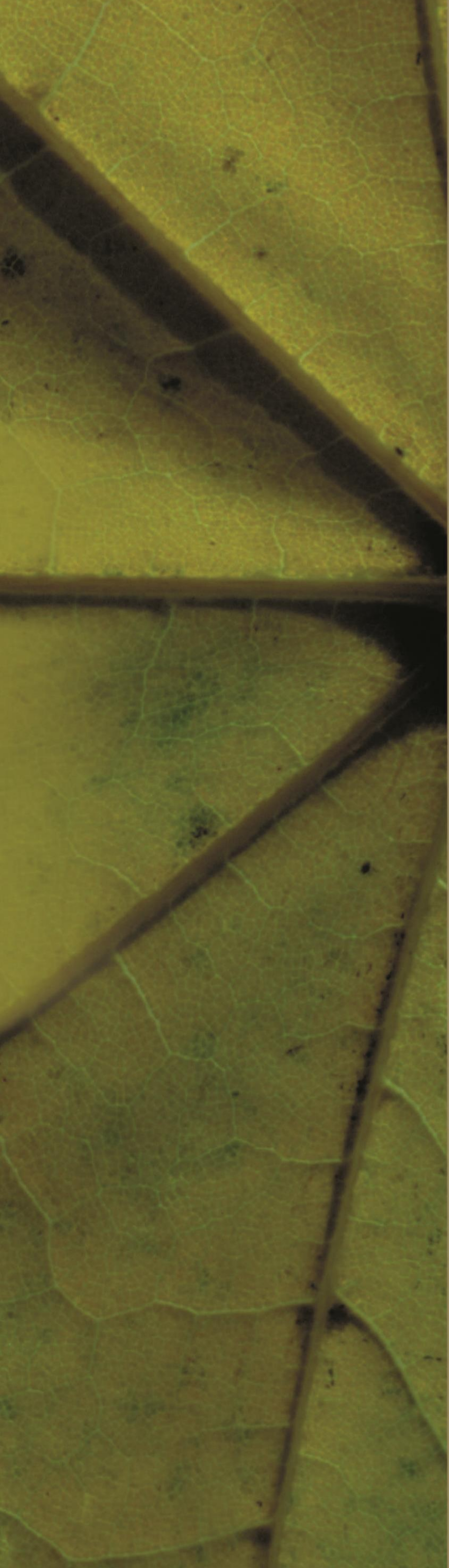

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Vol. 19, Nr. 2

Contents

ACTA SILVATICA ET LIGNARIA HUNGARICA

Vol. 19, Nr. 2

Tartalomjegyzék

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The Re-parametrization of the DAS Model Based on 2016-2021 Data of the National Forestry Database: New Results on Cutting Age Distributions

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Abstract – This paper presents the DAS forest model (Distributions Applied on Stands model), a forest stand-based model suitable for projecting standing volume, increment, harvest, and carbon sequestration on the stand, regional, or country levels. The forest subcompartment is the modelling unit of the DAS model, which uses National Forestry Database (NFD) data, including geospatial data. The model is suitable for further processing spatially explicit input parameters such as climate change forecasts. The model output is also georeferenced and can be further processed using GIS software. The model handles the data of approximately 600,000 forest subcompartments. Data on tree species, origin, age, growing stock, increment etc. of each subcompartment are stored in "tree-species rows", which are the sub-units of the model. The DAS model simultaneously processes the data of 1.2 million tree species rows and describes their development in time. It uses parameters based on the actual processes of the reference period. It also uses empiric cutting age distributions and a regeneration matrix derived from historic NFD data. The ForestLab project (TKP2021-NKTA-43) is currently engaged in the re-parametrization of the model based on 2016–2021 data. This study discusses the functions of the harvesting ratio distribution in the modelling process and in determining the subcompartments selected for harvest. The paper presents the latest results regarding the 2016–2021 cutting age distributions and the preparation of the new set of species-specific and yield class-specific average harvesting ratio distributions.

cutting age / harvesting ratio / forest model / climate change / carbon storage

Kivonat – A DAS modell újra paraméterezése az Országos Erdőállomány Adattár 2016-2021 közötti adatainak alapján: a vágáskor eloszlásokra vonatkozó új eredmények. Cikkünkben bemutatjuk a DAS modellt (Distributions Applied on Stands model), mely egy erdőrészlet alapú erdőállomány prognózis modell, amely alkalmas az élőfakészlet, a növedék, a kitermelt elő- és véghasználati fatérfogat és a szénmegkötés előrejelzésére erdőrészlet szinten, valamint regionális és országos szinten is. A modell az Országos Erdőállomány Adattár adatait használja. Alkalmas térben explicit input-paraméterek fogadására (pl. klímaváltozási előrejelzések) és az eredmények térképi megjelenítésre is, így azok térinformatikai szoftverekkel feldolgozhatóak. A modell kb. 600 ezer erdőrészlet és 1,2 millió fafajsor adatait kezeli. A szabályzó paramétersorok a referencia-időszak ténylegesen tapasztalt folyamatain alapulnak: a modellben valós vágáskor-eloszlások és valós felújítási viszonyok működnek, azaz a modell historikus adatokból levezetett véghasználati- és felújítási mátrixokat használ. A modell újra paraméterezése a 2016-2021 időszak historikus adatainak felhasználásával jelenleg zajlik az ErdőLab projekt (TKP2021-NKTA-43) keretében. Cikkünkben ismertetjük a véghasználati hozami terület arányok eloszlásának funkcióját a modellezési folyamatban és a véghasználatra kerülő terület meghatározásában. Emellett bemutatjuk a 2016-2021-es időszak

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vágáskor eloszlásaira vonatkozó legfrissebb vizsgálatunkat, és a modell újra paraméterezéséhez használt új fafaj- és fatermési osztály specifikus véghasználati mátrixok előállítása során elvégzett munkát.

vágáskor / véghasználati hozami terület arány / véghasználati mátrix / erdőállomány prognózis / klímaváltozás /szénmegkötés

1 INTRODUCTION

Forest sustainability and yield were significant problems for forest sciences in the past, particularly for forest taxation (Suzuki 2003). The 'normal forest' concept was developed in Germany in the 19th century. Hans Carl von Carlowitz – a silver mine administrator in Freiberg – was the first to recognize the necessity of sustainable forest management. In the early 18th century, Hundeshagen (1848) in Tuebingen developed a concept of an ideal forest with the same area for each age class over a cutting cycle. He called this ideal forest concept the 'normal forest'. The concept stipulated that the same age class distribution should remain whenever the oldest stand at the last age class is felled (Leslie 1966, Suzuki 2003). An age-vector space was introduced for normal forest modelling, with forest growth and thinnings represented by a transition matrix acting on the age-vector space (Suzuki 2003).

Yield prediction for domestic forest resources was crucial in Japan in the 1960s. The aim of predicting future forest resources led Japanese researchers to rediscover traditional German forest science and implement the normal forest concept in practice (Suzuki 2003). Matrix-algebra mathematics provides evidence that the time-independent distribution of harvesting ratios ensures a steady state forest in the long run. The concept of this stable state is inextricably linked to that of sustainable forest management and was referred to by Suzuki (2003) as the 'normal forest in the wide sense', contrasting it with Hundeshagen's (1848) normal forest with a single cutting age. The 'normal forest in the wide sense' term is identical to the normal forest with continuous cutting age distribution as described in Király's (1995) normal forest-type classification. Suzuki (2003) introduced a harvesting ratio or cut parameter dependent on the age called "Gentanritsu" (or "Gentan") to determine the forest area felled during a given period. Assuming a time-dependent change for the management objective, Yoshimoto (1996a) introduced a nonstationary Poisson process to capture the harvesting behaviour for Gentan probability estimation. He applied a time-dependent average growth function for stochastic modelling and introduced a time-dependent change in economic factors (Yoshimoto 1996b).

Forest growth modelling dominated the Hungarian forest sciences until the mid-1990s. Professor László Király applied the normal forest concept to beech stands in Hungary and developed a mathematical description of a normal forest (Király et al. 1992, Király – Mészáros 1995). His model was used in forest management planning practice. His research results and theses have gained international recognition, and his work has become fundamental in the Hungarian forestry science.

Forest growth modelling and carbon cycle modelling have become increasingly relevant as the complexity of the burden on forests and the growing need for sustainable forest management rise. Only conscious and careful planning and foresight can balance the contradictory goals of economic efficiency, nature conservation, and the competitive uses of wood yields (e.g. as raw material for wood products, a renewable energy source, or a carbon sink). Climate change exacerbates this set of problems by negatively influencing production conditions for Central European forests and increasing natural disturbance risks.

Simulating photosynthesis or empirical yield curves drive growth in forest carbon cycle models. Photosynthesis-driven process-based models (e.g. Biome-BGC, Running – Gower 1991, CENTURY, Metherall et al. 1993, 3-PG, Landsberg – Waring 1997, TEM, Tian et al. 1999) require input datasets such as leaf-area index (Running – Gower 1991), climate variables, and soil variables (McGuire et al. 2002). Empirical yield data-driven models like EFISCEN (Nabuurs et al. 2000), CO2FIX (Masera et al. 2003), or FORMICA (Böttcher et al. 2008a) require data on merchantable wood volume as a function of stand type and age. These are the same data represented in national forest inventories (NFI) and used by operational foresters in timber supply analysis and forest management planning tools (Kurz et al. 2009, Pilli et al. 2013). Yield-driven models are particularly well-suited to explicitly simulate human activities and natural disturbances on the current and near-future forest carbon stocks and fluxes (Pilli et al. 2017). These models simulate growth and calculate carbon stocks based on past observations, and they are the primary tool to simulate the detailed effects of different forest management options in short-term forest carbon dynamics (Böttcher et al. 2008b, Pilli et al. 2013) at forest stand to country levels (Pilli et al. 2016).

Hungarian researchers experimented with the EFISCEN model in the mid-1990s by contrasting it with the Király model. Researchers preferred the Király model for forest management planning purposes. In the second commitment period of the Kyoto Protocol, Hungary accounted for its carbon removals in the forest management sector against a Forest Management Reference Level developed with the assistance of the Joint Research Centre of the European Commission and in collaboration with two EU modelling groups using the G4M (IIASA 2023) and EFISCEN (UNFCCC 2011) models. The Biome-BGC model was also parametrized for Hungarian circumstances, resulting in the Biome-BGCMuSo model (ELTE 2023). The model performed the biospheric carbon dioxide balance estimation for Hungary in 2009 (Barcza et al. 2009).

The first Hungarian country-specific Carbon Sequestration Model for Forestations (CASMOR) was developed by Somogyi (1997) based on Comprehensive Mitigation Assessment Process COMAP (Sathaye et al. 1995). The CASMOFOR model (Somogyi 2019) is a newly developed version of the previous model based on IPCC methodology and considering domestic forest characteristics. The CASMOFOR model led to a new dynamic growth model for all Hungarian forests called CASMOFOR-NFDB (Somogyi et al. 2019; Somogyi 2020) to fulfil new reporting requirements arising under the Paris Agreement and Regulation (EU) 2018/841 and to develop a country-specific Forest Reference Level (FRL). The developed model is consistent with the Hungarian Greenhouse Gas Inventory (GHGI) and is based on IPCC methodological guideline principles. The main source of activity data used by this modelling approach is the National Forestry Database (NFD) and data from the Hungarian GHGI. NFD data of forest subcompartments as input is used instead of yield tables and silvicultural models to ensure higher consistency with the GHGI (Somogyi et al. 2019, Somogyi 2020).

Within the frame of the Agroclimate 2 project, a new Hungarian forest projection model, the DAS forest model (Distributions Applied on Stands model), was developed in 2015 (Kottek 2017). The DAS model is also based on NFD data, but unlike the CASMOFOR-NFDB model, it uses the same yield tables as the NFD and is georeferenced. Results are linked to forest subcompartments and can be further processed using GIS software. Thus, the DAS model is suitable for projecting standing volume, increment, harvest, and carbon sequestration on the stand, regional, or country levels. This paper introduces the DAS model structure and characteristics focusing on harvesting parametrization and age-dependent harvesting ratio estimation. The second part of the study presents the latest results on cutting age distributions derived from NFD data and the applied changes in the parametrization of the final harvesting probability related to the planned re-run of the model.

2 CHARACTERISTICS OF THE DAS MODEL

2.1 A forest subcompartment-based modelling approach

The DAS model is a forest-stand-based model suitable for projecting standing volume, increment, harvest, and carbon sequestration on the stand, regional, or country levels using forest stands as the modelling units. Also called subcompartments, these units have homogenous characteristics and are the base units of forest management in Hungary. The DAS model uses NFD data, including geospatial data. The model output is also georeferenced, and can be further processed using GIS software. The model handles the data of 600,000 forest subcompartments.

The sub-unit of the model is the "tree species row", assigned to a tree species in a forest subcompartment. Data on the growing stock of each forest subcompartment is stored in tree species rows. The tree species rows of the same forest stand vary in at least one of the following attributes: tree species, origin, age, or layer. The model simultaneously processes the data of more than one million tree species rows and describes their evolution in time.

The DAS model has a bottom-up architecture, meaning that stand volume stock data is produced by summing up volume stock data of the tree species rows contained in that stand. Regional and country-level data is also derived as the sum of the data of the subcompartments belonging to the given geographical unit. The model uses Microsoft Visual FoxPro programming language and runs in a Windows environment. The used input and the produced output files are in dBase, WKT and CSV format.

2.2 Increment modelling with yield tables

The model uses the yield functions by Gál (1980, 1988) to calculate the average stand height as a function of stand age. Yield functions are based on yield tables and are more suitable for computerized data processing. After the average height at the given age is calculated, the growing stock is estimated using the yield tables applied in the NFD. These yield tables are the digitalized versions of the graphic yield tables prepared by László Király and his colleagues in 1971-1972 and are used numerically in the NFD. The Hungarian dendrometry literature refers to these as first-generation nomograms. Using the same yield tables for growing stock estimation applied in the NFD ensures coherence and interconnectivity with the NFD and projects based on NFD data, such as the Hungarian Greenhouse Gas Inventory and numerous nature conservation, economic, wood industry and climate change projects.

Forest management planning usually takes place every ten years, during which measurements are taken. The measurement data are stored in the NFD. However, between two planning events, the annual increment is calculated for every tree species row based on the yield tables used in the NFD. The NFD adds the 10-year period average annual increment to the growing stock data of the previous year for each tree species row and subtracts officially registered annual harvest from this. However, in the DAS model, the total growing stock is recalculated as a function of stand age for every subsequent year. Average increment data are not used to recalculate growing stock. Height is recalculated instead as a function of the age using yield functions by Gál (1980, 1988). Afterwards, the growing stock is obtained from the official NFD yield tables. The harvested volume for thinning and precommercial harvests is not calculated separately because average precommercial extraction and mortality is included in the stock data predicted by the yield tables of Király. The yield table-based processing of the DAS model also allows for modelling the effect of changing climate parameters on stand productivity because the yield class parameters can be changed accordingly over time

2.3 Total area of final harvest as a driver

The model defines the final harvest by the area affected by final harvesting events. Clearcuts, gradual renewal cuttings, and other harvests generating the obligation of forest regeneration are regarded as final harvests. According to our previous examinations, the total final harvest area defined above is quite stable in time and is not closely related to the yield area derived from the cutting ages specified in the forest management plans. It is also independent of fluctuating wood market trends. Since 1990, the area under final harvest has been around 20–23 thousand hectares, with some observable expansion in the last decade.

The present study determined that a significant part of the forest stands is not harvested at the cutting age prescribed in the forest management plans. Historic data series reveal that only two-thirds of stands reaching their cutting age are harvested (Kottek et al. 2023). From this, the study concluded that forest-stand age class structure and forest management plan felling prescriptions do not determine the actual harvest regime in the medium term. Cutting age prescriptions can only be regarded as the potential for harvest, but external factors such as timber harvesting capacities, nature conservation restrictions, forest management purposes, ownership and legal regulations determine actual harvests. The DAS model uses a parameter sheet where the area under final harvest can be prescribed and changed according to the prerequisites of each scenario applied.

2.4 Cutting age distributions and the probability of final harvest as a function of the age of the stand

The DAS model does not apply the cutting ages that forest management plans predefine to define the cutting age of the subcompartments processed. The final harvests in the model are regulated by cutting age distributions, which assign a final harvest probability to each cutting age. Japanese forest modelling uses a similar cut parameter dependent on subcompartment age called “Gentanritsu” (or “Gentan”), and it determines the forest area cut at a period (Yoshimoto 1996a,b, Suzuki 2003). The age-dependent harvesting probability ratio distributions used in the DAS model are derived from historic NFD data. Thus, the model does not predefine a forest stand’s final harvest time. Subcompartments with special nature conservation requirements and continuous cover forests are excluded. Subcompartments actually harvested are selected randomly according to their age and area, in line with the age-dependent harvesting probability ratio distributions and the final harvest total area as prescribed in the parameter sheet. The model uses regulatory parameter distributions derived from the country’s forest estate and projects these distributions onto individual forest stands by random selection.

The advantage of this method is that different cutting age distributions can be applied in different sub-periods of the forecast. Moreover, management transitions can be modelled. For example, cutting age increases due to nature conservation considerations or cutting age decreases in private production forests due to related regulation changes can be considered. Also, cutting age distributions can be changed to adapt to various scenarios and periods. The model can also adapt to the changing age class structure of forests. If the area of a given age-class accumulates, its forecasted yields also increase. Salvage logging and sanitary felling can also be modelled by incorporating final harvests at younger age classes.

The cutting age distributions are usually not closed, i.e., 100% of the area is not harvested in the last age class affected by the final harvest. This means that some subcompartments are never harvested in the model if they reach the maximum of their cutting age and are not selected for harvesting. These subcompartments persist in medium-term projections and model the well-known but not precisely defined phenomenon of Forests Not Available for Wood Supply (FNAWS). However, long-term projections require additional parametrization because such stands may not exist forever. They might collapse, transform or be transformed into continuous cover forests.

2.5 Transition matrix of forest regenerations

A so-called forest regeneration transition matrix drives forest regeneration patterns in the DAS model. The currently used forest regeneration transition matrix is derived from 2006–2015 NFD data. Each subcompartment under regeneration in the NFD is linked to its previous state (i.e. before the final harvest). Thus, the NFD stores data on tree species and origin (coppice, high forest) of a stand for two states, i.e., before the final harvest and after regeneration. Such data are available for 69% of the regenerated stands for 2006–2015.

Figure 1 shows the forest regeneration distribution (i.e. the regeneration transition matrix) of sessile oak *(Quercus petraea)* forest stands as an example.

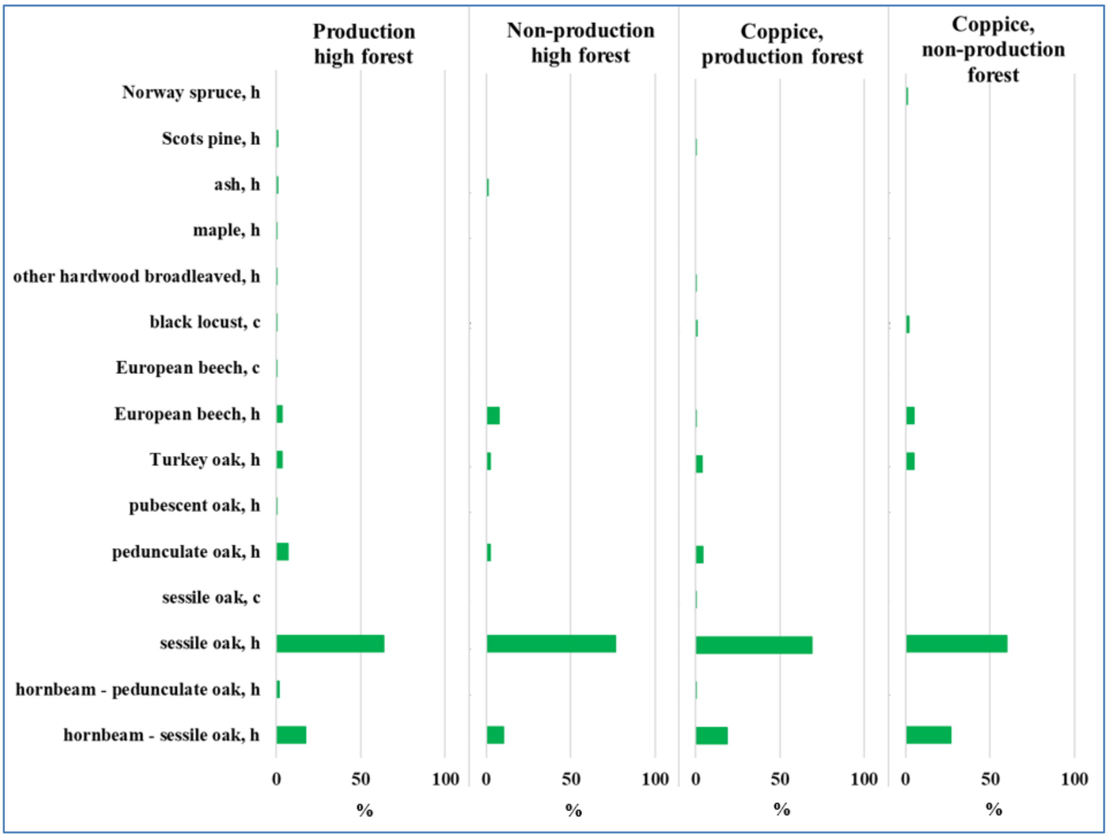

Figure 1. Forest regeneration transition matrix of sessile oak (Quercus petraea) stands (Y axis shows the tree species distribution after regeneration of former sessile oak stands; h: high forest, c: coppice)

Applying the forest regeneration transition matrix in the DAS model makes it possible to change the forest regeneration patterns in time or along different scenarios, allowing for the consideration of changing climatic conditions affecting tree species distribution and modelling of tree species replacements during regeneration.

2.6 Pools of the model

The DAS model uses pools for its processing. The pools are stand-attribute databases of sample forest subcompartments with all their descriptive data normalized to one hectare. The current model version uses three pools: regeneration, afforestation and found forests. Found forests are previously unknown by the Forest Authority and identified during field surveys associated with forest management planning. Found forests can be the result of natural forest area expansion or geodesic re-measurements.

The pools contain historical data of stands under afforestation and regeneration and stand data that entered the NFD as found forests. Stand attributes of subcompartments entering the model as new afforestation or replacing a final cut stand are selected from the pools during the model runs. Forest regeneration selection is driven by tree species, origin, yield class, and county code drive. In afforestation, stand attributes are selected according to the projected afforestation characteristics. The afforested stands enter from the afforestation pool in their completed, afforested state (with data on tree species composition, yield class, etc., stored at that time). For earlier years, data are counted backwards from this state for the estimated year of initial planting.

