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Young Generations' Perception of Deadwood in Forest Landscapes: Insights from Turkish Students

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ABSTRACT

Recently, citizens' perceptions toward deadwood in forests have become increasingly important in recreational forests for socially sustainable management. The present study aims to investigate how deadwood in forests is perceived by the young generations (university and post-university students). This study was implemented by submitting a web-based questionnaire to 485 Turkish students. The results showed that our student sample perceived the key role in deadwood for soil fertilization, the provision of microhabitats, and food for wildlife. A high percentage of students positively viewed lying deadwood in forests, while standing dead trees were less positively perceived. The socio-demographic characteristics of respondents (gender and age) played a key role in explaining the variations in individual preferences toward deadwood. In conclusion, the results of this study highlight that despite students' awareness of the ecological role of deadwood in forests, aesthetically they still prefer forests with moderate amount of deadwood or without deadwood. The findings obtained in this study can help decision-makers define a socially accepted forest management strategy.

Keywords: cultural services; lying deadwood; standing dead trees; landscape aesthetics; landscape preferences; Türkiye

INTRODUCTION

Over the last few decades, there has been growing recognition among the scientific community and policymakers regarding the vital role and significance of cultural services—non-material benefits that ecosystems provide to people (MEA, 2005)—in enhancing human health and well-being (Häyhä et al. 2015). Cultural services, as defined by the Millennium Ecosystem Assessment (MEA 2005), include a diverse range of non-material benefits derived from ecosystems, such as spiritual enrichment, cognitive development, reflection, recreation, aesthetic value of the landscape, cultural heritage, and educational experiences (Langemeyer et al. 2015). In particular, the aesthetic value of landscapes assumes a pivotal role, encompassing the pleasure derived from their inherent natural beauty (TEEB, 2010). This significance is particularly pronounced in today's post-modern society, which strongly emphasises individuality and consumerism (Brady 2006). The aesthetic value of landscapes bears substantial social and economic importance, especially concerning social cohesion and the sustainable development of tourism. Therefore, it is essential to take these aspects into account in the management of natural resources (Notaro et al. 2019).

The aesthetic value of forests is influenced by multiple attributes that are associated with the adopted forest management strategy and the applied silvicultural treatments, such as stand age, forest system, horizontal and vertical stand structure, tree species composition, stand density, and under-story cover (Getzner and Meyerhoff 2020). Recently, some authors have considered an additional attribute to evaluate the aesthetic appeal of forest landscapes—namely, the amount and spatial distribution of deadwood in forests (Tyrväinen et al. 2003, Jankovska et al. 2014). Many studies have emphasized that deadwood is commonly perceived in a negative light by most forest visitors. This perception is primarily attributed to the impact of deadwood on forest accessibility and its contribution to a decreased aesthetic value of the forest landscape (Pastorella et al. 2016, Paletto et al. 2017a, Pelyukh et al. 2019). However, visitor perception is contingent upon the origin of deadwood, whether it is natural or the result of silvicultural interventions (Kovács et al. 2020), as well as the level of decomposition (Nielsen et al. 2012, Rathmann et al. 2020). In various cases, deadwood is often perceived by visitors as a sign of ecological degradation (Herrmann et al. 2002) or mismanagement, especially in forests designated for recreational purposes or situated near settlements, such as urban and peri-urban forests (Simkin et al. 2020). A substantial accumulation of deadwood is associated with an increased susceptibility to fires and insect infestations (Deuffic and Lyser 2012), while concurrently diminishing the overall site appeal (Bayraktar et al. 2020).

Deadwood is defined as all non-living woody biomass not contained in the litter or the soil, such as standing dead trees, trees lying on the ground, dead roots and stumps (Harmon et al. 1986). It includes both coarse woody debris with a diameter equal to or larger than 10 cm and fine woody debris with a diameter less than 10 cm (Sefidi et al. 2013). Deadwood in forests serves diverse functions, with the most crucial being the provision of microhabitats and acting as a food source for saproxylic insects, fungi, bacteria, bryophytes, lichens, small mammals, and birds (Karahalil et al. 2017, Pastorelli et al. 2020). Moreover, deadwood assumes a critical function in the carbon, nitrogen, and phosphorus cycles, exerting an impact on soil fertility and productivity. In the last decades, the role of deadwood as a carbon pool in the forests has been emphasized as the countries strive to ensure the completeness of their National Greenhouse Gas (GHG) emissions Inventory Reports (e.g., the United Nations Framework Convention on Climate Change-UNFCCC, the Kyoto Protocol, and the Paris Agreement). According to these documents, the changes in stored carbon must be inventoried and constantly monitored over time (De Meo et al. 2019). In addition, deadwood also serves as a protective factor against rockfalls and landslides (Fuhr et al. 2015), while contributing to the regeneration of natural and semi-natural forests (Duvall and Grigal 1999).

