) natural regeneration growing under pine (*Pinus silvestris* L.) canopy: possibilities for inclusion into the next generation stand

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Key words: understorey; stand conversion; multi-species stand; silvicultural treatments

Abstract

In the past, mesotrophic forest habitats with pine (*Pinus* sp.) and oak (*Quercus* sp.) as the main tree species in some regions in Europe, were strongly distorted by introduction of pine monoculture, cattle and pig grazing, and litter raking. These kinds of activity significantly decreased the percentage of oak found naturally in these forest habitats. Currently the phenomenon of widespread occurring of broadleaved tree species, including oak, under the canopy of pine stands, have been observed. Natural oak regeneration is, to a great extent, facilitated by the jay (*Garrulus glandarius*).

During the study we aimed to determine: (i) the numbers of all and valuable Pedunculate (Sessile) oaks from understorey of harvestable pine stands; (ii) their patterns of spatial distribution; (iii) silvicultural treatments, which are needed during stand conversion, that can use natural oak regeneration.

We located our study in the Niepołomice Forest in Poland. In three forest compartments, a series of 0.05 ha sample plots were established in a 50x50 m base grid. Stand features, total oak numbers and total high quality oaks were determined.

Volume of oak in three forest compartments amounted to 18, 23 and 31% of growing stock in investigated stands. The numbers of oaks in understorey in the studied plots were 196, 216 and 265 trees per ha, which were sufficient to ensure adequate participation of that species in the target stand. Some authors indicated that 10 to 15 oaks in an area of 0.05 ha should be sufficient. This requirement (i.e. minimum 10 oaks per 0.05 ha) was met by 39 to 86% of sample plots. However, the proportion of all oaks classified as valuable (commercially viable) was small, accounted to 5–10% (from 11 to 26 per ha). Assuming a target number of oaks at rotation age of 150 trees ha^{-1}, about eight valuable oaks should grow on an area of 0.05 ha in the gaps selected for further treatment. Only one sample plot (from 84 studied) met this requirement. This is a problem for silviculture and we proposed three silvicultural procedures to manage such forests.

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Silviculture of mixed oak stands can be supported by natural succession processes

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Key words: close-to-nature silviculture, forest succession, mixed stands, silvicultural goal, stand dynamics and structure

Abstract

While in Central Europe far-from-nature monocultures were under high interest in the past, at the present time close-to-nature mixed forests are receiving more attention as many studies underline the importance of species diversity for most forest functions and services.

Here, we present the model for silviculture of mixed oak stands by means of natural succession processes by contrasting it with the common used in forest practice model which assumes development of oak excluding tree species admixtures within the same storey. We compare the selected growth parameters of oaks (mean diameter, height, slenderness), as well as the whole stand level productivity and structural diversity between both models at the three developmental stages.

We use three data sources. The first set of data consists of results of two inventories performed on 130 plots located in 13 mixed and pure oak young growths. The second data set bases on the detailed survey conducted on 2 plots (0.25 ha, each) in stands representing respectively two silvicultural models at the pole stage. The last data set includes data from 20 sample plots (0.25 ha, each) established in mature (80-90 years old) mixed and pure oak stands. All plots were established in eastern Poland and thus represent the conditions of continental climate.

The oak mixed-species stands consisting of early successional tree species (birch, aspen, pine) are characterized by a more diverse and balanced tree species composition and a greater vertical structural differentiation than the oak stands treated by classical model. The oaks that were growing under the influence of early successional tree species, were just a bit thinner, smaller and more slender at the same age than the oaks treated according to the traditional model. However, the latter ones are characterized by a slightly better technical quality.

The results obtained point out the great possibilities for use natural succession processes to optimize the silviculture of mixed oak stands, i.e. lower the costs of silvicultural treatments by biological rationalization.

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Thinning experimental design to evaluate inter and intra-annual radial increment responses in pine-oak Mediterranean forest stand

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Key words: band dendrometer; *Pinus sylvestris*; *Quercus pyrenaica*; SIMWOOD

Abstract

Forecasts for the coming decades predict an increasing demand for wood in Europe's future as renewable energy supply. SIMWOOD European project (Sustainable Innovative Mobilisation of Wood) aims to mobilize unused potential wood, respecting and achievement of climate protection objectives. In this context, the responses of pine-oak mixed stand (*Pinus sylvestris* L. and *Quercus pyrenaica* Willd.) to thinning treatments; unthinned (control), moderate (25 % of total basal area removed) and heavy (50 % of total basal area removed), are assessed at a site located in western Spain. Thinning was performed in 2015 and their effects were monitored over current year 2016 to the present. Inter and intra-annual radial increment are recorded through biweekly band dendrometer installed on a total of ninety trees (fifteen for each specie and treatment) in nine rectangular plots (40x50 m). Linear mixed model approach will let analyze climate, weather and thinning effects on the inter-annual and intra-annual radial increment rate. The effect of thinning and weather variables on radial increment is expected to reflect light and water availability dependence for both species as limiting growth factor emblematic from Mediterranean area. Therefore, understanding growth dynamics in mixed forest stands under contrasting climatic conditions and different levels of competition may serve to mobilize removable resources as wood, increasing economical stands function and establish strategies for adapting to forecasted climate change.

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Annual and seasonal response of European beech (*Fagus sylvatica*, L.) in interspecific neighbourhoods

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Key words: Drought stress, competition, carbon isotopes, self-acting dendrometers

Abstract

On many sites in Central Europe conifer monocultures are converted to mixed stands with European beech (*Fagus sylvatica*). However, some studies question the suitability of this species in a drier and warmer climate while other research suggests better growth responses, resistance and recovery of beech during respectively after dry years of beech in mixed than in pure stands. We examined 24 groups of 5 trees growing in three major geographic regions of Germany to investigate the effect of intra- and interspecific competition for light on (i) annual and (ii) seasonal radial growth of target tree beech trees and (iii) combined dendrochronological investigations and wood stable isotope measurements to further investigate the impact of neighborhood diversity on short-term drought response and soil water availability. The growth response of the target trees reflected the strength in competition (highest growth of beech if mixed with Scots pine > Norway spruce > valuable hardwoods > intraspecific competition). i.e. during the last 4 decades, target trees whose competitive neighborhood consisted of co-occurring species exhibited a superior growth performance compared to beeches in pure stands of the same investigation area. This general pattern was also found in exceptional dry years. Although the summer droughts of 1976 and 2003 predominantly caused stronger relative growth declines if target trees were exposed to interspecific competition, with few exceptions they still formed wider annual rings than beeches growing in close-by monocultures. Within the same study region, recovery of standardized beech target tree radial growth was consistently slower in monospecific stands than in the neighborhood of other competitor species. These findings suggest an improved water availability of beech in mixtures what is in line with the results of the stable isotope analysis. Our investigation strongly suggests that the sensitivity of European beech to environmental constrains depends on neighborhood identity. Therefore, the systematic formation of mixed stands tends to be an appropriate silvicultural measure to mitigate the effects of global warming and droughts on growth patterns of *Fagus sylvatic*a.