The afforestation pool contains normalized stand attributes derived from 17 thousand subcompartments with a 78 thousand-hectare area. The regeneration pool contains normalized stand attributes derived from 37 thousand subcompartments, with a 120 thousand-hectare area.

3 EXAMINATION OF CUTTING AGE DISTRIBUTIONS BETWEEN 2006-2021

3.1 Materials and methods

This study examines the cutting age distribution for 2016–2021 and combines it with previously collected data on the cutting age distributions for 2006–2015. The study prepared a new set of species-specific cutting age distributions that can be used for the planned re-run of the DAS model.

The present study collected all subcompartments under final harvest between 2016–2021 from the NFD, grouped the final harvest area by age, species, yield class (1-6) and forest stand function (economic/production forest, and other/non-production forest), and calculated the total area (harvested and not harvested) for each subcategory before harvest. This made it possible to calculate the ratio of the harvested area when compared to the total area in each age class separately for each sub-group by species, yield class, and forest function. The distribution of this ratio by age class describes the harvesting pattern and probability of each subgroup (Suzuki 2003) and can be used for the re-parametrization of the DAS model. In some cases, the ratio was equal to or above 100% due to data quality problems, which arose when very small areas belonged to an age class. In these cases, the study used the average ratio of the two adjacent age classes or 100% in the terminal cutting age class.

3.2 Results and discussion

This paper presents its results using the example of sessile oak (*Quercus petraea*) stands. *Figure 2* and *Figure 3* show the total area of the species for the three examined periods (i.e. 2006–2010, 2011–2015 and 2016–2021) divided into two categories, production forests and non-production forests. In sessile oak, the study observed notable differences between the production and non-production type of forests and presents the results according to this division. When we observed no significant difference between the two subcategories (e.g. pedunculate oak – *Quercus robur*) we created only one cutting age distribution for DAS model parametrization.

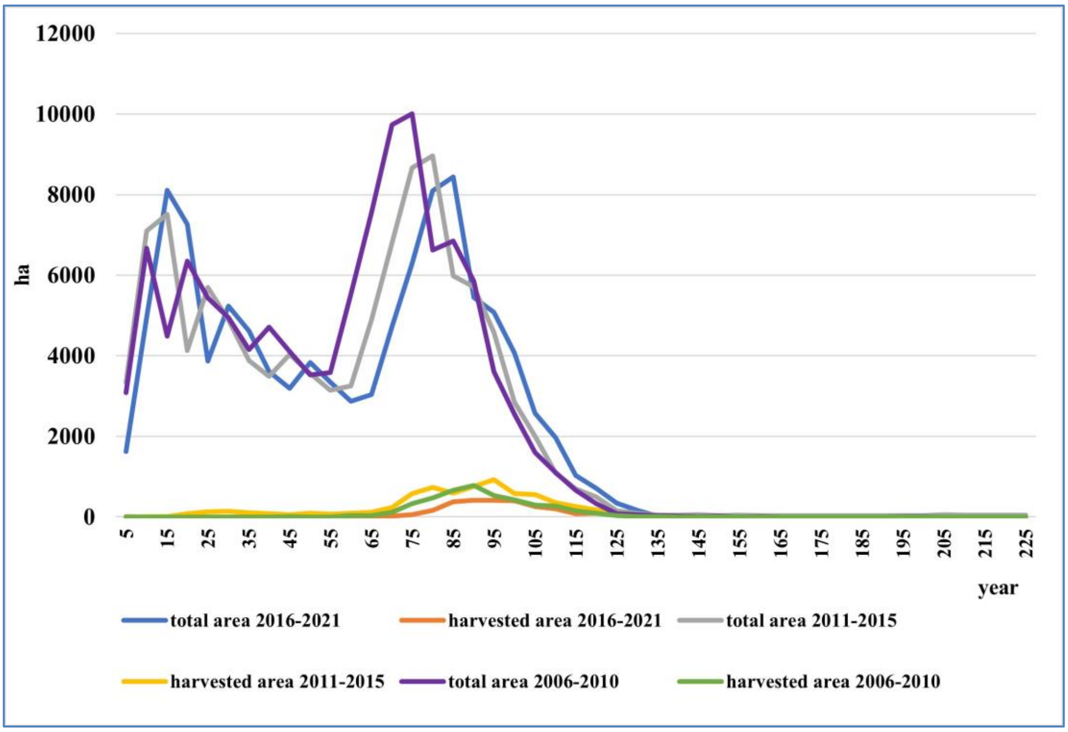

Figure 2. Total area and harvested area of sessile oak (Quercus petraea) production forests as a function of the age expressed in years

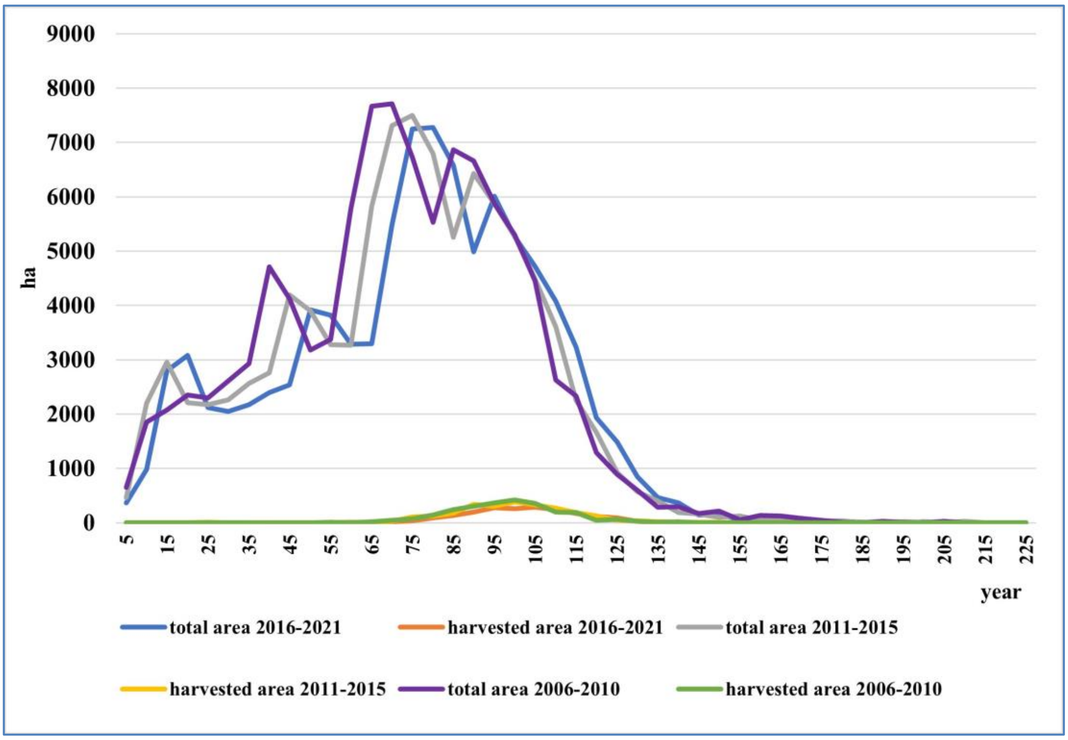

Figure 3. Total area and harvested area of sessile oak (Quercus petraea) non-production forests as a function of the age expressed in years

The figures illustrate that no stand is older than 135 years in the production forest category, while the age range is wider in the non-production forest category, with some stands older than 175 years. Forest functions may be the reason for this as the function of non-production forests relates more to nature, soil protection, and carbon storage. Thus, keeping these forests standing for longer is reasonable. The typical cutting age is also higher in non-production forests, presumably for the same reason. In addition, expensive regeneration in soil protection forests may make final harvests unprofitable. Furthermore, whether regeneration is feasible in the given area is often doubtful.

The age distribution of indigenous species with long rotation periods is quite uneven in Hungarian forests and far from the balanced distribution of normal forests. The current 70-100-year-old age groups are strongly overrepresented, as the example of sessile oak demonstrates. Many forests in Hungary were harvested during and immediately after the two world wars and regenerated afterwards. These forests have now come close to their maturity age (according to the current standards). The increase in cutting age observed in our previous study (Kottek et al. 2023) in the case of indigenous species is, therefore, closely related to the above unevenness of the age class structure. The main reason for rising harvesting ages is the social demand for close-to-nature forest management. This results in the maintenance of older forests as a silvicultural practice. Currently, age class structure provides an opportunity to satisfy this social expectation, which is a very fortunate possibility from a sector policy point of view. Another reason is that forest managers gradually increase the cutting age to equalize yields and evenly distribute regeneration capacities over time. This trend will probably continue as long as the predominance of the older age class persists.

Figure 4 and *Figure 5* show the age-dependent harvesting probability ratio distributions of sessile oak (*Quercus petraea*) production and non-production forests by yield class. In the production forest category harvesting rates are higher than in the non-production forest category. The harvesting probability ratio in both categories decreases from yield class 1 toward yield class 6. It is much more profitable to harvest the stands in yield classes 1 and 2 than in the less productive yield classes. Thus, yield classes 1 and 2 are preferred when selecting stands for the final harvest.

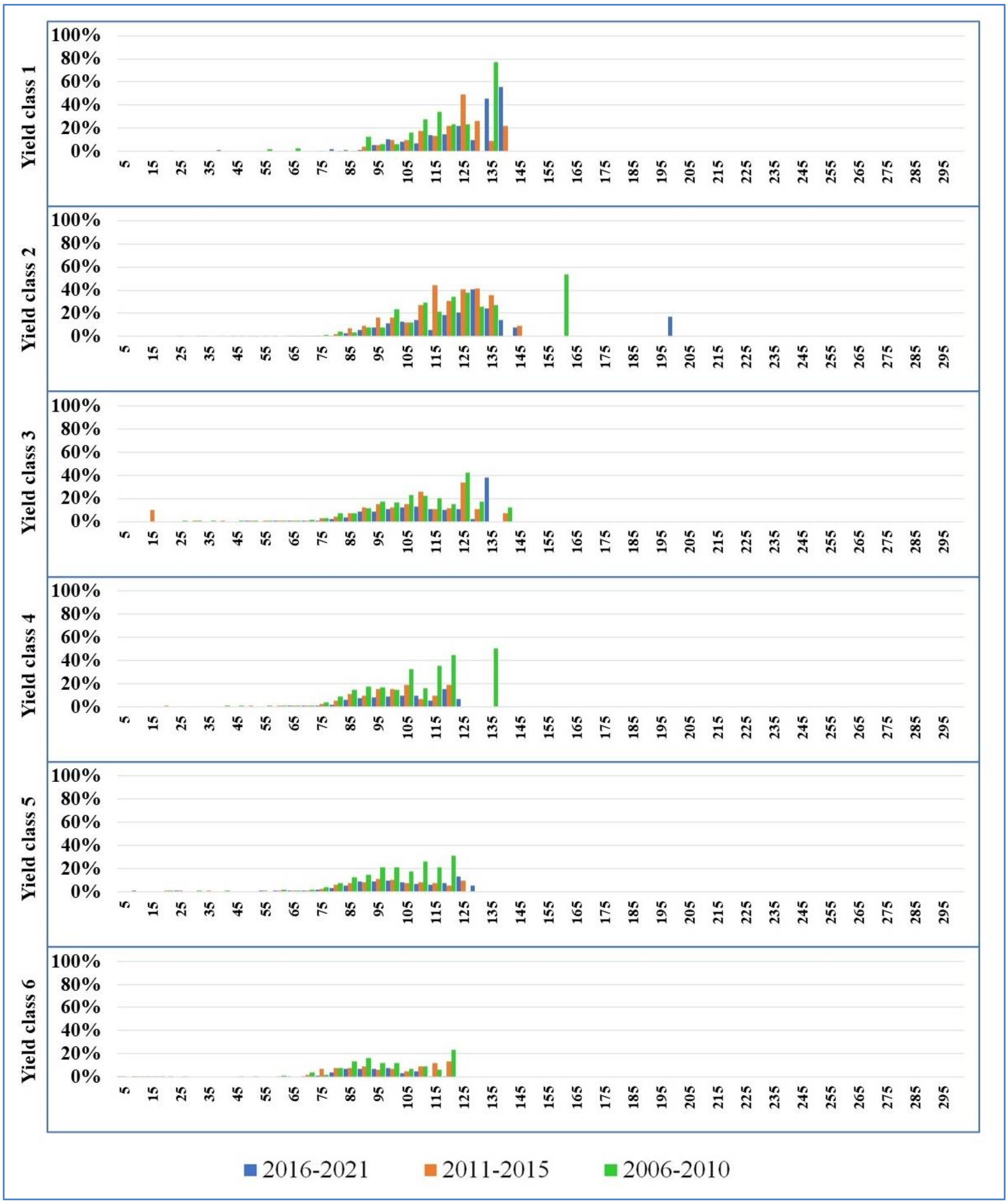

Figure 4. Distribution of age-dependent harvesting probability ratios of sessile oak (Quercus petraea) production forests

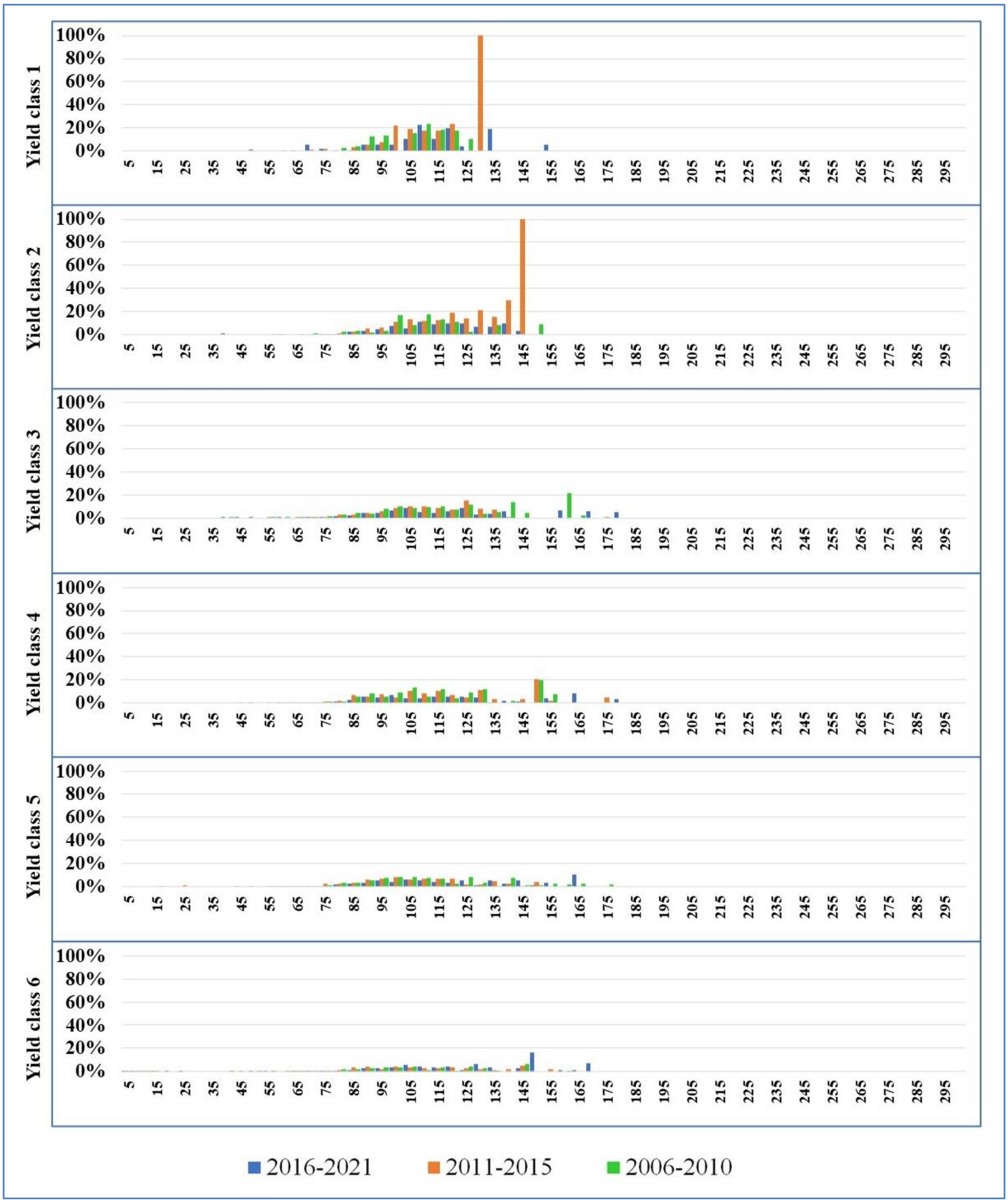

Figure 5. Distribution of age-dependent harvesting probability ratios of sessile oak (Quercus petraea) non-production forests

The same age-dependent harvesting probability ratio distributions shown above were created by yield class for fifteen species groups and production and non-production forests separately where notable differences between the two were observed. The 2011–2021 distribution average was then calculated. The values equal to or above 100% were then filtered out as described in the *Materials and Methods* section and an average age-dependent harvesting probability ratio distribution was created. Our previous study (Kottek 2022, Kottek et al. 2023) observed a decreasing trend in the harmonic mean of the cutting ages in black locust (*Robinia pseudoacacia*) private production forests since the Hungarian Forest Act change in 2017. Since this trend change is significant and can be well explained by the new regulation, the wood market demand, and the financial interest of private forest owners, we narrowed the reference period to 5 years in this case and used only the 2016–2021 dataset for the DAS model parametrization. In all other cases, we used the average age-dependent harvesting probability ratio of the 2011–2021 period. The above applies to the BAU scenario, which assumes that typical management practices of the reference period do not change in the whole projection period. The average age-dependent harvesting probability ratio distributions created this way will be used as parameters during the re-run of the BAU scenario of the DAS model.

4 CONCLUSIONS

This paper presented the DAS forest model, described its main characteristics, and outlined its ability to project standing volume, increment, harvest, and carbon sequestration on the stand, regional or country levels. We described the function of the age-dependent harvesting probability ratio distribution in the modelling process and in determining the selection of subcompartments for the final harvest. We presented our latest results regarding the cutting age distributions of the 2016–2021 period and described the preparation of the new set of species-specific age-dependent harvesting probability ratio distributions prepared for the re-parametrization of the model. Based on the investigation and the method used for selecting the subcompartments for final harvest in the DAS model, the study concludes that the DAS model can adapt to changing age class structure of forests. If the area of a given age class or subgroup of forest stands accumulates during modelling, its forecasted yields and harvests also increase. Stand subgroups can be created per tree species group, ownership, function (production forests and other forests), yield class, or as a combination of these factors. The DAS forest model could also be introduced into forest inventory practice because the model can serve as a procedure package that works very similarly to the NFD. It can be used to derive descriptive data in the short term at a relatively low level of aggregation. This feature also makes the model suitable for describing the probable state of forest stands previously included in the NFD but since removed for some reason. The DAS model can calculate stand attributes as long as there is no data collection about them or only the final cut date is known. In this case, the initial state for the modelling is the last known state as described in the NFD. The model is also suitable for forecasting the state of forests outside the NFD. In these cases, the initial state can be derived from remote sensing or from the systematic forest inventory. However, it should be noted that accurate long-term result can only be obtained if the modelling is supported by remote sensing and periodic field measurements.

We also conclude that the new data on cutting age distributions can be used to actualize the projections made by the DAS forest model and conduct new model runs considering the changes in harvesting patterns. In the framework of the ForestLab project (TKP2021-NKTA-43), we are planning to conduct new studies on the forest regeneration patterns of the 2016–2021 period, renew the forest regeneration matrix of the DAS model, and re-run the projections for 2024–2050.

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REFERENCES

BARCZA, Z. – HASZPRA, L. – SOMOGYI, Z. – HIDY, D. – LOVAS, K. – CHURKINA, G. – HORVÁTH L. (2009): Estimation of the biospheric carbon dioxide balance of Hungary using the BIOME-BGC model. Időjárás 113 (3): 203-209.

BÖTTCHER, H. – KURZ, W.A. – FREIBAUER, A. (2008b): Accounting of forest carbon sinks and sources under future climate protocol – factoring out past disturbance and management effects on age-class structure, Environmental Science & Policy 11 (8): 669–686. https://doi.org/10.1016/j.envsci.2008.08.005.

BÖTTCHER, H. – FREIBAUER, A. – OBERSTEINER, M. – SCHULZE, E.D. (2008a): Uncertainty analysis of climate change mitigation options in the forestry sector using a generic carbon budget model. For. Ecological Modelling 213 (1): 45–62. https://doi.org/10.1016/j.ecolmodel.2007.11.007.

ELTE (2023): Website of the Biome-BGCMuSo model. https://nimbus.elte.hu/bbgc/

GÁL, J. (1980): Fatermési függvények alkalmazása az üzemtervek számítógépes adatfeldolgozásában [Application of tree yield functions in the computerized data processing of forest management plans]; thesis; Sopron. (in Hungarian)

GÁL, J. (1988): Fatermési függvények bevezetése az üzemtervek számítógépes adatfeldolgozásába [Introduction of tree yield functions in the computerized data processing of forest management plans]; project report; Sopron. (in Hungarian)

HUNDESHAGEN, J.C. (1848): Die Forstabschätzung auf neuen wissenschaftlichen Grundlagen. H. Laupp'schen.

IIASA (2023): Global Forest Model (G4M). https://iiasa.ac.at/models-tools-data/g4m

KIRÁLY, L. – MÉSZÁROS K. (1995): Konvergens prognózisok szerepe az erdőgazdasági stratégiák tervezésében [Role of Convergent Prognosen in Planning Forestry]; Erdészeti és Faipari Tudományos Közlemények 1994-1995. 137.

KIRÁLY, L. – SZENTKÚTI, F. – GÁL, J. – MAGAS, L. – MÉSZÁROS, K. – SZÉLESY, M. – FACSKÓ, F. – RÁCS, A. – KOLLER, E. – SZABÓ, P. – FEJES, L. – STEINER, T. – VESZTERGOM, V. (1992): Zárójelentés az 1875. nyt. sz. OTKA kutatásról (1986-1991). Az erdőállománnyal való gazdálkodás optimális szabályozási stratégiájának megalapozása. [Establishing the optimal regulatory strategy for forest management. Projet report.] Erdészeti és Faipari Egyetem, Erdőrendezéstani Tanszék, Sopron.

