Austrian Journal of Forest Science

Centralblatt für das gesamte Forstwesen

Geleitet von
P. Mayer und H. Hasenauer
Gegründet 1875

141. Jahrgang ♦ Heft 2 ♦ 2024
Seite 81–172

AV-Medien
Der Lebensverlag.

Austrian Journal of Forest Science
Centralblatt für das gesamte Forstwesen

*Gegründet im Jahre 1875
von den Forstinstituten der Universität
für Bodenkultur (BOKU) und des
Bundesforschungs- und Ausbildungszentrum
für Wald, Naturgefahren und Landschaft (BFW)*

Ziel*:* Das Centralblatt für das gesamte Forstwesen veröffentlicht wissenschaftliche Arbeiten aus den Bereichen Wald- und Holzwissenschaften, Umwelt und Naturschutz, sowie der Waldökosystemforschung. Die Zeitschrift versteht sich als Bindeglied von Wissenschaftlern, Forstleuten und politischen Entscheidungsträgern. Daher sind wir auch gerne bereit, Überblicksbeiträge sowie Ergebnisse von Fallbeispielen sowie Sonderausgaben zu bestimmten aktuellen Themen zu veröffentlichen. Englische Beiträge sind grundsätzlich erwünscht. Jeder Beitrag geht durch ein international übliches Begutachtungsverfahren.

Aims and scope: The Austrian Journal of Forest Science publishesscientific papers related to forest- and wood science, environmental science, natural protections as well as forest ecosystem research. An important scope of the journal is to bridge the gap between scientists, forest managers and policy decision makers. We are also interested in discussion papers, results of specific field studies and the publishing of special issues dealing with specific subjects. We are pleased to accept papers in both German and English. Every published article is peer-reviewed.

Internet: http://www.boku.ac.at/cbl
Gedruckt mit der Förderung des Bundesministeriums für Bildung, Wissenschaft und Kultur in Wien.

Austrian Journal of Forest Science

Centralblatt für das gesamte Forstwesen

ORGAN DES DEPARTMENTS FÜR WALD- UND BODENWISSENSCHAFTEN DER UNIVERSITÄT FÜR BODENKULTUR UND DES BUNDESAMT UND FORSCHUNGSZENTRUM FÜR WALD

Begründet 1875

141. JAHRGANG HEFT 2 April bis Juni 2024 Seite 81–172

INHALT DIESES HEFTES

ÖSTERREICHISCHER AGRARVERLAG WIEN

Erscheinungsweise: jährlich 4 Hefte,
Alle Ausgaben seit 1955 sind als E-Paper unter https://epaper.forestscience.at/webregal frei zugänglich.

Printed in Austria. Die Herausgabe dieser Zeitschrift erfolgt mit Förderung durch das Bundesministerium für Wissenschaft und Forschung.

Die Offenlegung gemäß §25 Mediengesetz ist unter www.av-medien.com/impressum ständig abrufbar.

Medieninhaber und Herausgeber:
Österreichischer Agrarverlag, Druck- und Verlagsges.m.b.H. Nfg. KG, Sturzgasse 1a, 1140 Wien.
DVR-Nr. 0024449, HRB-Nr.: FN 150499 y; UID-Nr.: ATU 41409203, ARA: 9890.
Internet: http://www.forestscience.at. Layout: Markus Reithofer.

141. Jahrgang (2024), Heft 2, S. 81–110

Austrian Journal of Forest Science
Centralblatt für das gesamte Forstwesen

Effect of Drought Stress on Physiological and Biochemical Traits of *Quercus petraea* subsp. *iberica* Seedlings and Analysis of the Relationship with Morphological Traits

PEinfluss von Trockenstress auf physiologische und biochemische Merkmale von *Quercus petraea* subsp. *iberica* Sämlingen und Analyse der Beziehung zu morphologischen Merkmalen

Ebru Atar[1*], Zafer Yücesan[1], Fahrettin Atar[1], Ali Ömer Üçler[1]

Keywords: Water potential, proline, chlorophyll, sessile oak, carbohydrate, Turkey

Schlüsselbegriffe: Wasserpotential, Prolin, Chlorophyll, Traubeneiche, Kohlenhydrate, Türkei

Abstract

Due to climate change, forest tree species are expected to be impacted by drought. As drought becomes a worldwide problem, there is a need to investigate the responses of forest tree species to drought. In this study, the objectives were

(I) to determine the physiological and biochemical responses of seedlings grown from seeds obtained from different populations of *Quercus petraea* subsp. *iberica* naturally distributed in Turkey under drought stress,
(II) to establish the relationships between morphological variations among populations and the physiological and biochemical responses of seedlings to drought stress, and
(III) to provide recommendations for the selection of populations with better adaptation to drought for future afforestation activities.

[1] Department of Forest Engineering, Faculty of Forestry, Karadeniz Technical University, Trabzon, Turkey
*Corresponding author: Ebru Atar, eatar.61@gmail.com

It was determined that total carotenoid, proline, and total carbohydrate contents increased, while predawn xylem water potential, chlorophyll a, chlorophyll b, and total chlorophyll amounts decreased in seedlings exposed to drought stress as the stress intensity increased. Furthermore, strong relationships were revealed between root percentage and Dickson quality index, which are important for seedling quality classification, and the physiological and biochemical responses of populations to drought stress. The populations of Alucra, Koyulhisar, and Mesudiye with water potential above -1.0 MPa during the drought stress experiment and experiencing more severe summer drought in their natural habitats have apparently exhibited higher drought tolerance compared to other populations.

Zusammenfassung

Aufgrund des Klimawandels wird erwartet, dass Waldbaumarten von Trockenheit beeinflusst werden. Da Trockenheit und Dürreperiode weltweit zu einem Problem werden, besteht die Notwendigkeit, die Reaktionen von Waldbaumarten auf Wassermangel zu untersuchen. In dieser Studie waren die Ziele (I), die physiologischen und biochemischen Reaktionen von Sämlingen zu bestimmen, die aus Samen unterschiedlicher Populationen von *Quercus petraea* subsp. *iberica* stammen, die natürlicherweise in der Türkei verbreitet sind und unter Trockenstress aufgewachsen sind, (II) Beziehungen zwischen morphologischen Variationen zwischen den Populationen und den physiologischen und biochemischen Reaktionen der Sämlinge auf Trockenstress herzustellen und (III) Empfehlungen für die Auswahl von Populationen mit besserer Anpassung an Trockenheit für zukünftige Aufforstungsaktivitäten bereitzustellen. Es wurde festgestellt, dass der Gesamt-Carotinoid-, Prolin- und Gesamtkohlenhydratgehalt zunahm, während das Xylemwasserpotential vor dem Morgengrauen, die Chlorophyll-A- und Chlorophyll-B-Werte sowie die Gesamt-Chlorophyllmengen bei Sämlingen, die Trockenstress ausgesetzt waren, mit zunehmender Stressintensität abnahmen. Darüber hinaus wurden starke Beziehungen zwischen Wurzelprozentsatz und Dickson-Qualitätsindex, die für die Klassifizierung der Sämlingsqualität wichtig sind, und den physiologischen und biochemischen Reaktionen der Populationen auf Trockenstress aufgezeigt. Die Populationen von Alucra, Koyulhisar und Mesudiye, die während des Trockenstressexperiments ein Wasserpotenzial über -1,0 MPa aufwiesen und in ihren natürlichen Lebensräumen stärkere Sommertrockenheit ausgesetzt waren, zeigten im Vergleich zu anderen Populationen eine höhere Toleranz gegenüber Trockenheit und Dürreperioden.

1 Introduction

The effects of global warming and climate change manifest as drought, decreased water resources, increased flooding, reduction of agricultural and forest areas, heatwaves, etc. (Cook *et al*. 2015; Turan 2018; Çobanoğlu *et al*. 2023). Climate change is linked to escalating aridity pressure in every forest ecosystem across the globe, with a potentially major impact on their role as carbon sinks (Anderegg *et al*. 2015).

It is stated that there is a correlation between a species' tolerance to drought in their native habitats and the intensity of summer droughts in those regions (Lenoir *et al*. 2008; Franklin *et al.* 2016). The identification of drought-resistant origins and their utilization in suitable growing environments are of great importance for future seed transfer and breeding programs (Ericsson *et al.* 1993; Dirik 2000). In nature, water stress is prevalent for either long-term or short-term periods depending on the local climate. Therefore, most plants possess some degree of adaptation or response to enhance growth and survival rates during water stress and subsequent recovery (Arve *et al.* 2011). Even in regions where water scarcity has not significantly affected the growth of tree species so far, problems associated with drought stress can be encountered in the near future. Therefore, it becomes important to compare the tolerances of populations within the same climatic regions in relation to drought stress (Atar 2021). This approach will also play a crucial role in establishing the foundation for active gene conservation in an uncertain future (Chaves and Oliveira 2004). Therefore, it is important to identify relatively drought-tolerant origins, as the assurance of local origins may not be certain, for determining future afforestation strategies (Çalıkoğlu 2002).

The growth and adaptation of forest trees are regulated by genetic structure and environmental factors, as in other organisms (Kozlowski and Pallardy 1997). It has been reported by various researchers that water, either alone or in conjunction with other environmental factors, is an important factor determining vegetation distribution on Earth (Kozlowski and Pallardy 1997; O'Brien 1998). Due to the significance of water in plant development, numerous studies have been conducted on water stress resulting from either water scarcity or water excess (Bayar and Deligöz 2021; Illescas *et al.* 2022; Koç *et al*. 2022; Koç and Nzokou 2023). Water stress can change the metabolic and growth patterns in the plant, reduce respiration, photosynthesis and ion absorption, and in severe situations, culminate in plant mortality (Jaleel *et al*. 2009).

Plants exposed to stress factors respond with physiological and biochemical reactions to prevent or minimize damage (Scholz *et al*. 2012). Drought stress, which is an important stress factor, triggers many biochemical, physiological, and molecular responses in plants (Cotrozzi *et al.* 2016; Xiong *et al*. 2022). As a result, plants also develop adaptation mechanisms in response to stress conditions to adapt to changing environmental conditions (Ranjan *et al*. 2022). In the case of drought stress, plants close their stomata and reduce carbon dioxide uptake to prevent water loss (Pirasteh-

Anosheh *et al.* 2016). Additionally, plants exposed to prolonged drought stress regulate their carbon assimilation rates by making certain morphological (such as leaf orientation) or physiological (such as osmotic potential) adjustments (Wright *et al*. 2015). Plants exposed to drought stress regulate their osmotic potentials by accumulating certain organic solutes within their cells to maintain cell turgor. These organic solutes, known also as osmolites, accumulate as soluble sugars, such as glucose and sucrose, which are soluble carbohydrates (Huang *et al*. 2000). Additionally, another osmolite that can be accumulated under drought stress is proline (Anjum *et al*. 2011). The accumulated proline under stressful conditions provides energy for plant growth and survival, aiding the plant in tolerating stress (Sankar *et al.* 2007). Some studies have reported an increase in soluble sugar and proline content as a result of drought stress (Deligöz and Bayar 2018; Zolfaghari and Akbarinia 2018). On the other hand, it has been stated by many researchers that drought stress has a negative impact on photosynthesis as a consequence of both stomata regulation and structural changes (Ashraf and Harris 2013; Osakabe *et al*. 2014). Water stress leads to structural changes in chloroplasts that affect photosynthesis (Dubey 1997). Under drought stress, the content of photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids) can decrease (Pukacki and Kaminska-Rozek 2005; Terzi *et al*. 2010). Following relief from drought stress and exposure to adequate water conditions, the photosynthetic systems of plants are restored (Nar *et al*. 2009). These responses in plants against water deficiency vary depending on genotype, species, severity and duration of water loss, plant age, and developmental stage (Clua *et al*. 2009).

Oaks (*Quercus* sp.) are known for their drought tolerance (Johnson *et al*. 2019). However, the level of drought tolerance may vary among different oak species (Dickson and Tomlinson 1996; Popović *et al*. 2010; Deligöz and Bayar 2017; Bayar 2022). Turkey has a important diversity in terms of oak species. Sessile oak (*Quercus petraea*), which is among the oak species with a wide distribution range, is an important species in Turkey due to its ability to naturally grow in different ecological conditions, being a tree of temperate climates, and its tolerance to low rainfall and drought (Anşin and Özkan 2006). It is also valued for its adaptability to various growing conditions and the versatility of its wood, which finds applications in many areas. The general distribution of *Quercus petraea* includes Europe, the Balkans, Thrace, and Anatolia. *Quercus petraea* subsp. *iberica* is naturally distributed in the Marmara region and the entire Black Sea region (Öztürk 2013). Numerous studies have been conducted on various aspects of seedling development (Chaar *et al*. 1997; Farque *et al*. 2001), fertilization (Vernay *et al*. 2018; Durand *et al*. 2020), seed germination (Kollmann and Schill 1996; Tilki 2010), forest management and regeneration (Mölder *et al*. 2019; Kohler *et al*. 2020) related to the species *Quercus petraea*. The effects of drought stress on sessile oak have also been revealed through various studies (Bruschi 2010; Turcsán *et al*. 2016; Móricz *et al*. 2021; Matoušková *et al*. 2022; Nyamjav 2022). However, there is currently no study available in Turkey that specifically investigates the drought tolerance of *Quercus petraea* subsp. *iberica* and the variations in response to drought stress among different populations. In this study, the research questions we want to address are the following: (I) determining the physiological and biochemical responses of seedlings grown from seeds obtained from different populations of *Quercus petraea* subsp. *iberica* naturally distributed in Turkey under drought stress, (II) establishing the relationships between morphological variations among populations and the physiological and biochemical responses of seedlings to drought stress, and (III) providing recommendations for the selection of *Quercus petraea* subsp. *iberica* populations with better adaptation to drought for future afforestation activities.

2 Materials and Methods

2.1 Plant Material and Growth Conditions

The seeds were collected in September-October 2019 from six different populations of *Quercus petraea* subsp. iberica in the natural distribution areas in the Black Sea Region, including Trabzon-Merkez, Gümüşhane-Torul, Giresun-Alucra, Sivas-Koyulhisar, Ordu-Mesudiye, and Samsun-Vezirköprü (Table 1, Fig. 1). Healthy seeds were mostly identified by using the water flotation method, and they were then stored at cold temperature of 4°C until the sowing date. The seeds were sown in December 2019 in polyethylene bags measuring 12×20 cm, which were filled with a mixture of forest soil, peat, and river sand (2:2:1). The sowing took place in the open field nursery conditions of the Research and Application Greenhouse of the Faculty of Forestry at Karadeniz Technical University (40°59'N, 39°46'E, altitude 60 m above sea level).

Table 1: Coordinate and altitude information for each population.

Tabelle 1: Koordinaten- und Höheninformationen für jede Population.

Population	Latitude	Longitude	Altitude (m)
Trabzon	40° 59' 15''	39° 42' 29''	250
Torul	40° 39' 16''	39° 20' 23''	1370
Alucra	40° 21' 34''	38° 52' 33''	1750
Koyulhisar	40° 15' 46''	38° 01' 50''	1450
Mesudiye	40° 31' 08''	37° 48' 01''	1400
Vezirköprü	41° 15' 44''	35° 05' 39''	890

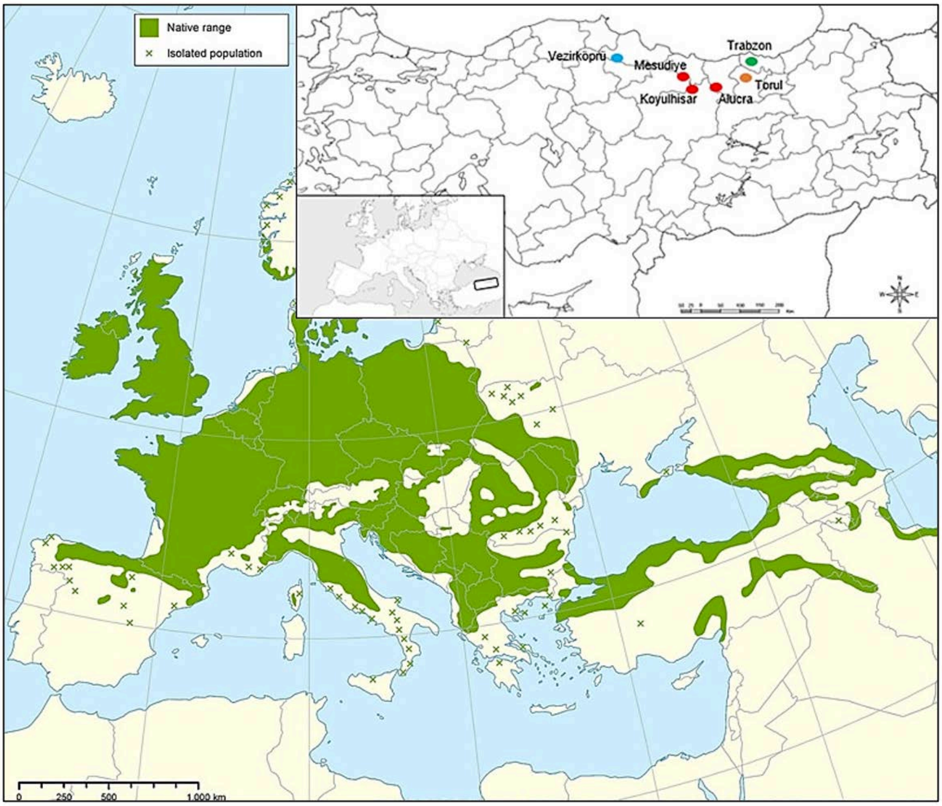


Figure 1: The geographical locations of the populations and the distribution of the groups obtained through hierarchical clustering analysis (Caudullo et al. 2017).

Abbildung 1: Die geografischen Standorte der Populationen und die Verteilung der Gruppen, ermittelt durch hierarchische Clusteranalyse (Caudullo et al. 2017).

2.2 Experimental Design

The seedlings grown in the open-field nursery conditions were irrigated close to field capacity every two or three days from May to August 2020. In July, the seedlings were moved to the Research and Application Greenhouse to protect them from possible rainfall. Furthermore, during the implementation of the water withholding method to induce drought stress in the seedlings, the temperature in the automated greenhouse system was kept as stable as possible, and the impact of temperature fluctuations in external weather conditions was minimized. In August, the seedlings were divided into two groups for the drought stress experiment. In the control group, irrigation continued regularly (every three days until field capacity water content was reached), while irrigation was ceased in the stress group to create drought stress. The stress group was subjected to water deprivation for 5, 15, 25, 35, 45, and 55 days to create drought stress, and measurements were taken during these days. The study was conducted on a total of 1260 seedlings using a randomized complete block design with 6 populations × 2 treatments [control and drought stress] × 6 measurements × 5 seedlings × 3 replications. During the drought stress experiment, a portable meteorological station (Davis Vantage Pro-2) was installed inside the greenhouse to determine daily air temperature and humidity changes. Throughout the experiment period, the average temperature ranged between 23.4°C and 24.5°C, and the average relative humidity varied between 78.4% and 82.7%.

2.3 Predawn xylem water potential and soil moisture content

Predawn xylem water potential (PWP) was measured using a pressure chamber device (PMS Instruments, Corvallis, OR, USA) following conventional methods. Predawn measurements were conducted on nine shoot samples (three seedlings × three replications) excised from the root collar level of each population, from both the control and drought stress groups, between 03.30 and 06.00 AM. Soil moisture was measured using a soil moisture meter device (TFA Dostmann). The soil moisture meter provides values ranging from 1 to 10, with values between 1–3 indicating dry, 4–7 indicating moist, and 8–10 indicating wet conditions on the device's scale.

2.4 Photosynthetic pigments

Photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll and carotenoid) were determined by Arnon's method (1949). Fresh leaves from the seedlings (nine seedlings in each treatment and population), obtained by cutting them from the root collar, were cut into small pieces with scissors to achieve a homogeneous mixture. Subsequently, the fresh leaf samples weighing 0.1 g were homogenized by grinding with 10 ml of 80% acetone solution, and mixed using a vortex for approximately 5–10 seconds. The absorbance of the supernatant was measured at 450, 645 and 663 nm wavelengths using a spectrophotometer (T80+UV/VIS spectrophotometer).

2.5 Total soluble carbohydrate and proline content

Total soluble carbohydrate and proline content were measured using all of the leaves from nine seedlings in each treatment and population. Leaf samples were dried at 65˚C for 48 hours. The total soluble carbohydrate content was determined using the phenol-sulfuric acid method according to Dubois *et al*. (1956). An amount of 0.1 g of dried leaf samples was homogenized with 80% ethanol for 24 hours. The supernatant was transferred to another test tube and treated with a 5% phenol solution and sulfuric acid. The total carbohydrate content was calculated by creating a standard curve using standard glucose and measuring the absorbance at 490 nm, expressed as mg g^{-1} dry weight. The amount of proline was determined using the acid-ninhydrin method (Bates *et al*. 1973). An amount of 0.1 g of dried samples was homogenized with 10 ml of 3% sulfosalicylic acid. Then, 2 ml of the supernatant was taken and 2 ml of acid-ninhydrin and 2 ml of glacial acetic acid were added to it. The prepared samples were kept in a water bath at 100˚C for 1 hour and the reaction was stopped in an ice bath. Toluene was added to the cooled samples and mixed in a vortex mixer for 15 seconds, making them ready for measurement. The absorbance value of each sample was measured at 520 nm, and the proline content was calculated using a calibration curve, expressed as µmol g^{-1} dry weight.

2.6 Morphological parameters

Morphological measurements were conducted in October 2020 using 30 randomly selected seedlings from each population. On one-year-old seedlings, the following morphological measurements were taken: seedling length (SL), root collar diameter (RCD), shoot fresh weight (SFW), shoot dry weight (SDW), root fresh weight (RFW), root dry weight (RDW), root percentage (RP), and Dickson quality index (DQI). The seedling height was measured using a meter with a measurement accuracy of ±1 mm, and the root collar diameter was measured using a digital caliper with a measurement accuracy of ±0.01 mm. Fresh shoot and root weights were measured using a precision scale with an accuracy of ±0.001 g, and then they were dried at 105°C for 24 hours. Shoot and root dry weights were also measured using a precision scale with an accuracy of ±0.001 g. The root percentage expresses the ratio of root dry weight to the total dry weight of the seedling [RP = RDW / (SDW + RDW)]. The Dickson Quality Index was calculated using the equation DQI = (SDW + RDW) / [(SL / RCD) + (SDW / RDW)].

2.7 Climate data and bioclimatic classification for populations

Long-term climate data (1976–2000) and bioclimatic characteristics according to the Emberger bioclimatic classification for populations selected from different growing conditions are provided in Table 2. The climate data was obtained from the WorldClim database (Fick and Hijmans 2017).

Table 2: Long-term climate data and bioclimatic types of Q. petraea subsp. iberica populations.

Tabelle 2: Langzeitklimadaten und bioklimatische Arten von Q. petraea subsp. iberica Populationen.

Population	T (°C)	P (mm)	M (°C)	m (°C)	PJJA (mm)	MJJA (°C)	S	Q	Bioclimatic type S	Bioclimatic type Q
Trabzon	15.4	789	25.2	2.2	154	24.0	6.4	119.7	Sub- Medit.	Rainfall Medit.
Torul	5.3	671	22.4	-10.0	122	20.3	6.0	74.1	Sub- Medit.	Little Rainfall Medit.
Alucra	5.1	620	25.0	-8.2	89	21.7	4.1	66.3	Medit.	Little Rainfall Medit.
Koyulhisar	6.0	596	26.4	-4.6	78	24.7	3.2	67.8	Medit.	Little Rainfall Medit.
Mesudiye	7.5	630	23.0	-6.0	93	21.3	4.4	77.1	Medit.	Little Rainfall Medit.
Vezirköprü	10.9	566	23.9	-2.1	103	24.0	4.3	76.6	Medit.	Little Rainfall Medit.

T is the mean annual temperature; *P* is the mean annual rainfall; *M is* the mean of the maximum temperature of the hottest month; *m* is the mean of the minimum temperature of the coldest month; *PJJA* is the sum of rainfall in June, July, and August; *MJJA* is the mean of the maximum temperature of June, July, and August; *S* is summer drought index value; *Q* is precipitation-temperature coefficient. Medit: Mediterranean

According to the Emberger bioclimatic classification (Akman 2011), the precipitation-temperature coefficient (Q) was applied to determine the Mediterranean bioclimatic zones, and the following formula was used. One of the most important factors in determining the Mediterranean climate is the identification of summer drought index (S). Emberger developed the following formula (Eq. 1) to determine the drought period.

$$Q = \frac{2000 \times P}{(M+m+546.24) \times (M-m)} \qquad S = \frac{PJJA}{MJJA} \qquad \text{(Eq. 1)}$$

The smaller the precipitation-temperature coefficient (Q), the drier the climate, and the larger it is, the more humid the climate is. Classifications based on Q values are as follows: $Q < 20$: Very arid Mediterranean, $20 \leq Q \leq 32$: Arid Mediterranean, $32 < Q \leq 63$: Semi-arid Mediterranean, $63 < Q < 98$: Little-Rainfall Mediterranean, $Q = 98$: Rainfall Mediterranean.

As the summer drought index (S) decreases, the severity of summer drought increases, and as the summer drought index increases, the severity of summer drought decreases. Classifications based on S values are as follows: $S < 5$: Mediterranean $S = 5–7$: Sub-Mediterranean $S > 7$: Not Mediterranean.

2.8 Statistical analysis

The data were analyzed using the "Windows SPSS Software 26.0" and "R v.4.1.3" statistical package programs. Variance analysis was applied to determine the statistical significance ($p<0.05$) of the differences in morphological, physiological, and biochemical characteristics among populations. Independent samples T-test was used to determine the statistical significance ($p<0.05$) of differences between drought stress treatments for each measurement day. Correlation analysis was performed to reveal the linear relationships between the measured morphological, physiological and biochemical characteristics. The results of the morphological, physiological, and biochemical characteristics were evaluated together with the long-term climate data of the populations, and the groupings formed among the populations were determined using hierarchical clustering analysis. The statistical significance of the grouping obtained by clustering analysis was tested using discriminant analysis.

3 Results

Statistically significant differences ($p<0.01$) were determined among the measurement time, drought stress application and populations for all measured physiological and biochemical parameters. Furthermore, significant differences at a 99% confidence level were determined among each measured parameter depending on the interactions of time × stress, time × population, stress × population, and time × stress × population (Table 3).

Table 3: Results of the variance analysis for the measured parameters.

Tabelle 3: Ergebnisse der Varianzanalyse für die gemessenen Parameter.

Factor	T	DT	P	T×DT	T×P	DT×P	T×DT×P
PWP	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SM	0.000	0.000	0.000	0.000	0.001	0.001	0.003
Chla	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chlb	0.000	0.000	0.000	0.000	0.000	0.003	0.000
TChl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TCr	0.000	0.000	0.000	0.000	0.000	0.009	0.000
TSSC	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Proline	0.000	0.000	0.000	0.000	0.000	0.000	0.000

PWP: Predawn xylem water potential, SM: Soil moisture, Chla: Chlorophyll a, Chlb: Chlorophyll b, TChl: Total Chlorophyll, TCr: Total carotenoid, TSSC: Total soluble carbohydrate content, T: Time, DT: Drought treatment, P: Population

3.1 Drought stress impacts on predawn xylem water potential and soil moisture content

Predawn xylem water potential values were found to vary depending on drought stress application and populations. The average PWP values of the populations included in the control group did not show much difference depending on the measurement time. In the control group, the average PWP value was measured highest at -0.15 MPa (Vezirköprü population, measurement on the 15th day) and lowest at -0.42 MPa (Koyulhisar population, measurement on the 55th day). In the drought group, the highest average PWP value was determined as -0.22 MPa (Torul population, measurement on the 5th day), and the lowest average PWP value was -2.13 MPa (Trabzon population, measurement on the 55th day). In Trabzon, Torul, and Vezirköprü populations, it was determined that starting from the 45th day of the drought stress experiment, the average PWP dropped below -1.00 MPa, and yellowing and drying began on the leaves of some seedlings. 55th day, PWP values dropped below -2.00 MPa, and most of the seedlings dried out. The average PWP values of the Alucra, Koyulhisar, and Mesudiye populations did not drop below -1.10 MPa even on the 55th day of drought stress, indicating that their drought tolerance is higher compared to other populations.

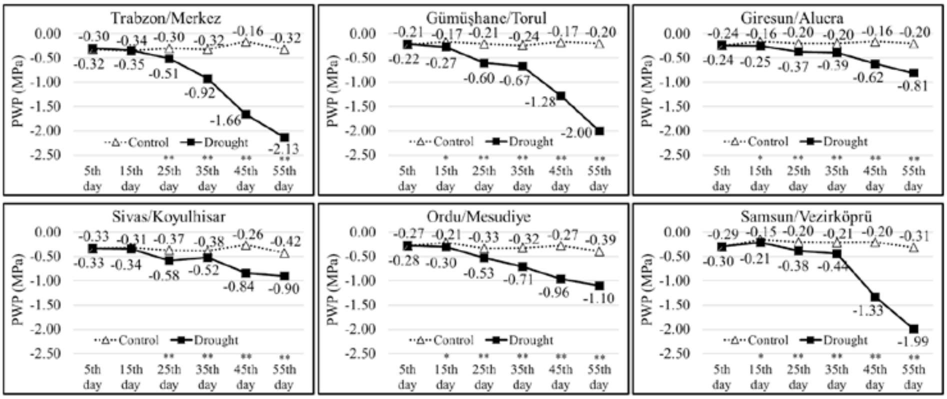


*Figure 2: PWP values and t-test results (*p<0.05, **p<0.01) for measurement days and populations.*

Abbildung 2: PWP-Werte und t-Test-Ergebnisse (*p<0.05, **p<0.01) für Messtage und Populationen.