In light of the multifunctional role of deadwood in forests, local decision-makers are required to adopt sustainable forest management strategies that carefully consider whether deadwood should be removed or retained based on the specific circumstances and priority objectives of forest planning (Müller and Bütler 2010, Paletto et al. 2021). Generally, in recreational forests, substantial amounts of deadwood are often cleared to enhance the landscape's aesthetic appeal and ensure the safety and accessibility of visitors (Paletto et al. 2017b, Bayraktar et al. 2020). Conversely, deadwood is typically left undisturbed in protected areas due to ecological considerations, particularly for supporting biodiversity conservation (Tomescu et al. 2011, Bujoczek et al. 2021). In this context, incorporating the perceptions, opinions, and preferences of forest users concerning stand characteristics into forest planning can foster social acceptance and help mitigate potential conflicts in the future (Cantiani 2012). Several studies have explored visitors' preferences and perceptions of the quantitative and qualitative aspects of deadwood in forests (Tyrväinen et al. 2003, Jankovska et al. 2014, Pastorella et al. 2016, Pelyukh et al. 2019, Simkin et al. 2020; Kovács et al. 2020), while there remains a notable gap in the international literature concerning the aesthetic perception of deadwood in forests among younger generations, particularly high school and university students. In the context of river ecosystems, Ladrera et al. (2020) investigated students' knowledge regarding rivers and their sustainable management, while Eder and Arnberger (2016) analysed adolescents' preferences for riverscapes characterized by varying fluvial dynamics as recreational environments. In their analysis, the aforementioned researchers underscored that students perceive riverscapes containing deadwood as possessing less aesthetic appeal and being more hazardous than riverscapes without deadwood. Conversely, while some studies have included students in their samples, they have not explicitly presented the outcomes specifically concerning the students' perceptions (Pastorella et al. 2016, Paletto et al. 2017a, Pelyukh et al. 2019).

The primary objective of this study is to investigate university students' preferences and perceptions regarding deadwood in forest landscapes from both aesthetic and management perspectives. In pursuit of this overarching aim, the present study has formulated the following three research questions:

1. Do students at different levels of education (undergraduate and graduate) and from various academic departments hold negative perceptions toward deadwood in forests?
2. Are there discernible variations in university students' perceptions concerning different components of deadwood, such as standing dead trees and lying deadwood?
3. To what extent do socio-demographic variables (gender and age) explain the observed differences in individual preferences among university students?

The three aforementioned research questions were chosen to highlight the differences among university students based on age, gender and level of education, whose importance as explanatory variables has been emphasized by other studies (see Paletto et al. 2017a, Fekete et al. 2023). On the other hand, observing the differences between deadwood components (e.g., standing dead trees, snags, lying deadwood, logs, and stumps) are crucial perceptual variables (Pastorella et al. 2016). To address the aforementioned research questions, this study was conducted by administering a web-based questionnaire to a cohort of undergraduate (Bachelor's) and graduate (Master's and PhD) students in Türkiye. In particular, the aim was to find out whether students from different educational levels and academic departments hold negative perceptions toward deadwood and whether variations existed in their perceptions regarding different components of deadwood were examined. Additionally, the aim was to determine to what extent socio-demographic variables, specifically gender and age, explain the observed differences in individual preferences among university students was explored.

MATERIALS AND METHODS

The present study was structured into three sequential steps to analyse the perceptions and preferences of undergraduate and graduate students toward deadwood in forest landscapes:

1. Preparation and pre-testing of a semi-structured questionnaire;
2. Sampling and web-based questionnaire administration;
3. Data processing and comparative analysis.

Step 1

The initial version of the questionnaire was formulated by the researchers involved in the project during May and July 2021. Subsequently, the preliminary questionnaire underwent pre-testing with three students from Istanbul University–Cerrahpaşa to assess its accuracy and adequacy. Following the pre-testing stage, certain questions were revised to improve clarity, and two questions were excluded to streamline the compilation process.

The final version of the questionnaire comprised thirteen closed-ended inquiries. The first question (Q1) examined the respondents' level of awareness regarding the term "deadwood" and the sources of their information (Q2), differentiating among technical-scientific articles, magazines/radio/television, internet/blog posts, and conferences/workshops/public meetings. The third question (Q3) was designed to investigate students' perspectives on the role of deadwood in forest landscapes, considering six positive aspects and two negative aspects associated with deadwood in forests. The aspects assessed in the survey were categorized in accordance with the framework proposed by Paletto et al. (2014) and encompassed the following dimensions: Bioenergy production; Provision of microhabitats for wildlife; Provision of food for wildlife; Potential increase in forest fire risk; Soil fertilization resulting from deadwood decomposition; Climate change mitigation through temporary carbon sequestration; Potential rise in harmful insects within the forest; and Soil protection from water erosion and landslides. Each aspect was assessed by the respondents on a 5-point Likert scale format, allowing them to assign a level of importance (positive or negative). The scale ranged from 1 (indicating "not important") to 5 (indicating "very important"). The subsequent question (Q4) examined the respondents' perspectives concerning the utilization of slightly decomposed deadwood for bioenergy production, presenting the following three options: (1) Yes, always. It provides a viable means to enhance an otherwise insignificant component of the forest economically; (2) Yes, but only when technically feasible for the trunks to be easily removed from the forest; (3) No, never, as dead trees play a pivotal role in maintaining ecological balance within the forests. This question served as a supplement to the level of importance ascribed to bioenergy production in the preceding inquiry. The subsequent three questions (Q5, Q6, Q7) focused on the visual-aesthetic preferences of the participants regarding forest stands characterized by varying amounts of deadwood. Inquiries Q5 and Q6 prompted the respondents to assess how the presence of significant standing dead trees and lying deadwood affects the aesthetic value of the forest landscape. Both samples were evaluated at the initial decay level.