KOTTEK, P. (2017): National Forest Projection – 2050 in Bidló A., Facskó F. (eds.) University of Sopron, Faculty of Forestry, VI. Faculty Scientific Conference Book of Abstracts. Publishing Office of the University of Sopron, 59., Sopron. (In Hungarian).

KOTTEK, P. (2022): Megváltoztatta-e a vágáskorokat az Evt. 2017. szeptemberi változása? Eredmények az erdőállomány-prognózis előkészítésének munkáiból. [Did the 2017 change of the Forest Act change the cutting ages? Results from the preparation of a forest projection. Presentation.] OEE Szakosztályülés Budapest.

KOTTEK, P. – KIRÁLY, É. – MERTL, T – BOROVICS A. (2023): Trends of Forest Harvesting Ages by Ownership and Function and the Effects of the Recent Changes of the Forest Law in Hungary. Forests 14 (4): 679. https://doi.org/10.3390/f14040679.

KURZ, W.A. – DYMOND, C.C. – WHITE, T.M. – STINSON, G. – SHAW, C.H. – RAMPLEY, G.J. – SMYTH, C. – SIMPSON, B.N. – NEILSON, E.T. – TROFYMOW, J.A. – METSARANTA, J. – APPS, M.J. (2009): CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological Modelling 220 (4): 480–504. https://doi.org/10.1016/j.ecolmodel.2008.10.018.

LANDSBERG, J.J. – WARING, R.H., (1997): A generalized model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance and partitioning. Forest Ecology and Management 95 (3): 209–228. https://doi.org/10.1016/S0378-1127(97)00026-1.

LESLIE, A. J. (1966): A Review of the Concept of the Normal Forest, Australian Forestry 30 (2): 139-147, https://doi.org/10.1080/00049158.1966.10675407.

MASERA, O.R. – GARZA-CALIGARIS, J.F. – KANNINEN, M. – KARJALAINEN, T. – LISKI, J. – NABUURS, G.J. – PUSSINEN, A. – DE JONG, B.H.J. – MOHRENF, G.M.J. (2003): Modelling carbon sequestration in afforestation, agroforestry and forest management projects: the CO2FIX V.2 approach. Ecological Modelling 164 (2–3): 177–199. https://doi.org/10.1016/S0304-3800(02)00419-2.

McGuire, A.D. – Wirth, C. – Apps, M. – Beringer, J. – Clein, J. – Epstein, H. – Kicklighter, D.W. – Bhatti, J. – Chapin, F.S. – de Groot, B. – Efremov, D. – Eugster, W. – Fukuda, M. – Gower, T. – Hinzman, L. – Huntley, B. – Jia, G.J. – Kasischke, E. – Melillo, J. – Romanovsky, V. – Shvidenko, A. – Vaganov, E. – Walker, D. (2002): Environmental variation, vegetation distribution, carbon dynamics and water/energy exchange at high latitudes. Journal of Vegetation Science 13 (3): 301–314. https://doi.org/10.1111/j.1654-1103.2002.tb02055.x.

Metherall, A.K. – Harding, L.A. – Cole, C.V. – Parton, W.J. (1993): CENTURY Soil Organic Matter Model Environment Technical Documentation, Agroecosystem Version 4.0, Great Plains System Research Unit, Tech. Rep. No. 4. USDA-ARS, Ft. Collins.

Nabuurs, G.J. – Schelhaas, M.J. – Pussinen, A. (2000): Validation of the European Forest Information Scenario Model (EFISCEN) and a projection of Finnish forests. Silva Fennica 34 (2): 167–179. https://doi.org/10.14214/sf.638.

Pilli, R. – Grassi, G. – Kurz, W.A. – Fiorese, G. – Cescatti, A. (2017): The European forest sector: past and future carbon budget and fluxes under different management scenarios, Biogeosciences Discussions 14: 2387-2405. https://doi.org/10.5194/bg-2016-525.

Pilli, R. – Grassi, G. – Kurz, W.A. – Moris, JV. – Abad Viñas, R. (2016): Modelling forest carbon stock changes as affected by harvest and natural disturbances. II. EU-level analysis, Carbon Balance Management 11:20. https://doi.org/10.1186/s13021-016-0047-8.

Pilli, R. – Grassi, G. – Kurz, W.A. – Smyth, C.E. – Blujdea, V. (2013): Application of the CBM-CFS model to estimate Italy's forest carbon budget, 1995 to 2020, Ecological Modelling 266: 144-171. https://doi.org/10.1016/j.ecolmodel.2013.07.007.

Running, S.W. – Gower, S.T. (1991): FOREST-BGC, A general model of forest ecosystem processes for regional applications. II. Dynamic carbon allocation and nitrogen budgets. Tree Physiology 9 (1–2): 147–160. https://doi.org/10.1093/treephys/9.1-2.147.

Sathaye, J. – Makundi, W. – Andrasko, K. (1995): A comprehensive mitigation assessment process (COMAP) for the evaluation of forestry mitigation options, Biomass and Bioenergy 8 (5): 345–356, ISSN 0961-9534, https://doi.org/10.1016/0961-9534(95)00027-5.

Somogyi, Z. – Tobisch, T. – Szepesi, A. (2019): National Forest Accounting Plan, Hungary, Budapest. Gödöllő, Magyarország: Nemzeti Agrárkutatási és Innovációs Központ (NAIK), 118. URL: http://cdr.eionet.europa.eu/hu/eu/mmr/lulucf/envxgc1ma.

Somogyi, Z. (1997): Mitigation Analysis in the Forestry Sector. In: Hungarian Country Studies Team: Hungarian Climate Change Country Study. Systemexpert Consulting Ltd., Budapest, 85-112.

Somogyi, Z. (2019): CASMOFOR version 6.1. University of Sopron, Forest Research Institute, Budapest. Website: http://www.scientia.hu/casmofor

Somogyi, Z. (2020): Az erdők szénlekötésének új referenciaszintje. [The new Forest Reference Level of Hungary] Erdészeti Lapok CLV: 38-41.

Suzuki, T. (2003): Gentan Probability and the Concept of the Normal Wood, in the Wide Sense; FBMIS 1: 65–74. ISSN 1740-5955.

Tian, H. – Melillo, J.M. – Kicklighter, D.W. – McGuire, A.D. – Helfrich, J. (1999): The sensitivity of terrestrial carbon storage to historical climate variability and atmospheric CO2 in the United States. Tellus Ser. B 51 (2): 414–452. https://doi.org/10.3402/tellusb.v51i2.16318.

UNFCCC (2011): Report of the technical assessment of the forest management reference level submission of Hungary submitted in 2011. https://unfccc.int/sites/default/files/resource/docs/2011/tar/hun01.pdf.

Yoshimoto, A. (1996a): A new stochastic model for harvesting behaviour with application to nonstationary forest growth and supply. Canadian Journal of Forest Research 26 (11): 1967–1972. https://doi.org/10.1139/x26-222.

Yoshimoto, A. (1996b): Economic analysis of harvesting behaviour using the modified Gentan probability theory. Journal of Forest Research 1 (2): 67–72. https://doi.org/10.1007/BF02348306.

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Comparative Studies on Leaf Micromorphology of the Abaxial Surface of *Quercus robur* L. subsp. *robur* and *Quercus robur* L. subsp. *pedunculiflora* (K. KOCH) MENITSKY

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Abstract – This study examined micromorphological traits on the abaxial surface of leaves using a Scanning Electron Microscope (SEM) to compare pedunculate oak and greyish oak taxa close-up. We selected a pedunculate oak population in Hungary and greyish oak population in Romania. The study randomly selected trees over 100 years old from these populations to investigate the differences between the two taxa based on leaf micromorphological characteristics. We focused mainly on indumentum because observing trichomes can be used in practice. Variation was found in trichome types, trichome-ray lengths, and stomata extent and shape. Stellate and fasciculate trichomes were absent on pedunculate oak leaves and densely developed on greyish oak leaves. The average length of the simple-uniseriate trichomes of pedunculate oak was 49.45 µm and 61.96 µm in greyish oak. On average, stomata surfaces on pedunculate oak leaves were 513.09 µm^2 and 440.28 µm^2 on greyish oak leaves. The study found no variation in epicuticular wax layer type. Despite the small sample size, in comparing the two populations, we found that the two taxa were distinguishable based on trichome types, and we believe that forestry practice could utilise this trait.

pedunculated oak / greyish oak / trichome / stomata / epicuticular wax /SEM

Kivonat – Összehasonlító mikromorfológiai vizsgálatok a *Quercus robur* L. subsp. *robur* és *Quercus robur* L. subsp. *pedunculiflora* (K. KOCH) MENITSKY levélfonákán. Pásztázó-elektronmikroszkópos felvételeken mikromorfológiai méréseket végeztünk a kocsányos tölgy és a szürke tölgy taxonok összehasonlítása céljából. A vizsgálatokhoz egy magyarországi kocsányos tölgy populációt és egy romániai szürke tölgy populációt választottunk ki. Ezekből a populációkból 100 év feletti fákat véletlenszerűen választottunk, hogy megvizsgáljuk a két taxon között a különbségeket a levelek mikromorfológiai karakterisztikája alapján. Legfőképpen a szőrözöttségre fordítottunk figyelmet, mert a szőrözöttség megfigyelése a gyakorlatban is alkalmazható. E két taxonon eltérő szőrtípusokat figyeltünk meg, méréseink alapján különbséget találtunk a szőrkarok hosszában és a sztómák méreteiben. A csillagszőrök és a nyalábszőrök a kocsányos tölgy levelek abaxiális oldaláról hiányoztak, ellenben a szürke tölgy levelek fonákán megfigyeltük őket. A kocsányos tölgy levélfonákán a fedőszőrök átlagos hossza 49,45 µm volt, a szürke tölgy esetében átlagban a 61,96 µm-t érték el. A kocsányos tölgyön a sztómák felülete átlagosan 513,09 µm^2 érte el, míg a szürke tölgyön ez az érték 440,28 µm^2 volt. A viaszréteg típusát viszont azonosnak találtuk. A két populáció összehasonlítása során

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megállapítottuk, hogy a kis mintaszám ellenére a két taxon a trichómák típusa alapján megkülönböztethető egymástól, és véleményünk szerint ez a bélyeg az erdészeti gyakorlatban is alkalmazható.

kocsányos tölgy / szürke tölgy / trichóma / sztóma / viaszréteg /SEM

1 INTRODUCTION

The German botanist Karl Koch determined the greyish oak as a species in 1849, but currently, it is classified as a subspecies of pedunculate oak (*Quercus robur* L.) and listed under the description of Yuri Menitsky (*Q. robur* L. subsp. *pedunculiflora* (K. Koch) Menitsky) (Bartha 2021). Genetic studies also confirmed the relationship of greyish oak (ssp. *pedunculiflora*) to pedunculate oak (subsp. *robur*), and it was shown that the ecological speciation of subsp. *pedunculiflora* has not been completed yet (Curtu et al. 2011). This xeromorphic dendrotaxon spreads from the Balkan Peninsula through Asia Minor and Crimea to the Caucasus and the northwestern part of Iran. Interestingly, the two subspecies show horizontal vicariance in Turkey, along the Anatolian axis (Uslu et al. 2011) and are well separated ecologically (Yilmaz – Yilmaz 2016). Carella (2018) reported new occurrences in southern Italy from the Bari region. The greyish oak is probably not native to Hungary, but hybrids or intermediate forms may occur in the peripherals of the Hungarian Lowlands (Mátyás 1967, Gencsi – Vancsura 1992). The taxon is listed as 'introduced' in the Royal Botanic Garden (Kew Garden) database in London (https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:60459295-2). In climate change context, KEFAG Kiskunsági Erdészeti és Faipari Ltd. has established experimental plots in Hungary to compare the growth capacities of native pedunculate oak seedlings versus greyish oak seedlings from Romania. The results have thus far revealed that the greyish oak seedlings show better growth than the pedunculate oak seedlings (Hegedüs 2021). In comparison, both oak taxa might be distinguishable by generative (the length of female inflorescence, the length of peduncle/the ratio of the length of lamina, the pattern of cupule) and vegetative (the width of lamina, the segmentation of lamina) morphological characters (Mátyás 1967, Gencsi – Vancsura 1992). Describing and characterising the morphological traits of generative organs is often challenging due to the irregular crop of oaks, and many authors (Halácsy 1904, Hayek 1927, Koch 1849, Enescu 2017) emphasised the differences in the abaxial surface of leaves ("subtus glauca, puberula"), which is considered the most important morphological trait in taxonomic differentiation.

Trichomes perform several functions, including reducing evaporation and protecting against environmental influences. Ecological conditions determine their development (Hülskamp, 2019), so it is possible to infer environmental factors from indumentum. Hardin (1976) described 10 types of trichomes in oak leaf hairs. Bussotti – Grossoni (1997) provided a classification of indumentum for Central European and Mediterranean oaks but did not study greyish oak. In their research on oak species in Iran, Panahi et al. (2012) investigated the leaf abaxial surface of subsp. *pedunculiflora* and compared them with six other oak taxa in Iran; however, *Quercus robur* was not in their examinations; only greyish oak samples were. Uzunova – Palamarev (1992) provided an overview of the epidermis of five *Quercus* taxa, including greyish oak, using herbarium leaf samples.

Stomata characteristics are also often used as morphological traits in taxonomic studies. Stomata location and density offer insights into transpiration mechanisms and ecological associations (Yocum, 1935). A comparison of stomatal density of *Quercus* petraea and *Q. robur* populations in northern Turkey found higher density in *Q. robur* (mean value: 517 stomata/mm^2). Yücedağ et al. (2019) examined the micromorphological traits of *Quercus robur* and *Quercus petraea* in natural populations in northern Turkey. They found variation in stomatal density that correlated with various genetic and environmental factors. In general, oak taxa have an anomocytic stomata type, and cells surrounding stomata are undifferentiated from the regular epidermal cells (Bačić 1981, Panahi et al. 2012). Bačić (1981) studied the stomata structure of various oak taxa and distinguished *Q. robur, Q. conferta* and *Q. cerris* samples due to the specific structure and shape of stomata cells in each. Nikolić et al. (2003) analysed stomatal and indumental characteristics of pedunculate oak (subsp. *robur*) provenances and found variations in 17 genotypes.

The epicuticular waxes on leaves are composed of lipids (Gülz – Boor, 1992), and the wax layer has specific functions in light and heat reflection and in the regulation of evaporation (Tschan – Denk, 2012). Gülz – Boor (1992) observed that the wax layer structure in *Q. robur* changed with age, and the number of wax crystalloids increased during May and concentrated around the stomata. Barthlott et al. (1998) classified epicuticular waxes in the genus *Quercus* and established a determination key based on the wax layer. By combining the above three characteristics, significant differences were reported in various oak taxa from the Iberian Peninsula (del Rio et al. 2014), Italy (Gellini et al. 1992), the Balkan Peninsula (Uzunova – Palamarev 1992) and Iran (Panahi et al. 2012). A smooth wax coating was observed on *Q. pedunculiflora* leaves, and a crystalline wax coating in other taxa (Panahi et al. 2012).

2 MATERIALS AND METHODS

This study investigated lower surface characteristics in subsp. *robur* and subsp. *pedunculiflora* leaves to find distinctive micromorphological traits for both taxa. This study compares three characteristics on the abaxial surface of leaves: 1. indumentum, 2. stomata, and 3. type of epicuticular wax, as these traits can be studied throughout the vegetation period and life cycle. Natural stands in the forest-steppe climatic zone were selected; in total, two populations (subsp. *robur* and subsp. *pedunculiflora*) located 808.5 km apart. The collection site of subsp. *robur* was in the Kunpeszér Forest (47.097934ºN, 19.292653ºE and 47.087969ºN, 19.314133ºE) in Hungary at 94 m altitude. The subsp. *pedunculiflora* samples were collected in the Danube Delta in Romania (45.037231ºN, 29.401113ºE and 45.029099ºN, 29.406569ºE) at 5 m altitude. The pedunculate oak was collected in August 2020; the greyish oak in August 2019. Both sites are located in the forest-steppe climatic zone characterised by continental and arid climatic conditions. Two trees were selected according to macromorphological characteristics to exclude hybrid phenotypes in each population. Age and height (≥ 100 years and ≥ 20 m) were also considered to exclude non-autochtonous material as much as possible.

Shoots were sampled from the outer and lower part of the crown to analyse mature, fully-developed leaves. Five leaves per individual tree were taken and desiccated. A HitachiS3400N Electron Scanning Microscope was used for the micromorphological studies at the Natural Resources Research Centre (NRRC) of the University of Sopron.

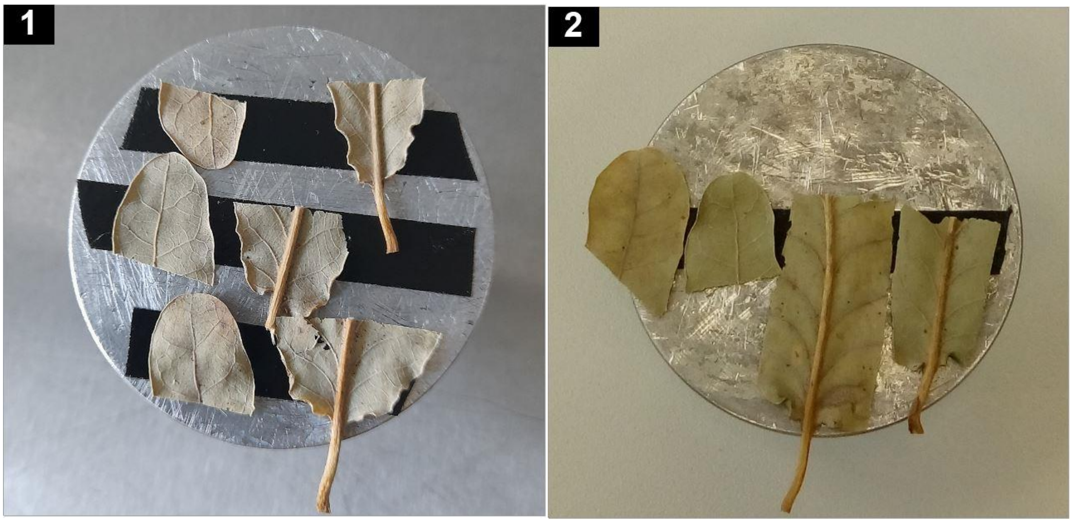

Figure 1-2. The greyish oak (1) and pedunculate oak (2) samples are fixed to an aluminium stub

The present study examined the trichome types, stomata, and wax layer on the abaxial surface of 10 leaves adjacent to the mid-vein and on the mid-petiole and compared these micromorphological features of both taxa (*Figure 1-2*). It did not examine the adaxial sides of the leaves. Trichome densities were observed at 100× magnification, while stomata and the wax layers were observed at 1000× magnification. The length of the trichome rays and the length, width, extent, and density of the stomata were measured using ArchiCAD 24. Trichome density was not determined. We only measured unsevered, whole and visible trichomes. Trichome type classification was based on Hardin (1976) and Bussotti – Grossoni (1997) and the categories of Barthlott et al. (1998) to determine the characteristics of the wax layer. Wax layer parameters were not measured due to technical reasons.

The present study used TIBCO Statistica 14.0.1 for data processing and T-test for data evaluation. The significance interval was $p<0.05$; sample numbers were above 220. *Table 1* lists the abbreviations used and their corresponding units of measurement and explanations.

Table 1. Abbreviations, their units and explanations

Abbreviations	Units	Description
Taxa		
Q.R.R.	-	*Quercus robur* L. *robur*
Q.R.P.	-	*Quercus robur* L. subsp. *pedunculiflora* (K. Koch) Menitsky
Trichomes		
RL	μm	Ray length
Stomata		
SL	μm	Stomata length
SW	μm	Stomata width
SD	no./mm^2	Stomata density
SS	μm^2	Stomata scope
LSP	μm	Length of stomatal pore

3 RESULTS

Glandular, simple-uniseriate trichomes were observed on the abaxial surface of *Quercus robur* L. subsp. *robur* leaves (*Figure 3*). The rays were thin-walled, short, and extended parallel to the epidermis, thus protecting the underlying cells. The stomata formed a disordered spatial structure and were protrusively distinct from the epidermis, with an elliptical shape and thick-walled guard cells. A crystalline, densely laminated wax layer structure covered the stomata and the stomatal epidermis (*Figure 4*).

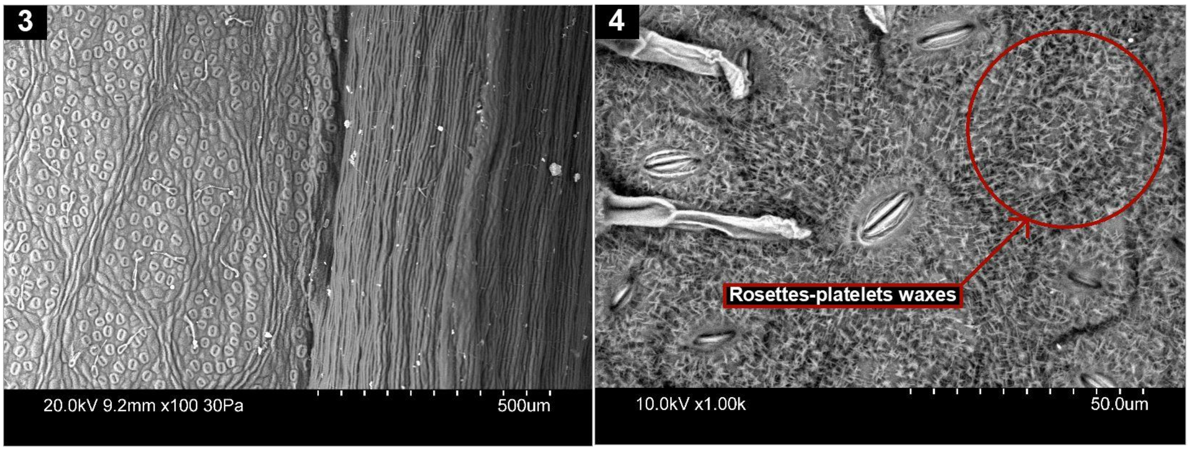

Figure 3. Abaxial surface of Quercus robur L. subsp. robur leaf at 100× magnification, with the simple-uniseriate trichomes next to the midrib

Figure 4. The epicuticular wax layer, stomata, and simple-uniseriate trichome at 1000× magnification on the abaxial surface of Quercus robur L. subsp. robur leaves

Simple-uniseriate trichomes similar to *Quercus robur* L. subsp. *robur* leaves were found on the abaxial surface of *Quercus robur* L. subsp. *pedunculiflora* leaves. As *Table 2* summarises, ray length was one of the differences between the two taxa. In addition, the simple-uniseriate trichome type, stellate trichomes and fasciculate trichomes were also observed on leaves of greyish oak. Stellate trichomes were also found on the thinner secondary veins (*Figure 5*), which were parallel to the epidermis. The number of rays varied from one to seven and were straight, short, thick-walled, and cylindrical, branching directly above the epidermis and flattening at the branching point. The fasciculate trichomes were observed only on and nearby the midrib (*Figure 6*). The long, relatively straight rays were disordered, convoluted and not adherent to the epidermis. The number of rays varied from one to four, branching directly above the epidermis. *Table 2* summarises the statistical data on trichome types.