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Diversity, fire and carbon stocks in Australian temperate mixed forests

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Key words: ecosystem services, forest inventory, Eucalypt forest, forest structure, fire

Abstract

Forest carbon is an integrated value since it is the net result of forest productivity, which underpins most ecosystem services. Maintaining and enhancing forest carbon is thus central to sustaining healthy and productive forests in accordance with sustainable forest management objectives. Temperate forests in south eastern Australia harbour some of the most carbon dense forest worldwide and represent an important component of the global forest carbon sink. It is thus important to understand the underlying factors driving forest carbon stocks and their resilience.

Diversity has been found to positively affect forest carbon storage capacity and productivity in mixed European forests. However, the impact of functional and structural diversity on carbon storage in native Australian temperate forest remains unknown. Fire, the main disturbance agent in south eastern Australia, can have a significant and variable impact on forest carbon storage depending on forest type and fire regime. However the interactions between fire history, forest diversity and forest carbon storage in these forests have not been explored.

In the absence of an Australian national forest inventory, we have built up an extensive network of plots encompassing c. 700 plots in stands of five different temperate forest types across a wide range of environmental conditions, fire histories and growth stages (time since last fire). Measurements of aboveground carbon stocks, including standing live and dead trees, coarse woody debris and litter were obtained for these plots.

We will use this network, the most comprehensive in south-eastern Australia, to examine the relationships between diversity, fire and carbon stocks in Australian temperate forest. By gaining understanding on the mechanism driving in forest carbon storage we can better foresee potential future changes to the carbon stocks of Australian temperate forest from altered forest structures and fire regimes.

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Improving the sample plan for the assessment index of site productivity based on height in uneven-aged mixed beech and fir forests (with spruce)

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Keywords: uneven-aged mixed forest; fir; spruce; beech; index of site productivity

Abstract

Mixed forests of beech and fir (with spruce), are the most important part of forest resources in Bosnia and Herzegovina. According to the data from the second state forest inventory in B&H (2006-2009) they occupy the area of 665 300 ha^2. Typical uneven aged structure of the tree crown has 70% forest stand; group-uneven aged structure has 22% and two story structure about 8% (Lojo, 2013).

Index of site productivity of a particular stand has been evaluated by constructing a height curve for the given tree species.

After overlaying the determined height curve with the appropriate index of site productivity disposition curves for a given tree species and analysing the curve height position, difficulties in assessing the index of site productivity have been encountered.

Height of the curve of determined stands often intersects two or more curves. In such cases, assessment of the index of site productivity is quite unreliable.

Three experimental plots of 9 hectares each with different amounts of tree species have been established (27 ha in total). Within these three separate plots, 30,110 trees in total have been included in the survey.

After testing several different models for data pair equalization and the index of site productivity curves determination, the Prodan model has been selected as the best dendrometric model for all investigated species of trees.

Methods used in the study are correlation analysis, variance analysis, multiple post hoc tests, comparison method and GIS spatial analysis.

It has been observed that a large number of tree heights with thickness below 30 cm (DBH), in all of the studied species, are outside of the disposition of the index of site productivity.

Tree heights with diameter below 30 cm (DBH) showed greater variability than trees above 30 cm in diameter (DBH). The highest variability was observed in the 7.5 cm diameter class.

We propose a new plan of measuring heights of the trees within interval of 30-70 cm (DBH) on every second sample plot.

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Effect of tree species on soil enzyme activities in relation to other soil properties

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Key words: forest soil, enzyme activity, tree species, soil organic matter

Abstract

In this research study, enzyme activity was used to assess differences occurring in soils as a result of the influence of different tree species. The aim of the study was to assess the effects of Scots pine (*Pinus sylvestris*), pedunculate oak (*Quercus robur*) and mixed forest stands on the enzymatic activity, physical and chemical characteristics of soil. Sample plots were located in central Poland, in the Przedbórz forest district (51.09.59.50 ° N, 20.00.24.25 ° E). The test area was dominated by Cambisols (WRB 2002). 15 research plots were established (5 plots under pine, 5 plots under oak and 5 plots under mixed forest). Soil samples from the depth of 0–15 cm were taken below the organic horizon. From each sampling point, 5 subsamples were taken to form a composite sample. In soil samples pH, soil texture, and organic carbon, nitrogen, base cation contents, dehydrogenase activity and urease activity were determined. Changes in the species composition of forest stands may lead to modifications of soil properties. Tree species affected soil organic matter (SOM) accumulation, pH and microbial activity. The highest enzyme activity in this study was reported in the soils of oak and mixed forest stands. The soil pH was lower under pine forest than under oak and mixed forest stands. pHs is presumably a major factor affecting microbial community composition and size, therefore, pH affects enzyme dynamics. We also noted a significant correlation between enzyme activity and C/N ratio which is often used to describe litter quality. A lower C/N ratio was found in oak and mixed stands compared with pine stands.

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Evolution of Israeli Forestry from Pure Even-Aged Pine Plantations to Sustainable Uneven-Aged Mixed Forests

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Key words: mixed forest, new plantation, forest regeneration, release thinning

Abstract

In 1990 KKL-JNF adopted a new forest policy that aimed at creating multi-aged and multi-layered mixed forests. In support of the new policy, ecological surveys were conducted in planting sites, to enable preparation of detailed planting plans that would be matched to site characteristics. Mechanical point site preparation was mainly applied, with especial care given to preservation of native broadleaf species that were found in planting sites. In forest areas that had undergone clear-cutting and regeneration following fires or other damaging factors, outstanding individuals and clusters of conifer species as well as native broadleaf species that were not affected were left as a basis for uneven-aged, multi-layered mixed second-generation growth.

In mixed plantations, native broadleaf seedlings were either randomly scattered among the coniferous species (single-tree mixture) or, alternatively, planted in separate patches of varied sizes (group mixture) to create a complex mosaic pattern. The difficulties in establishing mixed plantations, particularly because of grazing damage caused to native broadleaf species, led to the use of various methods such as: plastic tree shelters, irrigation, mulching, individual-seedling protection fences to improve their establishment.

In many planted forests in Israel, native broadleaf species can be recruited to young and mature forests by natural regeneration processes, rather than by planting, to form mixed uneven-aged forests. Therefore, direct seeding of oak acorns is recommended as another useful method for establishing mixed forests.