Until the 15th measurement day, the PWP values were close to each other in the control and drought groups. However, the PWP values decreased as the water deficiency increased, starting on the 25th measurement day in the drought group. As seen in Fig. 3, soil moisture levels in the control group were generally close to each other as a result of regular irrigation, while soil moisture levels in the drought group decreased constantly due to increased drought stress. As a result of the independent samples t-test, statistically significant differences at a 99% confidence level were found on each measurement day except for the 5th measurement day.

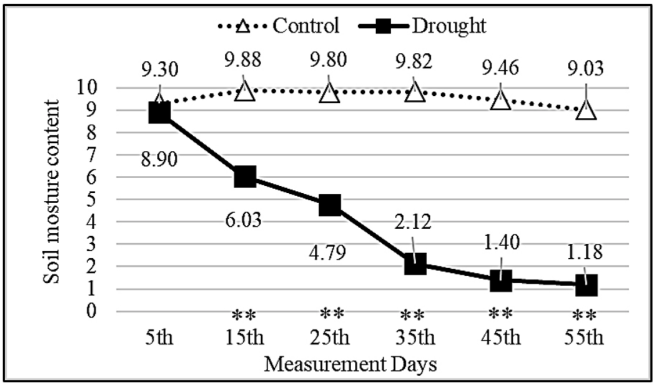


*Figure 3: Change of soil moisture depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 3: Veränderung der Bodenfeuchtigkeit in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

3.2 Drought stress impacts on photosynthetic pigments

The amounts of chlorophyll a, chlorophyll b and total chlorophyll generally showed fluctuating course depending on the measurement times in the control group. However, the chlorophyll levels in the drought group were lower compared to the control group starting on the 25th measurement day. According to the independent samples t-test results, statistically significant differences (p<0.05) were found between the results obtained on the 35th and 55th measurement days of the control and drought groups. The total carotenoid amounts of the drought group had higher values compared to the control group starting on the 15th measurement day. However, no statistically significant differences (p>0.05) were found between the results obtained from the control and drought groups on each measurement day (Fig. 4).

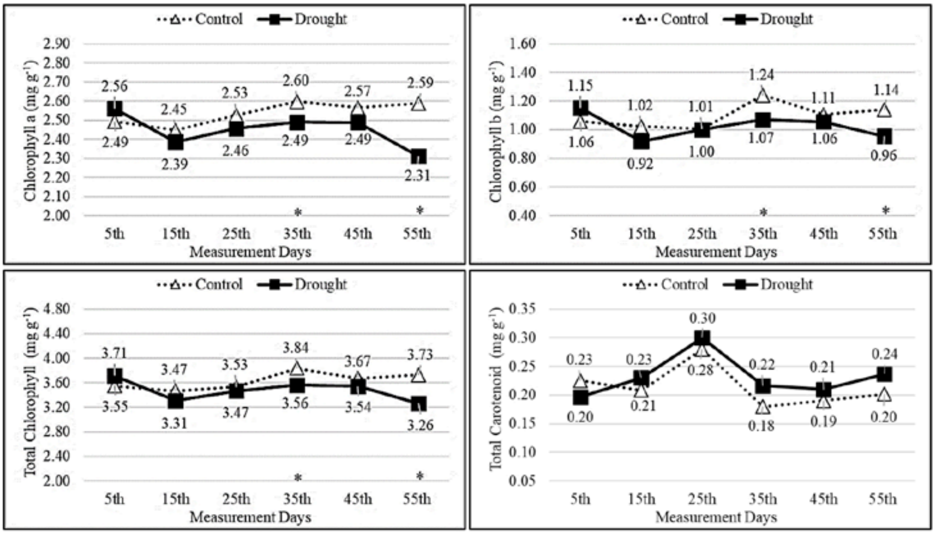


*Figure 4: Change of chlorophyll a, chlorophyll b, total chlorophyll and total carotenoid amounts depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 4: Veränderung der Mengen an Chlorophyll a, Chlorophyll b, Gesamtchlorophyll und Gesamt Karotinoide in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

In the control group, the minimum TChl was determined to be 2.60 mg g^{-1} (on the 15th measurement day in the Torul population), and the maximum TChl was 4.81 mg g^{-1} (on the 35th measurement day in the Vezirköprü population). In the drought group, the minimum TChl was 1.92 mg g^{-1} (on the 55th measurement day in the Trabzon population), and the maximum TChl was 4.54 mg g^{-1} (on the 45th measurement day in the Koyulhisar population). As the measurement days increased in the Trabzon, Torul, Mesudiye, and Vezirköprü populations, the total chlorophyll amounts of the seedlings belonging to the drought group generally remained lower compared to the control group. However, in the Alucra and Koyulhisar populations, it was observed that the total chlorophyll levels varied depending on the measurement days for both the control and drought groups (Fig. 5).

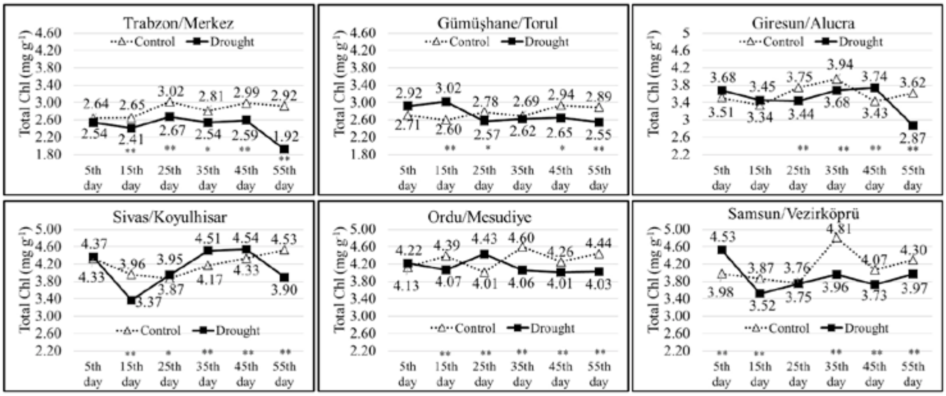


*Figure 5: Change of total chlorophyll amounts in each population depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 5: Veränderung der gesamten Chlorophyllmengen in jeder Population in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

3.3 Drought stress impacts on total soluble carbohydrate and proline content

In the control group, the total soluble carbohydrate and proline contents showed a close and gradually increasing trend depending on the measurement days. The drought group generally had close values to the control group until the 25th measurement day, but the total soluble carbohydrate and proline contents of the seedlings in the drought group increased from the 35th day with increasing drought stress (Fig. 6).

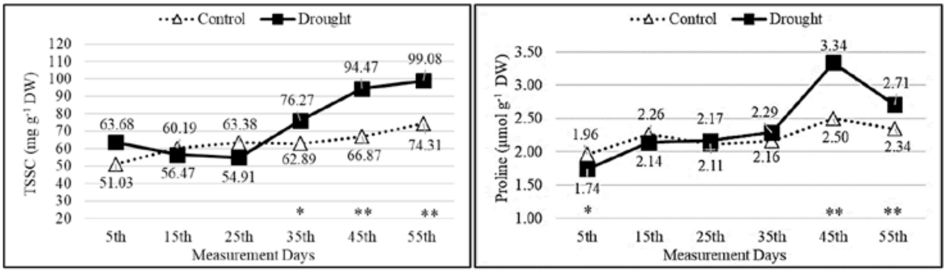


*Figure 6: Change of total soluble carbohydrate and proline contents depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 6: Veränderung des Gesamtgehalts an löslichen Kohlenhydraten und Prolingehalt in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

The TSCC of the populations in the drought group showed significant changes throughout the duration of drought stress. In the drought group, the TSCC was the lowest at 43.15 mg g^{-1} (on the 15th measurement day in the Torul population) and the highest at 122.31 mg g^{-1} (on the 55th measurement day in the Trabzon population). Until the 35th measurement day, the TSCC of the seedlings in the Trabzon, Torul, Alucra and Vezirköprü populations were close to each other in the control and drought groups. However, from the 35th day onward, the TSCC of the seedlings in the drought group increased due to the effect of drought stress. In both Koyulhisar and Mesudiye populations, the TSCC of the drought and control groups exhibited variation throughout the drought stress application, and on the 55th measurement day, the TSCC of the seedlings in the drought group was higher compared to the seedlings in the control group (Fig. 7). Except for the Mesudiye population, in other populations, as the duration of drought stress application increased, the seedlings in the drought group had higher proline contents compared to the seedlings in the control group. The seedlings exposed to drought stress accumulated proline as the stress increased (Fig. 8).

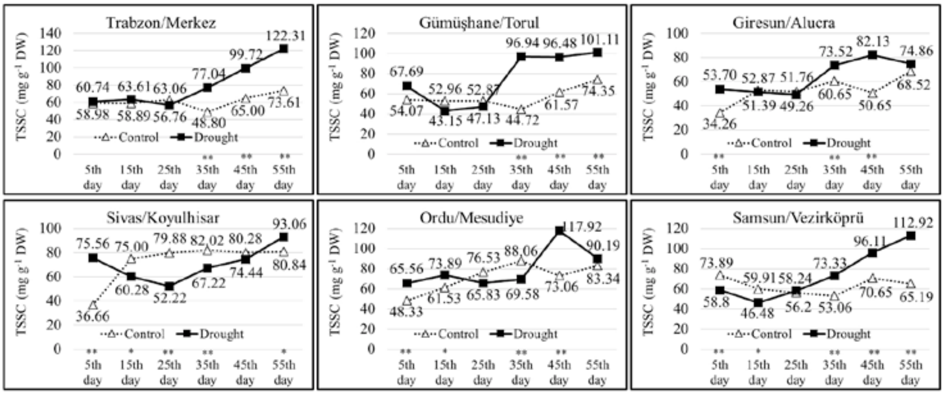


*Figure 7: Change of total soluble carbohydrate content in each population depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 7: Veränderung des Gesamtgehalts an löslichen Kohlenhydraten in jeder Population in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

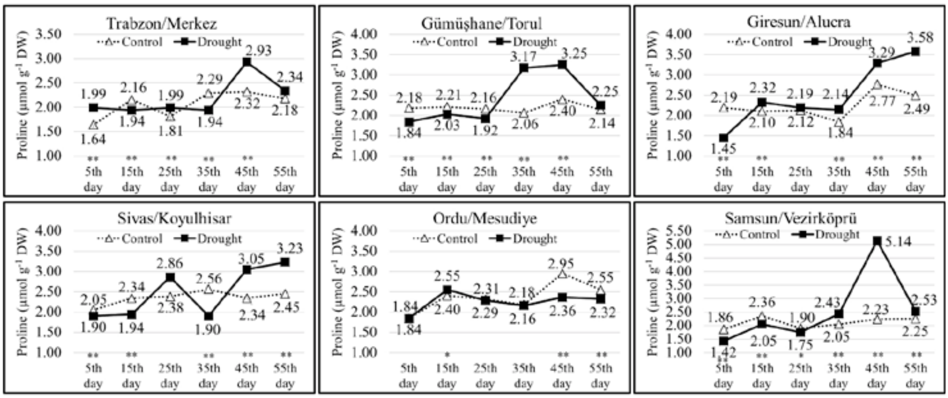


*Figure 8: Change of proline content in each population depending on measurement days and treatments. Asterisks show significant differences by independent sample t-test (*p< 0.05, **p< 0.01) between treatments.*

Abbildung 8: Veränderung des Prolingehalts in jeder Population in Abhängigkeit von Messtagen und Behandlungen. Sternchen zeigen signifikante Unterschiede zwischen den Behandlungen anhand des unabhängigen Stichproben-T-Tests (*p<0.05, **p<0.01).

3.4 Drought stress impacts on morphological parameters

In order to reveal the relationship between the responses of seedlings from different populations to drought stress and their morphological characteristics, some morphological characteristics of the seedlings were determined. Based on the results of the analysis of variance, there was a statistically significant difference among populations at the 99% confidence level in terms of SL, SFW, SDW, RP, and DQI values. In terms of RCD and RDW values, there was a statistically significant difference among populations at the 95% confidence level. However, there was no statistically significant difference among populations in terms of RFW value (Table 4).

Table 4: Mean values and analysis of variance results for morphological characteristics of populations.

Tabelle 4: Mittelwerte und Varianzanalyseergebnisse für morphologische Merkmale von Populationen.

Populations	SL (cm)	RCD (mm)	SFW (g)	SDW (g)	RFW (g)	RDW (g)	RP (%)	DQI
Trabzon	11.65	3.66	2.07	0.90	4.18	1.60	63.40	0.68
Torul	10.41	3.61	1.96	0.84	4.52	1.74	67.56	0.81
Alucra	6.61	3.45	1.13	0.52	4.57	1.89	79.09	1.14
Koyulhisar	4.96	3.72	0.81	0.39	3.99	1.73	81.21	1.41
Mesudiye	5.87	3.77	1.15	0.46	3.71	1.70	78.47	1.23
Vezirköprü	8.26	3.14	1.32	0.65	4.54	2.18	75.96	1.04
Mean	8.21	3.55	1.46	0.65	4.27	1.81	73.70	1.02
F	28.888	2.799	12.778	16.620	1.629	2.810	32.542	8.846
P	0.000	0.019	0.000	0.000	0.155	0.018	0.000	0.000

SL: Seedling length, RCD: Root collar diameter, SFW: Shoot fresh weight, SDW: Shoot dry weight, RFW: Root fresh weight, RDW: Root dry weight, RP: Root percentage, DQI: Dickson quality index

The significance of the groups formed among populations through hierarchical cluster analysis was tested using discriminant analysis, and the separation into two groups was found to be statistically significant. According to Emberger's precipitation-temperature coefficient (Q), the populations of Alucra, Mesudiye, Koyulhisar, Vezirköprü, and Torul, located in the low-rainfall Mediterranean Bioclimatic type, form the first group, while the population of Trabzon, located in the rainfall Mediterranean Bioclimatic type, forms the second group (Fig. 9). Although the discriminant analysis determined that the separation into two groups was statistically significant, the other potential groups that could be formed are shown in Fig. 1 and 9. Based on S and Q values (Table 2), the populations of Alucra, Mesudiye, and Koyulhisar, which have low values, were in the first group. The population of Vezirköprü formed another group. The populations of Torul and Trabzon, which have higher S and Q values compared to the other populations, were also in separate groups on their own. Indeed, it can be observed from the clustering that the climatic characteristics of populations and consequently their adaptation to their habitats have a significant influence on the morphological characteristics as well as the physiological and biochemical responses to drought stress.

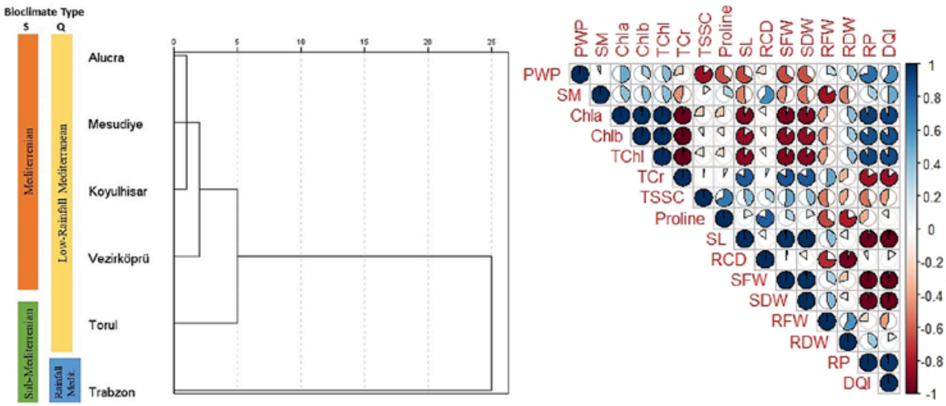


Figure 9: Dendrogram of population groups related to hierarchical cluster analysis, and correlation analysis result of measured morphological, physiological and biochemical parameters.

Abbildung 9: Dendrogramm der Bevölkerungsgruppen im Zusammenhang mit der hierarchischen Clusteranalyse und Korrelationsanalyseergebnis der gemessenen morphologischen, physiologischen und biochemischen Parameter.

According to the correlation analysis, it was determined that the PWP value has a positive correlation with Chla, Chlb, and TChl, while it has a negative correlation with TSCC and proline. Furthermore, the PWP value is strongly positively correlated with the RP and DQI of the seedlings, while it has a negative relationship with SL, SFW and SDW. It has been revealed that many measured parameters exhibit strong correlations, both negative and positive, with each other (Fig. 9). Indeed, the correlation analysis has showed that there are strong relationships between the physiological and biochemical responses of the seedlings to drought stress and their morphological characteristics.

Statistically significant relationships were found, both negative and positive, between climate data and the measured characteristics. The S and Q values, used in Emberger's climate classification, were positively correlated with TCr, TSCC, SL, SFW and SDW and negatively correlated with PWP, Chla, Chlb, TChl, RP and DQI (Table 5). Populations with low summer drought indexes (S) and rainfall-temperature coefficients (Q) had higher PWP values because they lost less water during drought stress due to their adaptation to the growing environments.

Table 5: Correlation analysis result of climate data and measured parameters.

Tabelle 5: Ergebnis der Korrelationsanalyse von Klimadaten und gemessenen Parametern.

	P	M	m	PE	ME	S	Q
PWP	-0.647**	0.142	-0.666**	-0.770**	-0.314	-0.654**	-0.813**
SM	0.117	0.591**	0.357	-0.244	0.423*	-0.386	0.177
Chla	-0.835**	0.243	-0.144	-0.879**	0.225	-0.915**	-0.648**
Chlb	-0.794**	0.222	-0.048	-0.811**	0.300	-0.869**	-0.565**
TChl	-0.820**	0.234	-0.103	-0.853**	0.258	-0.898**	-0.614**
TCr	0.759**	-0.197	0.009	0.767**	-0.323	0.830**	0.518**
TSSC	0.496*	-0.449*	0.444*	0.579**	-0.026	0.564**	0.635**
Proline	-0.821**	0.198	-0.360	-0.633**	0.158	-0.636**	-0.748**
SL	0.754**	-0.332	0.362**	0.958**	-0.101	0.948**	0.745**
RCD	0.448*	0.007	-0.134	0.050	-0.187	0.118	0.180
SFW	0.793**	-0.453*	0.248	0.950**	-0.254	0.989**	0.719**
SDW	0.732**	-0.376	0.305	0.943**	-0.149	0.950**	0.705**
RFW	-0.094	-0.097	-0.174	0.185	-0.132	0.219	-0.128
RDW	-0.715**	-0.027	-0.035	-0.352	0.154	-0.390	-0.447*
RP	-0.854**	0.324	-0.365	-0.979**	0.115	-0.975**	-0.803**
DQI	-0.766**	0.364	-0.330	-0.955**	0.179	-0.961**	-0.740**

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

4 Discussion

4.1 Drought stress impacts on physiological and biochemical characteristics

Plants reach their highest water potential values during the predawn (Cleary and Zaerr 1984). In many studies, it is indicated that the optimal PWP for plant growth is between -0.5 and -1.2 MPa, and when the PWP drops below -1.2 MPa, the plant requires irrigation. (McDonald 1984; Lopushinsky 1990). In the present study, at the beginning of the drought stress experiment, the highest average PWP was obtained as -0.22 MPa in the Torul population, while on the 55th day of the drought stress experiment, the lowest average PWP was determined as -2.13 MPa in the Trabzon population. Deligöz and Bayar (2017) found in their study on *Q. cerris* that the xylem water potential, which was -0.84 MPa at the beginning of the drought stress experiment, decreased to -1.73 MPa on the 30th day of the experiment in stressed seedlings. Also, in the control seedlings, the plant water potentials ranged from -0.56 MPa to -1.01 MPa. Thomas and Gausling (2000) stated that under moderate drought stress, *Q. petraea* and *Q. robur* seedlings had significantly lower predawn leaf water potentials compared to control seedlings. In a study conducted on *Q. variabilis*, it was reported that leaf water potential values decreased as drought stress increased (Wu *et al*. 2013). As a result of drought stress applied to *Q. cerris* and *Q. robur* seedlings, the lowest predawn xylem water potential was determined as -2.28 MPa for Q. cerris and -3.37

MPa for *Q. robur* (Deligöz and Bayar 2018). Consistent with previous research results, our study also revealed a significant decrease in xylem water potentials during the duration of drought stress.

Plant water potential values can vary depending on environmental conditions and plant species. Indeed, significant differences were observed among populations in terms of PWP values in the present study. In a study performed on seedlings belonging to 7 different origins representing different bioclimatic zones of *Pinus brutia*, it was determined that origins experiencing strong summer drought in their natural distribution areas had the lowest osmotic potential values and were the most resistant to drought effects (Dirik 2000). A seedling could survive at a predawn water potential of -2.0 MPa, but typical stomatal activities may be inhibited during the day, photosynthesis may progressively decline, and seedling development may cease (Lopushinsky 1990). In the present study, it has been determined that in particular populations of Trabzon, Torul, and Vezirköprü, the average PWP dropped below -1.0 MPa from the 45th day of the drought stress experiment. Some seedlings started showing yellowing and wilting symptoms. The PWP had dropped below -2.0 MPa by the 55th day, and many seedlings experienced severe wilting. On the other hand, in the populations of Alucra, Koyulhisar, and Mesudiye, it was observed that the average PWP remained above -1.0 MPa even on the 55th day of the drought stress, indicating their high drought tolerance.

Changes in light intensity and the amount of water in the soil significantly affect the synthesis of pigments (Matysiak 2001). This is because chlorophyll pigments are highly sensitive to various environmental factors (Lepeduš *et al*. 2003). It is known that carotenoids protect the photosynthetic membranes from damage caused by light and play a role in capturing photosynthetic light (Havaux 1998). In this study, it was found that from the 25th measurement day onwards, the drought group exhibited lower amounts of chlorophyll a, chlorophyll b, and total chlorophyll compared to the control group, while the total carotenoid amounts were higher. Additionally, positive correlations were observed between the PWP and chlorophyll amounts, whereas a negative correlation was found with total carotenoid. Similarly, Baquedano and Castillo (2007) reported a significant reduction in chlorophyll amounts in oak species due to the impact of drought stress. Mafakheri *et al*. (2010) pointed out that drought stress applied during plant growth significantly reduced the amounts of chlorophyll a, chlorophyll b, and total chlorophyll.

One of the responses of plants to drought stress is the alteration of carbohydrates in stressed plants (Vassey and Sharkey 1989). In response to drought conditions, carbohydrate accumulation increases in different parts of the plant (Krasenky and Jonak 2012). In the present study, the Trabzon, Torul, and Vezirköprü populations, which were significantly affected by water insufficiency and whose PWP values approached and fell below -2.0 MPa by the 55th measurement day, had higher carbohydrate accumulation compared to other populations. Similar to the results of the study, Deligöz and Bayar (2017) emphasized that starting from the 7th day of the drought experiment in *Q. cerris*, the total soluble carbohydrate content in drought-stressed seedlings was found to be significantly higher compared to the control seedlings. In studies conducted on *Q. pubescens* (Holland *et al*. 2016) and *Q. variabilis* (Wu *et al*. 2013) seedlings, it was found that the total soluble carbohydrate content increased with the increase in drought stress level. Many studies have also reported carbohydrate accumulation in plants under drought stress conditions (Morales *et al*. 2013; Maguire and Kobe 2015; Deligöz and Bayar 2018).

One of the most important responses of plants to drought stress is the accumulation of protective solutes such as proline (Yavaş *et al*. 2016). Many plants accumulate proline as a response to osmotic stress (Bhaskara *et al*. 2015). The concentration of proline increases with a decrease in water potential or an increase in plant water stress (Lansac *et al*. 1994). In the present study, it was determined that the proline amount of the seedlings in the drought group was higher than the seedlings in the control group due to the increase in drought stress in other populations except the Mesudiye population. It is believed that the lower accumulation of proline in the drought group of the Mesudiye population, compared to the control group, is due to the prioritization of carbohydrate accumulation rather than proline accumulation by the seedlings under drought stress to maintain osmotic balance. Indeed, when examining the results of carbohydrate analysis, it can be seen that the Mesudiye population had the highest carbohydrate accumulation among the populations with a value of 117.92 mg g^{-1} on the 45th measurement day. Cotrozzi *et al.* (2016) reported that drought stress caused an increase in proline amounts in *Q. ilex*, *Q. pubescens*, and *Q. cerris* species. Deligöz and Bayar (2018) stated that drought stress induced an increase in proline and carbohydrate contents in *Q. cerris* and *Q. robur*, and *Q. robur* had more proline accumulation than *Q. cerris*. Wu *et al*. (2013) indicated that drought stress increased proline amounts in *Q. variabilis* seedlings. Numerous studies have also observed an increase in proline amounts with the increase in drought stress (Sircelj *et al*. 2005; Shvaleva *et al*. 2006; Yang *et al*. 2007).

4.2 Drought stress impacts on morphological characteristics

It is seen that many of the studies conducted until recent years for determining seedling quality were based on morphological parameters (Apholo and Rikala 2003; Atar 2021; Güney *et al*. 2023). In a study conducted by Semerci (2002), a positive correlation was found between seedling length and survival success. However, some researchers have reported a negative correlation between these two parameters (Larsen *et al*. 1986; Tuttle *et al*. 1987). Furthermore, it is stated that the root collar diameter is a more important criterion in seedling quality classification compared to seedling length (Yahyaoğlu and Genç 2007). The root percentage is another important parameter used to determine seedling quality (Ayan *et al*. 2020; Güney *et al*. 2020). High root development potential is associated with a high survival rate in the field (Ritchie 1984). Among the populations, the highest mean RP (81.21%) was determined in the Koyulhisar population, which is one of the populations least affected by drought stress, and the lowest mean RP (63.40%) was determined in the Trabzon population, which was most affected by drought stress. Bruschi (2010) stated that there are significant differences in morphological characteristics in *Q. petraea* seedlings exposed to drought stress, both in terms of population and irrigation regime. The Dickson quality index is an important indicator in determining seedling planting success and survival rate (Bayala *et al*. 2009). According to Dickson *et al*. (1960), seedlings with a quality index close to or above 1 are considered to be of higher quality. In this study, the highest mean DQI was obtained in the Koyulhisar population with a value of 1.41, while the lowest mean DQI was found in the Trabzon population with a value of 0.68. The populations with the highest DQI values, namely Koyulhisar, Alucra, and Mesudiye, were determined to be the most drought-tolerant populations based on their responses to drought stress. In addition, it was determined that there was a strong positive correlation between PWP and RP and DQI values of the seedlings by correlation analysis. Indeed, Ritchie and Shula (1984) emphasized that evaluating the physiological characteristics of seedling material is crucial, regardless of how good they are in terms of genetic and morphological features, as accurate results cannot be obtained otherwise. Furthermore, they reported that the results would be more accurate when the morphological data used for seedlings aligned with physiological data.

5 Conclusions

In order to make afforestation efforts successful in arid and semi-arid areas, knowing the phenotypic characteristics of existing forest trees in nature may not always be sufficient. Therefore, it is important to determine the geographic variations of species and assess the morphological and physiological characteristics of seeds and seedlings obtained from these areas. The populations of Alucra, Koyulhisar, and Mesudiye, which have PWP above -1.0 MPa during the drought stress experiment and experience more severe summer drought in their natural habitats (with lower S and Q values), have exhibited higher drought tolerance compared to other populations. It can be concluded that these populations can be used in afforestation efforts in water-deficient arid and semi-arid regions.

The increase in the total soluble carbohydrate content of the populations of *Q. petraea* subsp. *iberica* under stress conditions can be expressed as an adaptation developed in response to adverse conditions. The increase in both proline and total soluble carbohydrate content serves as important criteria indicating drought tolerance in *Q. petraea* subsp. *iberica*. Moreover, the increase in carotenoid amounts can be considered a good adaptation criterion for drought tolerance, as it helps prevent membrane damage associated with water deficiency and contributes to the continuity of photosynthesis by assisting chlorophyll pigments.

In the study, it has been revealed that there are strong and significant relationships between the data obtained from the root percentage and Dickson quality index, which are important parameters in the seedling quality classification, and the drought stress resistance of the populations. Thus, it can be said that morphological parameters such as RP and DQI, which are simpler to measure than physiological and biochemical parameters, can be used in determining the drought tolerance of different populations. Additionally, the bioclimatic classification created using the summer drought index (S) and precipitation-temperature coefficient (Q) can be utilized as an indicator in the selection of populations that may exhibit drought tolerance. Also, it is crucial to integrate knowledge about intraspecific ecological amplitude and adaptation processes. However, there might still be biases and difficulties in unraveling the correlation between the environment and genetics.

The fact that there are statistically significant differences in terms of drought stress among the studied populations necessitates a more detailed study by considering all distribution areas of *Q. petraea* subsp. *iberica* in Turkey. In this context, future studies to establish in situ and ex-situ protection strategies for the species and the determination of origins that are highly adaptable to changes that may occur in the horizontal and vertical distribution areas of the species, especially at the point of adaptation to climate change, will reveal extremely important results for forestry strategies.

Acknowledgements

This study was a part of the PhD thesis prepared by Graduate School of Natural and Applied Sciences at Karadeniz Technical University. Also, we would like to thank Research Assistant Ali Bayraktar for his contributions to the laboratory works.

Funding

This work was funded by Office of Scientific Research Projects of Karadeniz Technical University. Project number: FHD-2020-8863.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

References

Akman Y (2011) İklim ve biyoiklim. Palme Yayıncılık, Ankara, Turkey.