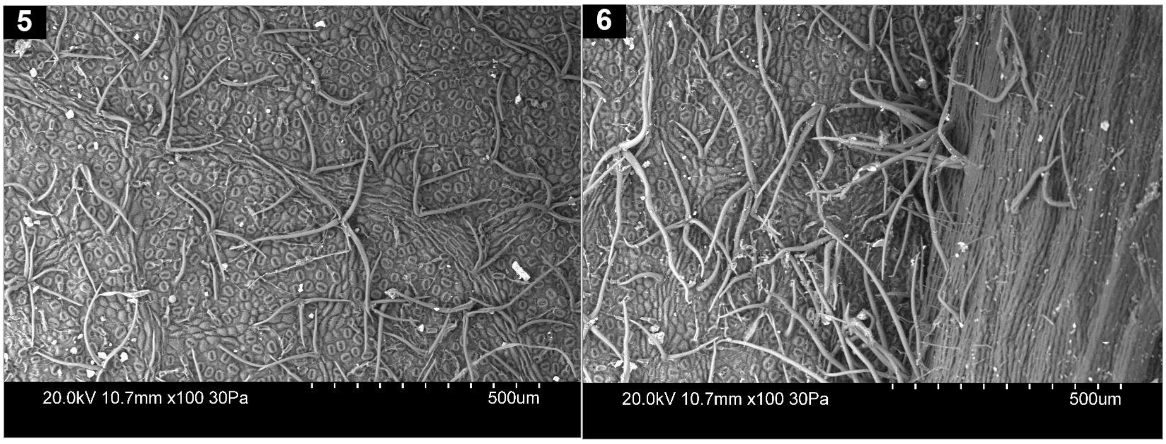

Figure 5. Stellate trichomes observed on the abaxial leaf surface of Quercus robur L. subsp. pedunculiflora (K. Koch) Menitsky
Figure 6. Fasciculate trichomes and stellate trichomes observed on the abaxial surface of the leaf of Quercus robur L. subsp. pedunculiflora (K. Koch) Menitsky, adjacent to the midrib

Table 2. Descriptive Statistics of Indumentum (Interpretation of variables: simple=simple-uniseriate trichome; stellate=stellate trichome; fasciculate=fasciculate trichome)

Variable	Number of measurements	Mean	Median	Minimum	Maximum	Std.Dev.
Q.R.R. RL by simple	236	49.45	48.20	19.00	98.60	15.09
Q.R.P. RL by simple	228	61.96	60.00	25.90	113.90	18.36
Q.R.P. RL by stellate	319	112.38	107.60	47.10	251.00	28.63
Q.R.P. RL by fasciculate	140	258.61	234.50	132.80	485.10	78.50

Stomata shape was elliptical, and the guard cells were ascending as on the *Quercus robur* L. subsp. *robur* leaves observed. In this regard, the extent of stomata on *Quercus robur* L. subsp. *robur* leaves were greater than those of *Quercus robur* L. subsp. *pedunculiflora* (K. Koch) Menitsky. *Table 3* summarises the descriptive statistical parameters of the stomata. The epicuticular wax layer of greyish oak also had a crystalline structure (rosettes-platelets wax, see *Figures 7* and *8*).

Table 3. Descriptive Statistics of Stomata

Variable	Number of measurements	Mean	Median	Minimum	Maximum	Std.Dev.
Q.R.R. LSP	262	12.30	12.38	5.20	18.90	2.08
Q.R.R. SL	222	25.68	25.60	18.90	34.20	2.46
Q.R.R. SW	226	20.30	20.30	15.80	26.40	2.27
Q.R.R. SS	222	513.09	507.00	295.20	779.60	88.45
Q.R.P. LSP	218	11.11	10.90	5.90	19.40	2.33
Q.R.P. SL	218	24.21	24.27	16.90	32.70	2.89
Q.R.P. SW	219	18.44	18.30	12.70	25.80	2.18
Q.R.P. SS	221	440.28	437.70	264.20	740.50	82.14

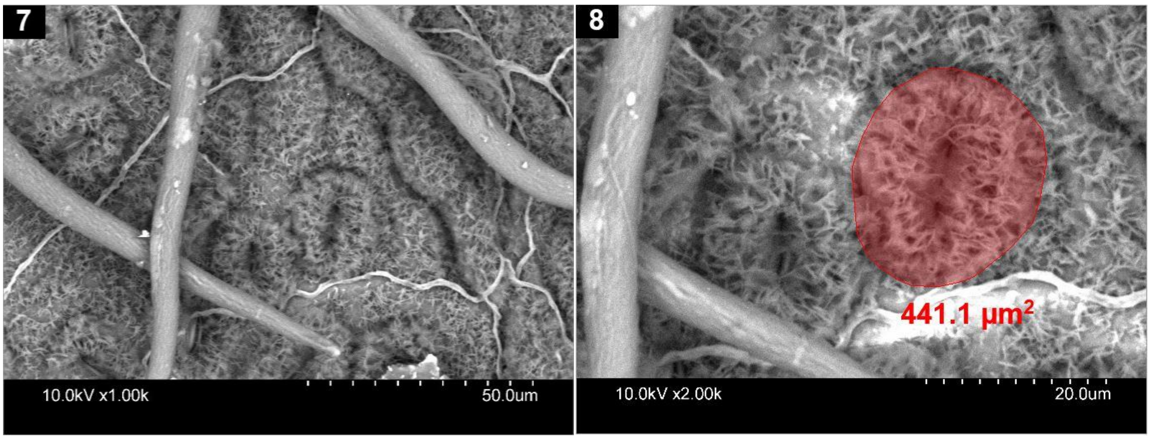

Figure 7. Greyish oak stomata with crystalline wax layer at 1000× magnification.
Figure 8. Area measurement of the stomata on the abaxial surface of a greyish oak leaf at 2000× magnification ArchiCAD 24

In comparison, significant differences were found in trichome types, measured for both taxa, respectively. On average, pedunculate oak had shorter rays (49.45 µm), while greyish oak had longer rays (61.96 µm) (*Figure 9*) on their trichomes. In addition, stellate and fasciculate trichomes were absent on pedunculate oak leaves but densely developed on greyish oak leaves. The average length of stellate and fasciculate trichomes were 112.38 µm and 258.61 µm, respectively.

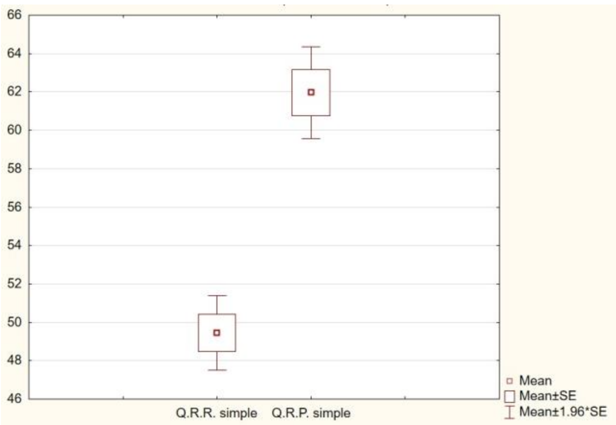

Figure 9. Comparison of the length of simple-uniseriate trichomes

Significant differences in the dimensional parameters of stomata appeared, specifically in length, width at their widest point, surface area, and length of stomatal pore. The stomata were dimensionally more extensive on pedunculate oak leaves than on greyish oak leaves. *Figures 10–13* show the comparison of stomatal parameters. Based on the measurements, the average stomatal density on the abaxial surface of pedunculate oak was 301.19 stomata/mm^2, and the stomatal density on the abaxial leaf surface of greyish oak was 313.75 stomata/mm^2. Nevertheless, the stomatal density of greyish oak was probably even higher than measured since trichomes intensively covered the surface, reducing stomatal density in many cases. (See *Figures 5–8.*, with trichomes of greyish oak).

The minimum-maximum values in *Tables 2–3* determine the overlap between the extent but the 95% confidence intervals are well separated, and no outliers were obtained (*Figures 9–13*).

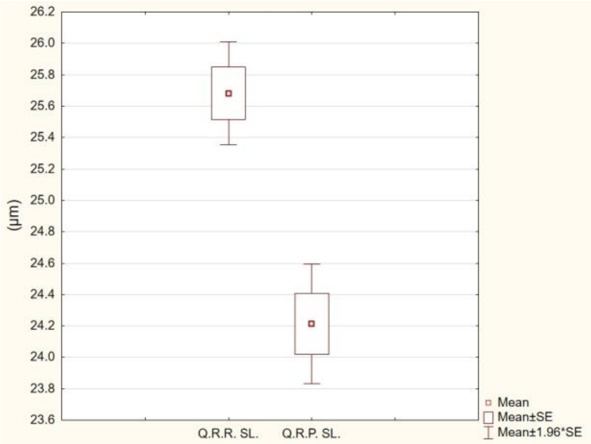

Figure 10. Comparison of stomata lengths.

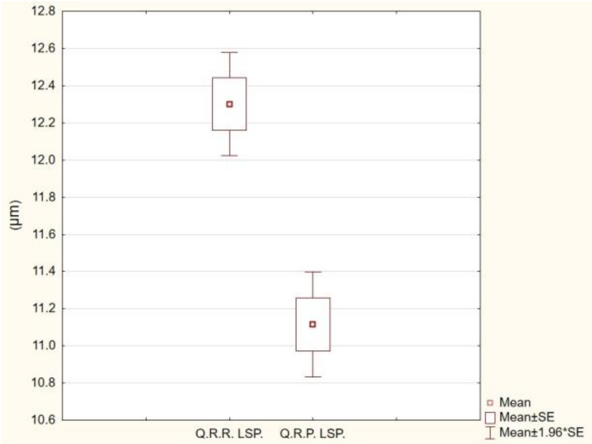

Figure 11. Comparison of stomata pore lengths

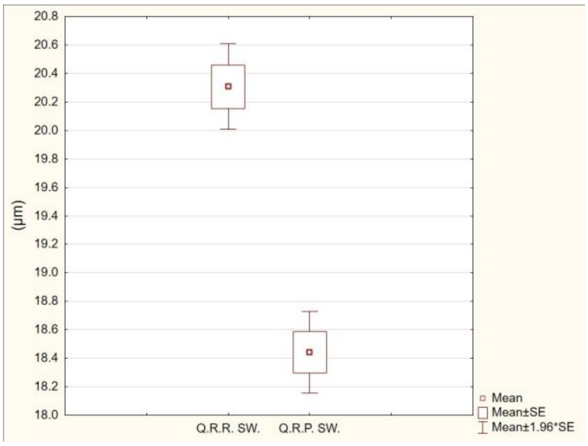

Figure 12. Comparison of stomata widths.

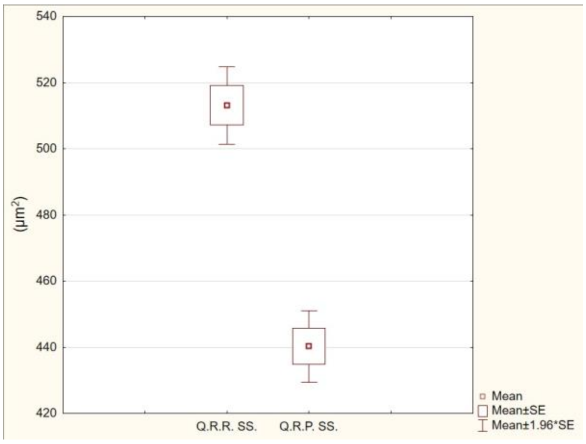

Figure 13. Comparison of stomata areas

4 DISCUSSION

The differences observed on trichome types and stomata were suitable to distinguish *Quercus robur* L. subsp. *robur* and *Quercus robur* L. subsp. *pedunculiflora* (K. Koch) Menitsky, whereas the wax layer type was unsuitable to distinguish the two taxa.

Significant differences in trichome density of the abaxial leaf surface were observed. Similar to the results reported by Gülz – Boor (1992), Bussotti – Grossoni (1997) and Nikolić et al. (2003), only simple-uniseriate trichomes were found on *Quercus robur* L. subsp. *robur* leaves. Simple-uniseriate, stellate trichomes were observed on the leaf abaxial surface of greyish oak. Additionally, fasciculate trichomes were found along the midrib of the abaxial surface. Those micromorphological characters were suitable to distinguish greyish oak from pedunculate oak. Our observations on trichome types and density support the results of Enescu (2017), who reported the indumentum of leaves as an appropriate trait for species identification, as observed by several authors in the past (Koch 1849, Schwarz 1937, Tutin et al. 1964). Analysing greyish oak and pedunculate oak by Kissling’s method, Ecaterina-Nicoleta Apostol found that the descriptive data on trichomes differentiated between these two taxa in Romania (Apostol 2019).

Measurements made by Nikolić et al. (2003) on *Quercus robur* L. subsp. *robur* leaves resulted in values (SL = 25.98 µm; SW = 19.05 µm) similar to our results (SL = 25.68 µm; SW = 20.30 µm). However, the stomatal density of *Quercus robur* L. subsp. *robur* leaves was higher in their study (SD = 654.4 no./mm^2) than in ours (SD = 301.19 no./mm^2).

A more concentrated wax layer around the stomata characterises the crystalline wax layer type (Barthlott et al. 1998). Prasad – Gülz (1990) also support our observations on *Quercus robur*; however, they analysed the chemical composition of the wax and the percentage of the components that determined the wax layer structure. The wax layer in *Q. robur* comprises aldehydes, alcohols, alkanes, fatty acids, esters, and triterpenes, which explains the crystalline structure (Prasad – Gülz 1990). No variation was found for wax layer type: a crystalline structure was observed on leaves of both pedunculate oak and greyish oak trees. This was contrasted with the results of Panahi et al. (2012), where smooth wax layers were reported on *Quercus robur* ssp. *pedunculiflora* leaves sampled in populations in Iran. Gülz – Boor (1992) observed that the wax layer could melt in mid-summer under high temperatures due to its plasticity and recrystallise towards the end of the vegetation period.

Nevertheless, the uncertainty of the wax layer type as a micromorphological characteristic – smooth or crystalline – might depend on sampling time.

The micromorphological differences supported our hypothesis that greyish oak was well-adapted to arid and continental ecological conditions, and its adaptation to the specific ecological requirements also manifested in micromorphological traits, such as trichome types and stomata extent. The micromorphological traits observed in greyish oak suggest that it is more drought-tolerant, which is particularly important for the forestry sector in a climate change context. In forestry practice, the presence of stellate and fasciculate trichomes on the abaxial surface of the leaves of *Quercus robur* L. subsp. *pedunculiflora* (K. Koch) Menitsky provides an appropriate morphological trait to distinguish greyish oak from pedunculate oak, as phenotypes of *Quercus robur* tolerant versus less tolerant to drought.

5 CONCLUSIONS

This study compared greyish oak with pedunculate oak based on leaf morphological characteristics using scanning electron microscopy. We found that scanning electron microscopy can better reveal micromorphological differences. However, we conclude that a random sample of a greyish oak leaf and a pedunculate oak is enough to distinguish between the presence of stellate and fasciculate trichomes and the absence of stellate and fasciculate trichomes in the case of pedunculate oak. Among the morphological traits, the indumentum was found to be the most useful because it can distinguish greyish oak from pedunculate oak and can be used in forestry practice. We also found a difference in stoma sizes, but this is not relevant in practice. We analysed wax layer types and concluded that these cannot be used to separate these two taxa. Our study included only two populations, and our results suggest that it would be useful to include more populations in the future, including hybrids from South-East Europe and the Balkan region. In addition to the leaf morphological studies, we will also aim to observe the micromorphology of the generative organs to separate greyish oak and pedunculate oak.

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REFERENCES

APOSTOL, E.N. (2019): Varibilitatea descriptorilor frunzelor în populaţii autohtone de stejar pedunculat *(Quercus robur* L.) şi stejar brumăriu (*Quercus pedunculiflora* K. Koch). Editura Silvică 127.

BAČIĆ, T. (1981): Investigations of stomata of three oak species with light and scanning electron microscope. Acta Botanica Croatica 40: 85-90.

BARTHA, D. (2021): An annotated and updated checklist of the Hungarian dendroflora. Acta Botanica Hungarica 63 (3-4): 227-284. https://doi.org/10.1556/034.63.2021.3-4.1

BARTHLOTT, W. – NEINHUIS, C. – CUTLER, D. – DITSCH, F. – MEUSEL, I. – THEISEN, I. – WILHELMI, H. (1998): Classification and terminology of plant epicuticular waxes. Botanical Journal of the Linnean Society 126: 237-260. https://doi.org/10.1111/j.1095-8339.1998.tb02529.x

BUSSOTTI, F. – GROSSONI, P. (1997): European and Mediterranean oaks (*Quercus* L.; Fagaceae): SEM characterization of the micromorphology of the abaxial leaf surface. Botanical Journal of the Linnean Society 124: 183-199. https://doi.org/10.1111/j.1095-8339.1997.tb01789.x

CARELLA, R. (2018) First observation of Quercus pedunculiflora C. Koch in the Italian Peninsula – Short Communication. 130 J. FOR. SCI., 59, 2013 (3): 130–135.

CURTU, A.L. – SOFLETEA, N. – TOADER, A.V. – ENESCU, M.C. (2011): Leaf morphological and genetic differentiation between *Quercus robur* L. and its closest relative, the drought-tolerant *Quercus pedunculiflora* K. Koch. Annals of Forest Science 68: 1163–1172. https://doi.org/10.1007/s13595-011-0105-z

DEL RÍO, S. – ÁLVAREZ, R. – CANDELAS, A. – GONZÁLEZ-SIERRA, S. – HERRERO, L. – PENAS, A. (2014): Preliminary Study on Taxonomic Review Using Histological Sections of Some Iberian Species from the Genus *Quercus* L. (Fagaceae). American Journal of Plant Sciences 5: 2773-2784. https://doi.org/10.4236/ajps.2014.518294

ENESCU, M.C. (2017): A Dichotomous Determination Key for Autochthonous Oak Species from Romania. Journal of Horticulture, Forestry and Biotechnology 21(4): 58-62.

GELLINI, R. – BUSSOTTI, F. – BETTINI, D. – GROSSONI, P. – BOTTACCI, A. (1992): Species of the genus *Quercus* in Italy: chatacterization by means of leaf surface observation. Giornale Botanico Italiano 126: 481-504. https://doi.org/10.1080/11263509209430301

GENCSI, L. – VANCSURA, R. (1992) Hamvas tölgy (*Quercus pedunculiflora*) (in: Gencsi, L. – Vancsura, R. Dendrológia 728 p.) 240 p. Mezőgazda Kiadó, Budapest

GÜLZ, P.-G. – BOOR, G. (1992): Seasonal Variations in Epicuticular Wax Ultrastructures of *Quercus robur* Leaves. Zeitschrift für Naturforschung 47: 807-814. https://doi.org/10.1515/znc-1992-11-1205

HALÁCSY, J. (1904): Conspectus Florae Graecae Vol. III. Lipsiae. 126.

HARDIN, J.W. (1976): Terminology and Classification of *Quercus* Trichomes. Journal of the Elisha Mitchell Scientific Society 92 (4): 151-161.

HAYEK, A. (1927): Prodromus Florae peninsulae Balcanicae Vol. I. Berlin. 77.

HEGEDÜS, I. (2021): A szürke tölgy (*Quercus pedunculiflora* C. Koch) a klímaváltozás tükrében. Sopron. 93.p.

HÜLSKAMP, M. (2019): Trichomes. Current Biology 29 (8): 265-279. https://doi.org/10.1016/j.cub.2019.02.010

KOCH, K. (1849): Beiträge zu einer Flora des Orientes II. Linnaea 22: 177-336.

MÁTYÁS, V. (1967) HAMVAS- VAGY SZÜRKETÖLGY (*Quercus pedunculiflora* C. Koch) (in: Keresztesi, B. ed. A tölgyek. 656 p.) 81-84p. Akadémiai Kiadó, Budapest

NIKOLIĆ, N.P. – MERKULOV, L.S. – KRSTIĆ, B.D. – ORLOVIĆ, S.S. (2003): A comparative analysis of stomata and leaf trichome characteristics in *Quercus robur* L. genotypes. Proceedings for Natural Sciences, Matica Srpska, Novi Sad 105: 51-59.

PANAHI, P. – JAMZAD, Z. – POURMAJIDIAN, M.R. – FALLAH, A. – POURHASHEMI, M. (2012): Foliar epidermis morphology in *Quercus* (subgenus *Quercus*, section *Quercus*) in Iran. Acta Botanica Croatica 71 (1): 95-113. https://doi.org/10.2478/v10184-010-0029-y

PRASAD, R.B.N. – GÜLZ, P.-G. (1990): Surface Structure and Chemical Composition of Leaf Waxes from *Quercus robur* L., *Acer pseudoplatanus* L. and *Juglans regia* L. Z. Naturforsch. (45): 813-817

SCHWARZ, O. (1937): Monographie der Eichen Europas und des Mittelmeergebietes. Dahlem bei Berlin, Selbstverlag. 200 p.

TSCHAN, G.F. – DENK, T. (2012): Trichome types, foliar indumentum and epicuticular wax in the Mediterranean gall oaks, *Quercus* subsection *Galliferae* (Fagaceae): implications for taxonomy, ecology and evolution. Botanical Journal of the Linnean Society 169: 611-644. https://doi.org/10.1111/j.1095-8339.2012.01233.x

TUTIN, T.G. – HEYWOOD, V.H. – BURGES, N.A. – VALENTINE, D.H. – WALTERS, S.M. – WEBB, D.A. (1964): Flora Europaea Volume 1. Lycopodiaceae to Platanaceae. Cambridge at the University Press. 504 p.

USLU, E. – BAKIŞ, Y. – BABAÇ, M.T. (2011): A study on biogeographical distribution of Turkish oak species and their relations with the Anatolian Diagonal. Acta Botanica Hungarica 53 (3-4): 423-440. https://doi.org/10.1556/abot.53.2011.3-4.21

UZUNOVA, K.G. – PALAMAREV, E.CH. (1992): The foliar epidermis studies of *Fagaceae* Dumort. from the Balkan penisnula. IV. *Quercus* L. (subgenus *Quercus*, sec. *Robur* Reichenb.). Fitologia 43: 3-29.