Interspecific pine-broadleaf competition for light may lead to increased pine overstory density and suppression of native broadleaves when the mixed plantations are 10-20-year-old. Therefore, implementation of repeated selective release thinnings is required in order to enlarge the space around native broadleaves and ensure that broadleaf trees, that are slow growing, would not be suppressed and loose vigor from shade inflicted by pines.

The conversion of the simply structured pure even-aged pine forests into complex mixed uneven-aged forests through proactive management seems to be a promising approach for the sustainability of these forests.

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Mixed forest model (IBEROMIX) integrated in SIMANFOR web simulator as tool to improve management

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Abstract

Mixed forest are focusing main concerns about management in Europe as main of the silvicultural theories are founded on pure stand data. As part of the effort to understand the underlying processes and develop new management tool a parametrization of IBERO model has been devoloped for mixed pine-oaks (*Pinus sylvestris, Pinus nigra* and *Quercus pyrenaica*) forests in northern Spain. IBERO is an individual tree growth model not spatially explicit. To allow simulations IBERO^{MIX} is implemented on SIMANFOR (a web based forest simulator). Main characteristics of the new parametrization and simulations with SIMANFOR will be presented in order to facilitate operational forestry at stand level.

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Building a worldwide forests and forestry research network based on functional traits mixed forests triplets: Design, implementation and first results on basal area growth

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Abstract:

Complementarity in forest mixtures can lead to increase stand productivity, mitigate the impact of different risks and generate more resilient and more resource-use efficient forests than pure stands. During the last years different systematic studies in temperate forest has been developed in Europe but there is a lack of such type of studies worldwide. We present here a network of 25 triplets covering a wide array of forest ecosystems and forest plantations worldwide. Each triplet consists in three plots of two complementary species (shade tolerant versus shade intolerant) where 10 to 20 dominant trees have been cored per plot. Our main hypothesis is that mixing effects are modulated by shade-tolerance. The mixtures covered are: *Pinus sylvestris/Pinus pinaster* (Spain), *Pinus sylvestris/Pinus nigra* (Spain), *Pinus sylvestris/Quercus pyrenaica* (Spain), *Pinus pinaster/Quercus pyrenaica* (Spain), *Fagus sylvatica/Quercus petraea* (Belgium), *Pinus sylvestris/Fagus sylvatica* (Sweden), *Pseudotsuga menziensii/Alnus rubra* (Oregon, US), *Tsuga heterophylla/ Acer macrophyllum* (US), *Juniperus procera/Podocarpus falcatus* (Ethiopia), *Nothofagus nervosa/Nothofagus obliqua* (Argentina), *Nothofagus dombeyi/Nothofagus obliqua* (Argentina), *Swietenia macrophylla/Samanea saman* (Costa Rica), *Fagus sylvatica/Pseudotsuga menziesii* (Germany), *Picea abies/Pinus sylvestris* (Germany), *Fagus sylvatica/Picea abies* (Germany), *Picea abies/Larix decidua* (Italy*), Quercus humboltii/Pinus patula* (Colombia), *Swietenia macrophylla/Cedrela odorata* (México), *Laguncularia racemosa/Avicennia germinans* (México), *Pinus durangensis/Pinus arizonica* (México), *Quercus falcate/Fraxinus excelsior* (Chile), *Sorbus torminalis/Pyrus piraster* (Chile), *Quercus falcata/Prunus avium* (Chile), *Juglans regia/Prunus avium* (Chile), *Quercus petraea/Pinus sylvestris* (Poland). In some cases, core was not allowed so permanent plots were established for further analysis. Additional triplets of selected mixtures are available for regional or local analysis. We'll present the general methodological approach and the different potential use of this network. As example, we'll develop in details the study of mixing effects on basal area growth and its relationship with shade tolerance in selected triplets.

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Analysis of tree interactions in a mixed Mediterranean pine stand

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Key words: Competition; *Pinus pinea*; *Pinus halepensis*; Neighborhood- analysis

Abstract

Studying species interactions in mixed forests is essential to assess their stability through time. This is a dynamic process that depend not only on intrinsic but also on extrinsic factors. *Pinus halepensis* Mill. and *Pinus pinea L.* are two main Mediterranean pines with similar ecological requirement, that coexist under certain conditions, mainly in coastal areas, and there is evidence of the instability of these mixtures outside of their natural occurrence area. Half of the area covered this mixtures in Spain (40,943 ha) comes from afforestations, often placed outside their natural ranges. Thereby, knowledge of the interactions between species of these afforestations is a key factor to design appropriate forestry tools that allow their long term stability. Using individual-tree spatially explicit growth models and multi-model analysis approach we test for several hypotheses to address the following questions: Is the competition at neighborhood scale an important constraint for tree growth in this mixtures?, What mode of competition (size-symmetric/size-asymmetric) is most important?, Can trees of the two species act as equivalent competitors (i.e. similar *net competitive effects* - no mixing effects)? and finally, are the *net competitive responses* similar between species?. Results indicate that competition by neighboring trees was an important variable in the basal area growth models, generated reductions in model errors of 27% and 12% for *P. pinea* and *P. halepensis* respectively. Size-symmetric competition was the more important mode of competition. Our analysis show that, at this stage (43 years), both species perform as equivalent competitors and had similar *net competitive effects*, but the *net competitive responses* were different between species. *P. pinea* showed a greater impact of competition on growth than *P. halepensis*, stressing the need for a silviculture designed to encourage the growth of *P. pinea,* in order to keep this species in the mixture.

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Growth and carbon isotopes relationships in *Pinus sylvetris* (L.) and *Fagus sylvatica* (L.) mixedwoods in the SW Pyrenees

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Key words: basal area increment; competition; CO2; drought stress; stable carbon isotope

Abstract

Mixedwoods can exceed relative and total production of pure forests. This overyield may arise from improvements in resource use efficiency availability, and fraction captured. In this study we explored growth and water-use efficiency relationships by creating 34-year series of basal area increment (BAI) and intrinsic water-use efficiency (iWUE) with annual resolution of *Pinus sylvestris* and *Fagus sylvatica* stands at two contrasting sites in the SW Pyrenees: Aspurz (625 m a.s.l. Mediterranean climate) and Garde (1335 m a.s.l. continental climate). At each site 5 trees of each species were sampled and stand density index (SDI) of the target and the other tree species was estimated as a proxy of intra- and inter-specific competition, respectively. Besides, due to the uneven age distribution of *F. sylvatica* in Aspurz, additional analysis of the 30 innermost tree-rings (5-year resolution) of trees born before and after 1950 was performed. Drought stress was considered through the standardized precipitation evapotranspiration index (SPEI). We found an increasing trend of iWUE in both species during the last decades. It was positively related to atmospheric CO_2 concentration (C_a) and negatively with SPEI of August at time scale of 4 months. Intra- and inter-specific competition dominated in Aspurz in both iWUE and BAI related processes, therefore negative mixture effects seemed to occur in the more water limiting site. On the other hand, species complementarity may have caused the observed increase in iWUE of *F. sylvatica* as density rises in Garde, which however did not provoke increases in growth. Nevertheless, these site differences should be carefully interpreted for *F. sylvatica*, as *F. sylvatica* trees were older in Aspurz and the response of trees born before 1950 to C_a was stronger in terms of iWUE and growth. The influence of iWUE on radial growth was positive and negative in *F. sylvatica* and *P. sylvestris*, respectively. This fact points to a higher CO_2 fertilization effect in *F. sylvatica* than in *P. sylvestris*, in which any photosynthetic advantage conferred by increased C_a might be overcome by drought stress.