Anderegg WR, Ballantyne AP, Smith WK, Majkut J, Rabin S, Beaulieu C, Birdsey R, Dunne JP, Houghton RA, Myneni RB, Pan Y, Sarmiento JL, Serota N, Shevliakova E, Tans P, Pacala SW (2015) Tropical nighttime warming as a dominant driver of variability in the terrestrial carbon sink. Proceedings of the National Academy of Sciences 112(51): 15591-15596.

Anjum SA, Xie X, Wang L, Saleem MF, Man C, Lei W (2011) Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research 6: 2026-2032.

Anşin R, Özkan CÖ (2006) Tohumlu bitkiler (Spermatophytha) odunsu taksonlar. KTÜ Orman Fakültesi Genel Yayın No: 167, Fakülte Yayın No: 19, Trabzon, Turkey.

Apholo P, Rikala R (2003) Field performance of silver-birch planting-stock grown at different spacing and in containers of different volume. New Forests 25: 93-108.

Arnon DI (1949) Copper Enziymes in Izolated Chloroplasts Polyphenoioxidase in Beta vulgaris, Plant Physiolgy, 24, 1-15.

Arve LE, Torre S, Olsen JE, Tanino KK (2011) Stomatal responses to drought stress and air humidity. In abiotic stress in plants-Mechanisms and adaptations (ed. by A Shanker and B Venkateswarlu) IntechOpen, London, UK.

Ashraf M, Harris PJC (2013) Photosynthesis under stressful environments: An overview. Photosynthetica 51: 163-190.

Atar F (2021) Effects of altitude on some seedling quality characteristics of *Carpinus betulus* L. (common hornbeam) and *Carpinus orientalis* Mill. (oriental hornbeam). Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi 22(2): 257-265.

Ayan S, Civek E, Yer Çelik E, Gülseven O, Akın Ş, Yılmaz E (2020) Akdeniz ve Arizona servisi fidanlarının morfolojik kalite özellikleri. Bartın Orman Fakültesi Dergisi 22(2): 580-590.

Baquedano FJ, Castillo FJ (2007) Drought tolerance in the Mediterranean species *Quercus coccifera* L., *Quercus ilex* L., *Pinus halepensis* Mill., and *Juniperus phoenicea* L. Photosynthetica 45(2): 229-238.

Bates LS, Waldren RP, Teare ID (1973) Rapid Determination of free proline for water stress studies. Plant and Soil 39: 205–207.

Bayala J, Dianda ZM, Wilson ZJ, Ouedraogo SJ, Sanon ZK (2009) Predicting field performance of five irrigated tree species using seedling quality assessment in burkina faso, West Africa. New Forests 38: 309-322.

Bayar E (2022) Influence of drought stress and N addition on the gas exchange, biochemical and growth traits in *Quercus ithaburensis*. Dendrobiology 88: 94-104.

Bayar E, Deligöz A (2021) Ecophysiological behavior of Mediterranean woody species under summer drought. Revista Bosque 42(3): 311-321.

Bhaskara GB, Yang TH, Verslues PE (2015) Dynamic proline metabolism: Importance and regulation in water limited environments. Frontiers in Plant Science 6: 484.

Bruschi P (2010) Geographical variation in morphology of *Quercus petraea* (Matt.) Liebl. as related to drought stress. Plant Biosystems 144(2): 298-307.

Caudullo G, Welk E, San-Miguel-Ayanz J (2017) Chorological maps for the main European woody species. Data in Brief 12, 662–666.

Chaar H, Colin F, Collet C (1997) Effects of environmental factors on the shoot development of *Quercus petraea* seedlings A methodological approach. Forest Ecology and Management 97(2): 119-131.

Chaves MM, Oliveira MM (2004) Mechanisms underlying plant resilience to water deficits: prospects for water-saving agriculture. J Exp Bot 55(407): 2365-2384.

Cleary BD, Zaerr JB (1984) Guidelines for measuring plant moisture stress with a pressure chamber. PMS Instrument Co., 2750 N. W. Royal Oaks Drive, Corvallis, Oregon, USA.

Clua A, Paez M, Orsini H, Beltrano J (2009) Incidence of drought stress and rewatering on Lotus tenuis effects on cell membrane stability. Lotus Newsletter 39(1):21-27.

Cotrozzi L, Remorini D, Pellegrini E, Landi M, Massai R, Nali C, Guidi L, Lorenzini G (2016) Variations in physiological and biochemical traits of oak seedlings grown under drought and ozone stress. Physiologia plantarum 157(1): 69-84.

Çalıkoğlu M, Tilki F (2002) Orman ağacı tohumlarında çimlenme-su stresi ilişkisi, İÜ Orman Fakültesi Dergisi 76-88.

Çobanoğlu H, Cantürk U, Koç İ, Kulaç Ş, Sevik H (2023). Climate change effect on potential distribution of Anatolian chestnut (*Castanea sativa* mill.) in the upcoming century in Turkey. Forestist 73(3): 247-256.

Cook BI, Ault TR, Smerdon JE (2015) Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1(1): e1400082.

Deligöz A, Bayar E (2017) Variations in physiological and biochemical traits of drought-stressed *Quercus cerris* seedlings. Turkish Journal of Forestry 18(4): 269-274.

Deligöz A, Bayar E (2018) Drought stress responses of seedlings of two oak species (*Quercus cerris* and *Quercus robur*). Turkish Journal of Agriculture and Forestry 42(2): 114-123.

Dickson R, Tomlinson PT (1996) Oak growth, development and carbon metabolism in response to water stress. Ann For Sci 53: 181-196.

Dickson A, Leaf AL, Hosner F (1960) Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle 36: 10-13.

Dirik H (2000) Farklı biyoiklim kuşaklarını temsil eden kızılçam (*Pinus brutia* Ten.) orijinlerinin kurak dönemdeki su potansiyellerinin basınç-hacim (p-v) eğrisi yöntemi ile analizi. İÜ Orman Fak. Dergisi Seri A 50(2): 93-130.

Dubey RS (1997) Photosynthesis in plants under stressful conditions. Handbook of photosynthesis (ed. by M Pessarakli) Dekker, New York.

Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F (1956) Calorimetric method for determination of sugars and related substances. Analytical Chemistry 28: 350-356.

Durand M, Rose C, Dupouey JL, Legout A, Ponton S (2020) Do tree rings record changes in soil fertility? Results from a *Quercus petraea* fertilization trial. Science of the Total Environment 712: 136148.

Ericsson G, Namkoong G, Roberds JH (1993) Dynamic gene conservation for uncertain futures. Forest Ecology and Management 62(1-4): 15-37.

Farque L, Sinoquet H, Colin F (2001) Canopy structure and light interception in *Quercus petraea* seedlings in relation to light regime and plant density. Tree physiology 21(17): 1257-1267.

Fick SE, Hijmans RJ (2017) WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology 37(12): 4302-4315.

Franklin J, Serra-Diaz JM, Syphard AD, Regan HM (2016) Global change and terrestrial plant community dynamics. Proceedings of the National Academy of Sciences 113(14): 3725-3734.

Güney D, Bayraktar A, Atar F, Turna İ (2020) Effects of root undercutting, fertilization and thinning on seedling growth and quality of oriental beech (*Fagus orientalis* Lipsky) seedlings. Artvin Coruh University Journal of Forestry Faculty 21(2): 214-222.

Güney D, Atar F, Turna İ, Bayraktar A (2023) Morphogenetic variations of *Pinus sylvestris* L. seedlings depending on altitude. Turkish Journal of Forestry Research 10(1): 80-89.

Havaux M (1998) Carotenoids As membrane stabilisers in chloroplasts. Trends Plant Sci. 3: 147-151.

Holland V, Koller S, Lukas S, Brüggemann W (2016) Drought and frost-induced accumulation of soluble carbohydrates during accelerated senescence in *Quercus pubescens*. Trees 30(1): 215-226.

Huang XM, Huang HB, Gao FF (2000) The growth potential generated in citrus fruit under water stress and its relevant mechanisms. Scientia Horticulturae 83(3-4): 227-240.

Illescas M, Morán-Diez ME, Martínez de Alba ÁE, Hermosa R, Monte E (2022) Effect of *Trichoderma asperellum* on wheat plants' biochemical and molecular responses, and yield under different water stress conditions. International Journal of Molecular Sciences 23(12): 67-82.

Jaleel CA, Manivannan P, Wahid A, Farooq M, Al-Juburi HJ, Somasundaram R, Panneerselvam R (2009) Drought stress in plants: a review on morphological characteristics and pigments composition. Int. J. Agric. Biol 11(1): 100-105.

Johnson PJ, Shifley SR, Rogers R, Dey DC, Kabrick JM (2019) The ecology and silviculture of oaks. 3rd ed. CABI Publishing, Boston, USA.

Koç İ, Nzokou P (2023) Combined effects of water stress and fertilization on the morphology and gas exchange parameters of 3-year-old *Abies fraseri* (Pursh) Poir. Acta Physiologiae Plantarum, 45(3): 49. doi: 10.1007/s11738-023-03529-4.

Koç İ, Nzokou P, Cregg B (2022) Biomass allocation and nutrient use efficiency in response to water stress: Insight from experimental manipulation of balsam fir, concolor fir and white pine transplants. New Forests 53(5): 915-933.

Kohler M, Pyttel P, Kuehne C, Modrow T, Bauhus J (2020) On the knowns and unknowns of natural regeneration of silviculturally managed sessile oak (*Quercus petraea* (Matt.) Liebl.) forests-a literature review. Annals of Forest Science 77: 1-19.

Kollmann J, Schill HP (1996) Spatial patterns of dispersal, seed predation and germination during colonization of abandoned grassland by *Quercus petraea* and *Corylus avellana*. Vegetatio 125: 193-205.

Kozlowski TT, Pallardy SG (1997) Growth control in woody plants. Academic Press, San Diaogo, USA.

Krasenky J, Jonak C (2012) Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. Journal of Experimental Botany 63(4): 1593-1608.

Lansac AR, Zaballos JP, Martin A (1994) Seasonal water potential changes and proline accumulation in Mediterranean shrubland species. Vegetatio 113(2): 141-154.

Larsen HS, South DB, Boyer JM (1986) Root growth potential, seedling morphology and bud dormancy carreiate with survival of lob-lolly pine seedlings planted in December in Alabama. Tree Physiology 1(41): 253-263.

Lenoir J, Gégout JC, Marquet, PA, de Ruffray P, Brisse H (2008) A significant upward shift in plant species optimum elevation during the 20th century. Science, 320(5884): 1768-1771.

Lepeduš H, Cesar V, Suver M (2003) The annual changes of choloroplast pigments content in current-and previous-year needles of norway spruce (*Picea abies* L. Karst.) exposed to cement dust pollution. Acta Botanica Croatica 62(1): 27-35.

Lopushinsky W (1990) Seedling moisture status. (ed. by R Rose, SJ Campbell and TD Landis) Target Seedling Symposium. Proceedings, Western Forest Nursey Association; August, Roseburg. OR. General Technical Report RM-200, 123-138.

Mafakheri A, Siosemardeh A, Bahramnejad B, Struik PC, Sohrabi Y (2010) Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Australian Journal of Crop Science 4(8): 580-585.

Matoušková M, Urban J, Volařík D, Hájíčková M, Matula R (2022) Coppicing modulates physiological responses of sessile oak (*Quercus petraea* Matt. Lieb.) to drought. Forest Ecology and Management 517: 120253.

Matysiak R (2001) Content of Carotenoids in needles of *Pinus sylvestris* L. growing in a polluted area. Dendrobiology 46: 39-42.

McDonald SE (1984) Irrigation in Forest-Tree Nurseries: Monitoring and Effects on Seedling Growth. Forest Nursery Manuel (ed. by ML Duryea and TD Landis) Martinus Nijhoff/DrW. Junk Publishers, Hague, Netherlands.

Morales CG, Pino MT, del Pozo A (2013) Phenological and physiological responses to drought stress and subsequent rehydration cycles in two raspberry cultivars. Scientia Horticulturae 162: 234-241.

Móricz N, Illés G, Mészáros I, Garamszegi B, Berki I, Bakacsi Z, Kampel J, Szabo O, Rasztovits E, Cseke I, Bereczki K, Németh TM (2021) Different drought sensitivity traits of young sessile oak (*Quercus petraea* (Matt.) Liebl.) and Turkey oak (*Quercus cerris* L.) stands along a precipitation gradient in Hungary. Forest Ecology and Management 492: 119165.

Mölder A, Sennhenn-Reulen H, Fischer C, Rumpf H, Schönfelder E, Stockmann J, Nagel RV (2019) Success factors for high-quality oak forest (*Quercus robur*, *Quercus petraea*) regeneration. Forest Ecosystems 6: 1-17.

Nar H, Saglam A, Terzi R, Varkonyi Z, Kadioglu A (2009) Leaf rolling and photosystem II efficiency in *Ctenanthe Setosa* exposed to drought stress. Photosynthetica 47(3): 429-436.

Nyamjav B (2022) Adaptability responses to drought stress in the oak species *Quercus petraea* growing on dry sites. Journal of Forest Science 68(11): 459-472.

O'Brien E (1998) Water-energy dynamics, climate, and prediction of woody plant species richness: an interim general model. Journal of Biogeography 25(2): 379-398.

Osakabe Y, Osakabe K, Shinozaki K, Tran LSP (2014) Response of plants to water stress. Frontiers in plant science 5: 86.

Öztürk S (2013) Turkey meşeleri teşhis ve tanı kılavuzu, Orman ve Su İşleri Bakanlığı, Orman Genel Müdürlüğü, Orman Zararlılarıyla Mücadele Dairesi Başkanlığı,Turkey.

Pirasteh-Anosheh H, Saed-Moucheshi A, Pakniyat H, Pessarakli M (2016) Stomatal responses to drought stress. Water stress and crop plants: A sustainable approach 1: 24-40.

Popović Z, Milanović S, Miletić Z, Smiljanić M (2010) Photosynthetic efficiency of Pedunculate oak seedlings under simulated water stress. Bulletin of the Faculty of Forestry 101: 139-150.

Pukacki PM, Kamińska-Rożek E (2005) Effect of drought stress on chlorophyll a fluorescence and electrical admittance of shoots in Norway spruce seedlings. Trees 19: 539-544.

Ranjan A, Sinha R, Singla-Pareek SL, Pareek A, Singh AK (2022) Shaping the root system architecture in plants for adaptation to drought stress. Physiologia plantarum 174(2): e13651.

Ritchie GA, Shula RG (1984) Seasonal changes of tissue-water relations in shoots and root systems of douglas-fir seedlings. Forest Science 30(2): 538-548.

Ritchie GA (1984) Assessing seedling quality. Forest Nursery Manual: Production of Bareroot Seedling (ed. by ML Duryea and TD Landis) Martinus Nijhoff/Dr. W. Junk. Publishers, Hague/Boston/Lancaster.

Sankar B, Jaleel CA, Manivannan P, Kishorekumar A, Somasundaram R, Panneerselvam R (2007) Drought-induced biochemical modifications and proline metabolism in *Abelmoschus esculentus* (L.) Moench. Acta Botanica Croatica 66(1): 43-56.

Scholz FG, Bucci SJ, Arias N, Meinzer FC, Goldstein G (2012) Osmotic and elastic adjustments in cold desert shrubs differing in rooting depth: coping with drought and subzero temperatures. Oecologia 170: 885-897.

Semerci A (2002) Sedir (*Cedrus libani* A. Rich.) fidanlarına ait bazı morfolojik ve fizyolojik karakteristikler ile İç Anadolu'daki dikim başarısı arasındaki ilişkiler. İç Anadolu Ormancılık Araştırma Müdürlüğü Teknik Bülten No: 279, Ankara.

Shvaleva AL, Silva FCE, Breia E, Jouve J, Hausman JF, Almeida M, Maroco JP, Rodrigues ML, Pereıra JS, Chaves MM (2006) Metabolic responses to water deficit in two *Eucalyptus globulus* clones with contrasting drought sensitivity. Tree Physiology 26(2): 239-248.

Sircelj H, Tausz M, Grill D, Batic F (2005) Biochemical responses in leaves of two apple tree genotypes subjected to progressing drought. J. Plant Physiol. 162: 1308-1318.

Terzi R, Sağlam A, Kutlu N, Nar H, Kadioğlu A (2010) Impact of soil drought stress on photochemical efficiency of photosystem II and antioxidant enzyme activities of *Phaseolus vulgaris* cultivars. Turkish Journal of Botany 34(1): 1-10.

Thomas FM, Gausling T (2000) Morphological and physiological responses of oak seedlings (*Quercus petraea* and *Quercus robur*) to moderate drought. Annals of Forest Science 57(4): 325-333.

Tilki F (2010) Influence of acorn size and storage duration on moisture content, germination and survival of *Quercus petraea* (Mattuschka). Journal of Environmental Biology 31: 325-328

Turan ES (2018) Turkey'nin iklim değişikliğine bağlı kuraklık durumu. Doğal Afetler Çevre Dergisi 4(1): 63-69.

Turcsán A, Steppe K, Sárközi E, Erdélyi É, Missoorten M, Mees G, Mijnsbrugge KV (2016) Early summer drought stress during the first growing year stimulates extra shoot growth in oak seedlings (*Quercus petraea*). Frontiers in Plant Science 7: 193.

Tuttle CL, South DB, Golden MS, Meldahl RS (1987) Relationship between initial seedling height and survival and growth of loblolly pine seedlings planted during a droughty year. Southern Journal of Applied Forestry 11(3): 139-143.

Vernay A, Malagoli P, Fernandez M, Perot T, Améglio T, Balandier P (2018) Improved *Deschampsia cespitosa* growth by nitrogen fertilization jeopardizes *Quercus petraea* regeneration through intensification of competition. Basic and Applied Ecology 31: 21-32.

Wright A, Schnitzer SA, Reich PB (2015) Daily environmental conditions determine the competition-facilitation balance for plant water status. Journal of Ecology 103: 648-656.

Wu M, Zhang WH, Ma C, Zhou JY (2013) Changes in morphological, physiological and biochemical responses to different levels of drought stress in chinese cork oak (*Quercus variabilis* BI.) seedlings. Russ. J. Plant Physl. 60(5): 681-692.

Xiong S, Wang Y, Chen Y, Gao M, Zhao Y, Wu L (2022) Effects of drought stress and rehydration on physiological and biochemical properties of four oak species in China. Plants 11(5): 679.

Yahyaoğlu Z, Genç M (2007) Fidan standardizasyonu. Standart fidan yetiştirmenin biyolojik ve teknik esasları, SDÜ Orman Fakültesi Yayın No: 75, Isparta, Turkey.

Yang Y, Liu Q, Han C, Qiao YZ, Yao XQ, Yin HJ (2007) Influence of water stress and low irradian on morphological and physiological characteristics of *Picea asperata* Masters. seedlings, Photosyntheticа 45(4): 613-619.

Yavaş İ, Akgül HN, Ünay A (2016) Bitkilerin kuraklığa dayanıklılığını arttırmaya yönelik uygulamalar. Türk Tarım-Gıda Bilim ve Teknoloji Dergisi 4(1): 48-57.

Zolfaghari R, Akbarinia M (2018) Physiological and biochemical responses of *Quercus brantii* seedlings to water deficit stress. Caspian Journal of Environmental Sciences 16: 165-177.

141. Jahrgang (2024), Heft 2, S. 111–144

Austrian Journal of Forest Science
Centralblatt für das gesamte Forstwesen

Visitors' attitudes and perceptions towards biodiversity conservation in production forests: the case study of University Forest Sailershausen in southern Germany

Besuchereinstellungen und -wahrnehmungen zur Biodiversitätserhaltung in Wirtschaftswäldern: eine Fallstudie im Universitätswald Sailershausen, Süddeutschland

Carlotta Sergiacomi[1*], Jörg Müller[2], Ruth Pickert[2], Marina Wolz[2], Alessandro Paletto[1]

Keywords: Saproxylic habitat sites, deadwood, social acceptance, questionnaire survey, Bavaria

Schlüsselbegriffe: Saproxylische Lebensräume, Totholz, soziale Akzeptanz, Umfragebögen; Bayern

Abstract

In recent years, the social acceptance of biodiversity conservation in forests is taking on increasing importance at an international level, both in the scientific community and among policy makers. In literature, many studies have investigated people's preferences for biodiversity conservation in protected areas, while there is a knowledge gap on the social acceptance of biodiversity conservation in production forests. The aim of this study is to investigate visitors' attitudes and perception towards biodiversity conservation through the creation of a Saproxylic Habitat Sites (SHSs) network in a case study in Germany (University Forest Sailershausen). To this end, a questionnaire survey was administered to a sample of 119 visitors from June to September 2023. The results show that the target of visitors is mainly composed by

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA), Research Centre for Forestry and Wood, Italy, p.za Nicolini 6, 38123 Trento (Italy)
[2] Field Station Fabrikschleichach, Department of Animal Ecology and Tropical Biology. Biocenter University of Würzburg, Glashüttenstr. 5, 96181 Rauhenebrach, Germany
*Corresponding author: Carlotta Sergiacomi, carlotta.sergiacomi@gmail.com

young people (under 30 years old) characterized by no or low income (66.1% of total respondents), mainly coming from Würzburg or other cities in Bavaria (86.4%). These visitors consider fauna and flora conservation and climate change mitigation as the most important ecosystem services provided by the University Forest Sailershausen. They perceive deadwood in the forest positively and assign higher aesthetic values to images of the University Forest Sailershausen with a high amount of deadwood (as within the SHSs) compared to images without deadwood. The preliminary results provided by this study can be considered a starting point for future research focused on the social acceptance of biodiversity conservation in production forests.

Zusammenfassung

In den letzten Jahren hat die soziale Akzeptanz des Schutzes der Biodiversität in Wäldern sowohl in der wissenschaftlichen Gemeinschaft als auch bei politischen Entscheidungsträgern auf internationaler Ebene an Bedeutung gewonnen. In der Literatur haben viele Studien die Präferenzen der Menschen für die Erhaltung der biologischen Vielfalt in Schutzgebieten untersucht, während es eine Wissenslücke über die soziale Akzeptanz gegenüber der Erhaltung der biologischen Vielfalt in bewirtschafteten Wäldern gibt. Das Ziel dieser Studie ist es, die Haltung und Wahrnehmung von Besuchern in einer Fallstudie in Deutschland (Universitätswald Sailershausen) hinsichtlich des Schutzes der Biodiversität durch die Schaffung eines Netzwerks saproxylischer Lebensräume (SHS = Saproxylic Habitat Sites) zu untersuchen. Zu diesem Zweck wurde von Juni bis September 2023 eine Fragebogenerhebung bei 119 Besuchern durchgeführt. Die Ergebnisse zeigen, dass sich die Zielgruppe der Besucher hauptsächlich aus jungen Menschen (unter 30 Jahren) zusammensetzt, die über kein oder nur ein geringes Einkommen verfügen (66,1 % aller Befragten) und mehrheitlich aus Würzburg oder anderen Städten in Bayern kommen (86,4 %). Diese Besucher betrachten den Schutz von Fauna und Flora und die Abmilderung des Klimawandels als die wichtigsten Ökosystemleistungen des Universitätswaldes Sailershausen. Sie nehmen Totholz im Wald positiv wahr und messen Bildern des Universitätswaldes Sailershausen mit einem hohen Totholzanteil (wie innerhalb der SHS) einen höheren ästhetischen Wert zu als Bildern ohne Totholz. Die vorläufigen Ergebnisse dieser Studie können als Ausgangspunkt für künftige Forschungen zur sozialen Akzeptanz der Erhaltung der Biodiversität in Wirtschaftswäldern dienen.

1 Introduction

Since the early 1990s, the importance of biodiversity conservation has been growing all over the world following the entry into force of the Convention on Biological Diversity (CBD) in 1993 (Ohtani, 2022). The main objectives established by the CBD were the following (Boisvert and Vivien, 2005):

(i) defining and applying incentives for the conservation of biological diversity;
(ii) favouring the instruments and actions that promote the sustainable use of biodiversity;
(iii) implement tools and mechanisms to enable the access to biological resources and the fair and equitable sharing of the benefits arousing from their utilization.

Therefore, since 1993 biodiversity conservation has also become a priority of policy makers and not only of the scientific community (Herkenrath, 2002).

In 2012, the United Nations (UN) Conference on Sustainable Development (Rio20+) reaffirmed one of the key aspects of the previous international environmental agenda, namely the importance of recognising the "intrinsic value of biological diversity, as well as the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its critical role in maintaining ecosystems that provide essential services, which are critical foundations for sustainable development and human well-being". Consequently, Rio20+ Conference emphasized the connection between biodiversity conservation and other benefits (*i.e.* ecosystem services) provided by natural resources to society (Carrière *et al.*, 2013). In this sense, biodiversity sustaining all life processes and contributing to human health and well-being (Mace *et al.* 2010) is strictly related to the "supporting services" as defined by the Millennium Ecosystem Assessment (MEA) Report (MEA, 2005). In fact, supporting services are the benefits that ecosystems provide in order to maintain the life of other species or, in other words, those related to habitat functioning themselves (*e.g.*, soil formation, primary production, nutrient cycling). These ecosystem services can be considered transversal to the other categories (i.e., provisioning, regulating and cultural services) or as support for the production of other environmental services (De Meo *et al*., 2018). Thus, there is a mutual relationship between supporting services and biodiversity as emphasized by the global strategic plan 2011–2020 of the Aichi biodiversity targets (Harrison, 2014; Liquete *et al*., 2016).

In 2015, the 2030 Agenda for Sustainable Development has included among its 17 goals: sustainable forest management; combating desertification; halting and reversing land degradation; halting biodiversity loss (SDG15). Particularly, target 15.2 of this goal fixed for 2020 the objective to promote sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally. According to this target, biodiversity conservation is a priority in all types of forests, including those primarily intended for timber production or to achieve other objectives. In addition, the target 15.9 set another important objective for 2020: to integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts. This target has taken up what has already been stated by Rio20+ Conference on the close relationship between biodiversity and human well-being and poverty reduction.

At European level, EU 2030 Biodiversity Strategy established in 2020 is the founding pillar of the European Union (EU) policy on biodiversity and is based on the following three principles (EC, 2020):

(i) protecting and restoring nature in the EU, by consolidating a coherent and effective network of protected areas and restoring degraded habitats;
(ii) enabling a new governance framework to ensure co-responsibility and co-ownership by all relevant actors in meeting the biodiversity commitments; and
(iii) adopting a global biodiversity agenda. Then, EU 2030 Biodiversity Strategy emphasized the network approach for biodiversity conservation as-well-as the implementation of restoration interventions on degraded habitats.

In addition, the importance of involving all stakeholders is a key point to ensure efficient and effective biodiversity protection (Hermoso *et al.*, 2022). Also the new EU Forest Strategy for 2030 has included protection and restoration of EU's forests to reverse biodiversity loss among its priorities. This Strategy underlined the importance of implementing dedicated actions for the production and the use of long-lived wood products, in the full respect of biodiversity objectives. As already stated by SDG15, also the new EU Forest Strategy for 2030 underlines the need to consider biodiversity conservation measures in all types of forests, even those intended for timber production.

From a practical point of view, there is a trade-off between timber production and biodiversity conservation in production forests as highlighted by many authors (Faith *et al.*, 1996; Boncina, 2011; Duncker *et al.*, 2012). To reconcile critical trade-offs between these two ecosystem services, integrating nature conservation measures into production forests can be a useful tool in this regard. The integration approach is characterized by several possible strategies, including the preservation of Saproxylic Habitat Sites (SHSs) also known as veteran tree islands or *îlot de senescence* (Aerts, 2013; Mason and Zapponi, 2015). SHSs are defined as small and permanently unmanaged patches capable of providing sustainable habitats for saproxylic organisms (Lachat and Bütler, 2008). A network of SHSs located in production forests is aimed at the conservation of some target saproxylic species (*e.g.*, Black woodpecker, Western barbastelle, Rosalia longicorn, European stag beetle, Hermit beetle) through the creation and maintenance of tree microhabitats. In Europe, a network of SHSs has been implemented in some countries on both a national scale (*i.e.*, Switzerland) and local scale (*i.e.*, Cansiglio in Italy, Mont-Ventoux massif and Vosges massif in France) (Rose and Callot, 2007; Lachat and Bütler, 2008; Mason *et al.*, 2016). However, from the visitors' perspective SHSs may appear as the result of neglected management and even a threat to the forest ecosystem (Sacher *et al.*, 2022).

In the international literature, some studies investigated people's preferences and attitudes for forest ecosystem services. Particular attention is given to the monetary assessment of ecosystem services, with regard to those services not traded on a real market, such as biodiversity conservation (Martín-López *et al.*, 2007; Sagoff, 2008;

Garcia *et al*., 2011). Several studies highlighted the importance recognised to supporting services in forests (Nikodinoska *et al.*, 2015; Pastorella *et al.*, 2016a, Howley *et al*., 2011; Lupp *et al*., 2016; Ranacher *et al*., 2017). In particular, some studies focused on the perception of biodiversity conservation measures mainly in protected areas (Thu Le *et al.*, 2016; Aseres and Sira, 2020; Bhat and Sofi, 2021), while other research focused on the characteristics of forests related to natural diversity (Paletto *et al.*, 2013; Langmaier *et al.*, 2023). In addition, some studies have focused on the perception that visitors have of lying deadwood and standing dead trees (Golivets, 2011; Paletto *et al.*, 2022; Tyrväinen *et al.*, 2003). However, there is a knowledge gap on the social assessment of biodiversity conservation in forests with another priority function (*e.g.*, timber production, protection against natural hazards, tourism and recreation).