The seventh question (Q7) was designed to compare two sets of photographs depicting the same forest type but varying in the abundance of deadwood, including standing dead trees, lying deadwood, and stumps. To obtain the visual material for this comparison, the two most typical forest types located near Istanbul, specifically in the Belgrade forest, were selected:

1. A forest dominated by Oriental beech (*Fagus orientalis* Lipsky) and hornbeam (*Carpinus orientalis* Mill.);
2. A Scots pine (*Pinus sylvestris* L.) plantation.

The original photos were subjected to modifications through the addition or removal of deadwood components to present respondents with a comprehensive range of scenarios. These modifications were made using the GNU Image Manipulation Program (GIMP), a freely accessible software available on the Internet. The GIMP was employed effectively to manipulate the images by adding or removing deadwood components, resulting in the creation of three distinct scenarios: (1) an image without deadwood; (2) an image with a moderate amount of deadwood; (3) an image with a high amount of deadwood. The respondents conducted pairwise comparisons of the modified photos to calculate the priority value for each photo using the eigenvalue method (Analytical Hierarchical Process - AHP). The photos were compared in pairs following the scheme outlined below:

Photo 1A	5	3	1	1/3	1/5	Photo 2A

Question eight (Q8) examined the respondents' viewpoints on four prospective deadwood management strategies aimed at biodiversity conservation in forests while simultaneously preserving recreational opportunities for visitors (Table 1). The four deadwood management strategies were selected through a literature review which highlighted the most common strategies adopted at an international level (Christensen et al. 2005, Lachat and Bütler 2008, Biache and Rouveyrol 2011, Bütler et al. 2013, Bače et al. 2019).

Participants evaluated the efficacy of each proposed strategy using a 5-point Likert scale format, ranging from 1 (not important) to 5 (very important).

The final five questions of the survey addressed the personal information of the respondents, encompassing the following aspects: gender (Q9), age (Q10), level of education (undergraduate/graduate) (Q11), academic departments (Q12), attended class (Q13), and membership status in environmental Non-Governmental Organizations (NGOs) (Q14).

Step 2

The questionnaire was administered between May and July 2021. Starting from the students of Istanbul University–Cerrahpaşa, a snowball sampling method was used to involve a greater number of students from different university programmes and courses in this study. The questionnaire link was distributed across diverse social networking platforms, including Facebook, Instagram, and Twitter. Furthermore, the initial cohort of students propagated the link within their personal networks and email contacts. At the conclusion of the data collection period, 485 students completed the questionnaire in its entirety.

Step 3

The collected data were subjected to data processing, resulting in the computation of primary descriptive statistics,

Table 1. Deadwood management strategies aimed at biodiversity conservation without compromising recreational opportunities considered in the survey.

Strategy	Description
Strategy 1	This Strategy is based on not removing both standing dead trees and lying deadwood from the forest, while paying attention to the forest fires and insect pollution risks. This Strategy is the one closest to the natural processes of mortality in undisturbed forests. Therefore, standing dead trees and lying deadwood are evenly distributed throughout the forest (Christensen et al. 2005).
Strategy 2	In this Strategy, only standing dead trees with a diameter greater than 60-70 cm are not removed from the forest, while lying deadwood and small standing deadwood are removed. This Strategy is focused on the conservation of habitat trees that provide ecological niches (microhabitats), such as cavities, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot (Bütler et al. 2013).
Strategy 3	In this Strategy, deadwood is removed during silvicultural interventions leaving only small quantities of lying deadwood scattered in the forest and some standing dead trees with a diameter greater than 60-70 cm. This Strategy is typical for managed forests where a small amount of deadwood is not removed in favour of soil fertility and biodiversity conservation (Paletto et al. 2021).
Strategy 4	In this Strategy, specific and delimited areas (e.g., islands) where deadwood is kept, including both standing dead trees and lying deadwood, were created. This Strategy is based on biodiversity conservation in specific extended rotation stands characterized by a high amount of standing dead trees and lying deadwood of all decay classes (Biache and Rouveyrol 2011).

namely the mean, median, and standard deviation (SD) for the data collected using the Likert-scale format (Q3 and Q8). The frequency distribution percentage (%) was calculated for all other questions, excluding Q7.