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The performance of European beech (*Fagus sylvatica* L.) in pure and mixed forests of the Carpathian Foothills in Ukraine

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Key words: European beech, forest types, growth curves

Abstract

Mixed forests dominated by European beech (*Fagus sylvatica* L.) that occur in the Carpathian Foothills are highly productive, and they provide important regulating and cultural ecosystem services. Since they have been affected by natural and anthropogenic factors, their area decreases, and their structure changes. A large-scale study of the beech growth rates has been carried out in four basic forest types of various species composition: European beech-Hornbeam-Oaks (BHO); European beech-Silver fir (BF); European beech-Silver Fir-Norway spruce (BFS), and mono-specific European beech (B) forest. The study covered tree-stands of age varying from 10 to 140 years. The research subjects were: species composition, height, DBH, number of trees per ha, and growing stock. It was found that the dominance of European beech in species composition of all mixed forest types increases in time. In the BHO forests up to 40 years old, the share of beech is 50-60%, and in the BF forests - 70-80%, while in 100 years old and older forests of both types the share of beech reaches up to 80-90%. In the young BFS forests, the share of beech is 50-60%, and at older age it increases up to 60-80%. The most intensive annual height increment takes place in 20 to 40 years old beech stands. However, it was found that the tree-species that compose mixed stands, influence the rate of the beech height increment at different ages which results in differences in the height of beech trees of the same age class reaching up to 2-3 meters. The maximum annual DBH increment in beech highly varies: from the age of 30-40 years in the B and BHO forest types, through 40-50 years in the BF type to 60-70 years in the BFS forest type. Also the reduction of the number of beech trees in time depends on the type of forest. The highest reduction takes place in the B type forests - during 90 years (*i.e.* from 10 to 100 years of age) the number of trees decreases there to 1-1.3%, only. At the age of 120 years, the growing stock in beech from the pure (B) forest is lower than it is in the mixed forests by 20 to 80 m^3 / ha, depending of their type. It means that this difference may be as high as up to 18%. Thus, with respect to all growth parameters taken into consideration, the results of the study confirm that European beech in mixed forests of the Carpathian Foothills of Ukraine performs better than in pure beech forests.

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Forest Planning for Recreation: Three-cities' urban area case study

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Key words: recreational attractiveness of forests; forest resistance and resilience

Abstract

While production of a high yield of the quality timber maintain the main aim of forest management in Europe, there is a need to develop management procedures that aim at satisfying social demands of the society. In Poland, around 11% of the forest cover is designated primarily for social services (FAO, 2010), such as: national defence, experimental purposes, spa, and out-door recreation close to larger cities/towns. The latter category, *i.e.* urban and peri-urban forests, includes 650 thousands ha of the state owned, and around 21 thousands ha municipally and privately owned ones, which corresponds to 7.5% of the total forest cover in Poland (Jaszczak, 2008). The Tree-cities urban area includes three larger cities bordering each other: Gdansk, Gdynia, and Sopot, that are situated at the Gdansk Bay coast in Poland. In the Three-cities' urban area (414,8 sq. km) live around 750 thousands inhabitants. An area of the state forests in the Gdansk Forest District about 15 thousands ha are designated primarily for recreation, of which some 9 thousands ha are located within the urban area's administrative borders (Grabowski, 2010). The post-glacial landscape is covered mostly with Scots pine and European beech forests, partly mono-specific and partly mixed ones. What is considered as adverse attribute of the Gdansk District forests is their very high average age that exceeds the average age of all commercial forests in Poland. The forests in matter are very frequently visited by the Tree-cities urban area inhabitants, mainly for walking and biking, and sometimes also for picknicking. A detailed example of a long-term management plan, aiming at increasing recreational attractiveness of forests have been elaborated by Stenka (2015). The main criteria taken into consideration to satisfy the visitors expectations were their security and aesthetics of forest interior, while the maintenance of the forest ecosystems' resistance and resilience was another criterion of high importance. Since the use of forests for recreation often leads to conflicts or misunderstanding between various groups of users and forest managers, the participatory approach to forest management combined with large-scale forestry related education of the stakeholders was a necessary condition to make the aforementioned plan accepted.

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Sustainable management of mixed forests in highland areas in the Czech Republic - The evaluation the quality of humus (forest floor, soil) under spruce, beech and mixed stands

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Key words: mixed forests, soil organic matter, resilience, highlands, the Czech Republic

Abstract

Structure, dynamics and functioning of tree species admixtures have been recently a research subject of increasing relevance across Europe. The reason is that mixed forests are frequently considered more resistant and resilient to human or non-human disturbances. Such forest stands have better adaptation strategies to global change as well as higher productivity and support for ecosystem services. A study conducted in the Drahanská vrchovina Hilly land (Czech Republic) aims to verify the assumption that the planting and cultivation of mixed forests in conditions of the beech altitudinal vegetation zone is more advantageous than the cultivation of stands with a simple species composition and dominant Norway spruce (*Picea abies* (L.) Karst.). Complex ecosystem analysis with a special focus on the structure, dynamics and processes of forest ecosystems is a basic methodological approach. The previous study and our first results showed that a higher quality of humus was recorded under mixed stands and a lower humus quality was found under spruce stands as demonstrated by pH parameters, C/N ratio, $Q_{4/6}$ ratio and UV/VIS and DRIFT spectra. The HA/FA ratio is higher in the spruce stand as compared with the mixed stand (beech, spruce) or with the pure beech stand, where young fulvic acids with the predominance of aliphatic groups prevail. Beech is a valuable soil-improving and production tree species at the sites of autochthonous mixed forests. Results obtained prove the suitability of beech distribution in the current sites of extensive spruce monocultures to convert them into the original mixed stands. Results of basic research will be made available to the scientific community, state administration institutions and forest owners and managers. The project was coordinated under the international cooperation programme COST Action FP1206 European Mixed Forests: Integrating Scientific Knowledge in Sustainable Forest Management (EuMIXFOR).