In the light of these considerations, the objective of this study is to investigate visitors' attitudes, preferences and perception towards biodiversity conservation, achieved through the creation of SHSs and the maintenance of deadwood and tree microhabitats in production forests. The study was conducted within the LIFE SPAN project (LIFE19 NAT/IT/000104) aimed at preserving saproxylic biodiversity in two production forests (*i.e.* Cansiglio Orientale Forest in Italy and University Forest Sailershausen in Germany). The present study focuses on investigating visitors' preferences and perceptions towards biodiversity conservation within SHSs in the University Forest Sailershausen in Bavaria (Germany).

2 Materials and methods

2.1 Study area

The study area is the University Forest Sailershausen (50°55′46″ N, 10°44′34″ E) located in the northern of Bavaria, in southern Germany (Figure 1). This study area was chosen because it is a typical broadleaved mixed forest of Central Europe heterogeneous in stand structure, age, and tree species composition, managed primarily for timber production and located within agricultural land for crop production. The area is managed by the forestry enterprise of the University of Würzburg, taking into account the principles of multifunctionality at the landscape level and the interactions between biodiversity and ecosystem functions (Müller *et al*., 2022; König *et al*., 2023).

The University Forest Sailershausen (hereinafter referred to as UFS) covers a total land area of 2,346 ha, thus divided: 2,176 ha of forest area with a growing stock of 600,000 m³ (276 m³ ha^{-1}) of which 547 ha are part of FFH/Natura 2000 network and the remaining 1,629 ha of production forest, 120 ha of extensively managed agricultural land, and 50 ha of human infrastructure (*i.e*., roads and paths). As for visitors, the area is mainly suitable to outdoor activities, while the presence of shops selling local products (*e.g*. food and wine or handicrafts) is quite low. The forest area consists of

74% deciduous forests and 26% coniferous forests: 10% Norway spruce, 16% pine, larch, Douglas fir, 21% European beech, 19% oak, 11% hornbeam, 19% noble hardwood (with high commercial value wood) and 4% other hardwood species. The forest management system supports old-grown trees as well as natural tree microhabitats, deadwood enrichment, rare and red list species. The focus of silvicultural treatments of the UFS management lies on old hardwood stands in very long-term regeneration periods, while maintaining the value growth on the individual stem and considering the nature conservation objectives. The group selection management (*Femelschlag* in German) is applied in order to encourage the natural regeneration of forest and at the same time to diversify the vertical stand structure. Oak species is given special consideration in all silvicultural interventions due to its outstanding economical, conservational, and cultural-historical importance.

Thus, being part of the University of Würzburg, several excursions for students take place at the UFS, for example from the Technical University of Munich, the FH Weihenstephan-Triesdorf, the Technical University of Dresden and the University of Bayreuth. Further, the UFS has a training cooperation with the Forestry School Lohr am Main. Since 2018, there is a cooperation with the Department of Animal Ecology and Tropical Biology of the University of Würzburg, where the canopy structure was experimentally enhanced in a large-scale experiment (Müller *et al*., 2023). Several Bachelor, Master and PhD theses are based on those study site at the University of Würzburg.

For 2023, the recreational-educational attendance of the site was characterized by eight field trips, with about 170 students in total, and by six forest tours with kindergarten, forestry enterprises and the population, with approximately 150 people in total. In addition, the UFS is regularly frequented by the inhabitants of neighbouring cities for leisure and recreation activities.

During the activities of the LIFE SPAN project, a network of 25 SHSs for the conservation of saproxylic species have been created on an area corresponding to 5% of the managed UFS. In the SHSs, thinning interventions, the creation of microhabitat trees and the opening of gaps of 0.15 ha have been carried out (see Figure 1). In addition, a marteloscope site – a research plot in the forest where all trees are measured and associated software are related to provide a framework for in-forest training in selection and marking (Kruse *et al.*, 2023) – was developed and set-up for educational-demonstrative purposes.

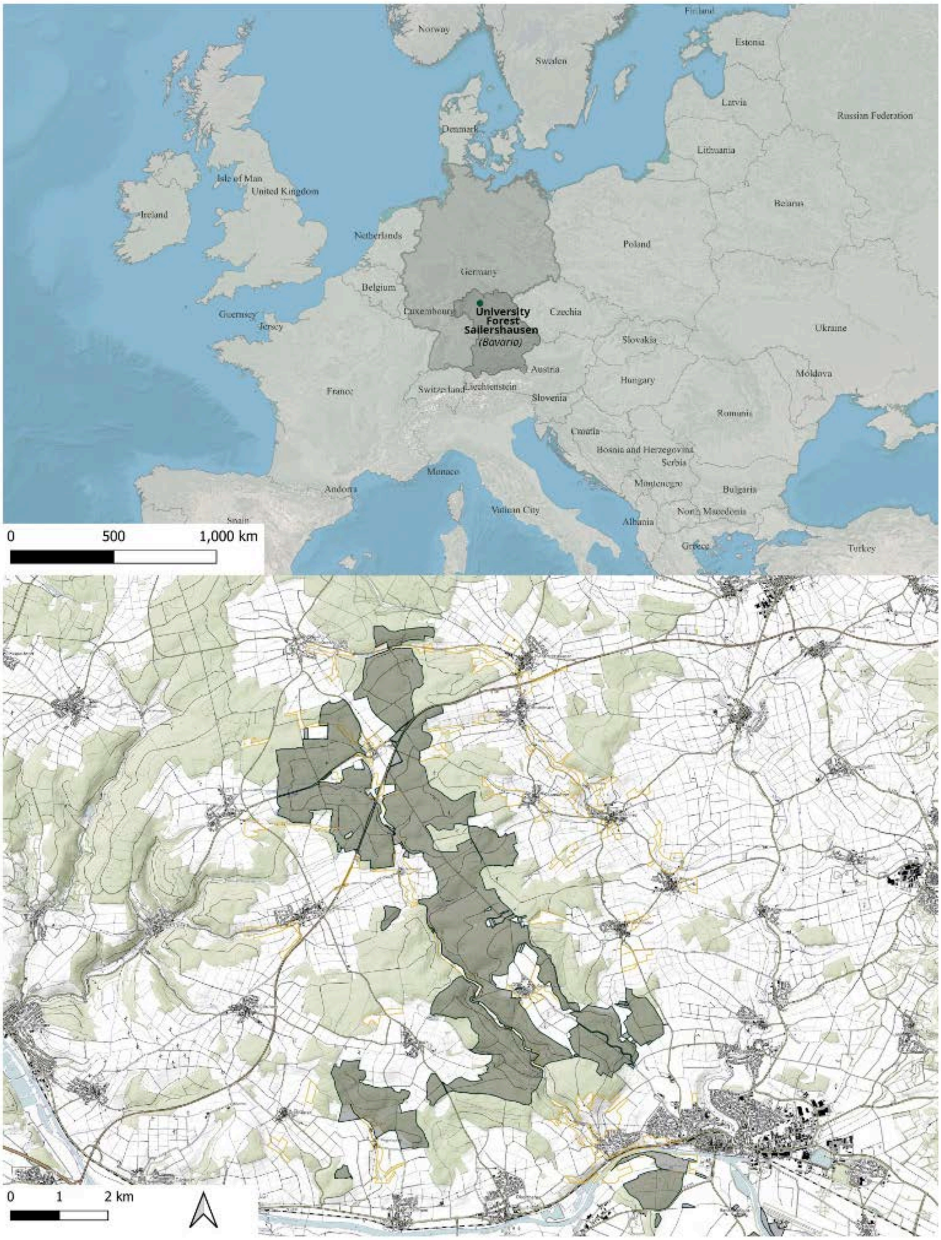


Figure 1: Location of the study area – University Forest Sailershausen (UFS) – in Bavaria (Germany).

Abbildung 1: Lage des Untersuchungsgebiets – des Universitätswaldes Sailershausen - in Bayern (Deutschland).

2.2 Research framework

The study aimed to investigate the attitudes, preferences and perceptions of visitors to the UFS was structured in three steps:

(1) preparation and pre-testing of the survey (semi-structured questionnaire);
(2) sampling and face-to-face administration of the questionnaire to a sample of visitors;
(3) statistical processing of data collected with the questionnaire.

Step 1

From early February to late April 2023, the preliminary version of the questionnaire was prepared by the research team of the LIFE SPAN project. In May 2023, the draft questionnaire was pre-tested with three students of the University of Würzburg, in order to highlight weaknesses and poorly formulated questions. After the pre-test phase, two questions have been changed to simplify them, while one question was eliminated because it was considered redundant. The final version of the questionnaire was made up of 19 questions divided in three thematic sections (see Annex 1).

In the first thematic section, the recreational use of the UFS was investigated in order to target visitors through questions concerning the characteristics of the visits (*e.g.* duration, means of transports, travel distance, costs incurred). In addition, the reasons for the visit were examined, distinguishing between a series of alternatives (*e.g.* hiking/trekking, sport activities, relaxing into the nature, *etc.*). The respondents assigned the importance of the above reasons using a 5-point Likert scale (1 not important, 2 not very important, 3 neutral, 4 important, 5 very important).

The second thematic section considered the visitors' attitudes and preferences towards the UFS. In particular, the perceived importance of the ecosystem services provided by the study area was investigated using a 5-point Likert scale (1 not important, 2 not very important, 3 neutral, 4 important, 5 very important). The ecosystem services to be evaluated have been selected on the basis of a preliminary literature review (D'Amato *et al.*, 2016; Aznar-Sánchez *et al.*, 2018; De Meo *et al.*, 2018).

After that, three images of the UFS with an increasing gradient of deadwood amount were shown to the respondents, in order to investigate their perception towards this component of forest ecosystem. Photos have not been edited and showed real views of the study area. Photo 1 shows the UFS without lying deadwood and standing dead trees, while in Photo 2 the same forest is represented with a medium-high amount of deadwood and in Photo 3 with a high amount of deadwood as within the SHS. Respondents were asked to assign their preferences from an aesthetic point of view using a 5-point Likert scale format (1 very ugly aesthetic landscape, 2 ugly aesthetic landscape, 3 neutral aesthetic landscape, 4 pleasant aesthetic landscape, 5 very nice aesthetic landscape). Then, respondents selected one or more alternatives, indicating whether they considered deadwood as a positive or negative element for the forest ecosystem.

In the last thematic section, data concerning the socio-demographic characteristics of the respondents were collected (*e.g.*, gender, age, level of education, personal annual income, *etc.*).

Step 2

In the second step, the final version of the questionnaire was administered both to groups of organized visitors and to individual visitors to the study area (18 years old and older) between June and September 2023. The questionnaire was administered to organized groups of mainly undergraduate students and forest tours after visiting the site, while individual visitors were sampled at a survey point near the site access. Therefore, both types of visitors – individuals and organized groups – were involved in the survey with the aim of better targeting the attendance of the site. As regards the method of sample selection, participants in the organised groups were all involved, while for individual visitors, one person in two was systematically selected at the sampling points where questionnaires were administered. The respondents were asked to complete the questionnaire by themselves, even if the interviewers remained available for clarification.

Step 3

In the last step, the collected data were processed to produce the main descriptive statistics: mean, median and standard deviation (SD) for the data collected using the Likert-scale format; percentage of frequency distribution (%) for other types of question.

For the data concerning the importance of ecosystem services (Q2.1), two non-parametric tests were performed to highlight statistically significant differences between groups of respondents. In particular, the non-parametric Kruskal-Wallis test (α=0.05) was used to highlight statistical significant differences considering gender, age, level of education, income; while the non-parametric Mann-Whitney test (α=0.05) was used to point out statistical significant differences between local visitors (from Würzburg) and non-local visitors (from other German regions or abroad), and between members and non-members of environmental NGOs. The non-parametric tests were applied, rather than parametric tests, for the following two reasons: the sample size is not large enough (119 questionnaires collected); the assumption of normality is violated (Shapiro-Wilk test: W=0.879, $p<0.0001$). All statistical test was performed using the XLStat 2020 software.

A Principal Component Analysis (PCA) was implemented to classify the target visitors to the UFS based on: the frequency of visits (Q1.1); the travel distance between the visitors' home and the site of visit (Q1.4); the reasons for the visit (Q1.9).

3 Results

3.1 Socio-demographic characteristics of respondents

At the end of data collection, 119 visitors to the UFS filled out all the thematic sections of the questionnaire. Table 1 shows the socio-demographic characteristics of respondents. The results showed that the sample of respondents was composed by 48.7% of females, 47.8% of males, and 3.5% of non-binary. Regarding the age, the majority of respondents were aged between 21 and 30 years old, followed by those between 31 and 40 years old and between 18 and 20 years old. The majority of respondents have a high level of education, but a low annual income. In addition, it is interesting to highlight that approximately a quarter of the respondents were members of an environmental NGOs. Considering the city of origin, the majority of respondents came from Würzburg city (37.0%) or other cities and towns of Bavaria (49.4%), while the remaining 13.6% came from other parts of Germany or other countries.

Table 1: Socio-demographic characteristics of the respondents.

Tabelle 1: Soziodemografische Merkmale der Befragten.

Variables	**Mode**	**% (*n*=119)**
Gender	Male	49%
	Female	48%
	Non-binary	3%
Age	< 20	9%
	21-30	65%
	31-40	10%
	41-50	3%
	51-60	5%
	61-70	6%
	>70	2%
Personal annual income	No income	29%
	< 15.000 €	37%
	15.000 – 30.000 €	12%
	30.000 – 45.000 €	16%
	> 45.000 €	6%
Educational level	Elementary school degree	8%
	Technical or middle school degree	10%
	High school degree	32%
	University or post-University degree	50%

3.2 Target visitors of the University Forest Sailershausen

The findings indicated that the majority of respondents declared they generally visit forests "at least once a week" (57.0%), followed by those who declared "at least once a month" (21.9%), "every day" (20.2%), and "at least once a year" (0.9%). Specifically considering the UFS, the results about the visitors' attendance showed that most of the respondents had never visited the study area before the day of the investigation (33.0%), followed by those who had been there only once in the last 12 months (22.3%). However, it is worth noting that 22.3% of the respondents were "regular" visitors who had been in the study area more than 12 times in the last 12 months. The sample actually consisted of 81.2% of daily hikers and the remaining 18.8% of tourists, who stayed in local accommodation facilities for one night (6.8%) or two or more nights (7.7%). With regards to the visit in progress, the majority of respondents stayed in the forest more than 4 hours (43.7%), followed by those who remained between 2 and 4 hours (37.8%) and those less than 2 hours (18.5%). The visitors reached the UFS mainly by car (77.3%), while the remaining arrived on foot (3.4%), by public transport (2.5%), bike (1.7%), or tour bus (15.1%). The latter were university and post-university students of Biology and Forest Science, who participated in educational excursions to the study site. Regarding the costs incurred for the visit in progress, the outcomes highlighted that a high number of visitors did not incur any costs for accommodation (88.2%), for meals (25.6%), for travel (24.1%) or for the purchase of local products (64.5%). The highest cost items were related to the travel (10.1% supported travel costs between € 11 and € 20 and 3.8% between € 21 and € 30), and to the meals (72.1% spent between € 1 and € 10). With reference to the latter cost item, visitors declared they mostly dined with a packed lunch (82.9%) and only less than 1% at a local restaurant. All cost items incurred for the visit undertaken at the time of the investigation are summarized in Table 2.

Table 2: Distribution (%) of costs incurred for today's visit to the University Forest Sailershausen.

Tabelle 2: Verteilung (%) der Kosten, die für den jeweiligen Besuch im Universitätswald Sailershausen anfallen.

Costs	**None**	**€ 1-10**	**€ 11-20**	**€ 21-30**	**More than € 30**
Accommodation	88.2%	2.9%	1.5%	5.9%	1.5%
Meals	25.6%	72.1%	1.2%	1.2%	0.0%
Travel	24.1%	48.1%	10.1%	3.8%	13.9%
Purchase of local products and others	64.5%	32.3%	3.2%	0.0%	0.0%

Observing the data on the reasons for visiting the study area, the results evidenced that (Table 3): education visit was the most important reason for visiting UFS with an average value of 4.07 (SD=1.97) in a scale from 1 (not important) to 5 (very important), followed by work (3.71±3.22), wildlife watching (2.87±2.25), and relaxing into the nature (2.73±2.26). Conversely, the two least important reasons were: hiking/trekking (1.95±1.50) and sport activities (1.56±1.36). Based on the high SD values, it is possible to assert that there were two groups of visitors: the first group was composed of students, researchers and professors who frequent the study site for work or educational reasons; while the second group was composed of hikers from the surrounding towns. Taking into account the socio-demographic characteristics of visitors, it is interesting to emphasize that females assigned a higher importance to relaxing into nature and wildlife watching compared to other genders, while males assigned highest importance to NWFPs collection. Moreover, young visitors (under 30 years old) emphasized the importance of hiking/trekking (average value of 2.00±1.27 for visitors under 20 years old and 2.04±1.47 for visitors between 21-30 years old); while older visitors stressed the relevance of NWFPs collection (average value of 1.82±1.50 for visitors between 31-40 years old and 1.78±1.37 between 41-50 years old). Regarding the city of origin of respondents, the results evidenced that the local visitors from Würzburg city highlighted the importance of the motivations related to sport activities (2.08±1.62) and hiking/trekking (2.13±1.36), while visitors from other German lands or abroad emphasized as the main reason wildlife watching (3.28±1.94). The main reasons of the visit both for the members and non-members of environmental NGOs were educational visit and work (4.18±1.71 and 4.22±1.78 vs. 4.00±1.92 and 3.44±2.14 respectively).

Table 3: Importance of the reasons to visit the University Forest Sailershausen in accordance with the visitors 'opinions (5-point Likert scale – from 1 not important to 5 very important).

Tabelle 3: Gewichtung der Gründe für den Besuch des Universitätswaldes Sailershausen in Übereinstimmung mit den Meinungen der Besucher (5-stufige-Likert-Skala - von 1 nicht wichtig bis 5 sehr wichtig).

Reasons	Mean	SD	Median	Min	Max
Hiking/Trekking	1.95	1.23	1	1.00	5.00
Sport activities	1.56	1.17	1	1.00	5.00
Relaxing into the nature	2.73	1.50	3	1.00	5.00
NWFP collection	1.70	1.17	1	1.00	5.00
Wildlife watching	2.87	1.50	3	1.00	5.00
Educational visit	4.07	1.40	5	1.00	5.00
Work	3.71	1.80	5	1.00	5.00

The results of Principal Component Analysis (PCA) highlighted that visitors who have travelled longer (*i.e.* greater travel distance) visited the UFS almost exclusively for an educational visit. In this group of visitors there were foreign students or students from all-over Germany. Conversely, those who most often frequented the UFS were those who did so for work reasons or to practice sport activities or hiking/trekking. In the first group there were presumably researchers from academia, while the second group probably included residents from the surrounding cities. The results of PCA are shown in Figure 2.

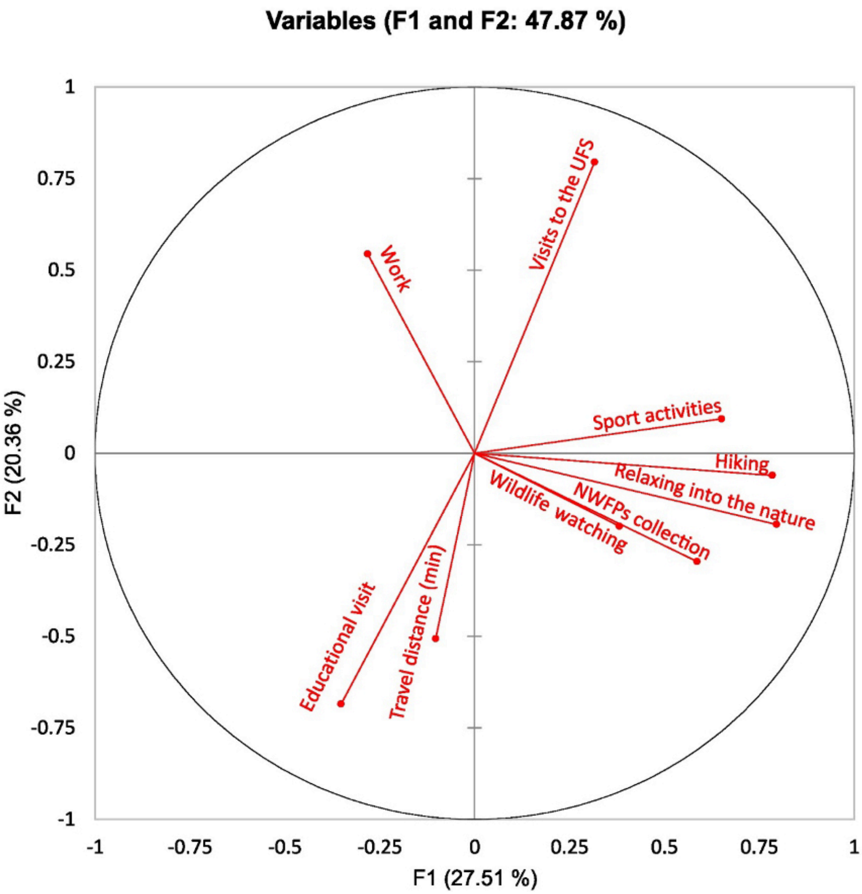


Figure 2: Results of principal component analysis (PCA) considering the frequency of visits, travel distance in minutes between the visitor's home and the site, and the reasons for the visit.

Abbildung 2: Ergebnisse der Hauptkomponentenanalyse (PCA) unter Berücksichtigung der Häufigkeit der Besuche, der Anreisezeit (in Minuten) zwischen dem Wohnort des Besuchers und der Örtlichkeit sowie der Gründe für den Besuch.

3.3 Attitudes and preferences towards the University Forest Sailershausen

The results of the second thematic section revealed that for the sample of respondents: flora and fauna conservation was the most important ecosystem service provided by the UFS with a mean of 4.34 (SD=1.19) in a scale from 1 (not important) to 5 (very important), followed by climate change mitigation (3.72±1.24) and timber and bioenergy production (3.53±1.40). Conversely, cultural and historical values were considered the least important ecosystem services provided by the study area (2.85±1.26). Observing data by socio-demographic characteristics, it is interesting to emphasise that the non-parametric Kruskal-Wallis test highlighted statistical significant differences for two ecosystem services: biodiversity (i.e. flora and fauna conservation) (p=0.049) and cultural and historical values (*p*=0.044). In particular, males assigned lower average values to cultural and historical values and a higher value to the biodiversity, compared to females and others. In addition, people over 40 assigned the highest values to most ecosystem services (*i.e.*, climate change mitigation, water provision, cultural and historical values), while younger people emphasized the importance of biodiversity more than other age classes. Regarding the level of education, the test findings evidenced statistically significant differences for biodiversity (*p*=0.011) and climate change mitigation (*p*=0.018). In particular, visitors with an elementary school degree assigned a lower importance to these two ecosystem services compared to the other three groups. Finally, it is interesting to highlight that visitors with higher incomes assigned greater importance to timber and bioenergy production, recreation, and climate change mitigation compared to those with the lowest incomes, which assigned greater importance to biodiversity conservation. The non-parametric Mann-Whitney test showed statistically significant differences between local and non-local visitors only for timber and bioenergy production ($p<0.0001$), highlighting that foreign visitors assigned higher importance to this ecosystem service compared to local visitors. The outcomes of the test revealed statistically significant differences between members and non-members of environmental NGOs only for biodiversity (*p*=0.011). Contrary to what was expected, non-members assigned a higher importance to biodiversity than members of environmental NGOs. The importance of ecosystem services by socio-demographic characteristics of respondents are presented in Table 1 of the Annex 2.

Regarding the visitors' perception towards deadwood in forest landscapes, the results highlighted that the preferred image of the UFS was the one represented in Photo 3 with a mean value of 4.05 (SD=1.10) in a scale from 1 (very ugly aesthetic landscape) to 5 (very nice aesthetic landscape), followed by Photo 2 (3.88±1.02) and Photo 1 (3.48±1.32). The non-parametric Kruskal-Wallis test showed statistically significant differences among the visitors' preferences towards the three photos (*p*=0.006). Therefore, the sample of visitors gave a preference to forest landscapes with the presence (high and medium) of deadwood rather than those without deadwood (Figure 3). Considering the socio-demographic characteristics of respondents (see Table 2 of the Annex 2), the results showed that females prefer Photo 1 and Photo 2, characterized by the almost total absence or low quantity of deadwood, while males assigned a higher value to Photo 3, characterized by a high deadwood amount. However, the non-parametric Kruskal-Wallis test showed statistically significant differences only for the Photo 1 (p=0.004). Observing the data by age, the results did not show a clear trend, as young people (less than 21 years old) assigned the highest values to both Photo 1 and Photo 3, while people over 40 gave a preference for Photo 2. Also for the level of education no statistically significant differences resulted, with a slight preference of people with high school degree for the photos without or with low amount of deadwood (Photo 1 and 2), and of people with middle school degree for the photo with high amount of deadwood (Photo 3). With regard to the city of origin, the findings revealed that for all three photos local people assigned a lower preference compared to people from other parts of Germany or foreigners. The non-parametric Mann-Whitney test confirmed the absence of statistically significant differences between these two groups of respondents. As expected, people who were not members of environmental NGOs assigned a higher preference to Photo 1 compared to the members (mean value 3.61 vs. 3.35), while members of environmental NGOs assigned higher preferences to Photo 2 (3.92 vs. 3.84) and Photo 3 (4.23 vs. 3.68). However, the non-parametric Mann-Whitney test showed no statistically significant differences between the two groups for all three photos. Taking into account the income of the respondents, the results evidenced that people with a higher income assigned a preference for the photos with a low and high amount of deadwood (Photo 2 and 3) compared to the other categories, while people with a lower income emphasized the aesthetic value of forest landscape without deadwood (Photo 1). However, the non-parametric Kruskal-Wallis test showed no statistically significant differences for all three photos. Finally, the findings revealed that the majority of respondents highlighted the positive roles of deadwood in forest landscapes for fauna conservation (31.7% of total responses), for flora conservation (23.0%), and for soil fertilization (20.8%). Conversely, only a minority of respondents emphasized the negative role of deadwood in forests related to: the risk of forest fires (4.2%), the risk of harmful insects (5.1%), or aesthetic appreciation (2.0%). Overall, these results showed that visitors perceived deadwood in forests more positively than negatively from an aesthetic-visual point of view and functions performed.

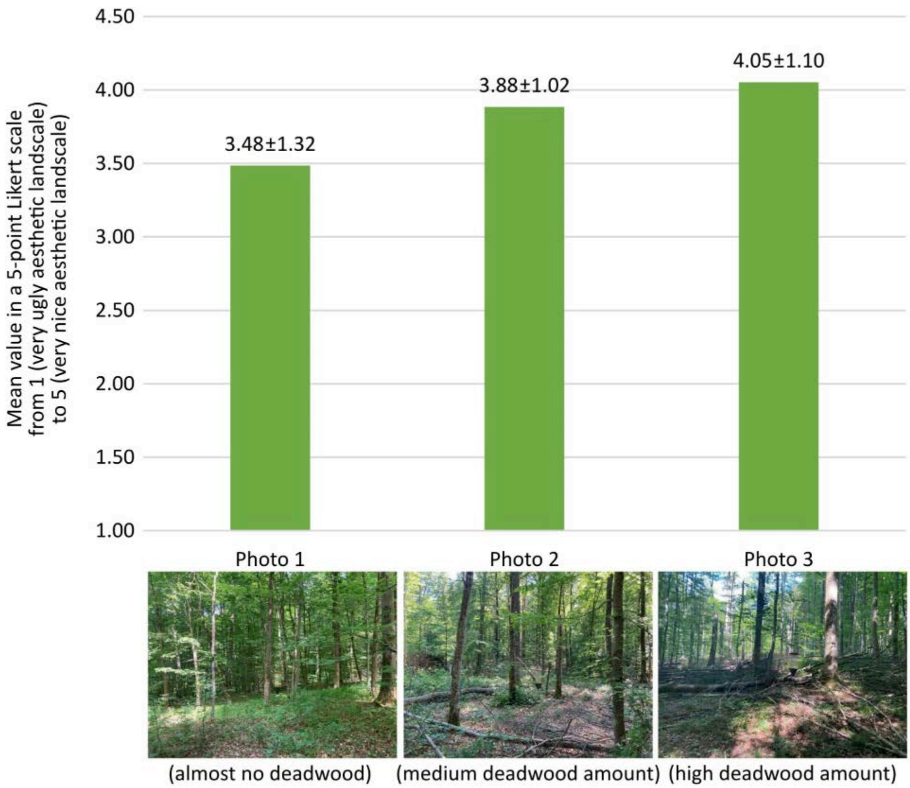


Figure 3: Visitors' perception (mean±standard deviation) towards deadwood in forest landscapes (5-point Likert scale – from 1 very ugly aesthetic landscape to 5 very nice aesthetic landscape).

Abbildung 3: Wahrnehmung der Besucher (Mittelwert±Standardabweichung) hinsichtlich dem Totholz in Waldlandschaften (5-stufige Likert-Skala – von 1 sehr unästhetische Landschaft bis 5 sehr schöne ästhetische Landschaft).

4 Discussion

4.1 Visitors' characteristics

First of all, the results showed that visitors of the UFS are mainly represented by young people (under 30 years old) characterized by no or low income under € 15,000 (66.1%), principally coming from Würzburg or other cities in Bavaria (86.4%). Besides, the PCA results highlighted that the sample is divided into three main groups based on visit frequency, travel distance, and reasons for visit:

i) visitors who come from far away for the first time to the site for educational visit reasons;
ii) visitors who come from nearby and regularly frequent the site for work reasons;
iii) visitors who come from nearby and often frequent the site for sporting or hiking reasons.