The non-parametric Kruskal-Wallis test (α=0.01) was employed to assess variations among respondents based on three personal characteristics (age, level of education, and attended class). The non-parametric Mann-Whitney test (α=0.01) was utilized to examine differences about other respondents' characteristics (gender, attended university programme, and membership in environmental associations). The Kruskal-Wallis and Mann-Whitney non-parametric tests were used instead of the parametric test due to the following reasons: the sample size was not sufficiently large, and the assumption of normality was violated, as evidenced by the Shapiro-Wilk test (p<0.0001).

Concerning the seventh question (Q7), the selected photos of the two forest types underwent a preliminary analysis to quantify the proportion (percentage) of deadwood, differentiating between lying deadwood, standing dead trees, and stumps in each photo. These photos were then processed using a computer program (GIMP 2.10.22) that superimposes a cross-hair grid over the photo plot. The grid serves as the equivalent of the traditional point intercept sampling "pins," intersecting with lying deadwood, standing dead trees, and stumps. Initially, we utilized the GIMP software to create an 88-point grid overlay on the photographs (Figure 1).

Figure 1. Oriental beech and hornbeam dominated the forest with a grid and intersection point.

Subsequently, we recorded each deadwood component that intersected with a point on the grid. The percentage of deadwood in each selected photo, categorized by deadwood component, is presented in Table 2.

The AHP method – a hierarchical weighted decision analysis technique aimed at resolving intricate decision problems and facilitating accurate decision-making and judgment within complex systems (Saaty 1987) – was utilized to process the data gathered through Q7 and evaluate the aesthetic appreciation of different deadwood management scenarios in the two forest types.

A reciprocal matrix was produced using the results of the pairwise comparison. In the reciprocal matrix, the row indicates the relative weight of each activity concerning the others (when i=j, then $a_{ij=1}$).

$$A = (a_{ij}) = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix}$$

Afterwards, the transpose of the vector of the weights w is multiplied by matrix A to obtain the vector represented by $l_{max}w$, which follows the principle:

Table 2. The amount of deadwood (%) in the photos used in the questionnaire.

Photo	Percentage of grid intersection deadwood components			
	Standing dead trees	**Lying deadwood**		
		Coarse woody debris	**Fine woody debris**	**Dead stump**
A1-Oriental beech and hornbeam dominated the forest with a high amount of deadwood	0	25.7	2.9	0
A2-Oriental beech and hornbeam dominated the forest without deadwood	0	0	0	0
A3-Oriental beech and hornbeam dominated the forest with a moderate amount of deadwood	0	20.0	0	0
B1-Scots pine plantation with a high amount of deadwood	0	8.6	2.9	0
B2-Scots pine plantation without deadwood	0	0	0	0
B3-Scots pine plantation with a moderate amount of deadwood	0	2.9	2.9	0

$$(A - \lambda_{max} I)w = 0$$

where: l_{max} is the largest Eigenvalue of matrix *A,* and *I* is the identity matrix of size *n*.

The value of l_{max} is always positive and is equal to or greater than the number of rows or columns in the matrix (*n*). The coherence of the respondents' information relies on the magnitude of the deviation between the value of λ_{max} and the value of *n*. In scenarios where l_{max} is equal to *n*, the responses demonstrate coherence. Consequently, the matrix *A* is examined for consistency utilizing the subsequent formula:

$$CI = (\lambda_{max} - n) / (n - 1)$$

$$CR = CI/RI$$

where: *CR* is the consistency ratio, *RI* is the expected consistency index obtained from randomly generated comparisons of the same order *n,* and *CR* is the consistency ratio. To ensure consistency in matrix *A*, it is essential for the value of *CR* to be lower than or equal to 0.1 (10%).

The priority scores (PV) attributed to each deadwood management scenario in the two forest types were employed to gain an in-depth comprehension of Turkish students' perceptions regarding three deadwood components.

RESULTS

Characteristics of Respondents

The results indicated that most survey participants were female (64.5%), while the remaining 35.5% were male. Regarding age distribution, the results demonstrated a relatively even representation among different age groups: 45.4% of the respondents were under 25 years old, 46.2% fall within the 25 to 34 years age range, while the remaining 8.5% were aged 34 years or above.

Regarding the educational level of the participants, the results showed that 48.9% were undergraduate students, whereas 51.1% were graduate students. Most students were studying in the Department of Landscape Architecture (23.3%), followed by the Department of Social Sciences (18.4%), while the remaining respondents were distributed, as illustrated in Figure 2.