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Sustainable management of mixed forests in highland areas in the Czech Republic - Soil properties under influence of acid deposition in spruce and mixed stand

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Key words: acid deposition, spruce and mixed forest, soil properties, Drahanska Hilly land, the Czech Republic

Abstract

Structure, dynamics and functioning of tree species admixtures have been recently a research subject of increasing relevance across Europe. The reason is that mixed forests are frequently considered more resistant and resilient to human or non-human disturbances. Such forest stands have better adaptation strategies to global change as well as higher productivity and support for ecosystem services. The aim of this study was to characterize the changes in through-fall and seepage waters as a result of acid deposition in spruce monocultures and in the mixed stand of beech, spruce, fir in the first generation after the original mixed forest at the age of 105–130 years in the fir-beech forest vegetation at an altitude of 610–650 m above sea level: The study evaluated the following characteristics: i) pH; ii) the content of cations (Ca, Mg, NH_4^+); iii) the content of anions (SO_4^{2-}, NO_3^-); iv) total deposition (N, S, Ca, Mg) and total potential wet acid deposition. Precipitation on the open area was not acids character, the more acids through-fall was in the spruce stand in the period 2006–2008. Total deposition of nitrogen (N-NO_3 and N-NH_4) and sulphur (S-SO_4), was in the open area 10.1 (2.1) kg.ha^{-1}.year^{-1}. Total N (S) deposition in through-fall in spruce stand was 18.5 (7.9) kg.ha^{-1}.year^{-1}, under the mixed stand 18.4 (9.9) kg.ha^{-1}.year^{-1}. The total calcium (magnesium) deposition in the open area was 3.3 (1.1) kg.ha^{-1}.year^{-1}. Total Ca (Mg) deposition in through-fall was 8.0 (2.0) kg.ha^{-1}.year^{-1} in spruce stand and 8.0 (2.0) kg.ha^{-1}.year^{-1} in mixed stand. The total quantity Ca and Mg which is leached from the forest floor to soil is higher in spruce stand compared to mixed stand. Results of basic research will be made available to the scientific community, state administration institutions and forest owners and managers. The project was coordinated under the international cooperation programme COST Action FP1206 European Mixed Forests: Integrating Scientific Knowledge in Sustainable Forest Management (EuMIXFOR).

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The impact of stand species and structural diversity on anticipated log quality in Central European forests

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Key words: diversity; timber quality; site condition

Abstract

Production of high-quality timber is one of the main goals of forestry in order to remain a sustained part of economy. However, other social and ecological requirements on forests, which are becoming more favoured, may often cause conflicts with the aim to maximise the income from forests. The present study focuses on the question if promoting both biologically and structurally diverse stands may reduce the quality of the timber that can be produced from temperate forests of Central Europe. The analysis was based on the examination of the relationship between stand species and structural diversity and anticipated quality of timber production under the conditions encountered in Central Europe. The data used in this study were collected within the regional forest inventories. The anticipated log quality was determined for individual trees visually in the field. The impact of species and structural diversity indicators on the proportion of logs of specific timber quality was assessed using regression analysis. Based on the recent research in this field we expect that the management goals to achieve high stand diversity and high-quality timber production are complementary to each other.

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Integrating effects of species mixture into individual-tree growth models based on national forest inventory data

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Key words: mixed forests; Swiss National Forest Inventory, non-linear mixed effect models; growth functions

Abstract

In an era characterized by rapid and uncertain climatic changes, there is an increasing need for predicting future tree and forest development using state-of-the-art statistical scenario models. Growth functions implemented in such models have recently been improved to account for the climate effects on tree growth. Yet, possible effects of tree species mixtures have rarely been considered. These effects are of particular relevance since mixed forests potentially exhibit higher levels of ecosystem services than mono-specific stands (e.g., increased productivity) and are expected to provide a higher flexibility if exposed to changing environmental conditions.

We focused on the growth functions of the individual-tree empirical scenario model MASSIMO which have been developed based on data from the Swiss National Forest Inventory (NFI). These species-specific functions for individual-tree basal area increment (BAI) include the influence of stand and tree characteristics (e.g., stand density index, basal area of larger trees, etc.) as well as climate, nitrogen and site topography as environmental covariates. With data from Swiss NFI plots that were repeatedly sampled over more than thirty years, we analyzed the effect of species mixture on BAI. We evaluated factor variables such as mono-specific versus mixed, mono-specific versus different species mixtures, target tree belonging to majority versus not belonging to majority, and continuous variables such as the proportion of trees of the same species as the target tree and the proportion of different tree species. Those variables were included in the BAI functions and fitted to NFI data using nonlinear mixed-effects models.

First results indicate that the incorporation of mixture variables improved the performance of the BAI functions for most considered tree species, although their effect size varies among the species. In further stages, the newly developed functions will be validated against independent datasets derived from long-term forest growth and yield plots in Switzerland and implemented in the scenario model for better predicting forest development in response to changes in climate and species composition.

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Forests in Lithuanian linguistics, folklore, mythology and art – mixed or monospecific prevail?

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Key words: tree species, cultural heritage, ecosystem services

Abstract

Such aspects of ecosystems as inspiration and aesthetic values, and following them cultural diversity, spiritual and religious systems are important to human communities, though the benefits provided by these ecosystem services are resistant to monetary evaluation and difficult to compare between countries and nations. Here we aim to identify impact of mixed forests on cultural heritage of Lithuania, whose territory belongs to the subzone of mixed forests and most of natural tree stands are mixtures. In Lithuanian language tree stand is named by a word derived from a tree name (mostly genus) with addition of suffixes. However, it does not specify that the stand consists of single tree species, only indicates the dominant trees. Pine stands are the only that merit also a particular word šilas, but even that does not necessarily mean monospecific nature of a forest. In traditional beliefs and folklore, prevalence of mixed forests and tree variety is obvious: e. g., the belief in an incarnation of dead people's souls in variety of trees: male – in oaks, birches, ashes, female – in spruces and lindens, or the example of human-tree shape-shifting in archaic fairy tale *Eglė the Queen of Serpents*. In some ancient Lithuanian beliefs, lesser deities or spirits are confined to monospecific forests (birch, linden or oak), part of which were held to be sacred in pre-Christian and part of the Christian period (up to the end of the 17th century), however, most of such recorded stands are mixed in natural conditions. In religious systems (beliefs, myths, etiological sagas), 10 local trees are mentioned, of them only *Alnus glutinosa, Picea abies* and *Pinus sylvestris* may form natural monospecific stands. Besides, conifers are often united as one entity in folk tradition. Forests that appear in formal Lithuanian art – paintings or literature are almost exclusively mixed. Mixed forests apparently provide more cultural ecosystem services than monospecific stands in Lithuania.