Presumably the first group includes foreign and non-foreign students, while the second group includes university researchers and technicians, while the third group includes inhabitants of the surrounding cities. The visitors of the sample declared that they generally frequent the forests every day (20.2%) or at least once a week (57.0%), while the "occasional" visitors to the UFS (*i.e.*, at least once a month and at least once a year) are 22.8% of the total. In international literature, Jarský *et al.* (2022) estimated that 70.5% of the Czech people went to the forest at least once a month in 2020 and 56.7% in 2019, while the number of people who could not visit the forest was 7.8% in 2020 and 12.8% in 2019. In a study conducted in Slovenia, Torkan and Krašovec (2019) showed that the majority of respondents visit forests weekly (approximately 28% of the total) or several times a week (approximately 26% of the total), while about 24% of respondents rarely visit forests. In addition, the results revealed that males showed a higher preference for sites with high deadwood amount. This result is confirmed by other studies, such as that of Tyrväinen *et al.* (2003), who found that males tend to approve the presence of dead trees and deadwood on the ground more easily than females, and that of Paletto *et al.* (2022), who identified a greater preference for deadwood by males due to a higher knowledge of the issue. Therefore, the sample of this study is comparable with what is reported by other studies in the literature. Regarding the reasons for visiting the UFS, the third group of visitors is the one most in line with the European literature which highlights hiking and relaxing in the nature as main reasons (Paletto *et al.*, 2017; Langmaier *et al.*, 2023). However, it is important to emphasize that the reasons for visits are strictly connected to the type of forest, proximity to urban areas, and the internal characteristics of a site.

4.2 Importance of forests' ecosystem services

Secondly, the sample of respondents emphasized the importance of supporting and regulating ecosystem services (*i.e.*, flora and fauna conservation and climate change mitigation) provided by UFS compared to the other categories of ecosystem services. This result confirms what has been reported by other studies conducted in other European forests. In particular, numerous studies focus on the systematic collection of data in large protected areas (Lupp *et al.*, 2016), where the value of forest ecosystem services is usually recognized by visitors. For example, in Sweden, Nikodinoska *et al.* (2015) found that the supporting services (habitat and species diversity, net primary production, and soil formation) are the most important ecosystem services provided by Abisko National Park in accordance with the visitors' opinions. Pastorella *et al.* (2016a) highlighted that in accordance with people's opinions the most important ecosystem services provided by Calabrian forests in southern Italy are biodiversity conservation, followed by landscape conservation and air quality improvement. However, in the literature there are few studies that investigate the perception of users of forest ecosystem services provided by unprotected areas, as has been done in this study. For example, in Italy, De Meo *et al.* (2011) and Paletto *et al.* (2014) highlighted the importance of regulating services (*i.e.* natural hazards protection) and cultural services (*i.e.* recreation and landscape aesthetic) provided by forests in accordance with the stakeholders' opinions. In a study conducted in Slovakia, Dobšinská and Sarvašová (2016) underlined that for the general public the two most important ecosystem services provided by Slovakian forests are recreation (approximately 80% of respondents) and non-wood forest products (12.2%). In Ireland, Howley *et al.* (2011) found that the role of forests to ensure a broad variety of plants and animals is the most important for society, while the role of forests in climate change mitigation through carbon dioxide (CO_2) sequestration has been found to be the most important ecosystem service in Germany (Lupp *et al.*, 2016) and Austria (Ranacher *et al.*, 2017). For an exhaustive and up-to-date meta-analysis of the social perception of ecosystem services provided by forests in Europe see Ranacher *et al*. (2020).

4.3 Perception of deadwood

Thirdly, the results of the present study highlighted that the visitors of the UFS have a positive perception of deadwood in forests, both from an aesthetic-visual point of view and the functionality in the ecosystem. In fact, 43.6% consider the photo of the site with a high amount of deadwood as very pleasant and 21.4% pleasant, while 29.9% and 40.2% consider the photo with a medium amount of deadwood very pleasant or pleasant respectively. Conversely, the photo of the UFS without deadwood is considered the least aesthetically pleasing. In addition, the respondents emphasized the positive roles (*e.g.*, for fauna and flora conservation and soil fertilization) of deadwood in forests more than the negative ones (*e.g.,* for the risk of forest fires, the risk of harmful insects, the aesthetic appreciation). In international literature, some studies have investigated people's preferences and perception towards deadwood in forests. In a study conducted in Italy, Paletto *et al.* (2022) revealed that for the majority of respondents standing dead trees and lying deadwood have neither a positive or a negative effect on forest landscape (52.2% and 34.1% respectively), while a minority was recorded who believe that standing dead trees and lying deadwood have a positive effect on forest landscape (7.5% and 23.0% respectively). Findings from southern Sweden, suggested that deadwood played a pivotal role in shaping a negative attitude towards forests as reported by Golivets (2011). However, it is worth noting that in the opinions of respondents the presence of lying deadwood did not significantly diminish the overall aesthetic value of forest stands in this context. Further exploring Swedish citizens' perspectives, Bakhtiari *et al.* (2014) demonstrated that leaving deadwood in forests was generally accepted as a means of preserving ecosystem naturalness. A study in Japan by Kovács *et al.* (2020) used a photograph evaluation approach to assess visitors' perceptions of naturally occurring deadwood compared to cut wood. Interestingly, Japanese visitors associated photos of naturally occurring deadwood with aesthetic and spiritual values, highlighting the influence of cultural and social contexts on perceptions. Conversely, deadwood stemming from silvicultural interventions was often negatively perceived by Japanese citizens. Additionally, the perception of deadwood is intertwined with its decomposition rate (Nielsen *et al.*, 2012; Rathmann *et al.*, 2020). In particular, Rathmann et al. (2020) observed a gradient in perception from negatively evaluated fresh and beginning decomposition stages to positively valued advanced and high decomposition stages. In a comparative case study between Italy and Bosnia & Herzegovina, Pastorella *et al*. (2016b) observed that Bosnian respondents have a more positive perception of dead wood in forests than Italian respondents. Finally, Sacher *et al*. (2022) summarized the results concerning people's preferences towards deadwood in forests by 35 studies conducted from the mid-1980s to 2021. Those authors also showed different results depending on the context (stand characteristics and location) and target group.

In summary, we can assert that the UFS is a forest area with very peculiar characteristics that make the results of this study not exportable to other contexts. Firstly, the visitor target is made up of a high number of students, academics and researchers who visit the site for work and educational reasons. This target group has a higher level of knowledge on forest ecology and management than the common visitors. Presumably this is one of the reasons for the high aesthetic and functional value assigned to the presence of deadwood and SHSs in the UFS. Furthermore, the ecosystem services provided by the UFS are of high importance in the eyes of visitors due to its location within agricultural land for crop production. In this highly anthropized context, the UFS has a key role in providing microhabitats for wildlife and improving air and water quality as was also recognized by the sample of visitors.

5 Conclusions

The conservation of biodiversity in production forests is a key theme in the coming years that the scientific community is starting to investigate from several perspectives (*e.g.*, ecological, economic, social). The present study provided preliminary data on the social perception for biodiversity conservation in a broadleaved mixed forest located in a matrix of production forest. In this context, biodiversity conservation through the creation of a network of SHSs and interventions aimed at the creation of tree microhabitats and deadwood is of key importance. To date, international literature has marginally investigated the social acceptance of biodiversity conservation in production forests, focusing mainly on protected areas. The main advantage of this study was to investigate a site different from the typical areas involved in socio-economic studies on biodiversity (*i.e.*, national and regional parks, Natura 2000 sites, and other protected areas). Therefore, the main findings obtained – although preliminary – are a starting point for a future debate on the analysis of social acceptance and the involvement of visitors in biodiversity conservation in production forests. In fact, the study allowed to test the methodology for the forests located near large cities where timber production is the primary goal of management. On the other hand, the main weakness of the study is the particularity of the visitors' sample, which cannot be considered representative of German forest visitors for the presence of a relevant group of specialized users: young people with greater knowledge and awareness on environmental issues but low income. This weakness is due to the greater difficulty in intercepting individual visitors and obtaining their willingness to be involved in the survey. Future studies will be undertaken on forests with different site and stand characteristics and to target visitors in order to highlight which variables most affect social preferences and individual willingness to pay for biodiversity conservation in production forests.

Acknowledgments

The present study was carried out in the context of the LIFE SPAN "Saproxylic Habitat Network: planning and management for European forests" (LIFE19 NAT/IT/000104) project aimed to identify possible sustainable forest management strategies capable of integrating nature conservation measures in production forests.

References

Aerts R. (2013). Old trees: extraction, conservation can coexist. Science 339: 904–904.

Aseres S.A., Sira R.K. (2020). Estimating visitors' willingness to pay for a conservation fund: sustainable financing approach in protected areas in Ethiopia. Heliyon 6(8): e04500.

Aznar-Sánchez J.A., Belmonte-Ureña L.J., López-Serrano M.J., Velasco-Muñoz J.F. (2018). Forest ecosystem services: An analysis of worldwide research. Forests 9: 453.

Bakhtiari F., Jacobsen J.B., Strange N., Helles F. (2014). Revealing lay people's perceptions of forest biodiversity value components and their application in valuation method. Global Ecology and Conservation 1: 27-42. https://doi.org/10.1016/j.gecco.2014.07.003

Bhat M.Y., Sofi A.A. (2021). Willingness to pay for biodiversity conservation in Dachigam National Park, India. Journal for Nature Conservation 62: 126022.

Boisvert V., Vivien F.-D. (2005). The convention on biological diversity: A conventionalist approach. Ecological Economics 53: 461-472.

Boncina A. (2011). Conceptual approaches to integrate nature conservation into forest management: A Central European perspective. International Forestry Review, 13, 13–22.

Carrière S.M., Rodary E., Méral P., Serpantié G., Boisvert V., Kull C.A., Lestrelin G., Lhoutellier L., Moizo B., Smektala G., Vandevelde J.-C. (2013). Rio+20, biodiversity marginalized. Conservation Letters 6(1): 6-11.

D'Amato D., Rekola M., Li N., Toppinen A. (2016). Monetary valuation of forest ecosystem services in China: A literature review and identification of future research needs. Ecological Economics 121: 75-84.

De Meo I., Cantiani M.G., Ferretti F., Paletto A. (2011). Stakeholders' perception as support for forest landscape planning. International Journal of Ecology 1: 1–8.

De Meo I., Cantiani M.G., Ferretti F., Paletto A. (2018). Qualitative Assessment of Forest Ecosystem Services: The Stakeholders' Point of View in Support of Landscape Planning. Forests 9: 465.

Dobšinská Z., Sarvašová Z. (2016). Perceptions of forest owners and the general public on the role of forests in Slovakia. Acta Silvatica & Lignaria Hungarica, 12: 23–33.

Duncker P.S., Raulund-Rasmussen K., Gundersen P., Katzensteiner K., De Jong J., Ravn H.P., Smith M., Eckmüllner O., Spiecker H. (2012). How Forest Management affects Ecosystem Services, including Timber Production and Economic Return: Synergies and Trade-Offs. Ecology and Society, 17, 1-17.

EC (2020). EU Biodiversity Strategy for 2030. Bringing nature back into our lives. Brussels, 20.5.2020 COM(2020) 380 final.

Faith D.P., Walker P.A., Ive J.R., Belbin L. (1996). Integrating conservation and forestry production: exploring trade-offs between biodiversity and production in regional land-use assessment. Forest Ecology and Management 85: 251-260.

Garcia S., Harou P., Montagné C., Stenger A. (2011). Valuing forest biodiversity through a national survey in France: A dichotomous choice contingent valuation. Int. j. biodivers. sci. ecosyst. serv. 7(2), 84–97. https://doi.org/10.1080/21513732.2011.628338

Golivets M. (2011). Aesthetic Values of Forest Landscapes. MSc Thesis, Swedish University of Agricultural Sciences 60, Alnarp, Sweden.

Harrison P.A. (2014). Linkages between biodiversity attributes and ecosystem services: a systematic review. Ecosystem Services 9: 191-203.

Herkenrath P. (2002). The implementation of the Convention on Biological Diversity – A non-government perspective ten years on. RECIEL 11(1), Blackwell Publishers Ltd.

Hermoso V., Carvalho S.B., Giakoumi S., Goldsborough D., Katsanevakis S., Leontiou S., Markantonatou V., Rumes B., Vogiatzakis I.N., Yates K.L. (2022). The EU Biodiversity Strategy for 2030: Opportunities and challenges on the path towards biodiversity recovery. Environmental Science & Policy 127: 263-271.

Howley P., Ryan M., Donoghue C. O. (2011). Forestry in Ireland: An examination of individuals' preferences and attitudes towards the non-market benefits of forests. Irish Geography 44(2-3): 291–302. https://doi.org/10.1080/00750778.2011.6

Jarský V., Palátová P., Riedl M., Zahradník D., Rinn R., Hochmalová M. (2022). Forest Attendance in the Times of COVID-19—A Case Study on the Example of the Czech Republic. International Journal of Environmental Research and Public Health 19(5), 2529. https://doi.org/10.3390/ijerph19052529

König A., Dahl S.-A., Windisch W. (2023). Energy intake and nutritional balance of roe deer (Capreolus capreolus) in special Bavarian landscapes in southern Germany. Animal Production Science 63: 1648-1663.

Kovács B., Uchiyama Y., Miyake Y., Penker M., Kohsaka R. (2020). An explorative analysis of landscape value perceptions of naturally dead and cut wood: a case study of visitors to Kaisho Forest, Aichi, Japan. Journal of Forest Research 25(5): 291-298. https://doi.org/10.1080/13416979.2020.1773619

Kruse L., Erefur C., Westin J., Ersson B. T., Pommerening A. (2023). Towards a benchmark of national training requirements for continuous cover forestry (CCF) in Sweden. Trees, Forests and People 12: 100391. https://doi.org/10.1016/j.tfp.2023.100391

Lachat T., Bütler R. (2008). Îlots de sénescence et arbres-habitat pour augmenter la biodiversité en forêt. La Forêt 6: 20-21.

Langmaier M., Hochbichler E., Payrhuber A. (2023). Importance of tree species composition and forest structure on recreational use – a case study for mountain forests in Upper Styria. Austrian Journal of Forest Science 4: 249-278. https://doi.org/10.53203/fs.2304.2

Liquete C., Cid N., Lanzanova D., Grizzetti B., Reynaud A. (2016). Perspectives on the link between ecosystem services and biodiversity: The assessment of the nursery function. Ecological Indicators 63: 249-257.

Lupp G., Förster B., Kantelberg V., Markmann T., Naumann J., Honert C., Koch M., Pauleit S. (2016). Assessing the recreation value of urban woodland using the ecosystem service approach in two forests in the Munich metropolitan region. Sustainability 8(11): 1156. https://doi.org/10.3390/su8111156

Mace G.M., Cramer W., Dìaz S., Faith D.P., Larigauderie A., Le Prestre P., Palmer M., Perrings C., Scholes R.J., Walpole M., Walther B.A., Watson J.E.M., Mooney H.A. (2010). Biodiversity targets after 2010. Current Opinion in Environmental Sustainability 2: 3-8.

Martín-López B., Montes C., Benayas J. (2007). The non-economic motives behind the willingness to pay for biodiversity conservation. Biological Conservation 139: 67-82. https://doi.org/10.1016/j.biocon.2007.06.005

Mason F., Zapponi L. (2015). The forest biodiversity artery: towards forest management for saproxylic conservation. iForest 9: 205-216. https://doi.org/10.3832/ifor1657-008

Mason F., Di Salvatore U., Zapponi L., Cantiani P., De Cinti B., Ferretti F. (2016). Îlots de senescence in the ManFor C.BD sites. Italian Journal of Agronomy, 11, 135-140.

MEA (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Müller J., Mitesser O., Cadotte M.W., van der Plas F., Mori A.S., Ammer C., Chao A., Scherer-Lorenzen M., Baldrian P., Bässler C., Biedermann P., Cesarz S., Claßen A., Delory B.M., Feldhaar H., Fichtner A., Hothorn T., Kuenzer C., Peters M.K., Pierick K., Schmitt T., Schuldt B., Seidel D., Six D., Steffan-Dewenter I., Thorn S., von Oheimb G., Wegmann M., Weisser W.W., Eisenhauer N. (2022). Enhancing the structural diversity between forest patches—A concept and real-world experiment to study biodiversity, multifunctionality and forest resilience across spatial scales. Global Change Biology, 29, 1437–1450. https://doi.org/10.1111/gcb.16564

Müller J., Scherer-Lorenzen M., Ammer C., Eisenhauer N., Seidel D., Schuldt B., Biedermann P., Schmitt T., Kuenzer C., Wegmann M., Cesarz S., Peters M., Feldhaar H., Steffan-Dewenter I., Claßen A., Bässler C., von Oheimb G., Fichtner A., Thorn S., Weisser W. (2021). BETA-FOR: Enhancing the structural diversity between patches for improving multidiversity and multifunctionality in production forests. Proposal for the first phase (2022-2026) of the DFG Research Unit FOR 5375/1.

Nielsen A.B., Heyman E., Richnau G. (2012). Liked, disliked and unseen forest attributes: relation to modes of viewing and cognitive constructs. Journal of Environmental Management 113: 456–466. https://doi.org/10.1016/j.jenvman.2012.10.014

Nikodinoska N., Paletto A., Franzese P.P., Jonasson C. (2015): Valuation of ecosystem services in protected areas: The case of the Abisko National Park (Sweden). Journal of Environmental Accounting and Management, 3: 355–369.

Ohtani S. (2022). How is People’s Awareness of “Biodiversity” Measured? Using Sentiment Analysis and LDA Topic Modeling in the Twitter Discourse Space from 2010 to 2020. SN Computer Science 3: 371.

Paletto A., Guerrini S., De Meo I. (2017). Exploring visitors' perceptions of silvicultural treatments to increase the destination attractiveness of peri-urban forests: A case study in Tuscany Region (Italy). Urban Forestry & Urban Greening 27: 314-323.

Paletto A., Balest J., De Meo I., Giacovelli G., Grilli G. (2014). Perceived influence and real power of stakeholders in forest management: A case study in Italy. In: Schiberna E., Stark M. (eds): Adaptation in Forest Management Under Changing Framework Conditions. Sopron, Foundation for Sustainable Forest Management: 163–175.

Paletto A., Becagli C., De Meo I. (2022). Aesthetic preferences for deadwood in forest landscape: A case study in Italy. Journal of Environmental Management 311: 114829. https://doi.org/10.1016/j.jenvman.2022.114829

Paletto A., De Meo I., Cantiani M.G., Maino F. (2013). Social Perceptions and Forest Management Strategies in an Italian Alpine Community. Mountain Research and Development, 33(2):152-160.

Pastorella F., Avdagić A., Čabaravdić A., Mraković A., Osmanović M., Paletto A. (2016b). Tourists’ perception of deadwood in mountain forests. Annals of Forest Research. 59: 311-326. https://doi.org/10.15287/afr.2016.482

Pastorella F., Giacovelli G., Maesano M., Paletto A., Vivona S., Veltri A., Pellicone G., Scarascia Mugnozza G. (2016a). Social perception of forest multifunctionality in southern Italy: The case of Calabria Region. Journal of Forest Science 62(8): 366-379. https://doi.org/10.17221/45/2016-JFS

Ranacher L., Stern T., Schwarzbauer P. (2017). Do wood products protect the climate? Public perception of the forest based sector’s contribution to climate change mitigation. Austrian Journal of Forest Science (3): 281–298.

Ranacher L., Sedmik A., Schwarzbauer P. (2020). Public perceptions of forestry and the forest-based bioeconomy in the European Union. Knowledge to Action 3, Joensuu: European Forest Institute. https://doi.org/10.36333/k2a03

Rathmann J., Sacher P., Volkmann N., Mayer M. (2020). Using the visitor-employed photography method to analyse deadwood perceptions of forest visitors: a case study from Bavarian Forest National Park, Germany. European Journal of Forest Research. 139(3): 431–442. https://doi.org/10.1007/s10342-020-01260-0

Rose O., Callot H. (2007). Redécouverte de Phloeostichus denticollis Redtenbacher, 1842 dans le massif des Vosges (France) (Coleoptera Phloeostichidae). L'Entomologiste 63: 129-133.

Sacher P., Meyerhoff J., Mayer M. (2022). Evidence of the association between deadwood and forest recreational site choices. For. Pol. Econ. 135, 102638. https://doi.org/10.1016/j.forpol.2021.102638

Sagoff M. (2008). On the economic value of ecosystem services. Environ. Values 17(2), 239–257. https://doi.org/10.3197/096327108X303873

Tyrväinen L., Silvennoinen H., Kolehmainen O. (2003). Can ecological and aesthetic values be combined in urban forest management? Urban For. Urban Green. 1, 135–149. https://doi.org/https://doi.org/10.1078/1618-8667-00014

Thu Le T.H., Lee D.K., Kim Y.S., Lee Y. (2016). Public preferences for biodiversity conservation in Vietnam's Tam Dao National Park. Forest Science and Technology 12: 144-152. https://doi.org/10.1080/21580103.2016.1141717

Torkan G., Krašovec U. 2019. Students' attitudes toward forest ecosystem services, knowledge about ecology, and direct experience with forests. Ecosystem Services 37, 100916. https://doi.org/10.1016/j.ecoser.2019.100916

Zapponi L., Minari E., Longo L., Toni I., Mason F., Campanaro A. (2014). The Habitat-Trees experiment: using exotic tree species as new microhabitats for the native fauna. iForest 8: 464-470. https://doi.org/10.3832/ifor1281-007

Annex 1

SPAN
SAPROXYLIC HABITAT NETWORK

Life

QUESTIONNAIRE

The questionnaire has been realized in the framework of the LIFE SPAN project aimed at integrating the conservation of saproxylic biodiversity (dead wood-associated species, which altogether constitute at least 30% of forest biodiversity) in forest management. The LIFE SPAN project is implemented in two study areas: one in Italy and one in Germany. The University Forest Sailershausen is one of the areas of intervention of the Project and the present survey aims to collect information from visitors to improve its usability.
The data collected will be processed anonymously and solely for monitoring the results of the Project.

Your support is precious to us and for this we thank you for your cooperation.

The data collected will be used exclusively for research and non-managed purposes, in aggregate and anonymous form, in compliance with the European Privacy Regulation (Reg. EU No. 679/2016, GDPR).
By continuing to complete the questionnaire, you consent to the use of the data for the research purposes described above.

Section 1 - Recreational use of the University Forest Sailershausen

The University Forest Sailershausen is located between Schweinfurt and Haßfurt in the northern of Bavaria. The University Forest Sailershausen covers an area of 2,176 ha of which 750 ha are part of the Natura 2000 area "Wässernachtal". It is dominated by beach- oak forests (80%), as well as extensively managed hay meadows (19%) and inland water bodies (1%). A smaller part of the forest in the South is part of the FFH and SPA area "Mainaue between Eltmann and Haßfurt", mainly with focus on migrating birds along the river Main. The land is owned by the University of Würzburg.

Q1.1. How many times did you visit the University Forest Sailershausen in the last 12 months? ___________

Q1.2. How long do you remain in the University Forest Sailershausen **today**? (single choice)

- ☐ All day (more than 4 hours)
- ☐ A few hours (2-4 hours)
- ☐ Less than 2 hours

Q1.3. What means of transport did you use to move from your home/holiday accommodation and reach the University Forest Sailershausen today? (single choice)

- ☐ Car
- ☐ Motorbike
- ☐ Public transport
- ☐ Other (indicate________________________)

Q1.3.bis. What were the transport costs? ____________ €

Q1.4. How long did it take to reach the University Forest Sailershausen from your home/holiday accommodation today? (single choice)

- ☐ Less than 1 hour
- ☐ Between 1 and 2 hours
- ☐ Between 2 and 3 hours
- ☐ Between 3 and 4 hours
- ☐ Between 4 and 5 hours
- ☐ More than 5 hours

Q1.5. How many people visit today the University Forest Sailershausen with you? (single choice)

- ☐ None (I am alone)
- ☐ 1 person
- ☐ 2 persons
- ☐ 3 persons
- ☐ 4 persons
- ☐ 5 persons
- ☐ More than 5 persons

Q1.6. In order to visit the University Forest Sailershausen today, how many days will you stay in an accommodation facility in the area? (single choice)

- ☐ I will not sleep in any accommodation facility
- ☐ 1 night
- ☐ 2 nights
- ☐ 3 nights
- ☐ 4 nights
- ☐ 5 nights
- ☐ More than 5 nights

Q1.6.bis. What was the approximate cost per night per person? _________ €/person/night

Q1.7. Where did you have lunch during today's visit to the University Forest Sailershausen? (single choice)

- ☐ Packed lunch
- ☐ Restaurant/Alpine refuge
- ☐ Other (indicate________________________)

Q1.7.bis. What was the approximate cost for lunch per person? ___________ €/person

Q1.8. What other types of expenses have you incurred or do you plan to incur today?

Type of expenses	**Amount of expenses**
Equipment rental (e.g. for trekking, mountain bike, horse riding)	___________ €
Guided tours (e.g. environmental guides, hiking guides)	___________ €
Purchase of local food and wine products	___________ €
Purchase of local handicraft products	___________ €

Q1.9. What are the main reasons for your visit to the University Forest Sailershausen?
(from 1=not important to 5=very important)

Reasons	**1**	**2**	**3**	**4**	**5**
Hiking/Trekking					
Sport activities (e.g., mountain biking, running, horse riding)					
Relaxing into the nature					
Non-wood forest products collection (e.g., mushrooms, berries)					
Wildlife watching (e.g., birdwatching)					
Educational visit					
Work					
Other (indicate)					

Section 2 – Attitudes and preferences towards the University Forest Sailershausen

Q2.1. In your opinion what are the importance of the following benefits provided by University Forest Sailershausen?
(from 1=very low importance to 5=very high importance)

Benefits	**1**	**2**	**3**	**4**	**5**
Timber and bioenergy production					
Tourism and recreation opportunity					
Fauna and flora (biodiversity) conservation					
Climate change mitigation					
Provision of clean water					
Protection of cultural and historical values and local identity					
Creation of job opportunities for the local populations					
Other (indicate_______________________________________)					

Q2.2. What is your favourite University Forest Sailershausen landscapes from an **aesthetic point of view**?
(from 1= very ugly aesthetic landscape to 5= very nice aesthetic landscape)

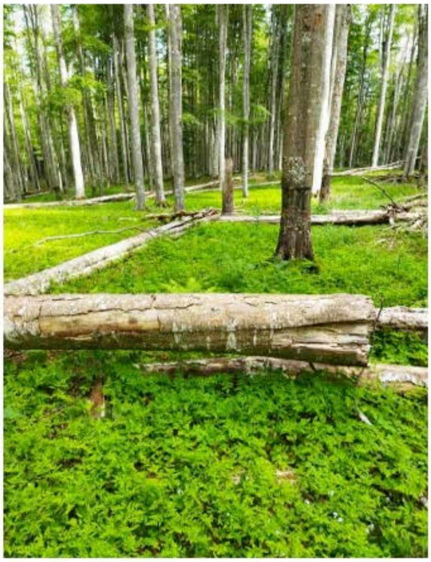
	1	2	3	4	5
Photo 1					
Photo 2					
Photo 3					

Photo 1

Photo 2

Photo 3

Q2.3. In your opinion, is standing (Snag) or ground (Log) deadwood a positive or negative element in forests (as shown in the figure below)? (single choice)



- ☐ Positive for fauna conservation (e.g., birds, mammals)
- ☐ Positive for flora conservation
- ☐ Positive for climate change mitigation
- ☐ Positive for soil fertilization
- ☐ Negative for the risk of forest fires
- ☐ Negative for the risk of harmful insects
- ☐ Negative for aesthetic deterioration
- ☐ I don't know

Section 3 - Personal information of respondent

We remind you that the answers to the questions given will be analysed in **aggregate** form and that the questionnaire is received **anonymously**.

Q3.1. Gender

☐ Male ☐ Female ☐ Other

Q3.2. Age

- ☐ Less than 20 years old
- ☐ 21-30 years old
- ☐ 31-40 years old
- ☐ 41-50 years old
- ☐ 51-60 years old
- ☐ 61-70 years old
- ☐ More than 70 years old

Q3.3. What is your level of education?

- ☐ Elementary school degree
- ☐ Technical or middle school degree
- ☐ High school degree
- ☐ University or post-University degree

Q3.4. What city/town do you live in? ___________________

Q3.5. Are you a member of any environmental association?

☐ YES ☐ NO

Q3.6. What was your individual annual after-tax income in 2022?

- ☐ I do not have personal income
- ☐ Up to € 14.999
- ☐ From € 15.000 and € 29.999
- ☐ From € 30.000 and € 44.999
- ☐ Over € 45.000

Q3.7 How often do you visit forest areas?

- ☐ Every day
- ☐ At least once per week
- ☐ At least once per month
- ☐ At least once per year
- ☐ Almost never

THE QUESTIONNAIRE IS FINISHED!

Thank you for your cooperation.

Annex 2

Table 1A: Importance of ecosystem services (mean±SD) provided by the University Forest Sailershausen (UFS) in accordance with the visitors' opinions (5-point Likert scale – from 1 not important to 5 very important). (Bold values indicate the highest value per column).

Tabelle 1A: Bedeutung der vom Universitätswald Sailershausen erbrachten Ökosystemleistungen (Mittelwert±Standardabweichung) gemäß der Besuchermeinungen (5-stufige-Likert-Skala – von 1 nicht wichtig bis 5 sehr wichtig). (Fettgedruckte Werte zeigen den höchsten Wert pro Spalte an).