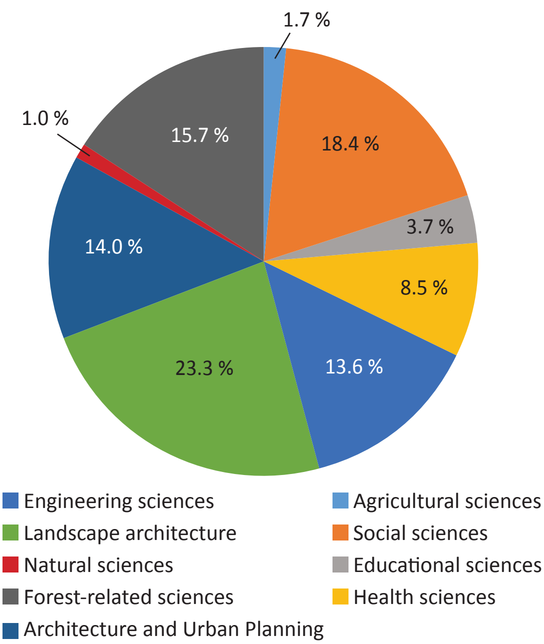

Figure 2. Frequency distribution (%) of a sample of students by departments.

For the purpose of statistical analysis and comparison, the student departments were classified into two groups: students affiliated with Forest and Landscape-related departments (39.6%) and students from other Departments (60.4%).

Moreover, the results revealed that 86.2% of the participants were not members of environmental NGOs, while the remaining 13.8% were affiliated with at least one environmental NGO.

Level of Knowledge

The results revealed that 57.9% of the surveyed students demonstrated prior familiarity with the concept of deadwood in forests, while the remaining 42.1% reported having no previous exposure to this notion. Among the respondents who claimed familiarity with the concept of deadwood in forests, the majority obtained their knowledge from various communication tools. Notably, 36.8% of the total students with prior knowledge of deadwood acquired it through technical-scientific articles, while 26.5% accessed information from internet/blog posts. Additionally, 18.1% reported gaining knowledge through magazine/ radio/television sources and 5.4% through attendance at conferences/public meetings/workshops. The remaining 13.2% cited other communication tools, such as personal contacts or newsletters from environmental NGOs.

When examining the data based on the respondents' characteristics, the findings revealed that males exhibit a higher level of knowledge than females (56.4% vs. 34.2%). However, for both groups, the primary source of information was technical-scientific articles (39.2% for males and 34.6% for females), followed by posts on the internet/blogs (21.6% for males and 30.8% for females).

In terms of age, the highest level of knowledge was evident among students aged 25-34 years (65.2%), followed by students over 34 years (53.7%) and students under 25 years (51.4%). Most students aged under 25 (33.6%) and between 25 and 34 (43.6%) relied on technical-scientific articles, while students over 34 mainly obtained information from online posts and blogs (31.6%).

Contrary to the prevailing assumption, graduate students exhibited a lower level of knowledge compared to their undergraduate counterparts, with percentages of 32.7% and 51.9%, respectively. Both groups predominantly relied on technical-scientific articles as their main source of information, constituting 40.7% of graduate students' sources and 34.1% of undergraduate students' sources, followed by posts on the internet/blogs, accounting for 19.8% among graduate students and 30.9% among undergraduate students. However, the distribution of students in forest and landscape-related departments differed significantly between the undergraduate and graduate levels, with a higher representation observed at the undergraduate level (62.0% vs. 18.1%). Furthermore, it is noteworthy to emphasize that students enrolled in Forest and Landscape-related departments demonstrated a significantly higher level of knowledge about deadwood compared to students in other Departments (69.8% vs. 23.9%). As it can be inferred, the predominant source of information for students in Forest and Landscape-related departments was technical-scientific articles, representing 47.0% of their information acquisition. In contrast, students from other Departments mainly relied on internet/blog posts (37.1%) and traditional media (31.4%) as their primary sources.

Conclusively, there was a notable disparity in the level of deadwood knowledge between members of environmental NGOs and non-members (52.2% vs. 40.4%). Of particular interest was the fact that members of environmental NGOs relied on two main sources for acquiring information, with 45.7% consulting technical-scientific articles and 40.0% accessing information through internet posts and blogs. Conversely, a substantial proportion of non-members (20.7%) obtained information about deadwood from traditional media outlets, such as magazines, radio, and television.

The Chi-square (χ^2) test showed statistically significant differences in the level of knowledge about deadwood in forests for the following characteristics: gender (p<0.0001), level of education (p<0.0001), and department (p<0.0001).

Perceived Importance of Deadwood in Forests

The results demonstrated that the sample of respondents considered deadwood as a pivotal component in forests due to three primary reasons: foremost, its role in soil fertilization after decomposition (mean ± standard deviation: 3.37±0.84), followed by its provision of microhabitats for wildlife (3.33±0.88), and its significance as a food source for wildlife (2.89±1.08). Considering the respondents' viewpoints, the negative aspects associated with deadwood were evaluated as follows: an elevated risk of forest fires (2.62±1.22) and an increase in harmful insects within the forest (2.37±1.20). Consequently, according to the respondents' perspectives, the positive aspects of deadwood in forests hold more significance compared to the negative aspects.