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Comparison of mixed-species stands growth dynamics in northern Portugal

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Key words: mixed stands; net primary production; aboveground biomass

Abstract

Research of ecosystems aboveground net primary production (ANPP) has been a central theme in ecological studies. Since the late 1980´s the productivity of monocultures *vs*. mixed-species forests has been a research topic of special interest. The main goal of this study was to investigate if mixed-species stands have additional growth and yield when compared with their pure component species and also to evaluate if the structure of the stand has influence on its productivity. In this way, two types of stand structures in northern Portugal were used: a) a naturally regenerated, with *Pinus pinaster* Aiton and *Quercus pyrenaica* Willd. species, uneven aged with no formal management plan forest stands, and b) an experimental design, with *Castanea sativa* Mill. and *Pseudotsuga menziesii* (Mirb.) Franco species, in a replacement series plantation, specifically established for this kind of research.

The productivity in naturally regenerated forests was estimated by measuring biomass and ANPP in *P. pinaster*, *Q. pyrenaica* and mixed stands, across the Vila Real district, in sites with a wide range of edapho and ecophysiological conditions. The main results indicated higher mean ANPP and production efficiency values for the mixed-species stands compared with the single-species stands. These results in mixed stands are important because of timber production and the recognized function of forests as a carbon sink.

The growth and yield in the experimental mixed-species stand were estimated with *C. sativa* and *P. menziesii* species in both pure and different proportions and with the same conditions of soil and climate. With stand aging the aboveground biomass values were higher in mixtures as a result of the enhanced biomass of the *P. menziesii* in the mixture. The mixtures had higher mean ANPP values than the pure treatments. Higher productivity in mixtures would indicate a facilitation of *P. menziesii* by *C. sativa*, since the productivity of the former in mixtures exceeds the productivity in pure treatments. The stratified canopy seems to be responsible for the different tree species performance. Further research is needed to identify the consequences of the different canopy structures as the stand ages and to analyse the interaction effects that lead to mixed canopies efficiency.

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Mixed oak coppices management and biodiversity conservation

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Key words:; coppices, sporadic tree species; tree silviculture; biodiversity, timber production

Abstract

In Italy coppice stands represent the 42**%** (3.663.143 ha) of the total forest area (8.759.200 ha). In particular, the coppices with standard dominated by Turkey oak (*Quercus cerris L*.) or formed by deciduous oaks species are an important resource in the basal and hilly area (1.209.858 hectare, 33% of total coppice stands). The human pressure has been intense for many centuries and mainly aimed to produce fire woods from shoots and sleepers from standards. The frequent coppicing (rotation of 12-22 years), finalised to favour Turkey oak, has modified the stand structure and species composition producing monospecific, even aged and simplify stands. Now the customary past management type have to be reconsidered, because coppice stands can become an important social and economic resource for the presence of many valuable sporadic trees as well as an important source to preserve the biodiversity.

The research activity of CREA-SEL has developed low impact silvicultural techniques in order to conserve and enhancing biodiversity favoring the sporadic tree species. The studies have been carried out in Tuscany, in the Colline Metallifere district (Grosseto). In pure and mixed young and aged coppices some silvicultural practices have been tested in order to differentiate the stand structure and to support the valuable timber production. In particularly, the single trees silvicultural approach has been carried out in order to valorize a few target sporadic and valuable trees (10-20) per hectare. The study, started in 2010, has interested 53 hectare selecting and favouring 536 target trees of *Sorbus torminalis* (L.) Crantz., *Sorbus domestica* L., *Acer sp.,* etc. All around them, localized and from above thinnings have been carried out, removing the closer competitors. The aim was create a free space for the target tree's crown growth. The diameter at breast height of the selected trees have been yearly monitored, while the total height and the crown area have been measured every five years.

The first results showed that the target trees are characterized by a more sustained growth increment, a more regular crown development and a lower mortality in comparison with the sporadic trees not supported by thinnings. This new coppice management can enhance the biodiversity at stand and landscape level and increase the valuable timber production.

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Influence of stand structure on resistance of common ash young stand to ash dieback

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Key words: *Fraxinus excelsior*; *Hymenoscyphus fraxineus*; natural regeneration; mixed forests

Abstract

In Europe, common ash (*Fraxinus excelsior*, L.) suffers from strong dieback caused by pathogen *Hymenoscyphus fraxineus*. Therefore, ash planting has been suspended and its existence is questioned. Prior to the dieback, ash sufficiently regenerated naturally in pure and mixed stands. As ash resistance varies among stands, the aim of this study was to evaluate health condition of 90 young stands in Latvia in relation to their structure. In each stand, one 2 × 100 m sampling plot was established; all advance regeneration and undergrowth species and degree of *H. fraxineus* damage for each ash were accounted. We analysed ash survival according to the previous and current composition of stand. Information on stand structure in previous rotation was obtained from the national inventory.

The mean ash health condition significantly declined with increasing amount of ash in the previous stand. The worst ash health condition was observed in previously pure stands, where 13% of ash saplings were dead, 4% diseased and 74% healthy. In the stands where ash was in admixture, only 8% of seedlings were dead, 4% damaged, but 79% healthy. Ash density did not differ significantly among stands with different structure. The mean ash regeneration density in stands previously formed by ash was relatively low – 4800 trees ha^{-1}, but in stands where ash was an admixture species, it was 5105 trees ha^{-1}, suggesting natural selection of potentially more resistant, hence healthier ash trees in mixed stands in the future. Regarding current species composition, decreased resistance of ash saplings to dieback in pure stands was indicated by the significant negative logarithmic relationship between the health condition and density of ash. Health condition of ash was the best in the most dense stands with increased number of advance growth and undergrowth individuals. The weakest ash dieback was observed in codominant young stands formed by birch and ash (87% of ash were healthy), as well as by birch (87%) and aspen (89%). The highest ash regeneration density occurred in stands with black alder (7300 trees ha^{-1}) and birch (6933 trees ha^{-1}) as the main species. This suggests successful regeneration of ash when growing in admixture with birch.

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Optimal continuous cover forestry with dead wood as a biodiversity indicator

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Key words: mixed species stands; biodiversity; optimal harvesting; uneven-aged forestry; dynamic optimization

Abstract

In this study we analyze continuous cover forest management with dead wood as biodiversity indicator. We study mixed species stands consisting of Norway spruce (*Picea abies* (L.) Karst.), birch (*Betula pendula* Roth. and *B. pubescens* Ehrh.) and other broadleaves (e.g. oak (*Quercus sp.*), maple (*Acer sp.*), beech (*Fagus silvatica*), aspen (*Populus tremula*). The analysis is based on an economic description of continuous cover forestry using an empirically estimated size-structured transition matrix model. For dead wood we use size-specific decomposition rates, with lower limits on the total amount of dead wood varying between 0 and 40 m^3 ha^{-1}. The optimization problem is solved in its general dynamic form using gradient-based interior point methods. Increasing the dead wood volume requirement has only small effect on the total stand density, but increases species diversity. In addition, increasing the dead wood requirement has only a minor effect on the total harvested amount, but harvests shift from timber harvests to biodiversity fellings to maintain the dead wood volume. In the optimal steady state with high levels of dead wood requirement two harvesting cohorts emerge: one for timber harvests, and the other for biodiversity fellings. Increasing dead wood requirement decreases steady state net timber income by over 30% compared to unconstrained solution.