	Timber and bioenergy	Recreation	Biodiversity	Climate change mitigation	Water provision	Cultural and historical values	Job opportunities
Gender							
Male	3.45±1.40	3.02±1.22	4.07±1.09	3.45±1.02	3.32±1.23	2.55±1.17	2.88±1.25
Female	3.56±1.20	2.96±1.13	**4.57±0.72**	3.87±1.11	**3.43±1.13**	3.11±1.11	3.16±1.08
Other	**4.25±0.96**	**3.50±1.29**	4.50±0.58	**4.25±0.50**	2.75±2.06	**3.25±0.50**	**3.50±1.00**
Age							
Less than 21 yr.	3.17±0.76	3.14±1-07	**4.71±0.49**	3.86±0.90	3.00±1.29	3.00±1.16	3.14±1.07
21-30 yr.	3.42±1.27	2.95±1.14	4.35±0.97	3.60±1.11	3.17±1.19	2.63±1.02	3.07±1.13
31-40 yr.	**3.92±1.38**	2.92±1.31	4.17±0.84	3.92±0.79	3.82±0.98	3.17±1.47	**3.50±1.24**
More than 40 yr.	3.57±1.45	**3.43±1.22**	4.29±0.99	**4.00±1.20**	**3.85±1.35**	**3.43±1.22**	2.46±1.27
Level of education							
Elementary degree	**3.56±1.59**	2.44±0.73	3.78±0.97	3.44±1.24	3.22±1.30	2.22±1.20	2.22±0.97
Middle school degree	3.38±1.69	**3.75±1.39**	**4.78±0.44**	**4.44±0.73**	**3.75±1.58**	**3.67±1.12**	3.00±1.20
High school degree	3.37±1.26	2.74±1.20	4.63±0.96	4.11±0.74	3.39±1.04	2.84±1.17	3.00±1.05
University degree	**3.56±1.19**	3.09±1.12	4.24±0.93	3.46±1.11	3.28±1.18	2.77±1.07	**3.19±1.16**
City of origin							
Würzburg city	2.90±1.03	**3.20±1.24**	**4.43±0.90**	**3.87±0.68**	3.10±1.08	2.72±1.16	**3.03±1.05**
Others	**3.84±1.23**	2.96±1.14	4.29±0.91	3.58±1.16	**3.47±1.18**	**2.84±1.11**	2.92±1.18
Environmental NGOs membership							
YES	3.09±1.23	3.05±1.13	4.09±0.75	**3.82±0.91**	**3.48±1.03**	2.50±0.96	**3.00±1.07**
NO	**3.63±1.22**	3.05±1.20	**4.44±0.95**	3.64±1.06	3.27±1.19	**2.91±1.16**	2.95±1.16
Income							
None	3.20±1-06	3.25±1.16	**4.70±0.47**	3.70±0.80	3.10±1.07	2.65±1.18	2.68±0.75
Up to €14,999	3.60±1.23	2.80±1.16	4.36±1.04	3.60±1.08	3.04±1.17	2.64±0.95	3.20±1.19
€ 15,000-29,999	3.09±1.22	3.27±1.19	4.18±0.98	3.55±1.13	**3.90±0.99**	**3.20±1.23**	**3.60±1.35**
€ 30,000-44,999	**3.75±1.60**	3.33±1.07	4.08±1.04	**3.92±0.95**	3.55±1.13	2.69±1.25	2.42±1.24
Over € 45,000	3.33±1.21	**3.67±0.82**	4.17±0.75	3.50±1.23	3.83±0.75	3.00±1.27	2.67±0.82

Table 2A: Visitors' preferences (mean±SD) towards three photos characterized by an increasing gradient of deadwood (5-point Likert scale – from 1 very ugly aesthetic landscape to 5 very nice aesthetic landscape). (Bold values indicate the highest value per column).

Tabelle 2A: Vorlieben der Besucher (Mittelwert±Standardabweichung) für drei Fotos, die sich durch einen zunehmenden Grad an Totholz auszeichnen (5-stufige Likert-Skala – von 1 sehr unästhetische Landschaft bis 5 sehr schöne ästhetische Landschaft). (Fettgedruckte Werte zeigen den höchsten Wert pro Spalte an).

	Photo 1	Photo 2	Photo 3
Gender			
Male	3.14±1.27	3.81±1.03	**4.12±1.14**
Female	**3.89±1.24**	**4.11±0.85**	4.02±1.02
Other	2.50±1.00	2.70±1.71	3.25±1.71
Age			
Less than 21 yr.	**4.14±1.22**	4.00±1.41	**4.57±0.79**
21-30 yr.	3.43±1.30	3.81±1.09	3.94±1.16
31-40 yr.	3.08±1.24	3.92±0.52	4.08±1.00
More than 40 yr.	3.54±1.45	**4.15±0.80**	4.31±1.03
Level of education			
Elementary degree	3.56±1.13	3.89±0.78	3.89±0.93
Middle school degree	3.44±1.42	4.00±1.32	**4.56±0.88**
High school degree	**3.79±1.40**	**4.11±1.10**	4.16±0.96
University degree	3.38±1.29	3.79±0.99	3.95±1.21
City of origin			
Würzburg city	3.31±1.26	3.68±1.19	3.68±1.25
Others	**3.57±1.35**	**3.98±0.92**	**4.23±0.99**
Environmental NGOs membership			
YES	3.35±1.36	**3.92±1.16**	**4.23±1.03**
NO	**3.61±1.30**	3.84±0.98	3.97±1.14
Income			
None	3.42±1.39	3.92±1.13	4.19±1.13
Up to € 14,999	**3.89±1.19**	3.89±1.05	3.93±1.07
€ 15,000-29,999	3.25±0.87	3.92±1.17	4.25±0.97
€ 30,000-44,999	3.06±1.48	3.63±0.96	3.88±1.26
Over € 45,000	3.57±1.40	**4.14±0.69**	**4.29±1.11**

141. Jahrgang (2024), Heft 2, S. 145–170

Austrian Journal of Forest Science
Centralblatt für das gesamte Forstwesen

Global Review of Literature on Forest Bathing

Globaler Überblick über die Literatur zum Waldbaden

A. Denche-Zamorano[1], Y. Rodríguez-Redondo[2*], J. Rojo-Ramos[3], V. Miguel-Barrado[4], A. Sánchez-Leal[3], E. Pérez-Calderon[4]

Keywords: Green therapy, nature-based therapy, nature therapy, healthcare, mental health, shirin-yoku

Schlüsselbegriffe: Grüne Therapie, naturbasierte Therapie, Naturtherapie, Gesundheitswesen, psychische Gesundheit, shirin-yoku

Abstract

Forest bathing, or shinrin-yoku, is a practice that involves immersion in forest environments to improve health and well-being, associated with stress reduction, immune system strengthening and mood enhancement. The aim of the present analysis is to quantify and evaluate scientific output, map collaboration among researchers, as well as identify prolific and prominent researchers, identify prolific journals, and analyze thematic trends. The set of 285 documents was extracted from the Web of Science, processed with Microsoft Excel and VOSviewer programs, and the analysis was performed following the traditional rules of bibliometrics. The number of publications show exponential growth, demonstrating the interest of the scientific community. The core of prolific journals is composed of only two journals, and the most prominent author is M. Yoshifumi from Chiba University (47 articles and 2208 citations). Japan and South Korea stand out as the most prolific countries. The researchers focus on the positive effects of forest bathing on mental health, especially in mitigating symptoms of depression, anxiety and stress.

[1] Promoting a Healthy Society (PHeSo) Research Group, Faculty of Sport Sciences, University of Extremadura, Cáceres, Spain
[2] Social Impact and Innovation in Health (InHEALTH), University of Extremadura, 06810 Mérida, Spain
[3] Physical Activity for Education, Performance and Health, Faculty of Sport Sciences, University of Extremadura, 10003 Caceres, Spain
[4] Department of Financial Economics and Accounting, Faculty of Economics and Business Administration, University of Extremadura, 06004 Badajoz, Spain
*Corresponding author: Y. Rodríguez-Redondo, yerayrguez@unex.es

Zusammenfassung

Waldbaden oder Shinrin-yoku ist eine Praxis, die das Eintauchen in Waldumgebungen zur Verbesserung der Gesundheit und des Wohlbefindens beinhaltet und mit Stressabbau, Stärkung des Immunsystems und Verbesserung der Stimmung in Verbindung gebracht wird. Ziel der vorliegenden Analyse ist es, die verfügbare wissenschaftlichen Literatur zu erfassen und zu bewerten, die Zusammenarbeit zwischen Forschern darzustellen sowie zentrale Forschende zu identifizieren, wichtige Zeitschriften zu identifizieren und thematische Trends zu analysieren. Die 285 Dokumente wurden aus Web of Science extrahiert, mit Microsoft Excel und VOSviewer bearbeitet und die Analyse wurde nach den traditionellen Gesetzen der Bibliometrie durchgeführt. Die Anzahl der Dokumente weist ein exponentielles Wachstum auf, was das Interesse der wissenschaftlichen Gemeinschaft an diesem Thema deutlich macht. Im Zentrum der Publikation stehen nur zwei Journale und der prominenteste Autor ist M. Yoshifumi von der Universität Chiba (47 Artikel und 2208 Zitate). Japan und Südkorea sind die Länder mit der höchsten wissenschaftlichen Output. Die Forscher konzentrieren sich auf die positiven Auswirkungen des Waldbadens auf die psychische Gesundheit, insbesondere auf die Linderung der Symptome von Depression, Angst und Stress.

1 Introduction

Today, due to climate change, population growth and uncontrolled development of cities, decreasing biodiversity and forest degradation, which has been steadily depleting over the last decades, are real problems for our planet (Sandifer *et al.*, 2015). This situation is motivating many collectives and individuals, world organisations, governments, public administrations and associations, to increase their concern and appreciation for natural environments, forests and ecosystems, given the benefits that nature and biodiversity can offer to quality of life and the health of the population, and the potential negative consequences resulting from their degradation (Bermejo-Martins *et al.*, 2022; Honeyman, 1992; Kotera *et al.*, 2022; Sandifer *et al.*, 2015; Ulrich, 1984; Ulrich *et al.*, 1991). For decades, researchers have studied how the beneficial relationship with nature has influenced human evolution and people's state of health (Q. Li, 2022; Millward & Appleton, 1988; Orians & Heerwagen, 1992; Wilson, 1984).

In 1982, the Japanese Ministry of Agriculture, Forestry and Fisheries introduced the term "Shinrin-yoku", which means "forest bathing" in Japanese (B. J. Park *et al.*, 2008). Forest bathing is a natural therapeutic technique that involves spending time in a forest or natural environment. This therapy is believed to have numerous positive effects on people's mental and physical health, as evidenced by several studies that investigated the relationship between forest bathing and its potential health benefits, such as: reducing stress (Miyazaki *et al.*, 2014a; Stier-Jarmer *et al.*, 2021; Zhu *et al.*, 2021), improving cardiovascular function (J. Lee *et al.*, 2009; Ochiai *et al.*, 2015;

Stier-Jarmer *et al.*, 2021; Tsunetsugu *et al.*, 2007), strengthening the immune system (Q. Li *et al*., 2007, 2008, 2010; Stier-Jarmer *et al.*, 2021) and alleviating symptoms of chronic diseases such as anxiety, depression and insomnia (Baek *et al.*, 2022; Kang *et al.*, 2022; H. Kim *et al.*, 2020; López-Pousa *et al.*, 2015; Qiu *et al.*, 2022; Stier-Jarmer *et al.*, 2021; Timko Olson *et al.*, 2020). We can establish some differences between forest bathing and forest therapy, both being nature-based practices aimed at promoting wellness, but differing in their approach and structure. Forest bathing, originating in Japan, involves immersing oneself in natural environments, mostly forests, to relax and connect with nature through sensory engagement and mindfulness. It emphasizes informal activities such as walking and meditation. Forest therapy, meanwhile, is a more structured approach, led by trained facilitators or therapists, that incorporates specific therapeutic techniques in the forest setting to address the physical, emotional and mental health needs of individuals. While both practices recognize the benefits of nature for personal wellness, forest therapy offers a more intentional and therapeutic framework for healing and support (Baek *et al.*, 2022; Kang *et al.*, 2022; H. Kim *et al.*, 2020; López-Pousa *et al.*, 2015; Qiu *et al.*, 2022; Stier-Jarmer *et al.*, 2021; Timko Olson *et al.*, 2020)..

Some authors suggest that by going into forests and surrounding oneself with trees and vegetation, the body and mind relax, benefiting from the healing effects of nature. This activity, such as forest bathing, could be done alone or in groups, including activities such as walking, meditation, yoga or just sitting and enjoying the environment (Yu *et al*., 2021). Even in pure virtual reality forests can serve as relaxation environment (Hejtmánek *et al.*, 2022).In this regard, one of the main benefits of forest bathing is its ability to improve people's mental health, notably its ability to reduce stress (Miyazaki *et al.*, 2014b; Stier-Jarmer *et al.*, 2021; Zhu *et al.*, 2021), as well as being an effective treatment for depression and anxiety (H. Li *et al.*, 2022; Q. Li *et al.*, 2016; Muro *et al*., 2021). Chronic stress is one of the leading causes of illness worldwide (Torrades, 2007) and spending time in nature has been shown to help lower cortisol levels (J. Lee *et al.*, 2011; B. J. Park *et al*., 2008; Tsunetsugu *et al.*, 2007, 2010), a stress-related hormone, in the body (Torrades, 2007). In addition, being surrounded by trees and vegetation also increases serotonin levels, a brain chemical related to well-being and happiness (B. J. Park *et al.*, 2020; S. Park *et al.*, 2021), thus improving people's mood and having positive effects on anxiety and depression (Muro *et al.*, 2021).

Forest bathing also has benefits for cardiovascular health (J. Lee *et al.*, 2009; Ochiai *et al.*, 2015; Stier-Jarmer *et al.*, 2021; Tsunetsugu *et al.*, 2007). Spending time in nature has been linked to a reduction in blood pressure (J. Lee *et al*., 2009; B. J. Park et al., 2007, 2010) and improved cardiovascular system function (Jimenez *et al*., 2021). In addition, walking in natural environments has positive effects on heart rate and respiration, which helps to strengthen the cardiovascular system (J. Lee *et al.*, 2009; B. J. Park *et al.*, 2008, 2010; Tsunetsugu *et al.*, 2007). Another important benefit of forest bathing is its ability to strengthen the immune system (Q. Li *et al.*, 2007, 2008, 2010), spending time in natural spaces has been found to be associated with an increase in the number of immune cells in the body, which helps prevent disease and accelerates recovery from existing illnesses (Q. Li *et al.*, 2007, 2008, 2010).

On the other hand, it has also been shown that forest bathing can have benefits in improving insomnia (H. Kim *et al.*, 2020; López-Pousa *et al.*, 2015). Studies have found that spending time in nature has the potential to enhance the quality of sleep, shorten the time required to initiate sleep, and extend the overall duration of sleep (H. Kim *et al.*, 2020; López-Pousa *et al.*, 2015). In addition, walking in natural environments can help regulate circadian rhythms, which may be beneficial for people with sleep disorders (H. Kim *et al.*, 2020; López-Pousa *et al.*, 2015).

Moreover, forest bathing not only has a prominent role in improving people's health, but the practice can also be understood as an opportunity for the improvement of socio-economic development in rural areas (Ohe *et al.*, 2017). The evolution of society, new tourism trends or the consequences of the COVID-19 pandemic have boosted the practice of recreational activities carried out in nature (Peng *et al.*, 2023; Vada *et al.*, 2019; Wen *et al.*, 2020). Thus, the importance of tourism modalities related to the health and well-being of tourists (Dillette *et al.*, 2020; Heung & Kucukusta, 2013; Peng *et al.*, 2023), with forest immersion being an emerging tourism practice worldwide (Farkic *et al.*, 2021; Kil *et al*., 2021; Ohe *et al*., 2017), should now be highlighted.

Thus, in previous literature there are some studies that have highlighted the effects that this immersion in nature can have from the point of view of different dimensions, thus adopting a multidisciplinary character (Farkic *et al.*, 2021; Ohe *et al.*, 2017). This study's main objective was to analyse the scientific production published in the Web of Science (WoS) on forest baths, checking the trend followed by annual publications, identifying the prolific and prominent researchers, journals with the highest production and lines of research on forest baths.

2 Material and Methods

2.1 Design and data sources

This scientific mapping was a descriptive bibliometric study based on data extracted from the Web of Science (WoS) core collection, in the editions: Science Citation Index Expanded (SCI-Expanded) and Social Sciences Citation Index (SSCI). Web of Science is a popular database for bibliometric analysis due to its broad multidisciplinary coverage, high quality content, citation tracking capabilities and advanced functionalities that allow efficient and reliable searching, filtering and generation of impact metrics; these being tools that other databases lack. (Ding & Li, 2020; Lu *et al.*, 2019; Mulet-Forteza *et al.*, 2019; Y. Wang *et al.*, 2022). The data strategy followed included the search vector: "forest bathing" (Topic) or "shinrin yoku" (Topic) or "Shirin-yoku"

(Topic) or "forest therapy" (Topic) and Articles or Review articles (Documents types); without time or language restrictions.

2.2 Data analysis

The phase of scientific development of the object of study was studied, applying Price's Law of Exponential Growth of Science (Dobrov *et al.*, 1979; Price, 1976). The author data was cleaned, eliminating duplicate identities. The most relevant journals in the subject were identified, applying Bradford's Law of concentration of scientific production, calculating the Bradford zones and the adjustment of the dataset to this law (Desai *et al.*, 2018; Morse & Leimkuhler, 1979; Venable *et al.*, 2016). This law states that the scientific literature can be divided into a core and fringe, where a small number of journals contain most of the important articles (Desai *et al.*, 2018; Morse & Leimkuhler, 1979; Venable *et al.*, 2016). Each of these zones should accumulate approximately 33% of the total papers. Lotka's Law was used to identify the prolific co-authors (Coile, 1977; Vega-Muñoz *et al.*, 2022). Hirsch index (h-index) was used to identify the most cited articles, considering as these, the h articles with h or more citations (Hirsch, 2005). Matching prolific co-authors to co-authors of the most cited papers, prolific co-authors who submitted one or more articles among the most cited papers were considered prominent co-authors (Mendoza-Muñoz *et al.*, 2022). A descriptive analysis was carried out with the countries involved in the topic. The keywords most used by the authors were located, applying Zipf's Law (Bulick & Bulick, 1978; Valderrama-Zurián *et al.*, 2021). Data processing and visualisation was carried out with Microsoft Excel v.2204 and VOSviewer software. The network plots generated for co-authors and keywords represented a strength of association analysis. This is a measure that indicates the strength of the relationship between two terms or elements in a bibliographic dataset. This measure is based on the frequency with which two terms appear together in the documents analyzed.

3 Results

We found 285 articles (234 articles and 51 article reviews) indexed in WoS and published between 1998 and 2022, assigned to 63 WoS categories. The categories with the highest number of articles were: Environmental Sciences (121), Public Environmental Occupational Health (119), Forestry (65), Environmental Studies (49) and Urban Studies (32).

The topic of study was found to be in a phase of exponential growth between 2006 and 2021 (the years prior to 2006 were excluded as there was no continuity in the annual publications, as well as the year 2022, as there was not yet complete data on the publications for that year), with an adjustment of 94.3% (R^2) (Figure 1).

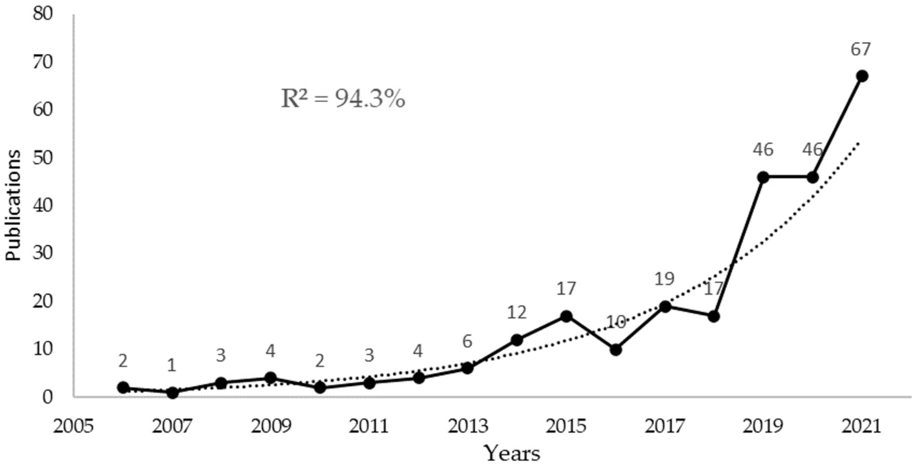


Figure 1: Exponential increase in yearly publications related to forest bathing.

Abbildung 1: Exponentieller Anstieg der Anzahl der Publikation zu Waldbaden.

The Bradford zones formed by the journals, according to the number of articles published, were adjusted, with a margin of error of 2%, to the estimates obtained by applying Bradford's law of dispersion of the scientific literature. The core group of journals with the most publications on the subject consisted of two journals that accounted for 43% of the articles: International Journal of Environmental Research and Public Health (94 articles) and Urban Forestry & Urban Greening (29 articles). Bradford's zone 1 was made up of 13 journals, accumulating 68% of the publications between the core journals and zone 1 (Table 1). In terms of the number of citations, the core was made up of three journals, which accounted for 37.9% of the citations: International Journal of Environmental Research and Public Health (2029 citations, 94 articles), Urban Forestry & Urban Greening (651 citations, 29 articles) and Ecosystem Services (486 citations, 1 article).

Table 1: Core and Zone 1 (Bradford's zone) of journals, according to number of articles published on forest bathing. JCR (Journal Citation Reports: Quartiles 1 to 4); Art. (Articles); % Art. (Percentage of total articles); % Acc. (Accumulated percentage of total number of articles); % O. A. (Percentage of articles of the journal in Open Access).

Tabelle 1: Kern und Zone 1 (Bradford's Zone) der Zeitschriften, hinsichtlich der Anzahl der Artikel publiziert zum Thema Waldbaden. JCR (Journal Citation Reports: Quartiles 1 bis 4); Art. (Artikel); % Art. (Anteil an Artikelgesamtanzahl); % Acc. (Kummulierter Anteil an Artikelgesamtanzahl); % O. A. (Anteil Artikel in Open Access Journalen).

Bradford's zones	Journals	Publishers	JCR	Art.	% Art.	% Acc.	Cites	%O.A.
Core	International Journal of Environmental Research and Public Health	MDPI	Q1	94	33%	33%	2029	99.8%
	Urban forestry & Urban Greening	Elsevier GMBH	Q1	29	10%	43%	651	5.4%
Zone 1	Forests	MDPI	Q1	19	7%	50%	232	99.8%
	Sustainability	MDPI	Q2	10	4%	53%	30	99.8%
	Journal of Physiological Anthropology	BMC	Q2.	8	3%	56%	249	100.0%
	Evidence-Based Complementary and Alternative Medicine	Hindawi LTD	Q2	6	2%	58%	246	98.1%
	Sante Publique	Soc Francaise Sante Publique	Q4	5	2%	60%	22	0.0%
	Environmental Health and Preventive Medicine	Springer	Q1	4	1%	61%	158	100.0%
	Frontiers in Psychology	Frontiers Media SA	Q2	4	1%	63%	53	99.7%
	Journal of Forest Research	Taylor & Francis LTD	Q3	4	1%	64%	46	2.3%
	Environmental Chemistry Letters	Springer	Q1	3	1%	65%	74	4.9%
	Healthcare	MDPI	Q2	3	1%	66%	4	99.9%
	International Journal of Environmental Health Research	Taylor & Francis LTD	Q2	3	1%	67%	18	2.0%
	Journal of Alternative and Complementary Medicine	Mary Ann Liebert INC	Q2	3	1%	68%	43	7.4%
	Landscape and Urban Planning	Elsevier	Q1	3	1%	69%	144	16.8%
	Scandinavian Journal of Forest Research	Taylor & Francis AS	Q2	3	1%	71%	275	17.9%

A total of 971 researchers were found with at least one article on the subject. With only one published article, 763 co-authors were found, with 122 researchers co-authoring only two articles, with the number of co-authors dropping to one researcher with 47 co-authored publications (Figure 2).

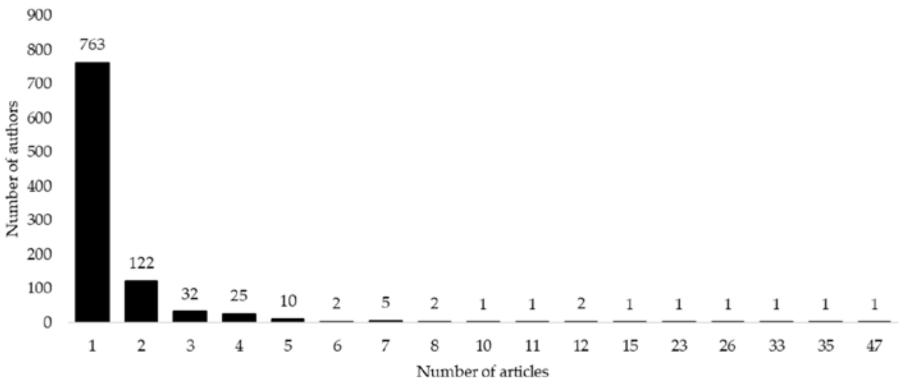


Figure 2: Histogram of publications per authors on forest bathing.

Abbildung 2: Histogramm der Anzahl Publikationen pro Autor zum Thema Waldbaden.

Applying Lotka's Law to the authors, it was estimated that the prolific authors should be the 31 authors with the highest number of publications. We found 54 co-authors with at least 4 articles, and 29 co-authors with 5 or more articles, so the latter were considered the prolific authors (Supplementary Material 1). A graph of the interrelationships of the 29 prolific co-authors was produced (Method: Fractionalization. Attraction: 6. Repulsion: -6). In this graph the colors represent groups of collaborating authors, the nodes are authors (their size indicates productivity/importance), and the lines indicate collaborations between them. Eight collaborative clusters were found. The main cluster was led by Yoshifumi Miyazaki, together with 14 other researchers (Figure 3).

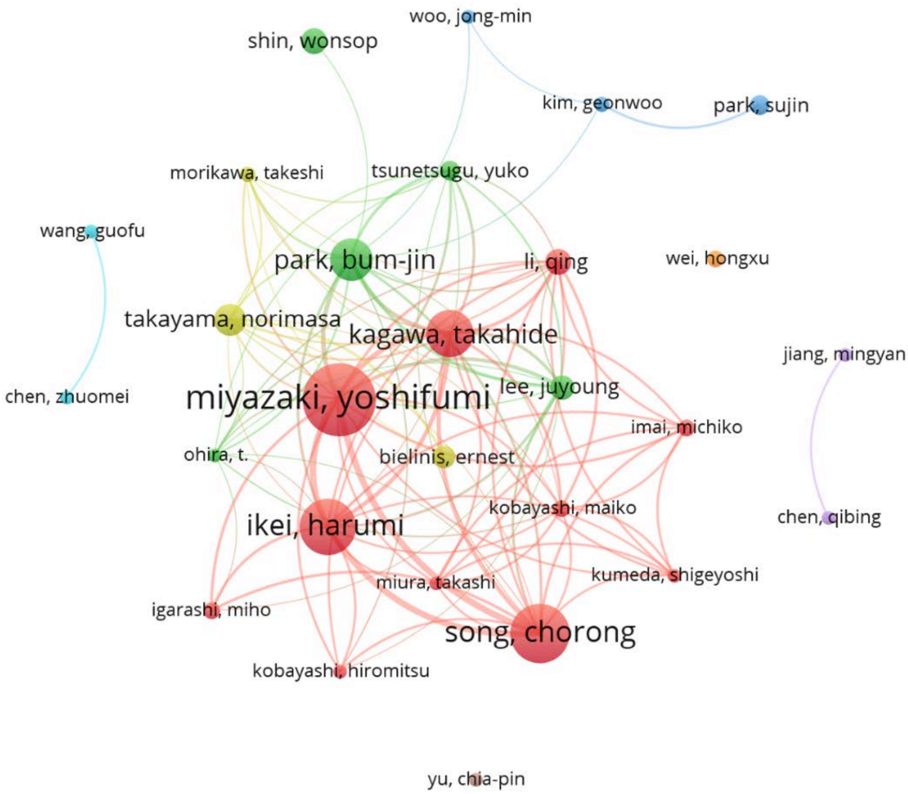


Figure 3: Interrelations of co-authors publishing on forest bathing. Each node (29 in total) represents a prolific author, and its size represents its productivity/influence. The lines between them represent their relationships, the thickness of the line the frequency of these relationships. Eight groups of contributors are represented by each color. These are: (1) Red: Y. Miyazaki, H. Ikei, C. Song, T. Kagawa, Q. Li, M. Imai, M. Kobayashi, S. Kumeda, T. Miura, H. Kobayashi and M. Igarashi. (2) Green: B.J. Park, J. Lee, T. Ohira, Y. Tsunetsugu and W. Shin. (3) Yellow: N. Takayama, E. Bielinis, T. Morikawa. (4) Blue: J.M. Woo, G. Kim and S. Park. (5) Light blue: G. Wang and Z. Chen. (6) Purple: M. Jiang and Q. Chen. (7) Orange: H. Wei. (8) Brown: C.P. Yu.