YILMAZ, O.Y. – YILMAZ, H. (2016): Bioclimatic factors affecting the distribution of *Quercus robur* L. (pedunculate oak) subspecies in Turkey. Eurasian Journal of Forest Science 4 (1): 31-39. https://doi.org/10.31195/ejejfs.258623

YOCUM, L.E. (1935): The stomata and transpiration of oaks. Plant Physiology 10 (4): 795-801. https://doi.org/10.1104/pp.10.4.795

YÜCEDAĞ, C. – SANDERS, J. – MUSAH, M. – GAILING, O. (2019): Stomatal density in *Quercus petraea* and *Q. robur* natural populations in Northern Turkey. Dendrobiology 81: 58-64.

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A Comparative Study of Hungarian and Indian University Students' Attitudes Toward Forestry

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Abstract – Attitudes toward using wood as a raw material vary greatly, from anti-logging and anti-felling propaganda to the propagation of wood use. This study examines attitudes toward wood, trees, and sustainable forest management in two distinct cultures – India and Hungary. Our questionnaire survey findings indicate that sustainable forest management is considered more important in India than in Hungary and that environmental education is more widespread in India (40 %) than in Hungary (19 %). Over 30 % of people in both countries do not plan to keep wood-related traditions or customs. Indian students lean more toward discontinuing the wide use of wood than Hungarian students do. However, anti-logging/anti-felling propaganda is more widespread in Hungary (85 %) than in India (62 %). Passing wooden tools to the next generation shows a decreasing trend, which is significant from a carbon sequestration, carbon storage perspective, and climate protection. The study findings suggest that keeping wood-related traditions and customs should be strengthened in both countries through environmental education.

wood / use of wood as a raw material / attitudes related to wood / sustainable forest management

Kivonat – Egyetemi hallgatók bizonytalan attitűdjei a fával, faanyagokkal, erdőgazdálkodással, fakitermeléssel, fatermékekkel és fenntartható erdőgazdálkodással kapcsolatban a keleti és nyugati kultúrákban: összehasonlító tanulmány India és Magyarország között. Óriási bizonytalanság tapasztalható a fa alapanyagként való felhasználásával kapcsolatos attitűdökben: egyrészt a fakitermelés- és fakivágás-ellenes propaganda, másrészt a fahasználat propagálása áll szemben egymással. Arra voltunk kíváncsiak, hogy mi a különbség a fáról, a faanyagról és a fenntartható erdőgazdálkodásról való gondolkodásban két különböző kultúra, India és Magyarország között. Kérdőíves felmérésünk eredményei azt mutatják, hogy Indiában sokkal fontosabbnak tartják a fenntartható erdőgazdálkodást, mint Magyarországon, valamint az, hogy Indiában (40 %) elterjedtebb a környezeti nevelés, mint Magyarországon (19 %). Mindkét országban több mint 30 %-uk nem tervezi a fához kapcsolódó hagyományok vagy szokások megtartását, ami azt sugallja, hogy a fával kapcsolatos hagyományokat meg kell erősíteni. Az indiai hallgatók úgy gondolják, hogy a fát a magyarokhoz képest nem szabad tovább széles körben használni. Megállapítottuk továbbá, hogy Magyarországon elterjedtebb a fakitermelés-ellenes propaganda (85 %), mint Indiában (62 %), és hogy csökkenő tendenciát mutat a faeszközök következő generációnak való átadásának szándéka. Ez utóbbi a klímavédelemhez hozzájáruló szénmegkötés és széntárolás szempontjából fontos. Ezek az

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eredmények azt sugallják, hogy a környezeti nevelés részeként mindkét országban erősíteni kell a fával kapcsolatos hagyományok és szokások megőrzését.

fa / faalapanyag felhasználása / fához kapcsolódó attitűdök / fenntartható erdőgazdálkodás

1 INTRODUCTION

Experts recommend using wood as widely as possible (Forest Products Laboratory 2010; Herzog et al. 2012; Winterbottom – Busch 2008). At the same time, forests protect the soil and climate (Sun – Vose 2016, Hundecha – Bardossy 2004). Forests also provide physical and mental renewal (Selhub – Logan 2012, Williams 2017) livelihoods (Nagy 2023). Sólymos (2014) formulates proposals to mitigate climate change effects, emphasizing the role of trees and parks in big cities by measuring climate change effects via carbon sequestration. Forests also produce raw materials, energy, and food. In sum, forests play a critical role in providing various ecosystem services, which are categorized into provisioning, regulating, supporting, and cultural services (Costanza et al. 1997).

The present study focuses on sustainability and environmental protection from a comparative perspective in a wood use context. Our research has two motivations: to consider the functioning of the changed Earth system as a warning of today's global and local problems and to examine uncertainty in attitudes toward wood use among university students in Hungary and India. Our comparative questionnaire study provides data on how young adults feel about wood use, wood raw materials, and how conscious they will be as users of wood raw materials in the future. The thinking, mentality, knowledge, opinions, and attitudes of the younger generation play a pivotal role in climate protection. Therefore, we explored these domains in two disparate cultures. Sustainability and climate protection in the present context require more than tree growth; they also require people growth through education.

The study topic is timely and relevant because media and conservationists frequently convey misleading information about forest management, the work of forestry professionals, and wood as a raw material (Folcz 2013, Kováts-Német 2010). Highlighting the uncertainty in attitudes about forests and the theme of wood in the context of renewable energies, Qu et al. (2011) found that Chinese students had a positive attitude toward renewable energy in general but a slightly less positive attitude toward forest bioenergy. Amberla et al. (2010) also reported that most of the public in Finland and Turkey hold a skeptical rather than positive view of reporting. Hartl (2008) notes that teacher training participants in Hungary observed that wood use as an industrial raw material and natural resource is absent from public thinking. According to the Hungarian National Forest Strategy 2016–2030, the wider and multi-stage sustainable use of harvested timber in the wood industry helps reduce climate change effects. As per the Strategy, wood products must be used for energy recovery at the end of their life cycle. Replacing fossil fuels with wood is beneficial in the long run. Trees gradually bind carbon from the atmosphere, ensuring that wood energy will be climate-neutral in the long term (National Forest Strategy 2016–2030). Therefore, an uncertainty in recent decades is the growing concern about global deforestation. Excessive timber extraction can negatively impact the environment and ecosystems (Donato et al. 2011, McNeill 2011, Paquette-Messier 2010). However, “excessive extraction of timber” refers to removing timber at a rate that surpasses the ability to regenerate naturally. The term “excessive extraction of timber” may be subjective because it lacks a clear and universally agreed-upon definition. Subjectivity arises from the fluidity in defining what “excessive” means, which can be contingent on several factors such as ecological conditions, societal needs, and legislative frameworks (FAO 2018).

Excessive over-harvesting can lead to many negative consequences, such as deforestation, forest ecosystem degradation, biodiversity loss, soil erosion, and altered water cycles. When extraction rates exceed the growth rates, it threatens forest sustainability and can have broader ecological impacts. The concept is often associated with unsustainable forestry practices and is of significant concern to environmental conservationists and the forestry industry, which seeks to maintain long-term productivity and sustainability.

A utilization rate as a percentage of the annual volume increment provides a more objective measure than the term "excessive extraction of timber" because it permits a scientific and balanced evaluation of timber harvesting practices. This metric aligns the economic interests of the timber industry with the imperative of environmental sustainability, ensuring that extraction does not exceed the natural capacity to regenerate (FAO 2018, Lund 2007).

The "circular economy" concept represents an ambitious paradigm shift toward sustainability, focusing on closed-loop systems where resources such as wood are reused, recycled, and recovered. It promotes innovation in design, business models, and consumption practices to reduce waste and environmental impacts (Ellen MacArthur Foundation 2013, Geissdoerfer et al. 2017, Kirchherr et al. 2017). Applying this concept to wood products, allowing for energy recovery at the end of their life cycle, exemplifies the potential integration of the circular economy into various industrial sectors. The "circular economy" concept is a shift from the traditional linear economic model, which typically follows the "take, make, dispose" pattern. In contrast, the circular economy aims to minimize waste and utilize resources by creating closed loops within the industrial system, emphasizing the need for a more restorative and regenerative approach to production, consumption, and waste management.

The deterioration of forests as timber sources (e.g., FAO 2020), rapid population growth, and land use changes, i.e., the encroachment into nature, also affect the use of wood raw materials (Foley et al. 2005, Meyfroidt et al. 2013). Concerns about wood materials, wood extracts, and the use of wood substitutes are increasing (e.g., Schimleck – Adebayo 2019), resulting in competition between wood products and wood substitutes. Examining the global impacts of wood as a building material compared to brick, aluminum, steel, and concrete buildings, Buchanan – Levine (2000) concluded that wood buildings require much lower process energy and release lower carbon dioxide emissions than other building materials. Gerencsér (2021) also recommends wood because of its low weight, favorable strength, and the minimal energy required to produce wood construction material. She argues that the transition to non-wood materials would result in increased energy consumption and carbon dioxide emissions. Industries that replace wood products with other materials believe their products have environmental benefits, which further increases uncertainty in public thinking (e.g., Durugy 1996, Kováts-Németh 2010 from a Hungarian perspective).

Stout et al. (2020) showed that the current generation does not possess solid knowledge about the wood products industry and its basic concepts. The study demonstrated that the 18–20 age group had a stronger overall opinion of the wood industry. Hence, addressing this age group is worthwhile because their future perceptions and opinions are more positive toward the wood products industry. Polzin – Bowyer (1999) also observed great uncertainty regarding university-student knowledge of forests and wood products. They found that forest and wood product knowledge is incomplete and based on misunderstandings. Outdoor environmental education is one method to fill these knowledge gaps. Prokop et al. (2007) found a notable positive increase in student attitudes toward biology three days after a field trip. Molnár (2018) and Pryor – Bowman (2016) demonstrated that preserving tradition is a vital base for sustainable development because it helps relay knowledge to future generations (Molnár 2018). Therefore, the present study incorporated wood-related traditions and customs into the research questionnaire.

Previous research conducted in Hungary showed that students who received environmental education are more sensitive toward wood use than students whose training excluded the subject (Nmarné Kendöl 2019). However, significant teacher training deficiencies exist in Hungary (Kárász Imre ed. 2002). In India, folk theaters help raise environmental awareness in rural India through forest preservation themes (Kabbinahithilu et al. 2022). Since environmental education conveys knowledge, we included it in our questionnaire.

Wood use in India and its relation to the National Forestry Policy (Government of India 1988) is an intricate topic involving various aspects, including environmental sustainability, economic growth, and social implications. As in Hungary, extensive use of wood has led to deforestation and environmental degradation concerns. The dichotomy in public opinion in India focuses on the need for sustainable growth and forest conservation. Some believe in promoting wood as a renewable resource, while others are concerned about adverse biodiversity impacts. There are also economic concerns. The wood industry contributes significantly to the Indian economy, offering employment and supporting various downstream industries. Therefore, the tribal and rural communities that depend on forests for livelihood are often at the intersection of the debate on wood use.

India's National Forest Policy (Government of India 1988) recognizes the importance of forests in environmental stability and ecological balance. The policy's primary principles encompass the following points: (1) Assuring the crucial role of forests in ecological equilibrium. (2) Safeguarding the nation's extensive biodiversity and genetic constituents. (3) Providing for the subsistence requisites of tribal and rural demographics. (4) Executing measures to curb soil erosion in the catchment vicinities of water bodies. (5) Aspiring to induct at least one-third of India's land area to forest or tree cover. (6) Fostering community involvement in forest stewardship and communal forestry initiatives. (7) Advocating for the sustainable employment of wood and overseeing wood-centric industries (Government of India 1988).

The present study explores the contrasting perspectives of Western (Hungary) and Asian (India) countries regarding wood, trees, wood products, forestry, and sustainable forest management. Guided by the underlying motive of climate protection, this research analyzes the influence of environmental education and identifies areas that require further development. This investigation is marked by its novelty, as no previous comparative studies *between Western and Asian countries* have been conducted to discern differences in perceptions concerning the importance of utilizing wood and wood-based materials among students. However, admittedly, differences in perceptions have been shown in international comparisons, for example, between Finland and the US (Amberla et al. 2010) or, most recently, between Italy and Turkey (Paletto et al. 2023).

The differential rates of deforestation between Western and Asian countries could be influenced by variations in the perceived value of wood and wood-based products. Understanding these differences could help formulate international policies and recommendations for sustainable wood utilization and forest management.

The study has three primary objectives: first, to determine whether student perceptions of wood and wood material usage vary; second, to assess student knowledge and proficiency in "wood and wood use" as it relates to sustainable development; and third, to promote wood as a raw material, contributing thereby to climate protection. Additionally, in an explorative vein, the study considers potential differences in attitudes toward using wood and wood raw materials, future tree planting intentions, recycling of damaged wooden tools, and the intention to replace damaged wood with wood. The exploratory nature of the study is reflected in the absence of specific hypotheses.

2 MATERIALS AND METHODS

2.1 Participants

The study was conducted in both countries simultaneously to ensure a synchronous perspective of attitudes and knowledge. Primary data collection was completed in 2023. Participants were undergraduate and postgraduate university students belonging to the middle class. We are aware that socioeconomic factors might confound the results. However, we were interested in the knowledge conveyed to students who might or might not have been exposed to environmental education classes. One university was chosen from each respective country. These selected universities have a broad appeal, drawing students from diverse geographic regions spanning a range of cultural backgrounds. While the study encompassed students from various academic disciplines, it is noteworthy that none of the participants specialized in fields related to forestry or natural resource management. The sole inclusion criterion for participation was native language fluency. No additional exclusion criteria were applied.

Random sampling was employed to minimize bias. Classifying students according to their study programs presented challenges, as the specific majors and degree programs offered in Hungary and India differ. The snowball sampling method was excluded since it may induce biases such as homogeneity bias, selection bias (limited control over the selection process), or lack of independence in the sample. All participants provided informed consent before participating in the study. The participants were not compensated financially for their study participation. However, they received course credit as a token of appreciation. Participants were recruited through flyers and email lists of the two universities. The Indian students were of Indian origin, while the Hungarian students were of Hungarian origin.

2.2 Materials

In the absence of a standardized questionnaire on the subject matter, the current study developed a purpose-specific structured self-completion questionnaire (for the questionnaire items, see Appendices). To enhance questionnaire validity and reliability, we engaged in iterative revisions guided by feedback from two domain experts in each participating country, thus addressing face validity. Subsequently, we refined the questionnaire based on their input. These subject-matter experts also conducted an assessment to ascertain the comprehensive coverage of the domain of wood use within the questionnaire, affirming content validity.

Subsequently, we conducted a pilot test of the questionnaire on a sample of ten students in each country to identify and rectify potential issues, including linguistic comprehensibility and participant familiarity with the five-point Likert-scale (1=totally disagree, 5=totally agree), before its implementation in the actual study. Given the nature of our questionnaire, which measures stable opinions and factual responses (c.f. Appendices for item details), we abstained from conducting a test-retest reliability analysis. Furthermore, we intentionally refrained from performing an internal consistency reliability analysis, as our items were intended for separate statistical analysis, and no thematic constructs were predefined.

The language of the informed consent was written in the participant's native language and was adjusted to Indian English for the Indian cohort and proofread by three Indian students in the case of the Indian survey. The informed consents were drafted in compliance with the stipulations outlined in EU legislation, encompassing elements such as the study's objectives, potential risks and advantages associated with participation, and the assurance of confidentiality regarding participant data.

Ordinal items within the questionnaire were measured on a 5-point Likert scale, aligning with the grading systems employed in both participating countries (with 5 indicating "strongly agree"). The questionnaire items, along with the results derived from inferential statistics, are presented in the Appendices, maintaining the order of presentation as observed in the experimental procedure.

2.3 Procedure

Data was collected online using *Google Forms*. Participants were briefed about the general purpose of the study and provided with an informed consent form delineating the study's objectives, the data collection methods, and the confidentiality safeguards. After reading the form, participants provided written consent to proceed. The informed consent form for the two versions of the questionnaire was written in English and Hungarian. Participants were informed that the data would be handled confidentially and that they had the right to withdraw from the study even after submitting their responses without any penalty.

Participant details, such as age range, gender, and study program, were first collected for scientific reasons. Participants completed the questionnaire during regular classes as part of the course requirement. Explicit instructions were disseminated to ensure that the questionnaire was to be completed independently, without external consultation. Participants were informed that their responses would be received and analyzed in a manner devoid of evaluative judgment. Participants were explicitly instructed to provide authentic responses, regardless of whether these responses deviated from conventional norms. No time constraints were imposed, allowing participants to proceed at their own pace. We made sure that the participants filled in all the items of the questionnaire, or else they could not proceed with the questions. The items, which can be seen in the Appencices, were not randomized, since no order-effects of the items could emerge. Filling in the questionnaire took approximately 10 minutes. All data were anonymized and coded numerically to ensure confidentiality. The datasets were stored in encrypted files accessible only to the principal investigators, that is, the authors of the study, in accordance with ethical guidelines (APA 2019).

2.4 Statistical analyses

For the statistical analysis, we used R-Studio (Rstudio Team 2020). The minimum number of participants needed for the study is 110 per country based on sample size calculations provided by the G*Power software (Faul et al. 2009) given the following criteria: two-tailed Mann-Whitney U test, d=0.5, power=0.95. These criteria yielded 110 participants per country.

Country (Hungary and India) served as the binary independent variable in our analyses, with the questionnaire items as the dependent variables. Mann-Whitney U tests were run given the ordinal scale and the non-normal distribution of data. These tests were conducted using the Holm-Bonferroni correction given the high number of comparisons in the item analyses. Each item was examined separately to determine potential differences between the two countries. We were also interested in the parallels between the two countries; therefore, non-significant results are also informative. The Mann-Whitney U test results are in the Appendices (*Table 2*).

After the Mann-Whitney U tests, we employed the Conditional Inference Tree method as an exploratory inferential statistics framework developed by Hothorn et al. (2006). We aimed to enter all the questionnaire items as potential predictors and examine which were most closely related to the response variable, Country. We examined which items or item best explains the difference between Hungary and India. For a brief introduction to Conditional Inference Trees, see, for instance, Levshina (2020). This decision-tree technique models the distribution of a response variable using a high number of independent variables (i.e., items). One of the strengths of this statistical approach is that this model allows for the entry of more independent variables than traditional statistical procedures. Another strength is that it avoids overfitting the statistical model (Hothorn et al. 2006).

This model also provides cut-offs on every significant independent variable. In this way, we can learn about the hierarchical structure of the independent variables explaining the response variable, Country. For example, a cut-off of 4 on a 5-point scale means that we can split the sample into two subsamples. The higher a predictor variable is in the tree hierarchy, the more weightage it has in explaining the response variable. Predictions at the so-called terminal nodes labeled 'y' give the proportions of the two levels of the factor on this route, with 'n' denoting the number of observations. We employed the *party* R package to perform the analysis (Hothorn et al. 2006). To reduce the type I error, we used Bonferroni correction with a minimum criterion of 99%. In the "Results" section, we introduce the Conditional Inference Tree model and, subsequently, emphasize the findings, focusing on three key items of interest.

3 RESULTS

We received data from 231 participants. The Indian sample contained 85 females and 32 males, for a total of 117 participants. The Hungarian sample included 102 females, 11 males, and one person diverse, yielding a total of 114 participants (see *Table 1*). For the sample size calculation, see Section 4.2.).

Data from Hungary or India did not show normal distribution (Kolmogorov-Smirnov test, p<0.001). Age groups differed significantly in the two countries (χ^2=9.907, p<0.001, see Table 1). The distribution of participants differed in the two countries regarding study program (χ^2=72.931, p<0.001, see Table 1). Likewise, gender distribution (see *Table 1*) differed markedly in the two countries (χ^2=12.764, p<0.001). However, these differences do not influence the conclusions given the standards in the curriculum: participants in both countries were exposed to the same syllabus during their school years and are exposed to the same media content presently. Hence, given their homogenous socioeconomic status and exposure to the same syllabus, differences in study programs would not affect their attitudes and response behavior. *Table 2* of the Appendices illustrates the item-level descriptive statistics for the ordinal variables along with the Mann-Whitney U tests. *Table 1* contains the distribution of gender, age groups, and study programs of the participants in the two countries.

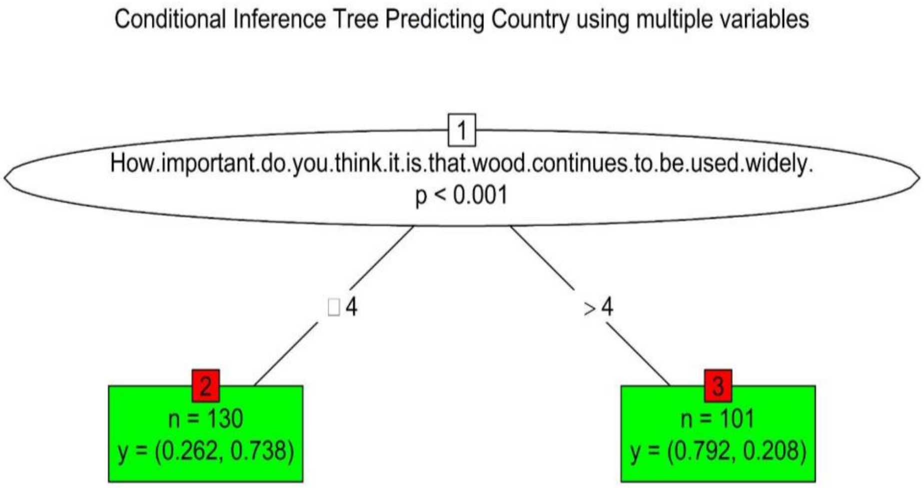

Figure 1. Conditional Inference Tree Predicting Country (Hungary and India) as response variable in this analysis in the entire sample of 231 participants. All variables, excluding gender, were entered in the analysis (a total of 22 items). P-values are Bonferroni-corrected. The item "How important do you think it is that wood continues to be used widely?" with a cut-off of 4 on a 5-point scale proved to be the only statistically significant predictor of Country. The predictions designated by "y = …" indicate probabilities.

Table 1. Distribution of gender, age groups, and study programs of the participants in the two countries. Number indicates column-wise percentages (%).

	Hungary	India
Gender		
Female	89.5	72.6
Male	9.6	27.4
Diverse	0.9	0
Age groups		
20-25 years old	67.5	81.2
26-31 years old	6.1	7.7
less than 20 years old	2.6	2.6
more than 31 years old	23.8	8.5
Study program		
Commerce	6	36
Humanities	16	41
Natural sciences	2	2
Other	76	21

Nominal associations were examined employing Chi-square tests on the item "How many environmental protection books do you have at home," see Appendices (*Table 4*). This item is presented separately from the other nominal items because it has four levels. For the results of the other binary nominal items, see Appendices (*Table 3*). Given the non-equidistant nature of the levels of this variable, we treated this item as a nominal variable.