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The functional role of tree diversity: scientific evidence from pan-European studies (BACCARA and FunDivEUROPE)

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Key words: ecosystem functioning and services, forest biodiversity, FunDivEUROPE, mixed forests

Abstract

A number of global change drivers, such as land use change, climate change, or air-borne eutrophication, have considerable impacts on the biological diversity of forest ecosystems. At the same time, there are ongoing activities to convert pure stands into mixed forests, assuming higher stability and other positive effects for the later. Understanding and forecasting the consequences of these impacts on ecological processes, functions and the delivery of ecosystem services is certainly one of the major challenges for ecological research.

Current investigations on the functional role of forest biodiversity are based on three distinct, but complementary approaches: (i) comparative studies in established stands of differing tree diversity, and (ii) experiments manipulating diversity by planting new stands with various species numbers, including silvicultural trials with only low diversity levels, and (iii) analyses of National Forest Inventory datasets.

The talk reviews studies from such approaches, including large-scale pan-European projects (BACCARA, FunDivEUROPE), suggesting a positive relationship between tree diversity and functions related to productivity, associated biodiversity, and soil parameters. However, no and even negative effects were also documented, and many studies find stronger effects of species identity than diversity. In addition, disentangling the diversity signal from confounding environmental heterogeneity remains difficult. Comparisons of tree species performance in pure and mixed plantations imply that changes in light acquisition and plant nutrition may be important underlying mechanisms for the observed diversity effects.

In sum, a clear general view of the functional role of tree diversity in forest ecosystems has not emerged so far, but different mixture effects on several functions and services are evident. The presence of certain functional traits, i.e. species identity, is certainly a major driver of ecosystem functioning; hence trait-based approaches may offer deeper insights for understanding the significance of biodiversity and for the management of forest ecosystems.

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Biodiversity of mixed forests in Ouarsenis mountains of Algeria

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Key words: Structural biodiversity; Mixed forest; Mountains; Mediterranean; Algeria

Abstract

The objective of our study is to present the richness, spatial distribution of the shrub and the structure of the main tree species of the Algerian mixed forests. The study area is the Ouarsenis Mountains which is the main link of the Western Tell. The methodological approach was based on a survey of plant species followed by a floristic analysis of 10 plots in two different stations in the park Theniet El-Had and 7 plots in the forest of Ain Antar. The transect method combined with the nearest neighbor method was used for the study of the shrub land tree layer. In each plot, two orthogonal transects of 50 m long have been installed. Each transect includes one observation point every meter (50 points total) where the distance to the nearest shrub and tree was measured and the morphological parameters of each species were identified. A total of 861 tree were sampled in Theniet park El-Had and 408 tree in the forest of Ain Antar. The results highlight the importance of plant diversity in both sites. The Shannon index is equal to 1.43 in the park and to 1.16 in the forest of Ain Antar with a Pielou Fairness of around 1. Species diversity is low and shrub species distribution is homogeneous with slight *Juniperus oxycedrus* dominance with an index of Berger-Parker of 0.33 and 0.50 respectively in the park and the forest of Ain Antar. The most dense shrubs has a phytovolume of 13,089.31 plants / ha and 1095.55 m3 / ha. *Juniperus oxycedrus* occupies the largest volume in the two sites. The influence of altitude, exposure and climate in addition to the anthropogenic factors on the structure of trees is noticed. Species richness was 122 species and 33 families in the accomplished 85 floristic surveys. Was noticed importance of therophytes by the invasion of annual grasses. Mediterranean species are the most spread, with an overall abundance dominated by very common species.

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Radial growth strategies of individual trees in primary mixed beech-dominated forests

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Key words: disturbance, tree growth, tree rings,

Abstract

Under the climate change scenarios, the mixed forest are nowadays more and more discussed. The main advantages of these stands are higher stability, resilience and productivity in comparison with monocultures in lower and middle latitudes in central Europe. But low level of knowledges and higher qualification needed for managing mixed forest seems to be obstacle for practical use in forest management. To overcome the lack of knowledges, we need the valuable reference stands of mixed forests for describing its complex processes and structures. Therefore, we decided to study mixed stands in nature reserves of mixed beech-dominated forests in Slovakia, where the structure and dynamics are well preserved. To study such a complex question of forest dynamic and structure, we established 36 plots (1000 m2) using a stratified random design in 3 localities. On each plot we surveyed the live and dead trees and cored the most of the trees on the plot (more than 2000 trees in total). By examining individual tree growth trends, trees were aggregated into three groups based on the growth strategies. Group I. was characterized by individuals with rapid juvenile growth rates indicating recruitment in a former canopy gap, in Group II. were individuals with signs of growth release - abrupt, sustained increases in tree growth indicating mortality of a former canopy and finally, group III. contained individuals with combination of both strategies. The main tree species composition consisted of beech (*Fagus sylvatica* L.), spruce (*Picea abies* (L.) Karst.), maple (*Acer pseudoplatanus* L.) and fir (*Abies alba* Mill.). The oldest trees were spruces followed by slightly younger beeches and the maples were the youngest. The fir trees were in overall younger with very few mature trees. For the beeches the II. growth strategy (growth release) was the most common, but for other tree species III. growth strategies (combination) was more characterized. Further, we found that tree age was not significant for occurring of growth release, but more important for some cases was the DBH value. Interesting result was the influence of the growth strategies on the tree longevity of different tree species. The result showed new knowledges about growth strategies from primary forests, which would be used for close to nature forest management planning.

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Stand density management diagram for mixed dry-afromontane forest in central highlands of Ethiopia

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Abstract:

Dry Afromontane forest are one of the most exploited and disturbed African biomes but Chilimo forest (central highlands of Ethiopia) represent one of the remnants. Preservation of this forest type and local communities' development must be balanced. The lack of forestry tradition and local knowledge block the application of sustainable forest management. Stand density management diagram (SDMD) is average stand-level model which graphically illustrate the relationships between yield, density and mortality throughout all stages of stand development. SDMDs also can guide for designing, displaying and evaluating alternative density management regime for even–aged and uneven-aged forest. However, information about stand density management diagram and other silvicultural operations are lacking for dry Afromontane forests. In this contribution we present a SDMD developed for dry Afromontane forests with data from Chilimo forest and by using species proportion as one of the driver variables. The relationship between stand density, dominant height, quadratic mean diameter and stand volume are represented in one graph. Two equations were fitted simultaneously one that relates quadratic mean diameter with stand density and dominant height, and another that relates total stand volume with quadratic mean diameter, stand density and dominant height for each species. Developed SDMD can be used by stakeholders to determine thinning prescriptions.