Abbildung 3: Beziehungen zwischen Koautoren mit Publikationen zum Thema Waldbaden. Jeder Knoten (29 insgesamt) zeigt einen Autor und die Größte des Knotens dessen Produktivität / Einfluss. Die Linien zeigen die Beziehungen zwischen den Autoren und die Linienstärke die Häufigkeit der Beziehungen. Die acht Gruppen warden mit Farben dargestellt.: (1) Rot: Y. Miyazaki, H. Ikei, C. Song, T. Kagawa, Q. Li, M. Imai, M. Kobayashi, S. Kumeda, T. Miura, H. Kobayashi and M. Igarashi. (2) Grün: B.J. Park, J. Lee, T. Ohira, Y. Tsunetsugu and W. Shin. (3) Gelb: N. Takayama, E. Bielinis, T. Morikawa. (4) Blau: J.M. Woo, G. Kim and S. Park. (5) Hellblau: G. Wang and Z. Chen. (6) Purpur: M. Jiang and Q. Chen. (7) Orange: H. Wei. (8) Braun: C.P. Yu.

To identify the prominent co-authors the most cited articles (documents with 47 or more cites), according to the h-index, and prolific co-authors (5 or more documents) were combined, identifying 22 authors with at least one paper among the most cited papers on forest bathing. Yoshifumi Miyazaki emerged as the prominent co-author (47 articles and 2208 citations, 18 most cited papers). Table 2 shows the prominent co-authors in the field of study.

Table 2: Prominent co-authors on forest bathing. Numbers in in brackets (asterisk) indicate number of documents included in the set of most cited documents (table S1).

Tabelle 2: Wichtige Koautoren zum Thema Waldbaden. Zahlen in Klammern (Stern) zeigen die Anzahl Publikationen, die auch unter den meist zitierten Publikationen sind (Tabelle S1).

Authors	Affiliation (Country/Region)	Articles (*)	Citations
Miyazaki, Yoshifumi	Chiba University (Japan)	47 (18)	2208
Song, Chorong	Chiba University (Japan)	35 (9)	1291
Ikei, Harumi	Chiba University (Japan)	33 (9)	1287
Kagawa, Takahide	Forestry Forest Products Research Institute (Japan)	26 (8)	2069
Park, Bum-Jin	Chungnam National University (South Korea)	23 (9)	1500
Takayama, Norimasa	Forestry Forest Products Research Institute (Japan)	15 (5)	804
Li, Qing	Nippon Medical School (Japan)	12 (9)	1016
Lee, Juyoung	Chiba University (Japan)	11 (4)	594
Bielinis, Ernest	University of Warmia Mazury (Poland)	10 (1)	229
Tsunetsugu, Yuko	Chiba University (Japan)	8 (7)	1347
Kobayashi, Maiko	Forestry Forest Products Research Institute (Japan)	7 (6)	652
Imai, Michiko	Chiba University (Japan)	7 (4)	355
Igarashi, Miho	Chiba University (Japan)	7 (2)	281
Morikawa, Takeshi	Chiba University (Japan)	6 (2)	269
Kim, Geonwoo	Korea Forest Research Institute (South Korea)	6 (1)	56
Ohira, T.	Forestry Forest Products Research Institute (Japan)	5 (3)	619
Kumeda, Shigeyoshi	Forestry Forest Products Research Institute (Japan)	5 (4)	341
Miura, Takashi	Forestry Forest Products Research Institute (Japan)	5 (4)	341
Woo, Jong-Min	Inje University (South Korea)	5 (3)	226
Wang, Guofu	Zhejiang Forestry Acad (China)	5 (2)	225
Yu, Chia-Pin	National Taiwan University (Taiwan)	5 (2)	192
Chen, Zhuomei	Zhejiang Forestry Acad (China)	5 (2)	151

The set of papers consisted of 280 articles written in English, 4 in French and 1 in German. Japan (78 articles, 4011 citations), South Korea (69 articles, 1665 citations), China (49 articles, 788 citations) and United States of America (34 articles, 1876 citations) were the countries with the highest number of publications, among the 35 countries found, publishing on the subject. Figure 4 shows the interrelationships between countries, the size of the node is a function of the number of articles cited from each country, while the colour is a function of the average date of publication, where it can be seen how there are countries that have been adding to the subject in recent years (Method: Fractionalization. Attraction: 10. Repulsion: -6). The lines between the nodes (countries) would indicate scientific collaborations between researchers from different countries in the publication of scientific articles.

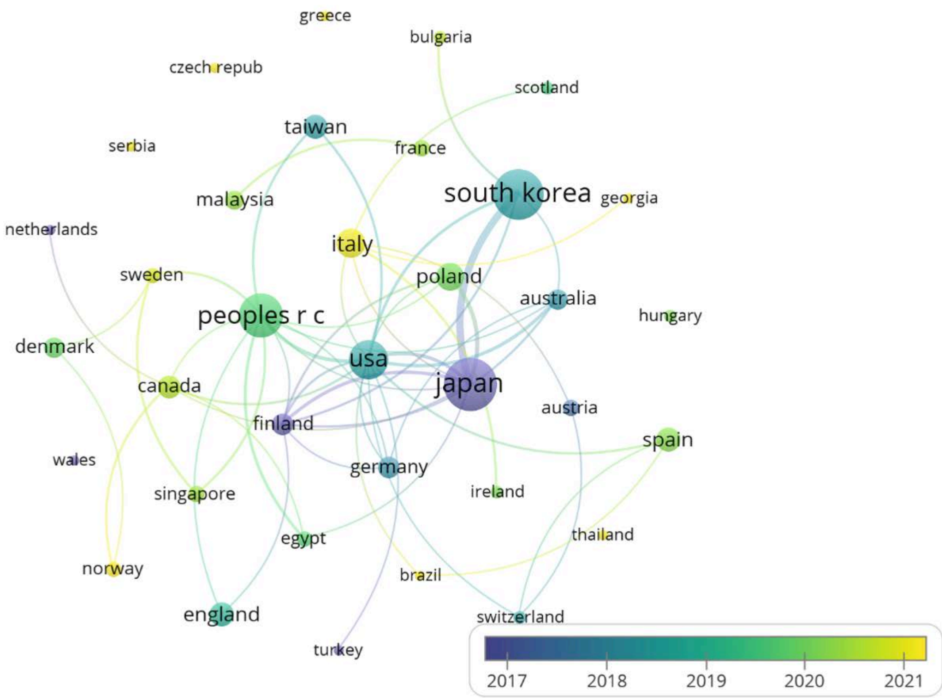


Figure 4: Interrelations of countries/regions and citations on forest bathing. Each node (35 in total) represents a region/country, and its size represents the number of citations that each one accumulates. The lines between them represent the collaborations between them, the thickness of the line the frequency of these. The color of each node represents the average year of publication.

Abbildung 4: Beziehungen zwischen Ländern/Regionen und Zitate zu Waldbaden. Jeder Knoten (insgesamt 35) zeigt ein Land/Region und die Größte zeigt die Anzahl der Zitate, die dieser gesammelt hat. Die Linien dazwischen zeigen die Kollaborationen an und die Linienstärke deren Häufigkeit. Die Farbe der Knoten zeigen das Jahresmittel der Publikationszeitpunkte.

Forty-seven articles were found with at least 47 citations, these being the most prominent articles on the object of study. The most cited article was a review entitled "Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation" with 486 citations (Sandifer et al., 2015), followed by "The influence of urban green environments on stress relief measures: A field experiment" (432 citations) (Tyrväinen et al., 2014) y "The effect of contact with natural environments on positive and negative affect: A meta-analysis" (265 citations) (McMahan & Estes, 2015). Table S1 (Supplementary materials) shows the 47 most cited articles.

Applying Zipf's Law to the keywords used most by the authors, 26 words stood out, used in at least 8 articles, being: forest therapy (74 occurrences), forest bathing (64), shinrin.yoku (37), heart rate variability (28) and blood pressure (21). Figure 5 shows the interrelationship graph of the 26 keywords most frequently used by the authors.

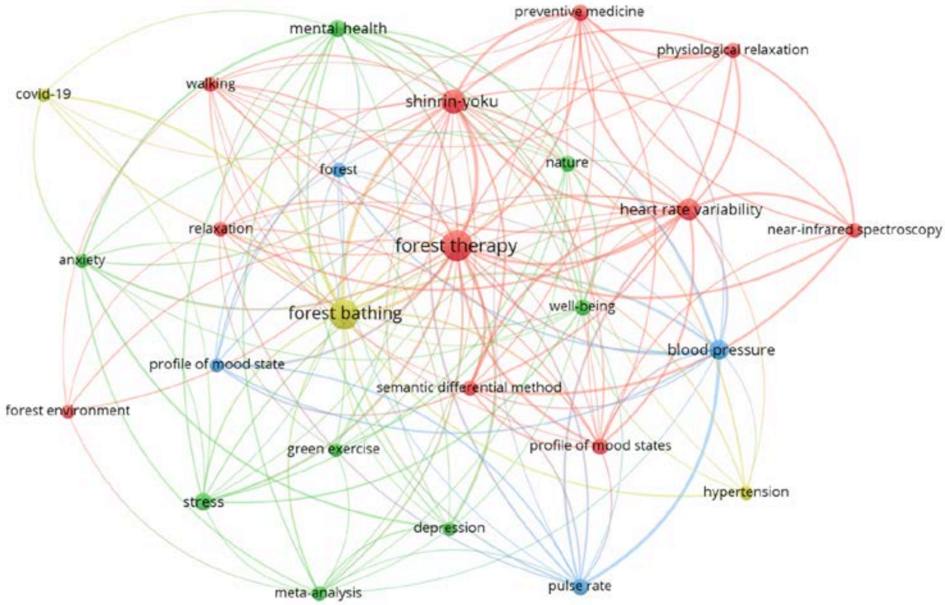


Figure 5: Interrelationships of the most used keywords on forest bathing. Each node (26 in total) represents an author keyword, and its size represents the number of occurrences it has. The lines between them represent the number of times they appear together; the thickness of the line represents their frequency. The color represents the groupings formed according to the occurrences. These are: (1) Red: Forest therapy, shinrin-yoku, heart rate variability, semantic differential method, profile of mood states, forest environment, relaxation, walking, preventive medicine, physiological relaxation and near-infrared spectroscopy. (2) Green: Well-being, nature, mental health, anxiety, stress, green exercise and meta-analysis. (3) Blue: Forest, blood presure, profile of mood state and pulse rate. (4) Yellow: Forest bathing, hypertension and covid-19.

Abbildung 5: Beziehungen zwischen den am häufigsten verwendeten Schlagwörter in Publikationen zum Thema Waldbaden. Jeder Knoten (26 insgesamt) zeigt ein Schlagwort und die Größe die Häufigkeit der Verwendung. Die Linien zeigen gleichzeitige Verwendung zweier Schlagwörter und die Linenstärke die Häufigkeit. Die Farben zeigen identifizierte Gruppen. (1) Rot: Forest therapy, shinrin-yoku, heart rate variability, semantic differential method, profile of mood states, forest environment, relaxation, walking, preventive medicine, physiological relaxation and near-infrared spectroscopy. (2) Grün: Well-being, nature, mental health, anxiety, stress, green exercise and meta-analysis. (3) Blau: Forest, blood presure, profile of mood state and pulse rate. (4) Gelb: Forest bathing, hypertension and covid-19.

4 Discussion

This is the first bibliometric analysis based on published research on forest baths on the WoS database (285 documents), verifying the trend followed by annual publications on the subject, identifying the most productive and cited co-authors and journals, the countries most involved in this object of study, the most referenced documents and the mostly used keywords by co-authors. However, we found similar bibliometrics based on the Scopus database (Paletto *et al.*, 2024), two mappings of research in the field of natural therapies (Rodríguez-Redondo *et al.*, 2023; X. Wang *et al.*, 2022), and a review using a different methodology than our study, which does not use the traditional laws of bibliometrics (Hansen *et al.*, 2017), in addition to literature reviews, scoping reviews and systematic reviews (Antonelli *et al.*, 2019; Corazon *et al.*, 2019; Hansen & Jones, 2020; Ideno *et al.*, 2017; Jones *et al.*, 2021; Langemeyer *et al.*, 2021; I. Lee *et al.*, 2017; Oh *et al.*, 2017; Rojas-Rueda *et al.*, 2019; Vibholm *et al.*, 2020; Wolf *et al.*, 2020).

We found that annual publications on forest baths followed a trend of exponential growth, with a very high volume of publications in the last three years, far exceeding the number of publications accumulated in the previous 20 years. These findings show the high interest of researchers, journals and publishers in this topic, giving support to a study like this one. Although they did not demonstrate exponential growth in annual publications on forest therapies, X. Wang *et al.* (2022). found a massive increase in annual publications on the topic. We also find growing interest outside the scientific field, in Germany organizations have promoted projects such as Kur- und Heilwald, which focus on the promotion of health and well-being through contact with nature. Projects of this type favor the discovery of this type of therapies making them more visible to the population.

Two journals that made up Bradford's core, International Journal of Environmental Research and Public Health (MDPI) and Urban forestry & Urban Greening (Elsevier), standing out as the most productive journals in the subject, coincided with the most productive journals found in the bibliometrics of Wang et al (X. Wang *et al.*, 2022). In this study, journals such as Forests (MDPI), Sustainability (MDPI) and Frontiers in Psychology (Frontiers Media) also appeared in the top 10 journals with the highest number of publications.

The term Shinrin-yoku (forest bathing) has its origins in Japan (B. J. Park *et al.*, 2010), from where it became established in the rest of Eastern Asia countries, and later expanded to the rest of the world. Thus, Japan is the country with the highest number of publications, followed by South Korea and China, something that has been reflected in the most productive authors: Miyazaki, Song, Ikei, Kagawa, Takayama, Li, among others, all of them Japanese; Park, Shin or Kim, co-authors from South Korea; and Wei, Chen, or Jiang, co-authors from China. All of them are among the prolific co-authors, coinciding with the most productive countries in forest therapies (X. Wang *et al.*, 2022). Similarly, many of the most cited papers were published by authors from those countries (J. Lee *et al.*, 2009, 2011, 2014; Q. Li *et al.*, 2008; Morita *et al.*, 2007; B. J. Park *et al.*, 2011). Among the prominent co-authors, a single co-author from a Western country is present, Bielinis (Poland), co-authored 10 papers, with "The effect of winter forest bathing on psychological relaxation of young Polish adults" (Bielinis *et al.*, 2018) being his most cited paper. However, the three most cited papers were published by co-authors from the USA (McMahan & Estes, 2015; Sandifer *et al.*, 2015) and Finland (Tyrväinen *et al.*, 2014). The most cited paper assessed the state of knowledge on the relationships between human health and nature and biodiversity, as well as the positive health effects found (Sandifer *et al.*, 2015), concluding that more initiatives and research by administrations and researchers are needed. Tyrväinen *et al*. (2014) investigated the psychological and physiological effects of short-term visits to urban natural environments, suggesting that short-term visits to natural areas have positive effects on the relief of perceived stress compared to the built environment, similar to the third most cited paper by McMahan and Estes (McMahan & Estes, 2015).

The effects of forest baths on mental health, such as anxiety and depression states, psychological discomfort or stress have been highly concerned among researchers and so numerous articles and reviews have been found that have evaluated this, finding positive health effects (Bielinis *et al.*, 2019; Chen *et al.*, 2018; J. G. Kim *et al.*, 2020; Kotera *et al.*, 2022; Q. Li, 2019; Song *et al.,* 2018), although results have been found in which they have reported that these effects are not clear (Vibholm *et al.*, 2020). Therefore for the above pathologies, forest baths have been presented as alternative non-pharmacological treatments (Rosa *et al*., 2021), as well as means of prevention of mental pathologies, or of other pathologies such as hypertension (Bielinis et al., 2021; Ochiai *et al.*, 2015; Wajchman-Świtalska *et al.*, 2021; Yeon *et al.*, 2021; Zhang *et al.*, 2020), finding positive effects on blood pressure. Relaxation exercises, physical activity and exercise in natural spaces, such as green exercise, or walking in green spaces, have been some of the topics of interest for researchers in which positive effects on the physical and mental health and well-being of participants have been evaluated (Kondo *et al.*, 2018; H. Li *et al.*, 2021; Rogerson & Barton, 2015; Shin *et al*., 2012; Yamaguchi *et al.*, 2006) even in virtual reality forest (Hejtmánek *et al.*, 2022).

When comparing what we found with what was found by Paletto *et al.* (2024) we observed that 285 documents were found in WoS, compared to the 224 found by them. In both cases, the oldest document is the one written by Ohtsuka et al. (1998), entitled "Shinrin-yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients", although they also found another document in the same year by the same author. The annual growth curves are similar in both databases, finding a gap between 1999 and 2005, both included. The most cited keywords coincide and when analyzing the connections between them we find a similar distribution, in the case of the review carried out in Scopus they did not apply Zipf's law to check the most relevant set of words, so they selected the words with four or more appearances, this being what is observed in their network graph. When we compare countries between both databases we observe that Japan and the United States present a similar number of documents, but that South Korea and China present a difference of 41 documents in the first case and 24 documents in the second, the number of publications located in Scopus being lower. Finally, when comparing the most powerful organizations resulting from the Scopus analysis with the most relevant authors in the WoS analysis, we find a certain discrepancy. The analysis carried out by Paletto *et al.* (2024) indicates that "Forestry and Forest Products Research Institute" (Japan) is the most powerful organization and "Chiba University" (Japan) the second, in the present analysis the opposite is found, the authors of "Chiba University" (Japan) accumulate a greater number of documents than those of "Forestry and Forest Products Research Institute" (Japan), this may be due to the difference in the number of documents that exists between both databases. We could say with this comparison that when locating documents related to forest toilets it would be more appropriate to use the Web of Science, since it provides a greater number of documents.

More research is needed to explore the effects of forest bathing in different populations, with different cultural characteristics, on the mental and physical health and quality of life of its practitioners. Recently in other countries research is emerging, with new researchers joining in and collaborations established between research groups are filling the gaps in this field of knowledge.

4.1 Limitations and Practical applications

This study was based on the publications of journals indexed in the WoS main collection, despite being the most widely used database in bibliometric studies and one of the most prestigious in the scientific field, this study presents a selection bias, as it does not include documents that could be published in journals indexed in other databases, this being an important limitation. Future research could carry out bibliometric studies that take into account other databases. This research provides important information on who are the most important researchers in the field of forest baths, which journals are most involved, most cited papers and most important research trends. This could facilitate both collaboration between researchers and the identification of research trends.

5 Conclusions

Forest bathing is a growing interest in the scientific field, with annual publications following an exponential growth trend. Countries such as Japan, South Korea and China are the leading producers in this field, with Yoshifumi Miyazaki, the prominent co-author, and International Journal of Environmental Research and Public Health, the journal with the highest number of publications.

The effects of forest bathing on mental health, such as depression, anxiety or stress, are the topics of greatest interest among researchers, and positive effects of forest bathing have been found on the symptomatology of all of them.

Forest baths have been proposed as a preventive treatment to improve mental health and reduce blood pressure. Among the activities to be carried out during forest bathing, relaxation exercises, physical exercise in nature or green exercise, or walking in the natural environment, are some of the activities that have been found in published research.

In short, given the growing interest in this practice from a scientific point of view and taking it to a more practical dimension, we believe that it is necessary to promote this type of therapeutic tourism based on natural resources, whose benefits could be defined in two ways: on the one hand, by promoting the socio-economic development of rural populations, while having a minimal impact on the environment. And, on the other hand, in terms of health, with all the benefits that this immersion in nature means for the health of the people who practise it. To this end, it would be necessary to increase the number of projects such as Kur- und Heilwald in Germany, which promote the use of natural resources.

Acknowledgments

The author ADZ (FPU20/04201) was supported by a grant from the Spanish Ministry of Education, Culture and Sport. Grants FPU20/04201 funded by NCIN/AEI/10.13039/501100011033 and, as appropriate, by “European Social Found Investing in your future” or by “European Union Next Generation EU/PRTR”.

Supplementary Material

Table S1: Most cited articles on forest bathing.

Tabelle S1: Meist zitierte Artikel zum Thema Waldbaden.

Article Title. Author (Year)	Type	Citations	Publisher	Journal Abbreviation
Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Sandifer et al. (2015)	Review	486	ELSEVIER	ECOSYST SERV
The influence of urban green environments on stress relief measures: A field experiment. Tyrvainen et al. (2014)	Article	432	ACADEMIC PRESS LTD- ELSEVIER SCIENCE LTD	J ENVIRON PSYCHOL
The effect of contact with natural environments on positive and negative affect: A meta-analysis. McMahan et al. (2015)	Article	265	ROUTLEDGE JOURNALS, TAYLOR & FRANCIS LTD	J POSIT PSYCHOL
Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. Lee et al. (2011)	Article	260	W B SAUNDERS CO LTD	PUBLIC HEALTH
Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. Morita et al (2007)	Article	212	W B SAUNDERS CO LTD	PUBLIC HEALTH
Shinrin-Yoku (Forest Bathing) and Nature Therapy: A State-of-the-Art Review. Hansen et al. (2017)	Review	177	MDPI	INT J ENV RES PUB HE
Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. Li et al. (2008)	Article	174	SAGE PUBLICATIONS INC	INT J IMMUNOPATH PH
A systematic review of evidence for the added benefits to health of exposure to natural environments. Bowler et al. (2010)	Article	160	BMC	BMC PUBLIC HEALTH
Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. Lee et al. (2014)	Article	154	TAYLOR & FRANCIS AS	SCAND J FOREST RES
Relationship between psychological responses and physical environments in forest settings. Park et al. (2011)	Article	139	ELSEVIER SCIENCE BV	LANDSCAPE URBAN PLAN
Influence of Forest Therapy on Cardiovascular Relaxation in Young Adults. Lee et al. (2014)	Article	139	HINDAWI LTD	EVID-BASED COMPL ALT
A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. Li et al. (2008)	Article	137	BIOLIFE SAS	J BIOL REG HOMEOS AG
Physiological Effects of Forest Recreation in a Young Conifer Forest in Hinokage Town, Japan. Park et al. (2009)	Article	129	FINNISH SOC FOREST SCIENCE-NATURAL RESOURCES INST FINLAND	SILVA FENN
Physiological Effects of Nature Therapy: A Review of the Research in Japan. Song et al. (2016)	Review	126	MDPI	INT J ENV RES PUB HE
Green spaces and mortality: a systematic review and meta-analysis of cohort studies. Rojas-Rueda et al. (2019)	Review	122	ELSEVIER SCI LTD	LANCET PLANET HEALTH
Green Perspectives for Public Health: A Narrative Review on the Physiological Effects of Experiencing Outdoor Nature. Haluza et al. (2014)	Article	120	MDPI	INT J ENV RES PUB HE
Emotional, Restorative and Vitalizing Effects of Forest and Urban Environments at Four Sites in Japan. Takayama et al. (2014)	Article	114	MDPI AG	INT J ENV RES PUB HE
Physiological and Psychological Effects of Forest Therapy on Middle-Aged Males with High-Normal Blood Pressure. Ochiai et al. (2015)	Article	106	MDPI	INT J ENV RES PUB HE
Therapeutic effect of forest bathing on human hypertension in the elderly. Mao et al. (2012)	Article	101	ELSEVIER	J CARDIOL
Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. Park et al. (2008)	Article	96	TAYLOR & FRANCIS AS	SCAND J FOREST RES
The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. Yamaguchi et al. (2006)	Article	88	CAMBRIDGE MED PUBL	J INT MED RES
Phytoncides (wood essential oils) induce human natural killer cell activity. Li et al. (2006)	Article	88	TAYLOR & FRANCIS INC	IMMUNOPHARM IMMUNOT
Physiological and Psychological Effects of a Forest Therapy Program on Middle-Aged Females. Ochiai et al. (2015)	Article	88	MDPI	INT J ENV RES PUB HE

The Effect of Cognitive Behavior Therapy-Based Forest Therapy Program on Blood Pressure, Salivary Cortisol Level, and Quality of Life in Elderly Hypertensive Patients. Sung et al. (2012)	Article	87	TAYLOR & FRANCIS INC	CLIN EXP HYPERTENS
Physiological and Psychological Effects of a Walk in Urban Parks in Fall. Song et al. (2014)	Article	85	MDPI	INT J ENV RES PUB HE
Does green space matter? Exploring relationships between green space type and health indicators. Akpinar et al. (2016)	Article	85	ELSEVIER GMBH	URBAN FOR URBAN GREE
Can Natural and Virtual Environments Be Used To Promote Improved Human Health and Wellbeing?. Depledge et al. (2011)	Article	80	AMER CHEMICAL SOC	ENVIRON SCI TECHNOL
Physiological and psychological responses of young males during spring-time walks in urban parks. Song et al. (2014)	Article	80	BMC	J PHYSIOL ANTHROPOL
The effect of winter forest bathing on psychological relaxation of young Polish adults. Bielinis et al. (2018)	Article	78	ELSEVIER GMBH, URBAN & FISCHER VERLAG	URBAN FOR URBAN GREE
Effects of Short-Term Forest Bathing on Human Health in a Broad-Leaved Evergreen Forest in Zhejiang Province, China. Xiang et al. (2012)	Article	77	CHINESE CENTER DISEASE CONTROL & PREVENTION	BIOMED ENVIRON SCI
Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. Kondo et al. (2018)	Review	76	ELSEVIER SCI LTD	HEALTH PLACE
Shinrin-yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients. Ohtsuka et al. (1998)	Article	73	SPRINGER	INT J BIOMETEOROL
Health and well-being benefits of spending time in forests: systematic review. Oh et al. (2017)	Review	72	SPRINGER	ENVIRON HEALTH PREV
Effect of Forest Walking on Autonomic Nervous System Activity in Middle-Aged Hypertensive Individuals: A Pilot Study. Song et al. (2015)	Article	70	MDPI	INT J ENV RES PUB HE
Effects of Forest Therapy on Depressive Symptoms among Adults: A Systematic Review. Lee et al. (2017)	Review	68	MDPI	INT J ENV RES PUB HE
Effects of Short Forest Bathing Program on Autonomic Nervous System Activity and Mood States in Middle-Aged and Elderly Individuals. Yu et al. (2017)	Article	66	MDPI	INT J ENV RES PUB HE
The effect of virtual reality forest and urban environments on physiological and psychological responses. Yu et al. (2018)	Article	66	ELSEVIER GMBH	URBAN FOR URBAN GREE
The effects of forest therapy on depression and anxiety in patients with chronic stroke. Chun et al. (2017)	Article	62	TAYLOR & FRANCIS LTD	INT J NEUROSCI
Effects of Horticultural Therapy on Asian Older Adults: A Randomized Controlled Trial. Ng et al. (2018)	Article	56	MDPI	INT J ENV RES PUB HE
Effects of viewing forest landscape on middle-aged hypertensive men. Song et al. (2017)	Article	52	ELSEVIER GMBH	URBAN FOR URBAN GREE
Effects of forest bathing (shinrin-yoku) on levels of cortisol as a stress biomarker: a systematic review and meta-analysis. Antonelli et al. (2019)	Review	52	SPRINGER	INT J BIOMETEOROL
The Effects of Forest Therapy on Coping with Chronic Widespread Pain: Physiological and Psychological Differences between Participants in a Forest Therapy Program and a Control Group. Han et al. (2016)	Article	49	MDPI	INT J ENV RES PUB HE
The Prefrontal Cortex Activity and Psychological Effects of Viewing Forest Landscapes in Autumn Season. Joung et al. (2015)	Article	48	MDPI	INT J ENV RES PUB HE
Evaluating the relaxation effects of emerging forest-therapy tourism: A multidisciplinary approach. Ohe et al. (2017)	Article	48	ELSEVIER SCI LTD	TOURISM MANAGE
Community greenness, blood pressure, and hypertension in urban dwellers: The 33 Communities Chinese Health Study. Yang et al. (2019)	Article	47	PERGAMON-ELSEVIER SCIENCE LTD	ENVIRON INT
Therapeutic Potential of Volatile Terpenes and Terpenoids from Forests for Inflammatory Diseases. Kim et al. (2020)	Review	47	MDPI	INT J MOL SCI
Lower COVID-19 mortality in Italian forested areas suggests immunoprotection by Mediterranean plants. Roviello et al. (2021)	Article	47	SPRINGER HEIDELBERG	ENVIRON CHEM LETT

References

Antonelli, M., Barbieri, G., & Donelli, D. (2019). Effects of forest bathing (shinrin-yoku) on levels of cortisol as a stress biomarker: A systematic review and meta-analysis. International Journal of Biometeorology, 63(8), 1117–1134. https://doi.org/10.1007/S00484-019-01717-X

Baek, J. E., Jung, J. H., Shin, H. J., Kim, S. H., Sung, S. Y., Park, S. J., Hahm, S. C., Cho, H. Y., & Lee, M. G. (2022). Effects of Forest Healing Anti-Aging Program on Psychological, Physiological, and Physical Health of Older People with Mild Cognitive Impairment. International Journal of Environmental Research and Public Health, 19(8). https://doi.org/10.3390/IJERPH19084863

Bermejo-Martins, E., Pueyo-Garrigues, M., Casas, M., Bermejo-Orduna, R., & Villarroya, A. (2022). A Forest Bathing Intervention in Adults with Intellectual Disabilities: A Feasibility Study Protocol. International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 13589, 19(20), 13589. https://doi.org/10.3390/IJERPH192013589

Bielinis, E., Janeczko, E., Takayama, N., Zawadzka, A., Słupska, A., Piętka, S., Lipponen, M., & Bielinis, L. (2021). The effects of viewing a winter forest landscape with the ground and trees covered in snow on the psychological relaxation of young Finnish adults: A pilot study. PLOS ONE, 16(1), e0244799. https://doi.org/10.1371/JOURNAL.PONE.0244799

Bielinis, E., Jaroszewska, A., Łukowski, A., & Takayama, N. (2019). The Effects of a Forest Therapy Programme on Mental Hospital Patients with Affective and Psychotic Disorders. International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 118, 17(1), 118. https://doi.org/10.3390/IJERPH17010118

Bielinis, E., Takayama, N., Boiko, S., Omelan, A., & Bielinis, L. (2018). The effect of winter forest bathing on psychological relaxation of young Polish adults. Urban Forestry & Urban Greening, 29, 276–283. https://doi.org/10.1016/J.UFUG.2017.12.006

Bulick, S., & Bulick, S. (1978). Book Use as a Bradford-Zipf Phenomenon. College & Research Libraries, 39(3), 215–219. https://doi.org/10.5860/crl_39_03_215

Chen, H. T., Yu, C. P., & Lee, H. Y. (2018). The Effects of Forest Bathing on Stress Recovery: Evidence from Middle-Aged Females of Taiwan. Forests 2018, Vol. 9, Page 403, 9(7), 403. https://doi.org/10.3390/F9070403

Coile, R. C. (1977). Lotka's Frequency Distribution of Scientific Productivity. Journal of the American Society for Information Science, 28, 1986.