We were interested in discovering which item(s) is most strongly associated with Country. To this end, we ran Conditional Inference Trees and entered 22 questionnaire items as potential explanatory variables, excluding gender, study program, and age group. The item "How important do you think it is that wood continues to be used widely?" with a cut-off of 4 on a scale of 5 points proved to be the only predictor of Country out of the 22 items ($p<0.001$, Bonferroni-corrected, cut-off=4, statistic=77.573, see Figure 1). Out of the entire sample of 231 participants, there are 130 for whom it can be predicted that if they score <=4 on the item mentioned, there is a 26.2 % probability that they are from India (see terminal node 2, *Figure 1*), which in turn implies that there is a 73.8 % probability that these participants are from Hungary (see terminal node 2, *Figure 1*). The left number represents the probability or prediction for Hungary, while the number on the right represents the same for India. The left branch of the tree explains and predicts cases who scored <=4 on the scale for the item.

Consistent with this result, the Mann-Whitney U test on the same item showed the highest difference, with Hungary (mean=4.61, median=5) scoring much higher than India (mean=3.25, median=3), displaying a difference of 2 points in median (see Appendices, *Table 2*). Because Mann-Whitney U tests could not point to the item most intimately related to Country, the Conditional Inference Tree analysis has an added value to our investigation.

In sum, we observed that the two cohorts can be most efficiently differentiated based on their perspectives regarding the widespread utilization of wood (see *Figure 1* and *Table 2* of the Appendices). We now summarize the three key findings of our survey based on the following three questionnaire items: "How important is sustainable forest management to you?" (blue bar representing the item in *Figure 2*), "How important do you think it is that wood continues to be used widely?" (green bar representing the item in *Figure 2*), and "Would you like to use such a wooden object in your home? (grey bar representing the item in *Figure 2*). For the descriptive and inferential statistics of these items, see *Table 2* of Appendices. We consider these question items to be the most important in our survey because wood materials play a significant role in sequestering carbon, which can significantly mitigate climate change impacts. *Figure 2* illustrates the differences in these three items between the two cohorts.

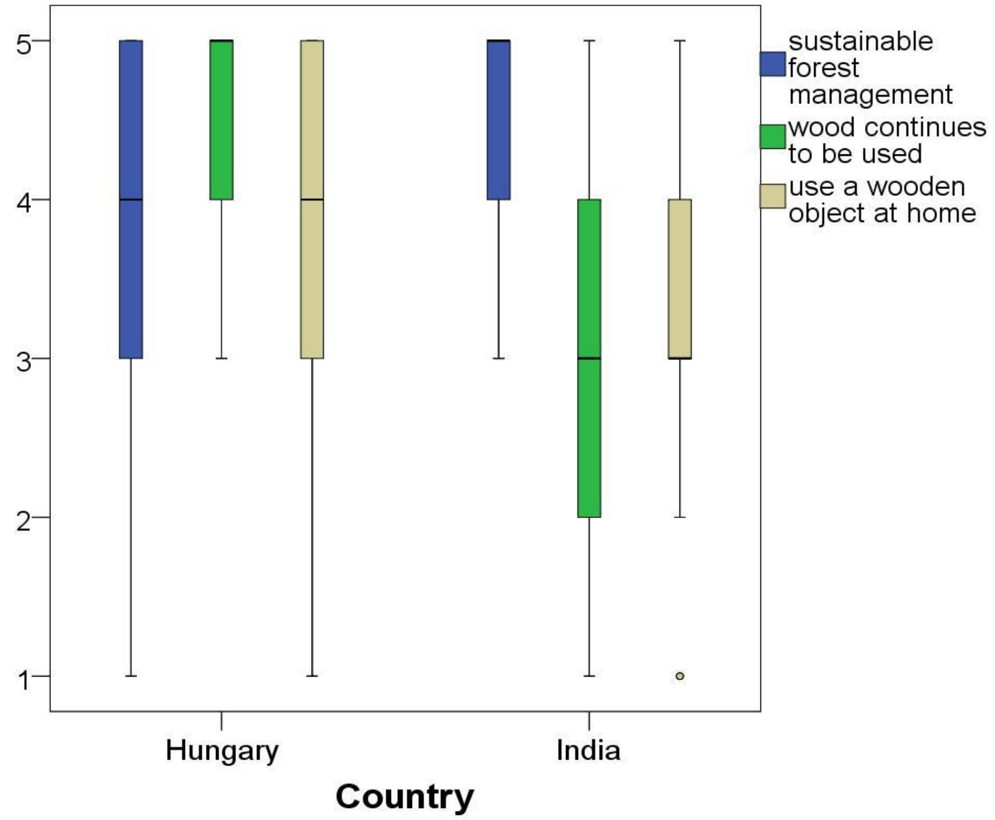

Figure 2. In the bar plot, three pivotal items are presented, categorized by country (Hungary and India). The y-axis represents the ordinal scale, with the x-axis denoting the grouping variable, 'Country'

4 DISCUSSION

Traditionally, wood in India served various purposes, including cooking, woodworking, and furniture construction. However, the transition to natural gas for cooking and steel for furniture has been noticeable. Nonetheless, wood continues to find extensive use in furniture making and construction. Fast-growing bamboo – a sustainable and cost-effective wood alternative – has gained prominence across industries. The launch of The National Bamboo Mission in India aimed to promote increased bamboo cultivation and reduce dependence on forest wood (Ministry of Agriculture and Farmers Welfare 2019). Furthermore, the government encourages the adoption of reconstituted wood panels and ply boards in furniture production to curtail forest logging. Given the large population, additional policy interventions, particularly focused on enhancing environmental awareness and minimizing wood consumption, are imperative (Koul – Kaur 2022).

Materials like steel, glass, plastic, and natural gas in furniture, construction, and cooking are gradually supplanting wood. Factors such as cost, functionality, and aesthetics influence consumer choices. Notably, coal and natural gas are prevalent choices for cooking and heating. Surprisingly, Indian railways, a substantial wood consumer, shifted from concrete to wooden sleepers for track expansion, citing increased durability and support for heavier locomotives (Ortega et al. 2021, Manalo et al. 2010). However, this transition still impacts

Indian forests, necessitating the conversion of more land for farming, resulting in reduced forest cover and adverse climatic effects, including flash floods and droughts (Patra et al. 2022).

To mitigate these consequences, the utilization of Non-Timber Forest Products (NTFPs) is gaining prominence. NTFPs encompass non-wood products derived from fast-growing trees, bamboo, or similar plants, which do not necessitate tree felling. Approximately 275 million rural, economically-disadvantaged Indians residing in challenging climates rely on NTFPs for sustenance and income (Ahamad et al. 2022). Beyond increased NTFP utilization, elevating environmental awareness and education play pivotal roles in forest preservation (Bamrara 2022).

In the following, we discuss the items individually from the perspective of sustainable forest management. The sight of a sick tree in both countries suggests a shared emotional framework for interpreting environmental degradation because it is a reminder of deforestation. Our findings about this shared emotional schema can be leveraged in the formulation of transnational conservation campaigns, cross-cultural environmental psychology, conservation efforts, public policies, and educational programs such as excursions, forestry programs available to everyone, and practice-oriented workshops given by forestry professionals, among others. The congruence in shared emotions illuminates the potential for constructing an international discourse on sustainable forest management, transcending the Western-Asian barrier. Exploiting this shared understanding could dramatically amplify the impact of conservation initiatives by making them more emotionally resonant and intellectually accessible to a broader audience, in line with the endeavors of the G20 Summit in 2023 (p. 10). Specifically, in alignment with the findings of Gharis et al. (2017), it is imperative to emphasize gender and racial diversity in recruiting forest-related programs.

Scrutinizing public perceptions regarding the vitality of forest ecosystems is pivotal in the sustainable forest management domain. Notably, the empirical data from the Indian cohort revealed a mean score of 3.85, with the Hungarian cohort manifesting a comparable mean score of 3.55. Both values situate in the middle range of the 5-point measurement scale utilized, suggesting that respondents do not exhibit significant emotional despondency upon encountering an ailing tree. This serves as an indicator of an underlying comprehension of forest ecology. Specifically, it elucidates that the individuals are cognizant that the morbidity or mortality of a tree is not inherently detrimental. On the contrary, such occurrences may engender advantageous consequences for the overall equilibrium of the forest ecosystem. When a tree dies, it provides nutrients and habitat for other plants and animals, with the dead wood helping to prevent soil erosion and flooding. In addition, tree death can create an opening in the forest canopy, allowing more sunlight to reach the forest floor, which promotes new tree growth. Respondents were aware of these aspects of forest ecology. These findings align with the recent research conducted by Paletto et al. (2023), which illustrated that Italian and Turkish students similarly possess a substantial understanding of deadwood and its significance within forest ecosystems. Additionally, most respondents in their study share the perception that standing dead trees within forests are aesthetically unfavorable, whereas substantial horizontal deadwood is regarded as aesthetically appealing.

Sustainable forest management acknowledges the natural mortality of trees rather than attempting to prevent all instances of sickness or death. Forestry experts prioritize practices that ensure the ongoing replanting of new trees to replace those that naturally expire. This critical aspect should receive heightened attention in environmental education for younger generations despite our prior findings indicating some understanding of forest ecology among respondents. Forester efforts are instrumental in maintaining the long-term health and productivity of forests for future generations. Our previous result suggests that respondents grasp the intricate nature of forests as dynamic ecosystems that undergo continuous changes, including the natural tree lifecycle. However, we propose that forestry professionals should place greater emphasis on environmental education on this facet of the forest's lifecycle.

For instance, students could engage in collaborative tree planting initiatives organized by forestry experts, followed by participation in tree care and maintenance activities. These tree-planting programs can align with significant environmental observances and incorporate traditions or customs related to trees, thereby enhancing the affective domain of attitudes.

Participants in both countries observed that wooden furniture is used more frequently in universities – a desirable result in the context of sustainable wood management because wood is a renewable resource. We propose that academic institutions should actively disseminate information to their student bodies concerning the long-term carbon sequestration properties inherent in the utilization of wooden instruments, thereby contributing to atmospheric preservation. In environmental education and other wood-related programs, forestry professionals should also emphasize that wooden furniture should be sourced from *sustainable forests*. The preference for wooden furniture is likely due to both countries having a long history of using natural materials (see, for example, Laborczy – Winkler 2016, for the Hungarian perspective). India's long history of using natural materials such as wood for furniture can be attributed to a confluence of geographical, cultural, and historical factors. India is endowed with a variety of forests, ranging from the temperate forests of the Himalayas to the tropical forests in the South. These forests have provided a rich resource of different types of wood, such as *teak*, *rosewood*, and *sheesham*, known for their durability. Second, traditional Indian homes often incorporate wooden furniture for its ornamental value (Narayan 2009). Third, Hinduism and other indigenous philosophies often consider wood and trees as sacred. For example, the Peepal tree (*Ficus religiosa*) is revered, and its wood might be used for making religious artifacts. This religious sanctity attributed to trees further enhances the preference for wooden furniture (Gadgil – Guha 1993).

Other factors, such as the availability and abundance of wood in both countries, the low cost of wood, and cultural preferences also play a role. Moreover, by using wood furnishings, universities demonstrate their commitment to sustainability and eco-consciousness (e.g., University of Bristol 2023). Furthermore, wood has natural sound-absorbing properties, which can help to reduce noise levels in crowded areas such as lecture halls.

The prevalence of environmental education books is generally limited, with most students owning fewer than five books in both countries. This underscores the necessity for an increased availability of literature covering topics such as forestry, sustainable forest management, and environmental protection. We contend that the demand for more books on environmental subjects is not merely a literary need; it is a societal imperative in sustainable forest management. The multi-faceted impact that such literature can wield — ranging from educating future generations and engaging the public to influencing policy and fostering interdisciplinary research — makes this a pressing necessity. In addition, books can also mobilize the younger generation toward sustainability.

Sustainable forest management is considered significantly more important in India than in Hungary, with a minimum of 3 on the Likert scale in the Indian sample, and a minimum of 1 in the Hungarian sample (i.e., every participant gave at least 3 as a response in the Indian sample, while in the Hungarian sample, the minimum was 1). For the difference in the span of responses between the countries, see *Figure 2*. *Figure 2* shows that the Indian cohort is more homogenous regarding this question item and tends to rate it incredibly important. An explanation for the significantly higher value is that India faces unique challenges in implementing sustainable forest management. Bahuguna (2000) examined India's multifaceted forest management challenges, with a particular focus on the substantial population as a central issue. The author contended that India's burgeoning population has several adverse implications for sustainable forest management. Firstly, a larger population exerts heightened pressure on land resources, frequently resulting in deforestation to accommodate agriculture, infrastructure, and developmental projects. Secondly, increased population contributes to elevated pollution levels, with greater waste generation posing a threat to forest ecosystems and associated water bodies. Thirdly, the rising population drives up the demand for forest products, potentially leading to unsustainable practices such as increased poaching and illegal logging. In response to these concerns, Bahuguna (2000) advocated for government investments in sustainable forest management strategies like afforestation and reforestation. Additionally, he underscored the importance of public education regarding the significance of forests and the imperative to safeguard them. Our study supports these calls and emphasizes the need for environmental education by forestry professionals.

The land need for agriculture, housing, and infrastructure development motivates illegal logging, which undermines sustainable forest management efforts, another possible explanation for why the Indian cohort might hold this issue as more important than the Hungarian cohort. As per the estimate of the Forest Survey of India (FSI), illegal logging comprises about 20 % of the total timber production in India. Illegal logging is also a major cause of deforestation in India. Second, a sizable portion of India's population depends on forests for their livelihoods. Ensuring sustainable forest management while also addressing poverty requires careful planning, capacity building, and alternative livelihood options, again underscoring the importance of sustainable forest management in India. Third, forest land in India is often owned and managed by government departments, tribal communities, private individuals, and corporations, which hinders sustainable forest management practices. Fourth, India is home to diverse ecosystems and rich biodiversity, which are under threat due to climate change, habitat loss, and invasive species. India has made significant efforts to promote sustainable forest management through afforestation programs, such as the National Afforestation Programme (NAP) and the Green India Mission (GIM), community-based conservation projects (e.g., The Singchung Bugun Village Community Reserve located in Arunachal Pradesh, India), and the implementation of laws and regulations protecting forests (see the forest-related Acts of 1927, 1972, 1980, 1988, and 2006). Two other successful projects in India are the Van Panchayats community-managed forests in Uttarakhand, established in the 1970s to give local communities control over their forests. The Van Panchayats have successfully protected forests and promoted sustainable forest management. The other example is the Joint Forest Management Programme a government-sponsored program supporting community-based forest management launched in 1990 that has successfully involved local communities in forest management.

According to the Food and Agriculture Organization of the United Nations, India has 24.3% forest cover (Food and Agriculture Organization 2020). Hungary's forest wood stock is increasing, and the carbon dioxide sequestration of domestic forests is 3-4 million tons per year, which contributes to mitigating the effects of climate change-inducing air pollution. The amount of forest plantations is 4,000–5,000 hectares per year (Hungarian Forests 2016). Currently, forests cover 22.5 % of Hungary. According to plans, the area covered by forests will increase to 27 % by 2030 (Erdő-Mező Online 2020). In 2019, the Ministry of Agriculture set the primary goal of increasing the area covered with trees in the country and launched the Country Afforestation Program and the Urban Afforestation Program. The program goal is for forests and trees to cover 27 % of the country's territory by 2030, implying that India has a much larger resource to protect and manage sustainably, hence the higher value for the importance of sustainable forest management. According to the World Bank, India has a population of 1.4 billion, while Hungary has a population of around 10 million, entailing that India has a much larger demand for forest products, such as timber, fuelwood, and paper.

The most salient divergence observed between the Hungarian and the Indian cohorts pertained to the questionnaire item, "How important do you think it is that wood continues to be used widely?" The Indian sample exhibited a median value of 3, while the Hungarian sample yielded a median value of 5, consistent with the result of the Conditional Tree Analysis (see *Figure 1*). To observe the variation in response spans between the two countries, please refer to *Figure 2*. *Figure 2* illustrates that the Hungarian cohort exhibits greater homogeneity concerning this question item and generally assigns a higher level of importance to it. Thus, the disparate cultural viewpoints between the Indian and Hungarian populations may be discerned through their respective attitudes toward the prospective employment of wood as a material resource. Excessive or unsustainable wood extraction leads to deforestation, habitat loss, and ecological imbalance in India. Wood usage in India, therefore, needs to be reduced. Another explanation could be the concept of "Sacred Groves," virgin forest areas preserved by local communities in India due to cultural and religious beliefs. These areas are often left undisturbed and are considered a testament to traditional environmental conservation methods in Indian culture. The existence of such practices might contribute to a more cautious attitude toward widescale wood usage (Khan et al. 2008).

In Hungary, a notable challenge pertains to the escalating demand for wood, a sentiment widely shared among Hungarian respondents. This heightened demand for wood can be attributed to numerous factors, notably the robust growth of the Hungarian economy. Wood finds extensive use in thriving industries within Hungary, including the construction sector (a significant wood consumer), wooden furniture manufacturing, packaging (e.g., cardboard boxes and pallets), and paper production, with Hungary being a prominent paper producer.

Furthermore, the rising popularity of wood-fired heating, considered a more environmentally friendly alternative to fossil fuels, contributes to this demand. Importantly, Hungary's heavy reliance on imported natural gas, exacerbated by the energy crisis and the Russia-Ukraine conflict that commenced in February 2022, has resulted in substantial spikes in energy prices. Consequently, wood has emerged as an increasingly appealing choice for heating residences and businesses in winter.

The rising demand for wood has placed significant pressure on Hungary's forest resources. To address this, the Hungarian government implemented an export ban on firewood in August 2022 and directed forestry companies to augment their production. Nonetheless, the effectiveness of these measures in meeting the escalating wood demand remains uncertain. Beyond environmental concerns associated with increased logging, there are apprehensions regarding its social impact. Many Hungarians rely on forests for their livelihoods, and heightened wood demand could result in job losses within the forestry sector.

In response, the Hungarian government actively promotes sustainable forest management practices and explores innovative technologies to enhance wood utilization efficiency. Despite these efforts, the persistent demand for wood will likely pose an enduring challenge for Hungary in the near future. Consequently, the prevailing sentiment among the Hungarian cohort is that wood should continue to be utilized more extensively, considering these complex factors.

Wood utilization in India carries substantial environmental implications. Despite being one of the world's most forested countries, India grapples with significant deforestation challenges. This deforestation stems from numerous factors, including agricultural expansion, infrastructure development, and illicit logging practices. Moreover, the combustion of wood for fuel represents a substantial contributor to greenhouse gas emissions within India. Additionally, the manufacturing and disposal of wood products generate waste materials, such as sawdust and lumber scraps, which can pollute the environment and contribute to climate change. Considering these multifaceted concerns, the prevailing sentiment among Indians is against the continued widespread use of wood.

The G20 Summit (G20 Summit Declaration 2023), held in New Delhi, India, in September 2023, embodied this sentiment through the launch of the Global Biofuel Alliance. The Summit also issued a voluntary call for countries to restore all forest-fire-degraded lands by 2030. Additionally, the Summit advocated for low-GHG/low-carbon emissions, climate-resilient, and environmentally sustainable development pathways, emphasizing an integrated and inclusive approach. The G20 Summit Declaration (5/c, p. 1) also highlights the urgent promotion of Lifestyles for Sustainable Development (LiFE) and the conservation of biodiversity and forests.

Significantly, sustainable alternatives to wood exist in India, including bamboo, recycled materials, and engineered wood products. These alternatives are advocated for their sustainability attributes, such as rapid growth, renewability, and diminished environmental impact. Wood utilization can yield environmental consequences, including deforestation, carbon emissions, and waste generation. The discourse surrounding wood reduction may stem from climate change mitigation, carbon footprint reduction, or the endorsement of circular economy principles. In India, wood retains its substantial cultural, economic, and practical significance across multiple sectors, encompassing furniture, handicrafts, construction, and energy generation. Achieving a delicate equilibrium among these diverse considerations is imperative to foster sustainable wood utilization that addresses environmental imperatives and socioeconomic requisites.

On the item "I feel the positive effects of the presence of trees in my immediate surroundings," the Indian cohort yielded a median of 5, while the Hungarian cohort had a median of 4, indicating that Indians feel a more positive effect of wood. Previous research has also demonstrated that using wood as a raw material in schools positively affects psychological, physical, and mental health (Dadvand et al. 2015; Kuo – Taylor 2004). Specific types of wood are often used in sacred rituals and ceremonies in India. For example, sandalwood is considered sacred, while *neem* wood is associated with purification and protection. Furthermore, due to the diverse climates in India, wood is appreciated for its ability to keep spaces cooler in hot weather and provide warmth during colder seasons.

The observation that Indians are attuned more to the positive effects of trees in their immediate environment can also be scrutinized through the lens of sustainable forest management. This heightened perception of the advantages conferred by trees and wood signifies an implicit understanding of ecosystem services, including biodiversity conservation, carbon sequestration, and air and water purification, among others. Therefore, this perceptual alignment with environmental well-being is potentially a propitious harbinger for adopting sustainable forest management practices within the Indian context.

For the item "The knowledge that felled wood used for raw material takes years to grow back affects my use of wood," in India, we measured a median of 4, while in Hungary, a median of 3, indicating that for Indian students their knowledge affects their wood use significantly more by the regrowth of woodcut as raw material. Indian students who possess more knowledge — whether through formal education or other means — may have a multi-dimensional impact on wood use. Their understanding of sustainability, laws, and scientific methods could make them more inclined to practice or advocate for the regrowth of woodcuts as raw material. Students with a formal education are often better equipped to understand, critique, and improve existing laws and policies related to forestry management in India. Considering that the participants from the Indian sample predominantly belong to the middle socioeconomic stratum, it is reasonable to postulate that they have been recipients of formalized education wherein the subject matter of sustainable forest management was introduced and elucidated.

Responses to the question "Are you planning to plant a tree in your home or garden?" were comparable in both countries, with the respondents recognizing the importance of trees in mitigating climate change, improving air quality, offering natural shade, reducing heat, and preserving biodiversity. Also, many people plant fruit-bearing trees in their gardens, such as mango in India or apple in Hungary. Planting a tree can be a way to carry forward these traditions and provide educational opportunities in the form of family or school gardens. We observed a mean value of 4.3 or higher, which aligns with the prescribed forest sustainability criteria and the most recent findings from Italy and Turkey (Paletto et al. 2023). Consequently, no further intervention from forestry professionals is necessary for this inquiry.