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Spatio-temporal variability on natural regeneration in a mixed Mediterranean pine forest

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Key words: *Pinus pinea, Pinus pinaster,* Natural regeneration, mixed species stands

Abstract

The risks, uncertainties and increasing damage inflicted on forests by climate change, can be mitigated by the mixing of complementary tree species, such as mixtures formed by stone pine (*Pinus pinea* L.) and maritime pine (*Pinus pinaster* A.). However, the effect that the mixture can have on the natural regeneration processes is not well known, being this one of the most important processes involved in the long term stability of the mixtures. For this reason, understanding the role of different drivers - such as temperature, precipitations, soil characteristics, overstory layer stocking density and degree of mixture - on the regeneration process of these coexisting species is basic for improving the knowledge of the dynamics of mixed Mediterranean forests. For this study, we have used 122 plots of 0.02 ha established in a mixed forest of stone pine and maritime pine in the Northern Plateau of Spain (public Forest Nº 23, province of Valladolid). Plots were installed immediately following shelterwood cuttings, and the establishment, survival and growth of seedlings and saplings was annually monitored from 2005 to 2013. Natural regeneration of each species was classified into four different categories (C1, C2, C3 and C4); C4 being the most viable and durable, and C1 the least. Our findings show large spatial and temporal variability, as well as interspecific differences, in the density of established seedlings and saplings throughout the years of the study. This variability was greater for the C1 and C2 categories, those less viable, than for the C3 and C4 categories. Stone pine regeneration was found to be more successful than maritime pine regeneration, especially within the two first categories, however, this difference seems to be less important for the last categories. The observed patterns of establishment and survival are linked with attributes as climate, time elapsed since cuttings, site conditions, density and percentage of the mixture in order to interpret the dynamics of regeneration as well as growth and species composition.

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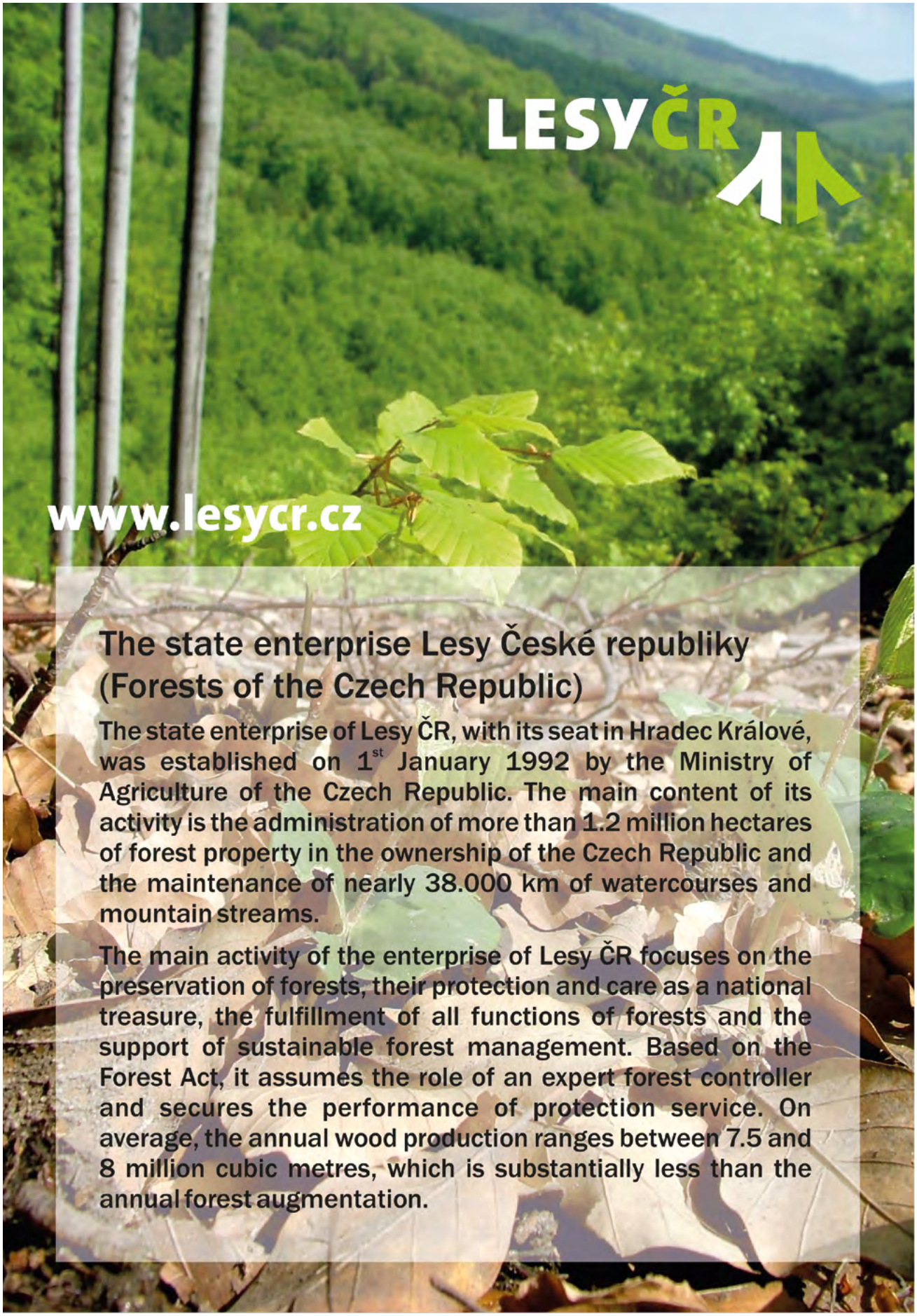

The state enterprise Lesy České republiky (Forests of the Czech Republic)

The state enterprise of Lesy ČR, with its seat in Hradec Králové, was established on 1st January 1992 by the Ministry of Agriculture of the Czech Republic. The main content of its activity is the administration of more than 1.2 million hectares of forest property in the ownership of the Czech Republic and the maintenance of nearly 38.000 km of watercourses and mountain streams.

The main activity of the enterprise of Lesy ČR focuses on the preservation of forests, their protection and care as a national treasure, the fulfillment of all functions of forests and the support of sustainable forest management. Based on the Forest Act, it assumes the role of an expert forest controller and secures the performance of protection service. On average, the annual wood production ranges between 7.5 and 8 million cubic metres, which is substantially less than the annual forest augmentation.

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