Regarding the data by gender (Table 3), female respondents assigned higher importance to all positive and negative aspects compared to male respondents, except for the food sources for wildlife. However, the non-parametric Mann-Whitney test revealed statistically significant differences only for one negative aspect: the increased risk of forest fires (p=0.005).

Regarding age, the results highlighted that younger students attributed higher importance to three positive aspects associated with deadwood compared to their older counterparts: bioenergy production, carbon sequestration, and soil erosion protection. However, the most pronounced differences between younger and older students are evident concerning the two negative aspects related to deadwood. The non-parametric Kruskal-Wallis test showed statistically significant differences among age classes for: carbon sequestration (p<0.0001), soil erosion protection (p<0.0001), increased risk of forest fires (p=0.001), and increase of harmful insects in the forest (p<0.0001).

Upon examining the data based on the respondents' level of education, an interesting observation emerged: undergraduate students exhibited a greater emphasis on the importance of the two negative aspects and four positive aspects (bioenergy production, soil fertilization, carbon sequestration, and soil erosion protection) compared to graduate students. Conversely, graduate students placed a higher emphasis on the role of deadwood in providing microhabitats for wildlife. The non-parametric Mann-Whitney test showed statistically significant differences

Table 3. The importance of positive and negative aspects related to the deadwood in forests in accordance with the respondents' opinions (mean and standard deviation).

Characteristics	Bioenergy production	Shelter wildlife	Food wildlife	Soil fertilization	Carbon sequestration	Soil erosion protection	Fires risk	Harmful insects
Gender								
Male (n=172)	2.42±1.15	3.33±0.90	2.97±1.02	3.35±0.91	2.72±1.27	2.70±1.24	2.41±1.23	2.22±1.24
Female (n=313)	2.59±1.06	3.34±0.84	2.84±1.11	3.37±0.80	2.97±1.17	2.91±1.15	2.73±1.20	2.46±1.17
Age								
Less than 25 years old (n=220)	2.68±1.05	3.28±0.94	2.85±1.14	3.36±0.85	3.14±1.07	3.13±1.05	2.84±1.14	2.70±1.14
25-34 years old (n=224)	2.45±1.09	3.37±0.82	2.92±1.03	3.39±0.81	2.71±1.28	2.62±1.23	2.47±1.25	2.16±1.17
More than 34 years old (n=41)	2.24±1.24	3.46±0.67	2.88±0.98	3.29±0.96	2.46±1.29	2.41±1.30	2.27±1.28	1.78±1.21
Level of education								
Undergraduate students (n=237)	2.70±1.01	3.26±0.96	2.89±1.11	3.39±0.85	3.18±1.04	3.12±1.06	2.87±1.15	2.75±1.15
Graduate students (n=248)	2.38±1.15	3.40±0.79	2.88±1.05	3.35±0.82	2.60±1.29	2.56±1.24	2.38±1.24	2.02±1.14
Department								
Forest and Landscape-related departments (n=192)	2.45±1.12	3.44±0.86	3.08±0.98	3.45±0.82	3.15±1.07	2.98±1.09	2.66±1.20	2.64±1.16
Other departments (n=293)	2.59±1.07	3.27±0.89	2.76±1.12	3.31±0.85	2.17±1.26	2.74±1.24	2.59±1.23	2.20±1.20
Membership in environmental NGOs								
YES (n=67)	2.42±1.12	3.52±0.66	2.99±1.11	3.51±0.80	3.00±1.14	2.94±1.01	2.63±1.23	2.54±1.08
NO (n=418)	2.55±1.09	3.31±0.89	2.87±1.07	3.34±0.84	2.86±1.22	2.82±1.21	2.62±1.22	2.35±1.22

In bold, the highest mean value by groups of respondents

between undergraduate and graduate students for the following aspects related to the deadwood in forests: bioenergy production (p=0.002), carbon sequestration (p<0.0001), soil erosion protection (p<0.0001), increased risk of forest fires (p<0.0001), and increase of harmful insects in the forest (p<0.0001).

When analysing the data according to academic departments, the results revealed that both students majoring in Forest and Landscape-related disciplines and those from other departments considered soil fertilization the most significant function performed by deadwood. However, it is noteworthy that students from other departments assign a marginally higher average value exclusively to bioenergy production than students majoring in Forest and Landscape-related disciplines. Conversely, students in Forest and Landscape-related disciplines placed greater emphasis on all other positive and negative aspects related to deadwood in forests. The non-parametric Mann-Whitney test showed statistically significant differences between the two groups of students for the following aspects: food sources for wildlife (p=0.002), carbon sequestration (p<0.0001), and increase of harmful insects in the forest (p<0.0001).