Hungarian students were more willing to choose new wooden furniture for their homes. In recent years, there has been a growing global trend toward sustainability and eco-friendliness in Hungary. Wood is a renewable resource when sourced responsibly, and it can be considered a more environmentally friendly option than synthetic materials or non-renewable resources. Moreover, in Hungary, the cost of wooden furniture is relatively affordable. This is not the case in India, where the cost of wooden furniture can be quite high. Also, the tropical climate in many parts of India might make the maintenance of wooden furniture more challenging due to concerns such as termites, which affects purchase willingness.

More Indian than Hungarian students would regret forgetting a tree-related tradition or custom. We asked this question because traditional and customary practices offer not just an alternative but an invaluable complement to modern sustainable forest management methods. Recognizing and integrating these traditional systems into mainstream policy, environmental education, and scientific research can engender a more holistic and effective approach to conserving forests.

Concerning the possession of wooden tools or objects, 27.2 % of the Hungarian students and 30.7 % of the Indian students reported owning these. Wooden furniture is available in many styles and designs, making the home unique (Kaputa et al. 2018). In principle, wooden tools can certainly align with the goals of sustainable forest management, but this is contingent on responsible practices at every stage of their lifecycle—from raw material sourcing to manufacturing and finally to consumer usage and disposal. Moreover, constant monitoring and adaptive governance mechanisms are essential to ensure that these practices are indeed sustainable. Specifically, if the wood used for making tools comes from forests that are managed sustainably and certified (*certified timber*) by entities like the Forest Stewardship Council (FSC), this is in line with sustainable forest management (Auld et al. 2008). Another vital aspect is utilizing local wood species since it can reduce transportation costs and carbon footprint, contributing to sustainability. We contend that the latter two facets of sustainable forestry warrant heightened emphasis from the relevant authorities.

Students from both countries would feel sorry if one of their wooden tools went to waste, with no significant difference between the two countries. This result is conducive to the objectives of sustainable forest management. When people feel a sense of loss or guilt over wasting a wooden tool, they inherently place a higher value on wood. This could translate into broader awareness and support for sustainable forest management practices (Brown – Kasser 2005). Second, emotional attachment to wooden objects often encourages care and maintenance, reducing the frequency of disposal and the demand for new wooden tools. This can be seen as an indirect contribution to reducing logging pressures on forests (Gifford – Nilsson 2014). Third, the affective connection to wooden tools might shift consumer preferences toward sustainably sourced and manufactured products, which in turn would motivate industry practices to align with sustainable forest management (Thøgersen 1999).

We found that environmental education is more important in India than in Hungary. India is a highly populated country, with diverse ecosystems and biodiversity. Promoting sustainable development practices, creating awareness, resource conservation, and encouraging conservation efforts and renewable energy sources are crucial for India's long-term growth. Hungary may face different environmental challenges because it is a landlocked country in Central Europe. While it still faces issues such as pollution and resource management, the scale and nature of these challenges may differ vastly from those in India. Hungary's smaller population of around 9,500,000 people and different ecological contexts may influence the relative importance placed on environmental education compared to India.

We found that anti-logging/anti-felling propaganda is far more widespread in Hungary (85 %) than in India (62 %). Hungary has a relatively elevated level of environmental awareness and activism compared to other countries. The environmental movement in Hungary dates to the 1970s when environmental organizations began to emerge. This heightened environmental consciousness has contributed to a greater emphasis on deforestation. Second, since the fall of communism in Hungary in 1989, concern for environmental issues has increased. In contrast, India faces different challenges, such as air and water pollution, waste management, and sustainable development. Additionally, the considerable size and heterogeneity in educational attainment within the Indian populace may lead to a non-uniform prioritization of forestry-related concerns. To encapsulate, it is plausible that issues such as poverty and social inequality may eclipse environmental matters in the collective consciousness of India. These observations further illuminate the pivotal role media plays in shaping public sentiment, both detrimentally and constructively. We strongly advocate for the critical evaluation and possible censorship of media content about trees, timber, and forestry, given its potential to disseminate misleading information that may obfuscate public perception. On the educational front, we recommend fortifying the environmental curriculum in India by incorporating a greater wealth of teaching materials and content focused on trees, wooden materials, and forestry. Conversely, in Hungary, the integration of environmental education should be amplified across higher educational institutions and various pedagogical platforms, also emphasized by Kendöl et al. (2022), who demonstrated that deepening the relationship with wood is vital for current and future generations.

For the item "Is there an old wood-related custom or tradition – e.g., erecting a memorial tree, tree planting, etc. – still followed in your place of residence?," we could not reveal a difference between the two countries. Consistent with this result, for the item "Do you plan to keep a wood-related tradition or custom?" we did not reveal a difference either. Surprisingly, more than 30% in both countries do not plan to keep wood-related traditions or customs. Because modern technologies and industrialization have brought significant changes to societies in both countries, traditional wood-related practices may not fit into the fast-paced and industrialized life anymore. Second, traditional wood-related practices are often passed down through generations via oral tradition. However, as societies modernize and people migrate, there is a decline in the transmission of traditional knowledge and skills related to wood craftsmanship. Younger generations may not have the same opportunities or interest in learning these skills, leading to a decline in wood-related traditions. The commercialization and globalization of markets also impact the demand for traditional wood crafts or products. Also, in an era of increasing environmental awareness, the impact of deforestation is a growing concern. This leads to a shift in attitudes toward using wood and a greater emphasis on sustainable practices. In addition, it is also conceivable that the decline in wood-related traditions is even an environmentally conscious choice to protect forests.

To illustrate, some ancient wood-related traditions involve cutting trees at certain heights and times to stimulate new growth, known as coppicing or pollarding. These practices can help maintain forest health and productivity in the long term. Wood-related traditions possess inherent sustainability principles that are intricately linked with effective forest management. Therefore, integrating such traditions into modern sustainable forest management protocols could provide robust, adaptive, and socially inclusive strategies for conserving forest ecosystems. Our finding suggests that wood-related traditions should be strengthened (in the light of the small percentage of positive responses), as these traditions and customs also build the basis of sustainable forest management.

We found that 90 % of students in both countries had wooden objects in their homes/families for a long time. Several explanations present themselves. The extended lifespan of well-crafted, eco-friendly, durable, and adequately sourced wooden objects mitigates the need for frequent replacements, thereby reducing pressure on forest resources (Hoadley 2000). The growing awareness of the benefits of sustainable forest management in both countries motivates households to prefer wooden products sourced from sustainably managed forests (Toppinen et al. 2013). Wooden objects serve as carbon sinks for the duration of their lifespan, making them an ecologically viable choice in the context of climate change mitigation strategies (Skog 2008). Wooden objects can often be more cost-effective overall due to their durability, providing an economic rationale for their widespread ownership (O'Connor et al. 2004).

Regarding the item "I feel the positive effects of the presence of trees in my immediate surroundings," we observed that Hungarian students attach more importance to using a wide range of wood items than Indian students. Hungary has a long woodworking history, and wood is a traditional material used in Hungarian furniture or architecture. Also, wood cost is relatively low in Hungary, making it affordable to use for furniture and other objects.

Wood is a natural resource that takes a considerable time to replenish itself. A tree that takes 30 years to mature can be felled in less than 30 minutes. This knowledge has a significant relation with wood consumption. But contrary to this notion, we found that planting a new tree instead of a mature tree is much more beneficial, as the growing tree binds much more carbon than the "old" tree. People need to be made aware of the three types of forests and the concept of economic forests and certified timber.

Tree-planting ceremonies are often held in Hungary to commemorate special occasions, such as the birth of a child or the opening of a new business. Tree planting is seen a as means to give something back to the environment and make a positive impact on the community. Indian students regret forgetting a tree-related tradition or custom more than Hungarian students. Probably because of the strong connection Indians and the Hungarians have with tree and wood products, they did not like the prospect of throwing out a wooden tool or furniture that broke. Instead, they would prefer to use it in some other way or repair it. Hungarian students showed a strong preference for using such wooden objects in their homes and portraying Hungarian craftsmanship. Hungarian students also have a high interest in choosing a new piece of wooden furniture. This finding can be of importance as it exhibits the increased interest in such products and concerned industries can use the information for their commercial planning.

5 CONCLUSIONS

Our main objective was to find out the factors that determine the attitudes toward wood and the willingness to use wood in these two distinct cultures. People's attitudes, knowledge, and mentality regarding wood and trees have become incredibly important in the era of energy crisis and climate protection. However, there is much uncertainty and confusion in people's attitudes toward wood and trees. By identifying the gaps in knowledge and the level of uncertainty, we can propose future directions in environmental education and culture, for example, and strengthen social capital and cultural capital. To that end, we tested university students in India and Hungary.

In summation, given the objectives and empirical findings of our research study, we advocate incorporating forest management strategies across a broad spectrum of societal strata and media. The active participation of community stakeholders in organized forestry initiatives is highly encouraged. Experts in the domain of forestry, along with universities, faculties, and professional foresters, are uniquely positioned to disseminate specialized knowledge and authentic information pertinent to environmental education on timber, lignocellulosic materials, sustainable sourcing, and the application of wooden instruments. Forestry enterprises are advised to arrange an expansive array of programs and events aimed at enhancing the awareness and understanding of sustainable forest management, as well as the properties and utilities of wood-based materials, among the attendees. Initiatives that permit participants to assume roles as active agents tend to amplify the emotional spectrum, thereby enhancing their engagement. Such an approach is instrumental in bolstering two pivotal domains concerning environmental attitudes toward timber utilization. Specifically, preserving wood-related traditions and implementing tree-planting initiatives are integral components of sustainable forest management. This catalyzes the intended outcome: the judicious, conscious application of wood, thereby rendering a substantial positive impact on climate conservation efforts. The study also has a few weaknesses. First, the study is cross-sectional, which means it cannot establish cause-and-effect relationships. For example, the study found that environmentally conscious people are more likely to have positive attitudes toward wood use. However, people who have positive attitudes toward wood use may be also more likely to be environmentally conscious. Another study limitation is the absence of control for socioeconomic status as a variable. However, we deliberately targeted people who received environmental education during their school years. Despite these weaknesses, the study provides valuable insights into the attitudes toward wood use. Future research on the attitudes toward wood use could focus on intervention studies in environmental education and longitudinal studies that can establish cause-and-effect relationships or on studies conducted in other countries. The findings of the present study can inform public policy decisions about wood use and develop educational programs about the environmental and economic benefits of wood.

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Ethical considerations: This study was conducted in accordance with the ethical guidelines outlined by the Declaration of Helsinki (WMA 2022). All ethical considerations, including informed consent, confidentiality, and debriefing, were carefully adhered to throughout the study.

Conflict of interest statement: The authors declare that they have no conflicts of interest.

Data availability: The raw data is accessible within the FigShare repository under the identifier https://figshare.com/articles/dataset/Raw_data_Hungary_and_India/24272386.

REFERENCES

AMBERLA, T. – WANG, L. – JUSLIN, H. – PANWAR, R. – HANSEN, E. – ANDERSON, R. (2010): Students' Perceptions of Forest Industries Business Ethics - A Comparative Analysis of Finland and the USA. EJBO - Electronic Journal of Business Ethics and Organization Studies 15(1). Online: http://ejbo.jyu.fi/pdf/ejbo_vol15_no1_pages_44–54.pdf

AHAMAD, F. – BHUTIANI, R. – RUHELA, M. – RAI, N. (2022): Non-timber forest products: Current status and development. In Environmental pollution and natural resource management 103–119. Cham: Springer International Publishing. Online: https://www.springerprofessional.de/en/non-timber-forest-products-current-status-and-development/23292052

AMERICAN PSYCHOLOGICAL ASSOCIATION (2017): Ethical principles of psychologists and code of conduct. Online: https://www.apa.org/ethics/code/ethics-code-2017.pdf

AULD, G. – GULBRANDSEN, L. H. – MCDERMOTT, C. L. (2008): Certification schemes and the impacts on forests and forestry. Annual Review of Environment and Resources 33: 187–211. https://doi.org/10.1146/annurev.environ.33.013007.103754

BAHUGUNA, V. K. (2000): Forests in the economy of the rural poor: An estimation of the dependency level. Ambio 29(3): 126–129. https://doi.org/10.1579/0044-7447-29.3.126

BAMRARA, A. (2022): The Impact of Awareness Regarding Environmental Protection Laws on Ecological Degradation. In Handbook of Research on Sustainable Development Goals. Climate Change, and Digitalization 31–43. IGI Global. ISBN13: 9781799884828 https://doi.org/10.4018/978-1-7998-8482-8.ch003

BROWN, K. W. – KASSER, T. (2005): Are psychological and ecological well-being compatible? The role of values, mindfulness, and lifestyle. Social Indicators Research 74(2): 349–368. http://dx.doi.org/10.1007/s11205-004-8207-8

BUCHANAN, A. – Levine, B. (2000): Wood-based building materials and atmospheric carbon emissions. Environmental Science & Policy 2(6): 427–437. https://doi.org/10.1016/S1462-9011(99)00038-6

COSTANZA, R. – D'ARGE, R. – DE GROOT, R. – FARBER, S. – GRASSO, M. – HANNON, B. – VAN DEN BELT, M. (1997): The value of the world's ecosystem services and natural capital. Nature 387(6630): 253-260. https://doi.org/10.1038/387253a0

DADVAND, P. – NIEUWENHUIJSEN, M. J. – ESNAOLA, M. – FORNS, J. – BASAGAÑA, X.– ALVAREZ-PEDREROL, M. – SUNYER, J. (2015): Green spaces and cognitive development in primary schoolchildren. Proceedings of the National Academy of Sciences 112 (26): 7937–7942. https://doi.org/10.1073/pnas.1503402112

DONATO, D.C. – KAUFFMAN, J.B. – MURDIYARSO, D. – KURNIANTO, S. – STIDHAM, M. – KANNINEN, M. (2011): Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience 4: 293–297. https://doi.org/10.1038/ngeo1123

DURUGY, A. (1996): Marketingprogram az erdőgazdálkodás és a fából készült termékek társadalmi megítélésének jobbítására. [Marketing program to improve forest management and social perception of wood products.] D&T Piackutató és Marketing Tanácsadó Iroda, Vác. ISBN: 2399985404964

ELLEN, MACARTHUR FOUNDATION. (2013): Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition. Online: https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an

FAO (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS) (2018): The State of the World's Forests 2018 – Forest Pathways to Sustainable Development. Online: http://www.fao.org/3/I9535EN/i9535en.pdf

FAO (FOOD AND AGRICULTURE ORGANIZATION) (2020): The state of the world's forests 2020. Online: https://www.fao.org/state-of-forests/2020/en/

FAUL, F. – ERDFELDER, E. – LANG, A. – BUCHNER, A. (2007): G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods 39: 175–191. https://doi.org/10.3758/BF03193146

FOLEY, J. A. – DEFRIES, R. – ASNER, G. P. – BARFORD, C. – BONAN, G. – CARPENTER, S. R. – ZAKS, D. P. (2005): Global Consequences of Land Use. Science 309(5734): 570–574. https://doi.org/10.1126/science.1111772

FOLCZ, Á. (2013): Az erdészek és szakmájuk társadalmi megítélése. [Social perception of foresters and their profession.] Erdészeti Lapok CXLVIII (11): 364–365. Online: http://erdeszetilapok.oszk.hu/01786/pdf/EPA01192_erdeszeti_lapok_2013_11_364_365.pdf (in Hungarian)

FOREST PRODUCTS LABORATORY (2010): Wood handbook—Wood as an engineering material. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p. https://doi.org/10.2737/FPL-GTR-190

G20 Summit Declaration (2023, September 9-10): New Delhi, India. Online: https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/G20-New-Delhi-Leaders-Declaration.pdf

GADGIL, M. – GUHA, R. (1993): This Fissured Land: An Ecological History of India. Oxford University Press. ISBN-13 978-0198077442

GEISSDOERFER, M. – SAVAGET, P. – BOCKEN, N. M. P. – HULTINK, E. J. (2017): The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production 143: 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

GERENCSÉR, K. (2021): A fa ezer arca. [The thousand faces of the tree] Soproni Egyetemi Kiadó, Sopron. 88–103 p. ISBN 978-963-334-4 (in Hungarian)

GHARIS, L. – SHELBY, G. L. – OSBORNE, D. C. (2017): How Do University Students Perceive Forestry and Wildlife Management Degrees? Journal of Forestry 115: 540–547. https://doi.org/10.5849/JOF-2016-080R3

GIFFORD, R. – NILSSON, A. (2014): Personal and social factors that influence pro-environmental concern and behaviour: A review. International Journal of Psychology 49(3): 141–157. https://doi.org/10.1002/ijop.12034

GOVERNMENT OF INDIA (1988): National Forest Policy. Ministry of Environment and Forests. New Delhi. Online: https://asbb.gov.in/Downloads/National%20Forest%20Policy.pdf

HARTL, É. (2008): A „Környezetünk az erdő" pedagógus továbbképzés környezettudatos nevelésben betöltött helye, szerepe és hatékonysága. PhD dissertation. [The place, role and effectiveness of the "Our Environment is the Forest" teacher training in environmentally conscious education. PhD dissertation.] Sopron. (in Hungarian)

HERZOG, T. – NATTERER, J. – SCHWEITZER, R. (2012): Timber Construction Manual. American Institute of Timber Construction. 672 p. ISBN: 978-0-470-54509-6

HOADLEY, R. B. (2000): Understanding wood: A craftsman's guide to wood technology. Newtown, CT: Taunton Press. ISBN-13: 978-1561583584

HOTHORN, T. – HORNIK, K. – ZEILEIS, A. – STROBL, C. (2006): Conditional inference trees. Biometrical Journal 48(3): 317–339. Online: https://cran.irsn.fr/web/packages/partykit/vignettes/ctree.pdf

HUNDECHA, Y. – BARDOSSY, A. (2004): Modeling of the effect of land use changes on the runoff generation of a river basin through parameter regionalization of a watershed model. Journal of Hydrology 292(1–4): 281–295. https://doi.org/10.1016/j.jhydrol.2004.01.002

KABBINAHITHILU VENKATARAMANA, P. – KUMAR, S. (2022): Effectiveness of folk theatre in conveying environmental consciousness: a case study of Yakshagana. Media Asia 49 (2): 111–129. https://doi.org/10.1080/01296612.2021.2005961

KAPUTA, V. – BARČIĆ, A. P. – MAŤOVÁ, H. – MOTIK, D. (2018): Consumer preferences for wooden furniture in Croatia and Slovakia. BioResources 13 (3): 6280–6299. https://doi.org/10.15376/biores.13.3.6280-6299

KÁRÁSZ, I. (Ed., 2002): II. Felsőoktatási Környezettani Képzési Ankét. Előadások. [II. Higher Education Environmental Training Questionnaire. Presentations.] Eszterházy Károly Főiskola Környezettudományi Tanszék. Eger. 1–64 p. (in Hungarian)

KIRCHHERR, J. – REIKE, D. – HEKKERT, M. (2017): Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling 127: 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

KHAN, M. L. – KHUMBONGMAYUM, A. D. – TRIPATHI, R. S. (2008): The sacred groves and their significance in conserving biodiversity: An overview. International Journal of Ecology and Environmental Sciences 34(3): 277–291. Online: https://www.activeremedy.org/wp-content/uploads/2014/10/ml-khan-et-al-2008-the-sacred-groves-and-their-significance-in-conserving-biodiversity.pdf

KOUL, M. – KAUR, I. (2022): To stay tall, trees need surgical interventions too! Science Reporter October 2022: 38–39 Online: https://nopr.niscpr.res.in/bitstream/123456789/60619/3/SR%2059%2810%29%2038-39.pdf

KUO, F. E. – TAYLOR, A. F. (2004): A potential natural treatment for attention-deficit/hyperactivity disorder: Evidence from a national study. American Journal of Public Health 94(9): 1580–1586. https://doi.org/10.2105%2Fajph.94.9.1580

KOVÁTS – NÉMETH, M. (2010): Az erdőpedagógiától a környezetpedagógiáig. [From forest pedagogy to environmental pedagogy.] Apáczai Kiadó, Pécs. ISBN 978 963 9687 18 9 (in Hungarian)

LABORCZY, G. – WINKLER A. (2016): The Hungarian wood-based panel industry and its impact on the environment. Acta Silv. Lign. Hung. 12 (2): 157–171. https://doi.org/10.1515/aslh-2016-0014

LEVSHINA, N. (2020): Conditional Inference Trees and Random Forests. In: Paquot, M., Gries, S.T. (eds) A Practical Handbook of Corpus Linguistics. Springer, Cham. Online: https://pure.mpg.de/rest/items/item_3253245_4/component/file_3393904/content

LUND, H. G. (2007): Accounting for the world's rangelands. Rangelands 29(1): 3-10. https://doi.org/10.2111/1551-501X(2007)29[3:AFTWR]2.0.CO;2

NARAYAN, K. (2009): Storytellers, saints, and scoundrels: Folk narrative in Hindu religious teaching. University of Pennsylvania Press. Online: https://books.google.hu/books?id=XnvMLkX6lIoC&printsec=copyright&redir_esc=y#v=onepage&q&f=false

MANALO, A. – ARAVINTHAN, T. – KARUNASENA, W. – TICOALU, A. (2010): A review of alternative materials for replacing existing timber sleepers. Composite Structures 92(3): 603–611. https://doi.org/10.1016/j.compstruct.2009.08.046

MEYFROIDT, P. – LAMBIN, E. F. – ERB, K. H., HERTEL –T. W., ET AL. (2013): Globalization of land use: distant drivers of land change and geographic displacement of land use. Current Opinion in Environmental Sustainability 5(5): 438–444. https://doi.org/10.1016/j.cosust.2013.04.003

MCNEILL, J.R. (2011): Valami új a nap alatt. A 20. század környezettörténete - A szerző utószavával: Visszatekintés a 21. század első évtizedére. [Something new under the sun. Environmental History of the 20th Century - By Author: A Look Back at the First Decade of the 21st Century.] Ursus Libris Kft., Budapest. ISBN 9789639718418

MINISTRY OF AGRICULTURE AND FARMERS WELFARE (2019): Operational Guidelines National Bamboo Mission. National Bamboo Mission. Online: https://nbm.nic.in/Documents/pdf/NBM_Revised_Guidelines.pdf

MOLNÁR, K. (2018): A néphagyományokban rejlő környezettudatosság. [Environmental Awareness Hidden in Folklore.] Tanulmánykötet Mészáros Károly tiszteletére. 67–72 p. Online: http://publicatio.uni-sopron.hu/1571/1/Tankot_MKT_2018_09_Molnar_Katalin.pdf (in Hungarian)