Corazon, S. S., Sidenius, U., Poulsen, D. V., Gramkow, M. C., & Stigsdotter, U. K. (2019). Psycho-Physiological Stress Recovery in Outdoor Nature-Based Interventions: A Systematic Review of the Past Eight Years of Research. International Journal of Environmental Research and Public Health, 16(10). https://doi.org/10.3390/IJERPH16101711

Desai, N., Veras, L., & Gosain, A. (2018). Using Bradford's law of scattering to identify the core journals of pediatric surgery. The Journal of Surgical Research, 229, 90–95. https://doi.org/10.1016/J.JSS.2018.03.062

Dillette, A. K., Douglas, A. C., & Andrzejewski, C. (2020). Dimensions of holistic wellness as a result of international wellness tourism experiences. Https://Doi.Org/10.1080/13683500.2020.1746247, 24(6), 794–810. https://doi.org/10.1080/13683500.2020.1746247

Ding, Z., & Li, F. (2020). Publications in Integrative and Complementary Medicine: A Ten-Year Bibliometric Survey in the Field of ICM. Evidence-Based Complementary and Alternative Medicine, 2020. https://doi.org/10.1155/2020/4821950

Dobrov, G. M., Randolph, R. H., & Rauch, W. D. (1979). New options for team research via international computer networks. Scientometrics 1979 1:5, 1(5), 387–404. https://doi.org/10.1007/BF02016658

Farkic, J., Isailovic, G., & Taylor, S. (2021). Forest bathing as a mindful tourism practice. Annals of Tourism Research Empirical Insights, 2(2), 100028. https://doi.org/10.1016/J.ANNALE.2021.100028

Hansen, M. M., & Jones, R. (2020). The Interrelationship of Shinrin-Yoku and Spirituality: A Scoping Review. Https://Home.Liebertpub.Com/Acm, 26(12), 1093–1104. https://doi.org/10.1089/ACM.2020.0193

Hansen, M. M., Jones, R., & Tocchini, K. (2017). Shinrin-Yoku (Forest Bathing) and Nature Therapy: A State-of-the-Art Review. International Journal of Environmental Research and Public Health, 14(8). https://doi.org/10.3390/IJERPH14080851

Hejtmánek, L., Hůla, M., Herrová, A., & Surový, P. (2022). Forest digital twin as a relaxation environment: A pilot study. Frontiers in Virtual Reality, 3. https://doi.org/10.3389/frvir.2022.1033708

Heung, V. C. S., & Kucukusta, D. (2013). Wellness Tourism in China: Resources, Development and Marketing. International Journal of Tourism Research, 15(4), 346–359. https://doi.org/10.1002/JTR.1880

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America, 102(46), 16569–16572. https://doi.org/10.1073/PNAS.0507655102/ASSET/8BAD4608-B7BF-4215-8D0A-5C29F690AE48/ASSETS/GRAPHIC/ZPQ0420598740002.JPEG

Honeyman, M. K. (1992). Vegetation and stress: A comparison study of varying amounts of vegetation in countryside and urban scenes. The Role of Horticulture in Human Well-Being and Social Development. https://archive.org/details/vegetationstress00hone

Ideno, Y., Hayashi, K., Abe, Y., Ueda, K., Iso, H., Noda, M., Lee, J. S., & Suzuki, S. (2017). Blood pressure-lowering effect of Shinrin-yoku (Forest bathing): A systematic review and meta-analysis. BMC Complementary and Alternative Medicine, 17(1), 1–12. https://doi.org/10.1186/S12906-017-1912-Z/FIGURES/6

Jimenez, M. P., Deville, N. V., Elliott, E. G., Schiff, J. E., Wilt, G. E., Hart, J. E., & James, P. (2021). Associations between Nature Exposure and Health: A Review of the Evidence. International Journal of Environmental Research and Public Health, 18(9), 4790. https://doi.org/10.3390/IJERPH18094790

Jones, R., Tarter, R., & Ross, A. M. (2021). Greenspace Interventions, Stress and Cortisol: A Scoping Review. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 2802, 18(6), 2802. https://doi.org/10.3390/IJERPH18062802

Kang, M. J., Kim, H. S., & Kim, J. Y. (2022). Effects of Forest-Based Interventions on Mental Health: A Meta-Analysis of Randomized Controlled Trials. International Journal of Environmental Research and Public Health, 19(8), 4884. https://doi.org/10.3390/IJERPH19084884

Kil, N., Stein, T. V., Holland, S. M., Kim, J. J., Kim, J., & Petitte, S. (2021). The role of place attachment in recreation experience and outcome preferences among forest bathers. Journal of Outdoor Recreation and Tourism, 35, 100410. https://doi.org/10.1016/J.JORT.2021.100410

Kim, H., Kim, J., Ju, H. J., Jang, B. J., Wang, T. K., & Kim, Y. I. (2020). Effect of Forest Therapy for Menopausal Women with Insomnia. International Journal of Environmental Research and Public Health, 17(18), 1–8. https://doi.org/10.3390/IJERPH17186548

Kim, J. G., Khil, T. G., Lim, Y., Park, K., Shin, M., & Shin, W. S. (2020). The Psychological Effects of a Campus Forest Therapy Program. International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 3409, 17(10), 3409. https://doi.org/10.3390/IJERPH17103409

Kondo, M. C., Jacoby, S. F., & South, E. C. (2018). Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. Health & Place, 51, 136–150. https://doi.org/10.1016/J.HEALTHPLACE.2018.03.001

Kotera, Y., Richardson, M., & Sheffield, D. (2022). Effects of Shinrin-Yoku (Forest Bathing) and Nature Therapy on Mental Health: A Systematic Review and Meta-analysis. International Journal of Mental Health and Addiction, 20(1), 337–361. https://doi.org/10.1007/S11469-020-00363-4/TABLES/6

Langemeyer, J., Madrid-Lopez, C., Beltran, A. M., & Mendez, G. V. (2021). Urban agriculture: A necessary pathway towards urban resilience and global sustainability? Landscape and Urban Planning, 210, 104055.

Lee, I., Choi, H., Bang, K. S., Kim, S., Song, M. K., & Lee, B. (2017). Effects of Forest Therapy on Depressive Symptoms among Adults: A Systematic Review. International Journal of Environmental Research and Public Health 2017, Vol. 14, Page 321, 14(3), 321. https://doi.org/10.3390/IJERPH14030321

Lee, J., Park, B. J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. Http://Dx.Doi.Org/10.1080/02827580902903341, 24(3), 227–234. https://doi.org/10.1080/02827580902903341

Lee, J., Park, B. J., Tsunetsugu, Y., Ohira, T., Kagawa, T., & Miyazaki, Y. (2011). Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. Public Health, 125(2), 93–100. https://doi.org/10.1016/J.PUHE.2010.09.005

Lee, J., Tsunetsugu, Y., Takayama, N., Park, B. J., Li, Q., Song, C., Komatsu, M., Ikei, H., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. (2014). Influence of forest therapy on cardiovascular relaxation in young adults. Evidence-Based Complementary and Alternative Medicine : eCAM, 2014. https://doi.org/10.1155/2014/834360

Li, H., Zhang, X., Bi, S., Cao, Y., & Zhang, G. (2022). Psychological benefits of green exercise in wild or urban greenspaces: A meta-analysis of controlled trials. Urban Forestry & Urban Greening, 68, 127458. https://doi.org/10.1016/J.UFUG.2022.127458

Li, H., Zhang, X., Bi, S., Liu, H., Cao, Y., & Zhang, G. (2021). Green Exercise: Can Nature Video Benefit Isometric Exercise? International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 5554, 18(11), 5554. https://doi.org/10.3390/IJERPH18115554

Li, Q. (2019). [Effect of forest bathing (shinrin-yoku) on human health: A review of the literature]. Sante Publique (Vandoeuvre-Les-Nancy, France), S1(HS), 135–143. https://doi.org/10.3917/SPUB.190.0135

Li, Q. (2022). Effects of forest environment (Shinrin-yoku/Forest bathing) on health promotion and disease prevention -the Establishment of 'Forest Medicine'. Environmental Health and Preventive Medicine, 27. https://doi.org/10.1265/EHPM.22-00160

Li, Q., Kobayashi, M., Inagaki, H., Hirata, Y., Li, Y. J., Hirata, K., Shimizu, T., Suzuki, H., Katsumata, M., Wakayama, Y., Kawada, T., Ohira, T., Matsui, N., & Kagawa, T. (2010). A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects. Journal of Biological Regulators and Homeostatic Agents, 24(2), 157–165.

Li, Q., Kobayashi, M., Kumeda, S., Ochiai, T., Miura, T., Kagawa, T., Imai, M., Wang, Z., Otsuka, T., & Kawada, T. (2016). Effects of Forest Bathing on Cardiovascular and Metabolic Parameters in Middle-Aged Males. Evidence-Based Complementary and Alternative Medicine : eCAM, 2016. https://doi.org/10.1155/2016/2587381

Li, Q., Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., Hirata, K., Suzuki, H., Li, Y. J., Wakayama, Y., Kawada, T., Park, B. J., Ohira, T., Matsui, N., Kagawa, T., Miyazaki, Y., & Krensky, A. M. (2008). Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. International Journal of Immunopathology and Pharmacology, 21(1), 117–127. https://doi.org/10.1177/039463200802100113

Li, Q., Morimoto, K., Nakadai, A., Inagaki, H., Katsumata, M., Shimizu, T., Hirata, Y., Hirata, K., Suzuki, H., Miyazaki, Y., Kagawa, T., Koyama, Y., Ohira, T., Takayama, N., Krensky, A. M., & Kawada, T. (2007). Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. International Journal of Immunopathology and Pharmacology, 20(2 Suppl 2), 3–8. https://doi.org/10.1177/03946320070200s202

López-Pousa, S., Bassets Pagès, G., Monserrat-Vila, S., De Gracia Blanco, M., Hidalgo Colomé, J., & Garre-Olmo, J. (2015). Sense of Well-Being in Patients with Fibromyalgia: Aerobic Exercise Program in a Mature Forest-A Pilot Study. Evidence-Based Complementary and Alternative Medicine : eCAM, 2015. https://doi.org/10.1155/2015/614783

Lu, C., Bing, Z., Bi, Z., Liu, M., Lu, T., Xun, Y., Wei, Z., & Yang, K. (2019). Top-100 Most Cited Publications Concerning Network Pharmacology: A Bibliometric Analysis. Evidence-Based Complementary and Alternative Medicine, 2019. https://doi.org/10.1155/2019/1704816

McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. Https://Doi.Org/10.1080/17439760.2014.994224, 10(6), 507–519. https://doi.org/10.1080/17439760.2014.994224

Mendoza-Muñoz, M., Vega-Muñoz, A., Carlos-Vivas, J., Denche-Zamorano, Á., Adsuar, J. C., Raimundo, A., Salazar-Sepúlveda, G., Contreras-Barraza, N., & Muñoz-Urtubia, N. (2022). The Bibliometric Analysis of Studies on Physical Literacy for a Healthy Life. International Journal of Environmental Research and Public Health, 19(22), 15211. https://doi.org/10.3390/IJERPH192215211/S1

Millward, R., & Appleton, J. (1988). The Experience of Landscape. In The Geographical Journal (Vol. 154, Issue 1). Wiley. https://doi.org/10.2307/633509

Miyazaki, Y., Ikei, H., & Song, C. (2014a). Forest medicine research in Japan. Nihon Eiseigaku Zasshi. Japanese Journal of Hygiene, 69(2), 122–135. https://doi.org/10.1265/jjh.69.122

Miyazaki, Y., Ikei, H., & Song, C. (2014b). [Forest medicine research in Japan]. Nihon Eiseigaku Zasshi. Japanese Journal of Hygiene, 69(2), 122–135. https://doi.org/10.1265/JJH.69.122

Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., Nakashima, T., Ohira, H., & Shirakawa, T. (2007). Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. Public Health, 121(1), 54–63. https://doi.org/10.1016/J.PUHE.2006.05.024

Morse, P. M., & Leimkuhler, F. F. (1979). Technical Note—Exact Solution for the Bradford Distribution and Its Use in Modeling Informational Data. Https://Doi.Org/10.1287/Opre.27.1.187, 27(1), 187–198. https://doi.org/10.1287/OPRE.27.1.187

Mulet-Forteza, C., Genovart-Balaguer, J., Mauleon-Mendez, E., & Merigó, J. M. (2019). A bibliometric research in the tourism, leisure and hospitality fields. Journal of Business Research, 101, 819–827. https://doi.org/10.1016/J.JBUSRES.2018.12.002

Muro, A., Feliu-Soler, A., Canals, J., Parrado, E., & Sanz, A. (2021). Psychological benefits of Forest Bathing during the COVID-19 pandemic: A pilot study in a Mediterranean forest close to urban areas. Https://Doi.Org/10.1080/13416979.2021.1996516, 27(1), 71–75. https://doi.org/10.1080/13416979.2021.1996516

Ochiai, H., Ikei, H., Song, C., Kobayashi, M., Takamatsu, A., Miura, T., Kagawa, T., Li, Q., Kumeda, S., Imai, M., & Miyazaki, Y. (2015). Physiological and Psychological Effects of Forest Therapy on Middle-Aged Males with High-Normal Blood Pressure. International Journal of Environmental Research and Public Health 2015, Vol. 12, Pages 2532-2542, 12(3), 2532–2542. https://doi.org/10.3390/IJERPH120302532

Oh, B., Lee, K. J., Zaslawski, C., Yeung, A., Rosenthal, D., Larkey, L., & Back, M. (2017). Health and well-being benefits of spending time in forests: Systematic review. Environmental Health and Preventive Medicine, 22(1), 1–11. https://doi.org/10.1186/S12199-017-0677-9/FIGURES/1

Ohe, Y., Ikei, H., Song, C., & Miyazaki, Y. (2017). Evaluating the relaxation effects of emerging forest-therapy tourism: A multidisciplinary approach. Tourism Management, 62, 322–334. https://doi.org/10.1016/J.TOURMAN.2017.04.010

Ohtsuka, Y., Yabunaka, N., & Takayama, S. (1998). Shinrin-yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients. International Journal of Biometeorology, 41(3), 125–127. https://doi.org/10.1007/s004840050064

Orians, G. H., & Heerwagen, J. H. (1992). Evolved Responses to Landscapes. Adapted Mind: Evolutionary Psychology and the Generation of Culture. http://search.epnet.com/login.aspx?direct=true&db=psyh&an=1992-98504-015

Paletto, A., Notaro, S., & Cristian, P. (2024). Forest bathing: A quantitative exploration of emerging trends, patterns, and growth areas. Journal of Forest Research, 1–7. https://doi.org/10.1080/13416979.2024.2324206

Park, B. J., Furuya, K., Kasetani, T., Takayama, N., Kagawa, T., & Miyazaki, Y. (2011). Relationship between psychological responses and physical environments in forest settings. Landscape and Urban Planning, 102(1), 24–32. https://doi.org/10.1016/J.LANDURBPLAN.2011.03.005

Park, B. J., Shin, C. S., Shin, W. S., Chung, C. Y., Lee, S. H., Kim, D. J., Kim, Y. H., & Park, C. E. (2020). Effects of Forest Therapy on Health Promotion among Middle-Aged Women: Focusing on Physiological Indicators. International Journal of Environmental Research and Public Health, 17(12), 1–15. https://doi.org/10.3390/IJERPH17124348

Park, B. J., Tsunetsugu, Y., Ishii, H., Furuhashi, S., Hirano, H., Kagawa, T., & Miyazaki, Y. (2008). Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. Http://Dx.Doi.Org/10.1080/02827580802055978, 23(3), 278–283. https://doi.org/10.1080/02827580802055978

Park, B. J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., & Miyazaki, Y. (2007). Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest)—Using salivary cortisol and cerebral activity as indicators. Journal of Physiological Anthropology, 26(2), 123–128. https://doi.org/10.2114/JPA2.26.123

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. Environmental Health and Preventive Medicine, 15(1), 18–26. https://doi.org/10.1007/S12199-009-0086-9

Park, S., Choi, Y., Kim, G., Kim, E., Kim, S., & Paek, D. (2021). Physiological and Psychological Assessments for the Establishment of Evidence-Based Forest Healing Programs. International Journal of Environmental Research and Public Health, 18(17). https://doi.org/10.3390/IJERPH18179283

Peng, J., Yang, X., Fu, S., & Huan, T. C. (T C.). (2023). Exploring the influence of tourists' happiness on revisit intention in the context of Traditional Chinese Medicine cultural tourism. Tourism Management, 94, 104647. https://doi.org/10.1016/J.TOURMAN.2022.104647

Price, D. D. S. (1976). A general theory of bibliometric and other cumulative advantage processes. Journal of the American Society for Information Science, 27(5), 292–306. https://doi.org/10.1002/ASI.4630270505

Qiu, Q., Yang, L., He, M., Gao, W., Mar, H., Li, J., & Wang, G. (2022). The Effects of Forest Therapy on the Blood Pressure and Salivary Cortisol Levels of Urban Residents: A Meta-Analysis. International Journal of Environmental Research and Public Health, 20(1). https://doi.org/10.3390/IJERPH20010458

Rodríguez-Redondo, Y., Denche-Zamorano, A., Muñoz-Bermejo, L., Rojo-Ramos, J., Adsuar, J. C., Castillo-Paredes, A., Vega-Muñoz, A., & Barrios-Fernandez, S. (2023). Bibliometric Analysis of Nature-Based Therapy Research. Healthcare, 11(9), Article 9. https://doi.org/10.3390/healthcare11091249

Rogerson, M., & Barton, J. (2015). Effects of the Visual Exercise Environments on Cognitive Directed Attention, Energy Expenditure and Perceived Exertion. International Journal of Environmental Research and Public Health 2015, Vol. 12, Pages 7321-7336, 12(7), 7321–7336. https://doi.org/10.3390/IJERPH120707321

Rojas-Rueda, D., Nieuwenhuijsen, M. J., Gascon, M., Perez-Leon, D., & Mudu, P. (2019). Green spaces and mortality: A systematic review and meta-analysis of cohort studies. The Lancet. Planetary Health, 3(11), e469–e477. https://doi.org/10.1016/S2542-5196(19)30215-3

Rosa, C. D., Larson, L. R., Collado, S., & Profice, C. C. (2021). Forest therapy can prevent and treat depression: Evidence from meta-analyses. Urban Forestry & Urban Greening, 57, 126943. https://doi.org/10.1016/J.UFUG.2020.126943

Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosystem Services, 12, 1–15. https://doi.org/10.1016/J.ECOSER.2014.12.007

Shin, Y. K., Kim, D. J., Jung-Choi, K., Son, Y. J., Koo, J. W., Min, J. A., & Chae, J. H. (2012). Differences of psychological effects between meditative and athletic walking in a forest and gymnasium. Http://Dx.Doi.Org/10.1080/02827581.2012.706634, 28(1), 64–72. https://doi.org/10.1080/02827581.2012.706634

Song, C., Ikei, H., Park, B. J., Lee, J., Kagawa, T., & Miyazaki, Y. (2018). Psychological Benefits of Walking through Forest Areas. International Journal of Environmental Research and Public Health 2018, Vol. 15, Page 2804, 15(12), 2804. https://doi.org/10.3390/IJERPH15122804

Stier-Jarmer, M., Throner, V., Kirschneck, M., Immich, G., Frisch, D., & Schuh, A. (2021). The Psychological and Physical Effects of Forests on Human Health: A Systematic Review of Systematic Reviews and Meta-Analyses. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 1770, 18(4), 1770. https://doi.org/10.3390/IJERPH18041770

Timko Olson, E. R., Hansen, M. M., & Vermeesch, A. (2020). Mindfulness and Shinrin-Yoku: Potential for Physiological and Psychological Interventions during Uncertain Times. International Journal of Environmental Research and Public Health, 17(24), 1–13. https://doi.org/10.3390/IJERPH17249340

Torrades, S. (2007). Estrés y burn out. Definición y prevención. Offarm, 26(10), 104–107.

Tsunetsugu, Y., Park, B. J., Ishii, H., Hirano, H., Kagawa, T., & Miyazaki, Y. (2007). Physiological Effects of Shinrin-yoku (Taking in the Atmosphere of the Forest) in an Old-Growth Broadleaf Forest in Yamagata Prefecture, Japan. Journal of PHYSIOLOGICAL ANTHROPOLOGY, 26(2), 135–142. https://doi.org/10.2114/JPA2.26.135

Tsunetsugu, Y., Park, B. J., & Miyazaki, Y. (2010). Trends in research related to 'Shinrin-yoku' (taking in the forest atmosphere or forest bathing) in Japan. Environmental Health and Preventive Medicine, 15(1), 27–37. https://doi.org/10.1007/S12199-009-0091-Z

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. Journal of Environmental Psychology, 38, 1–9. https://doi.org/10.1016/J.JENVP.2013.12.005

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. Science, 224(4647), 420–421. https://doi.org/10.1126/science.6143402

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Vada, S., Prentice, C., & Hsiao, A. (2019). The influence of tourism experience and well-being on place attachment. Journal of Retailing and Consumer Services, 47, 322–330. https://doi.org/10.1016/J.JRETCONSER.2018.12.007

Valderrama-Zurián, J. C., García-Zorita, C., Marugán-Lázaro, S., & Sanz-Casado, E. (2021). Comparison of MeSH terms and KeyWords Plus terms for more accurate classification in medical research fields. A case study in cannabis research. Information Processing & Management, 58(5), 102658. https://doi.org/10.1016/J.IPM.2021.102658

Vega-Muñoz, A., Salazar-Sepúlveda, G., Contreras-Barraza, N., & Araya-Silva, L. (2022). Scientific Mapping of Coastal Governance: Global Benchmarks and Trends. Journal of Marine Science and Engineering, 10(6), 751. https://doi.org/10.3390/jmse10060751

Venable, G. T., Shepherd, B. A., Loftis, C. M., McClatchy, S. G., Roberts, M. L., Fillinger, M. E., Tansey, J. B., & Klimo, P. (2016). Bradford's law: Identification of the core journals for neurosurgery and its subspecialties. Journal of Neurosurgery, 124(2), 569–579. https://doi.org/10.3171/2015.3.JNS15149

Vibholm, A. P., Christensen, J. R., & Pallesen, H. (2020). Nature-based rehabilitation for adults with acquired brain injury: A scoping review. International Journal of Environmental Health Research, 30(6), 661–676. https://doi.org/10.1080/09603123.2019.1620183

Wajchman-Świtalska, S., Zajadacz, A., & Lubarska, A. (2021). Recreation and Therapy in Urban Forests—The Potential Use of Sensory Garden Solutions. Forests 2021, Vol. 12, Page 1402, 12(10), 1402. https://doi.org/10.3390/F12101402

Wang, X., Gong, X. F., Xiong, K. X., Guo, D. S., Liu, L. J., Lin, C. M., & Chang, W. Y. (2022). Mapping of Research in the Field of Forest Therapy-Related Issues: A Bibliometric Analysis for 2007–2021. Frontiers in Psychology, 13, 3590. https://doi.org/10.3389/FPSYG.2022.930713/BIBTEX

Wang, Y., Xia, Y., Li, R., Sun, R., & Fang, J. (2022). Research Trends of Acupuncture Therapy on Polycystic Ovary Syndrome: A Bibliometric Analysis. Evidence-Based Complementary and Alternative Medicine, 2022. https://doi.org/10.1155/2022/1989401

Wen, J., Wang, C. C., & Kozak, M. (2020). Post-COVID-19 Chinese domestic tourism market recovery: Potential influence of traditional Chinese medicine on tourist behaviour. Https://Doi.Org/10.1080/13032917.2020.1768335, 32(1), 121–125. https://doi.org/10.1080/13032917.2020.1768335

Wilson, E. O. (1984). How Nature Benefits Your Mental Health. 157.

Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R. A., Bosch, M. van den, & Bardekjian, A. C. (2020). Urban Trees and Human Health: A Scoping Review. International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 4371, 17(12), 4371. https://doi.org/10.3390/IJERPH17124371

Yamaguchi, M., Deguchi, M., & Miyazaki, Y. (2006). The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. The Journal of International Medical Research, 34(2), 152–159. https://doi.org/10.1177/147323000603400204

Yeon, P. S., Jeon, J. Y., Jung, M. S., Min, G. M., Kim, G. Y., Han, K. M., Shin, M. J., Jo, S. H., Kim, J. G., & Shin, W. S. (2021). Effect of Forest Therapy on Depression and Anxiety: A Systematic Review and Meta-Analysis. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 12685, 18(23), 12685. https://doi.org/10.3390/IJERPH182312685

Yu, C. P., Chen, H. T., Chao, P. H., Yin, J., & Tsai, M. J. (2021). The Role of Social Context in Physiological and Psychological Restoration in a Forest: Case Study of a Guided Forest Therapy Program in Taiwan. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 10076, 18(19), 10076. https://doi.org/10.3390/IJERPH181910076

Zhang, Z., Wang, P., Gao, Y., & Ye, B. (2020). Current Development Status of Forest Therapy in China. Healthcare 2020, Vol. 8, Page 61, 8(1), 61. https://doi.org/10.3390/HEALTHCARE8010061

Zhu, Z., Zhao, X., OuYang, Q., Wang, Y., Xiong, Y., Cong, S., Zhou, M., Zhang, M., Luo, X., & Cheng, M. (2021). Waterfall Forest Environment Regulates Chronic Stress via the NOX4/ROS/NF-κB Signaling Pathway. Frontiers in Neurology, 12, 155. https://doi.org/10.3389/FNEUR.2021.619728/BIBTEX

Guidelines for publication

1. Only original, unpublished work is accepted.
2. Manuscripts must be written double-spaced, one sided and ready for printing. For literature quotations, use the name of the author and year (in parentheses) in the text, and arrange the list at the end of the work alphabetically.
3. Original contributions should be arranged as follows: 1) Title of the manuscript in German and English; 2) by: Given names and surname of the author(s); 3) Key words: 3-6 terms; 4) Summary (English and German - Zusammenfassung); text of the article, literature, adress of the author (the authors). 5) An explanatory capture text in English and German should be given for all tables and Figures.
4. All figures must be provided in electronic form and as a printed copy (photos on good paper) using a separate sheet. The text for the Figures must be on a separate sheet, and sequentially numbered.
5. After the review process, and the final approval by the editor in chief the author(s) receives galley proofs for final minor corrections. Only setting (typing) errors can be corrected at this stage.
6. Each author of an original article receives 20 off prints free of charge. Further copies can be ordered at the author(s) expense.

Richtlinien zur Veröffentlichung

1. Es werden nur Originalarbeiten angenommen.
2. Die Manuskripte müssen druckreif zweizeilig geschrieben sein; jedes Blatt nur einseitig beschreiben! Literaturzitate sind im Text mit dem Namen des Autors und in Klammern beigefügter Jahreszahl anzuführen und am Ende der Arbeit alphabetisch geordnet zusammenzustellen.
3. Die Gliederung der Originalbeiträge ist wie folgt zu gestalten: 1) Titel der Arbeit in Deutsch und Englisch; 2) von: Vor- und Zuname des Autors (der Autoren) Oxfordklassifikation; 3) Schlagwörter: 3-6 Begriffe, Key words: 3-6; 4) Zusammenfassung, Summary, Text, Literatur, Anschrift des Verfasser (der Verfasser). 5) Den Tabellen, Übersichten und Abbildungen ist ein erklärender Text in deutscher und in englischer Sprache beizufügen.
4. Die Vorlagen für die Abbildungen sind in reproduktionsfähigem Zustand (Fotos auf Hochglanzpapier) auf besonderen Blättern einzusenden, ebenso sind die Erklärungen der Abbildungen auf einem getrennten Blatt, fortlaufend nummeriert, beizuschließen.
5. Von den Arbeiten erhält der Autor Korrekturabzüge. In den Korrekturbogen dürfen nur mehr Satzfehler berichtigt werden.
6. Jeder Autor einer Originalarbeit erhält kostenlos 20 Sonderdrucke. Darüber hinaus benötigte Sonderdrucke müssen bei der Rücksendung der Korrekturabzüge bestellt werden. Die Kosten hierführ sind vorher beim Verlag zu erfragen.

Please send your manuscript (3 copies) to:
Manuskriptsendungen in dreifacher Ausführung sind erbeten an:

Univ.-Prof. Dr. Hubert Hasenauer
Centralblatt für das gesamte Forstwesen
Institut für Waldbau,
Peter-Jordan-Straße 82,
A-1190 Wien.