As anticipated, individuals affiliated with environmental NGOs accorded greater significance to all favourable aspects related to deadwood than the other respondents, with the exception of bioenergy production, which was most emphasized by non-members of environmental NGOs. However, the non-parametric Mann-Whitney test showed no statistically significant differences between members and non-members of environmental NGOs for all positive and negative aspects.

Aesthetic Preferences

The results indicated that a significant proportion of the respondents (35.3%) perceive standing dead trees to exert a negative aesthetic impact on the forest landscape. Conversely, 33.6% of the respondents attributed no aesthetic impact to standing dead trees, while 31.1% consider these elements to impact the landscape positively. On the other hand, most respondents (54.6%) hold a positive view of lying deadwood in the forest landscape. Among the participants, 26.0% believed that lying deadwood had no aesthetic impact, whereas 19.4% expressed a perception of a negative impact on the forest landscape. Observing the data by characteristics of the respondents (Table 4), the findings revealed that male participants attributed a significantly more positive aesthetic impact to both standing dead trees and lying deadwood than their female counterparts.

Specifically, 36.0% of male respondents expressed a positive aesthetic impact for standing dead trees, whereas only 28.4% of female respondents shared this viewpoint. Similarly, 62.2% of male respondents perceived lying deadwood as positively enhancing the forest landscape, while this perspective was shared by 50.5% of female respondents. Conversely, a substantial proportion of female participants (38.3%) believed that standing dead trees diminish the aesthetic value of the forest landscape,

Table 4. Frequency distribution (%) of aesthetic preferences for deadwood in forest landscape by characteristics of the respondents.

Socio-demographic characteristics	Standing dead trees			Lying deadwood		
	Negative	Neutral	Positive	Negative	Neutral	Positive
Gender						
Male (n=172)	38.3	33.2	28.4	29.7	34.3	36.0
Female (n=313)	31.9	17.6	50.5	15.1	22.7	62.2
Age						
Less than 25 years old (n=220)	42.7	27.7	29.5	33.2	16.8	50.0
25-34 years old (n=224)	29.0	40.6	30.4	21.4	21.4	57.1
More than 34 years old (n=41)	29.3	26.8	43.9	12.2	22.0	65.9
Level of education						
Undergraduate students (n=237)	41.8	27.4	30.8	34.2	18.6	47.3
Graduate students (n=248)	29.0	39.5	31.5	18.1	20.2	61.7
Department						
Forest and Landscape-related departments (n=192)	34.9	24.5	40.6	26.0	16.7	57.3
Other departments (n=293)	35.5	39.6	24.9	25.9	21.2	52.9
Membership in environmental NGOs						
YES (n=67)	34.3	29.9	35.8	22.4	14.9	62.7
NO (n=418)	35.4	34.2	30.4	26.6	20.1	53.3

with 31.9% expressing a similar sentiment toward lying deadwood. However, the Chi-square (χ^2) test showed that the differences between males and females for lying deadwood were significant (p<0.0001), while they were not significant for standing dead trees (p=0.105).

The findings demonstrated that older students had a more favourable perception toward both standing dead trees and lying deadwood than their younger counterparts. Specifically, 42.7% and 33.2% of students under the age of 25 expressed a negative aesthetic viewpoint toward standing dead trees and lying deadwood in forest landscapes, whereas only 29.3% and 12.2% of students aged over 34 shared a similar opinion. The Chi-square (χ^2) test showed statistically significant differences among age classes for both deadwood components: standing dead trees (p=0.005) and lying deadwood (p=0.0013).

Similarly, undergraduate students, who were typically younger than graduate students, exhibited a stronger inclination to perceive standing dead trees (41.8%) and lying deadwood (34.2%) in forest landscapes as having a negative aesthetic impact. Conversely, graduate students showed a distinctive preference for acknowledging the positive aesthetic effect of lying deadwood (61.7%). The Chi-square (χ^2) test showed statistically significant differences between undergraduate and graduate students both for standing dead trees (p=0.004) and lying deadwood (p<0.0001).

It is worth noting that students enrolled in Forest and Landscape-related programs expressed a higher appreciation for the positive impact of standing dead trees and lying deadwood than students from other disciplines, with percentages of 40.6% versus 24.9% for standing dead trees and 57.3% versus 52.9% for lying deadwood. However, the Chi-square (χ^2) test showed statistically significant differences among students from different departments only for standing dead trees (p<0.0001).

The results indicated that the respondents affiliated with environmental NGOs ascribed a higher value to the positive aesthetic impact of standing dead trees and lying deadwood within the forest landscape compared to individuals who were not affiliated with such NGOs. However, the Chi-square (χ^2) test showed no statistically significant members and non-members of environmental NGOs for both deadwood components.

Regarding the pairwise comparison between photos, the AHP results showed that the respondents preferred that Oriental beech and hornbeam dominated the forest without deadwood (Photo A2 – PV=0.3963), followed by the situation with a moderate amount of deadwood (Photo A3 – PV=0.3612), while the situation with a high amount of deadwood was the least appreciated aesthetically (Photo A1 – PV=0.2425). Similarly, the respondents assigned a preference for the Scots pine plantation without deadwood (Photo B2 – PV=0.4046), followed by the situation with a moderate amount of deadwood (Photo B3 – PV=0.3508), and then with a high amount of deadwood (Photo B1 – PV=0.2446).