NAGY, G. (2023): Fent és lent. [Up and down.] HVG Fenntartható fejlődés plusz. 72–74 p. (in Hungarian)

ORTEGA, R. S. – POMBO, J. – RICCI, S. – MIRANDA, M. (2021): The importance of sleepers spacing in railways. Construction and Building Materials 300: 124–326. https://doi.org/10.1016/j.conbuildmat.2021.124326

PALETTO, A. – BAYRAKTAR, S. – BECAGLI, C. – DE MEO, I. (2023): Young Generations' Perception of the Role of Deadwood in Forests: Comparison between Italy and Türkiye. Ecologies 4: 426–441. http://dx.doi.org/10.3390/ecologies4020027

PATRA, S. – KUMAR, A. – SAIKIA, P. (2022): Deforestation and Forests Degradation Impacts on Livelihood Security and Climate Change: Indian Initiatives Towards Its Mitigation. In Environmental Degradation: Challenges and Strategies for Mitigation. Springer, Cham. 371–392 p. http://dx.doi.org/10.1007/978-3-030-95542-7_18

PAQUETTE, A. – MESSIER, C. (2009): The role of plantations in managing the world's forests in the Anthropocene. Frontiers in Ecology and the Environment 8 (1): 27–34. https://doi.org/10.1890/080116

POLZIN, P.E. – BOWYER, J.L. (1999): Misperceptions about forests and wood products: A statewide survey in Montana. Forest Products Journal 49 (9): 37–42. Online: https://www.proquest.com/openview/c57427ab6244fcb057738f493a4776f5/1?pq-origsite=gscholar&cbl=25222

PRYOR, A. – BOWMAN, P. (2016): Folklore and education: A short history of a long endeavor. The Journal of American Folklore 129 (514): 436–458. https://doi.org/10.5406/jamerfolk.129.514.0436

PROKOP, P. – TUNCER, G. – KVASNIČÁK, R. (2007): Short-Term Effects of Field Programme on Students' Knowledge and Attitude Toward Biology: a Slovak Experience. J Sci Educ Technol 16 (3): 247–255. https://doi.org/10.1007/s10956-007-9044-8

QU, M. – AHPONEN, P. – TAHVANAINEN, L. – GRITTEN, D. – MOLA-YUDEGO, B. – PELKONEN, P. (2011): Chinese University Student's Knowledge and Attitude Regarding Forest Bio-Energy, Renewable and Sustainable Energy Reviews 15 (8): 3649–3657. https://doi.org/10.1016/j.rser.2011.07.002

RSTUDIO TEAM (2020): RStudio: Integrated Development for R. Online: https://www.r-project.org/conferences/useR-2011/abstracts/180111-allairejj.pdf

SELHUB, E. M. – LOGAN, A. C. (2012): Your Brain on Nature: The Science of Nature's Influence on Your Health, Happiness, and Vitality. John Wiley&Sons. Canada. ISBN: 978-1-118-106747

SKOG, K. E. (2008): Sequestration of carbon in harvested wood products for the United States. Forest Products Journal 58(6): 56-72. Online: https://www.fs.usda.gov/research/treesearch/31171

SÓLYMOS, R. (2014): A világ, Európa és Magyarország erdei, az erdők fenntartásának és fejlesztésének tudományos alapjai. [Forests of the world, Europe and Hungary, the scientific basis of the maintenance and development of forests.] Online: http://real-eod.mtak.hu/9819/1/Solymos_Rezso_szekfoglalo2004.pdf

STOUT, K. – MONTAGUE, I. – SHMULSKY, R. (2020): Millennial Generation Perceptions Surrounding the Wood Products Industry. BioProducts Business 5 (3): 25–36. https://doi.org/10.22382/bpb-2020-003

SUN, G. – VASE, J. M. (2016): Forest management challenges for sustaining water resources in the Anthropocene 7 (3): 68. https://doi.org/10.3390/f7030068

TOPPINEN, A. – RÄMÖ, A. K. – RÄMÖ, A. K. (2013): Consumer perceptions of environmental and social sustainability in wood products: insights from Finland. Scandinavian Journal of Forest Research 28(3): 305–315. https://doi.org/10.1080/02827581.2013.824021

THØGERSEN, J. (1999): The ethical consumer. Moral norms and packaging choice. Journal of Consumer Policy 22(4): 439–460. https://doi.org/10.1023/A:1006225711603

UNIVERSITY OF BRISTOL (2023, MARCH 8): Sustainable Furniture. https://www.bristol.ac.uk/sustainability/doing/our-achievements/sustainable-furniture/

WILLIAMS, F. (2017): The Nature Fix: Why Nature Makes Us Happier, Healthier, and More Creative. Best Science & Technology. 223 p. ISBN: 9780393609394 (ISBN10: 0393609391)

WINTERBOTTOM, M. D. – BUSCH, A. (2008): Wood in the Landscape: A Practical Guide to Specification and Design. Kindle Edition. ISBN 978-0471294191

WMA - The World Medical Association-WMA Declaration of Helsinki (2022): Ethical Principles for Medical Research Involving Human Subjects. Online: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/

APPENDICES

Table 2. Item-level descriptive and inferential statistics for the ordinal variables for India and Hungary. Country, mean, sd (standard deviation), median, minimum, maximum, range, skew (skewness), kurt (kurtosis), and se (standard error of the mean) are depicted. Results from the Mann-Whitney U tests along with the Holm-Bonferroni-corrected p-values can be seen below every variable. "n.s" denotes non-significant results after Holm-Bonferroni correction.

Ordinal variables	Country	mean	sd	median	min	max	range	skew	kurt	se
How sad are you at the sight of a sick tree?	India	3.85	1.15	4	1	5	4	-0.74	-0.21	0.11
	Hungary	3.55	1.01	3	1	5	4	-0.12	-0.67	0.09
	W=5451, p=0.01248, n.s.									
The furnishings in my college are made of wood rather than other materials.	India	3.21	1.29	3	1	5	4	-0.28	-0.97	0.12
	Hungary	3.49	0.89	3	1	5	4	0.06	-0.45	0.08
	W=7313, p=0.1879, n.s.									
How important is sustainable forest management to you?	India	4.42	0.75	5	3	5	2	-0.84	-0.74	0.07
	Hungary	3.68	1.12	4	1	5	4	-0.61	-0.12	0.1
	W=4127, p=1.045e-07, p<0.001 (Holm-Bonferroni-corrected)									
How important do you think it is that wood continues to be used widely?	India	3.25	1.17	3	1	5	4	-0.1	-0.81	0.11
	Hungary	4.61	0.66	5	3	5	2	-1.39	0.61	0.06
	W=10979, p<2.2e-16, p<0.001 (Holm-Bonferroni-corrected)									

Ordinal variables	Country	mean	sd	median	min	max	range	skew	kurt	se
I feel the positive effects of the presence of trees in my immediate surrounding.	India	4.46	0.84	5	1	5	4	-1.72	3.27	0.08
	Hungary	4.17	0.92	4	1	5	4	-0.94	0.30	0.09
	W=5383, p=0.005082, p<0.05 (Holm-Bonferroni-corrected)									
The knowledge that felled wood used for raw material takes years to grow back affects my use of wood.	India	3.75	1.02	4	1	5	4	-0.26	-0.74	0.09
	Hungary	3.29	1.14	3	1	5	4	-0.26	-0.65	0.11
	W=5234, p=0.003316, p<0.05 (Holm-Bonferroni-corrected)									
Are you planning to plant a tree in your home or garden?	India	4.37	1.04	5	1	5	4	-1.64	1.97	0.1
	Hungary	4.42	1.01	5	1	5	4	-1.87	2.89	0.09
	W=6832.5, p=0.7009, n.s.									
How sad would you feel if a tree-related tradition or custom was forgotten?	India	3.68	1.13	4	1	5	4	-0.55	-0.38	0.1
	Hungary	3.31	1.16	3	1	5	4	-0.14	-0.63	0.11
	W=5398, p=0.009332, p<0.05 (Holm-Bonferroni-corrected)									
Do you believe that the number of wo-oden items (e.g., furniture, utensils, ornaments...) used in your home has increa-sed in recent years?	India	2.88	1.31	3	1	5	4	0.2	-1.06	0.12
	Hungary	2.96	1.12	3	1	5	4	0.12	-0.56	0.11
	W=6981, p=0.5269, n.s.									

Ordinal variables	Country	mean	sd	median	min	max	range	skew	kurt	se
How sad would you feel if one of your wooden tools or furniture broke?	India	3.82	1.08	4	1	5	4	-0.66	-0.24	0.1
	Hungary	3.95	1.03	4	1	5	4	-0.67	-0.34	0.1
	W=7085.5, p=0.3913, n.s.									
How pleasant is it to look at an old wooden object?	India	4.04	0.99	4	1	5	4	-0.67	-0.25	0.09
	Hungary	4.03	1.08	4	1	5	4	-1.23	1.11	0.1
	W=6761.5, p=0.8478, n.s.									
Would you like to use such a wooden object in your home?	India	3.49	1.04	3	1	5	4	-0.1	-0.66	0.1
	Hungary	3.85	1.11	4	1	5	4	-0.85	0.11	0.1
	W=8106, p=0.003277, p<0.05 (Holm-Bonferroni-corrected)									
How willing would you be to choose new wooden furniture for your home?	India	3.36	1.13	3	1	5	4	-0.16	-0.68	0.1
	Hungary	4.04	0.93	4	2	5	3	-0.68	-0.43	0.09
	W=8977, p=2.39e-06, p<0.001 (Holm-Bonferroni-corrected)									

Table 3. Item-level descriptive statistics for the nominal variables for India and Hungary. Responses were "yes" or "no" for each nominal variable. Numbers represent the number of respondents who gave affirmative and negative responses (%).

Nominal variables	Country	yes	no	χ2	p-value
Did your studies teach you about wood use or forests?	India	40%	60%	12.009	*p*<0.001
	Hungary	19%	81%		
Have you encountered anti-logging/anti-tree felling information in the media or lectures?	India	62%	38%	16.307	*p*<0.001
	Hungary	85%	15%		
Is there an old wood-related custom or tradition – e.g., erecting a memorial tree, tree planting, etc. – still followed in your place of residence?	India	54%	46%	5.1577	p=0.0231 (n.s. after Holm-Bonferroni correction)
	Hungary	68%	32%		
Do you plan to keep a wood-related tradition or custom?	India	63%	37%	0.1629	p=0.6865
	Hungary	66%	34%		
Do you have any wooden objects that have been in your family for a long time (e.g., grandparents' furniture, old objects, etc..)?	India	90%	10%	0.76591	p=0.3815
	Hungary	93%	7%		

Table 4. Item-level descriptive statistics for the nominal variable "How many environmental protection books do you have at home" with country as the independent variable.

Nominal variables	**Country**	**< 5 books**	**6-10 books**	**11-20 books**	**> 20 books**	**χ2**	**p-value**
How many environmental protection books do you have at home?	India	82%	15%	2%	1%	11.137	p=0.0004682
	Hungary	63%	29%	4%	4%		

Guide for Authors

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Contents and Abstracts of the Bulletin of Forest Science

Bulletin of Forest Science (Erdészettudományi Közlemények) is a journal supported by the Forest Research Institute of the Faculty of Forestry of the University of Sopron. The papers are in Hungarian, with English summaries. The recent issue (Vol. 12, 2022) contains the following papers. The full papers can be found and downloaded in *pdf* format from the journal's webpage (www.erdtudkoz.hu).

Vol. 12, Nr. 1, 2022

Tamás KOLLÁR:

Forest Yield function and table of beech *(Fagus sylvatica)* stands by the FRI's long duration research network database…5–29

Abstract – Yield table of beech by the Forest Research Institute's long duration research network was publicised in 1968, and later in 1983. Since then, a great amount of data was accumulated from the University of Sopron – Forest Research Institute's (UOS – FRI) long duration forest yield and silvicultural research network by continuous recordings. From that database new yield functions and yield tables were made in favour of more accurate estimation of beech yield. 1542 digitalised records from 337 parcels were processed, from those great differences were noticed compared to the previous tables. Besides making the traditional yield table, the methods of calculations were given in detail, from which a forest stand's individual growth trends can be calculated. The tables were made for 100% beech mixture ratio, closure and density.
https://doi.org/10.17164/EK.2022.01

Tamás ÁBRI, Zsolt KESERŰ and Károly RÉDEI:

Growth conditions of 'Nyírségi' black locust (*Robinia pseudoacacia* 'Nyírségi')…31–42

Abstract – Black locust is one of the most common hard broadleaved tree species in Hungary. The popularity of this tree, which has been growing in Hungary for more than 300 years, is due to its rapid growth, hard, durable wood, good nectar production, and its high plasticity to different soils. Nevertheless, it is a well-known fact that the occurrence of low stem quality (crookedness of the stem) is very common in black locust stands, which significantly affects the workability and the value of the wood, resulting in low industrial wood yield. In order to improve the stem quality as well as increase the yield, large-scale research work was started in the 1960s at the Hungarian Forestry Research Institute. As a result of this project (selection breeding) we have many black locust cultivars, nowadays. One of them is the 'Nyírségi' black locust, which is found in several variety comparison trials. There is no scientific work, that summarize the decades-long results of this cultivar. This study may contribute to the improvement of growing technology of selected black locust cultivars as a stopgap publication.
https://doi.org/10.17164/EK.2022.02

Abstract – Significant changes were recorded in the bathymetric and water-quality parameters of the Lake Sfânta Ana, a crater lake in Romania, during the past decades. The role of the crater, as the catchment area of the lake needs to be clarified. The existence of the subsurface inflow, as a feeding component in the hydrological budget of the lake, is an open question. The occurrence of free, gravitational water in the soil of the crater is a fundamental condition of the subsurface inflow. The study is focusing on the questions related to the occurrence and frequency of free water in the soil under forest stands of different species composition and age structure. The results show that free water does occur in the soil, and the different forest structures, consisting of middle aged and old European beech stands, middle-aged Norway spruce stands and mixed aged European beech with Northern spruce and Silver fir stands, have an influence on the frequency of the occurrence. Free water occurrence in the soil is significantly lower in old even aged European beech stands than in the middle aged beech and mixed aged stands.
https://doi.org/10.17164/EK.2022.03

Abstract – Climate change is one of the key issues of recent times. One of the main reasons is the increasing amount of greenhouse gases released into the atmosphere, mainly derived from industrial and logistics activities. Carbon dioxide is the most important and also one of the most common greenhouse gases. In order to reduce the effects of climate change, it is therefore necessary to know the places where carbon dioxide is generated, its quantity and its effects on the environment. The aim of the research is to specify the conversion factors for determining the carbon footprint of wood industry processes, and then to develop a uniformly applicable calculation methodology. During the literature research, the carbon dioxide emissions from road transport and the electricity and heat consumption of wood industry companies were examined, and then the conversion factors that characterize them were given in terms of carbon dioxide equivalent (CO_2e). The presented methodology can be adapted for practice and contributes to the systematic and scientific determination of companies' carbon dioxide emissions.
https://doi.org/10.17164/EK.2022.04

Vol. 12 Nr. 2

Abstract – The genetic information concerning the adaptation of main tree species to different environmental conditions could provide considerable knowledge to determine forest management responses to climate change. In the present study, we carried out a parallel mapping of SNP markers revealed in 18 Middle- and Southeast-European sessile oak

[*Quercus petraea* (Matt.) Liebl.] populations and EST sequences of stress-responsive loci downloaded from an EST repository to determine the group of those SNPs, which are associated with the genetic background of adaptation processes in oaks. Regression analysis revealed 16 significant correlations between four outlier SNP loci representing high F_{ST} values and 94 climatic variables. All variables with significant correlations were found to be related to precipitation or temperature. The stress-responsive loci identified in this study may serve as a basis for common research to support future sustainable management of sessile oak in Hungary.
https://doi.org/10.17164/EK.2022.05

Gábor ILLÉS and Norbert MÓRICZ:

Investigating the climate analogue area of domestic tree species in the light of climate change…91–112

Abstract – We performed the climate envelope analysis of nine stand forming tree species, which are native not only in wider Europe but in Hungary as well. We identified climate analogue areas in order to evaluate the impact of climate change on forests. Beside the European tree species distribution database we used the bioclimatic variables of – not only the historical climate records but – an ensemble of climate models, which are based on the RCP 4.5 and RCP 8.5 scenarios. The investigated four periods were: the past period of 1961–1990, the present period of 2011–2040, the near future period of 2041–2070, and the far future period of 2071–2100. The spatial rearrangements of species' climate envelopes were modelled by the method of random forests with the exclusion of extrapolated areas. The results showed that the models predicted reliably the historical distribution areas of species. The models predicted significant rearrangements in the spatial extents of the species' climate envelopes for the future-, and even for the present period. Considering the Hungarian aspects we concluded that, according to the optimistic scenario, by the end of this century, the spatial extent of suitable areas for oak species may drop to one fifth of the value measured at the turn of the 2000s. The only exception is downy oak, whose suitable area can multiply at the expense of other oak species. Another species on the losing side is beech whose climatically suitable area can reduce to one tenth of its former value. Beside the above, black pine can gain more and more areas. According to the models, the extent of the areas for which it will probably not be possible to find climate analogue provenances in Europe increases by two to three times. The modeling results of the climate envelopes of tree species can provide guidelines for climate adaptation, i.e. the identification of threatened areas and the selection of source and destination areas for reproductive material.
https://doi.org/10.17164/EK.2022.06

Mátyás BÁDER and Huba KOMÁN:

Determining the juvenile age of different wood species using a mathematical model…113–119

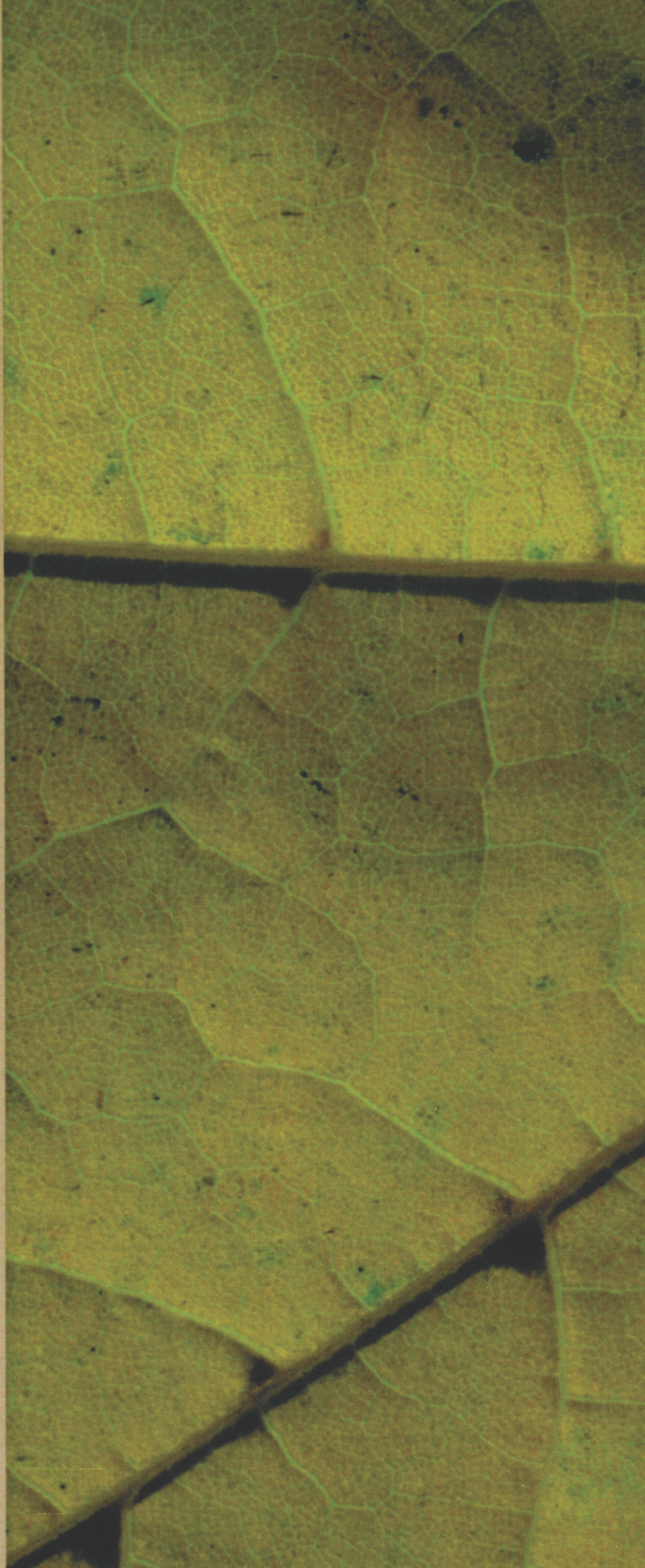
Abstract – The boundary of the juvenile wood around the pith during growth of the tree is as important for the laboratory study of many properties of wood as it is for the use of wood. In addition to demonstrating the adequacy of the mathematical model used, the study fills a gap in the knowledge of the fibre length values of two wood species. The saturation function fitted to the fibre length values of the London planetree (*Platanus* × *hybrida* Brot.) and Japanese pagoda tree *(Styphnolobium japonicum* (L.) Schott) species included in the study models the annual increase of the fibre length well and allows the juvenile age limit to be determined. The adequacy of the fit of the function is confirmed by high coefficients of determination for both species. For London planetree, the limit between juvenile and mature

wood is 15 years, while for Japanese pagoda tree it is 18 years. These values are not extreme taking into account the same data of several other tree species. The initial and final fibre lengths of London planetree are between 1 and 2 mm, almost one and a half times greater than those of Japanese pagoda tree.
https://doi.org/10.17164/EK.2022.07

Márton KORDA, Géza RIPKA, Anikó HIRKA and György CSÓKA:

Rapid spread and presently known distribution of *Aceria fraxiniflora* (felt) (Acari: eriophyoidea) in Hungary…121–128

Abstract – The microscopic eriophyoid mites parsitize on the shoots, foliage, flowers and fruits of herbaceous and woody plants. Majority of the host plants is woody species. The authors report the remarkably quick spread of *Aceria fraxiniflora* on green ash (*Fraxinus pennsylvanica*). The galls induced by the species have been found at many locations in the capital and 17 counties out of 19. During the surveys the gall mite – first time in Europe – was recorded on white ash (*F. americana*). The abundance of galls on flowers and fruits may suggest a potential regulation effect on the spontaneous spread of green ash.
https://doi.org/10.17164/EK.2022.08



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