Observing the data by characteristics of the respondents (Table 5), the results showed that males assigned a higher preference to the situation with a moderate amount of deadwood for both forest types (PV=0.3807 for Photo A3 and 0.3639 for Photo B3) than females (PV=0.3475 for Photo A3 and 0.3405 for Photo B3). Conversely, females clearly preferred the situation without deadwood for both forest types.

Table 5. Priority scores for three deadwood management situations in two forest types by characteristics of the respondents.

Characteristics	Oriental beech and hornbeam dominated the forest			Scots pine plantation		
	A1	A2	A3	B1	B2	B3
Gender						
Male (n=172)	0.2957	0.3236	0.3807	0.2988	0.3373	0.3638
Female (n=313)	0.2166	0.4359	0.3475	0.2169	0.4427	0.3405
Age						
Less than 25 years old (n=220)	0.2149	0.4305	0.3547	0.2244	0.4283	0.3472
25-34 years old (n=224)	0.2505	0.4000	0.3498	0.2552	0.3997	0.3451
More than 34 years old (n=41)	0.2994	0.3361	0.3647	0.2982	0.3085	0.3933
Level of education						
Undergraduate students (n=237)	0.2244	0.4070	0.3687	0.2259	0.4239	0.3502
Graduate students (n=248)	0.2611	0.3852	0.3537	0.2633	0.3861	0.3506
Department						
Forest and Landscape-related departments (n=192)	0.2406	0.3774	0.3819	0.2415	0.3925	0.3660
Other departments (n=293)	0.2434	0.4083	0.3483	0.2464	0.4123	0.3413
Membership in environmental NGOs						
Yes (n=67)	0.2657	0.3824	0.3519	0.2667	0.3831	0.3502
No (n=418)	0.2389	0.3984	0.3627	0.2411	0.4008	0.3508

The results showed that the age of students was a variable that influenced aesthetic-visual preferences. In fact, older students (more than 34 years old) assigned a preference for the situation with an average amount of deadwood (PV=0.3647 for Photo A2 and 0.3933 for Photo B2) compared to the other two groups of students. Conversely, younger students definitely preferred the situation without deadwood for both forest types (PV=0.4305 for Photo A2 and 0.4283 for Photo B2).

Regarding the level of education, the results showed that both the undergraduate and graduate students preferred the situations without deadwood in both forest types, but with a slight preference given by the undergraduate students (PV for Photo A2 0.4070 vs. 0.3852, and Photo B2 0.4239 vs. 0.3861).

In addition, the results showed that students of Forest and Landscape-related departments assigned a lower preference for the Scots pine plantation without deadwood (Photo B2) compared to the students of other Departments (PV of 0.4123 vs. 0.3925). This difference was even more evident for the Oriental beech and hornbeam-dominated forest: for students of Forest and Landscape-related departments the most valuable photo was the one with a moderate amount of deadwood (Photo A3 – PV of 0.3819), while for the students of other Departments the most valuable situation was the one without deadwood (Photo A2 – PV of 0.4083).

As expected, the members of environmental NGOs assigned a higher preference to situations with a moderate or high amount of deadwood compared to the non-members of environmental NGOs. However, the higher priority scores were still found for the situation without deadwood both for members and non-members of environmental NGOs.

Finally, it is important to highlight that for all comparisons, the consistency ratio (CR) resulted in less than 0.1.

Preferences for Deadwood Management Strategies

The results showed that for the sample of students, the preferred deadwood management strategy was Strategy 1 with an average value of 2.57±1.01, followed by Strategy 2 focused on the conservation of standing dead trees with a diameter greater than 60-70 cm as habitat trees (2.24±0.93). Conversely, Strategy 4, based on the creation of islands of senescence for the conservation of deadwood in forests, was considered the least efficient by our sample of students (1.98±1.24). The frequency distribution for the four strategies is shown in Figure 3.

Observing the data by characteristics of the respondents (Table 6), there were no substantial differences between the various groups of students.

The most efficient deadwood management strategy for males and females was Strategy 1, followed by Strategy 2. As expected, the non-parametric Mann-Whitney test showed no statistically significant differences between males and females for all four deadwood management strategies.

Regarding age, the results showed that both young and old students preferred Strategies 1. The second preferred strategy for students under 25 years and over 34 years was Strategy 2, while students between 25 and 34 years old preferred Strategy 3. The non-parametric Kruskal-Wallis test showed statistically significant differences among age classes only for Strategy 4 (p=0.002).

Observing the data by departments, the results highlight that students of all departments prefer Strategy 1, followed by Strategy 2 for students of Forest and Landscape-

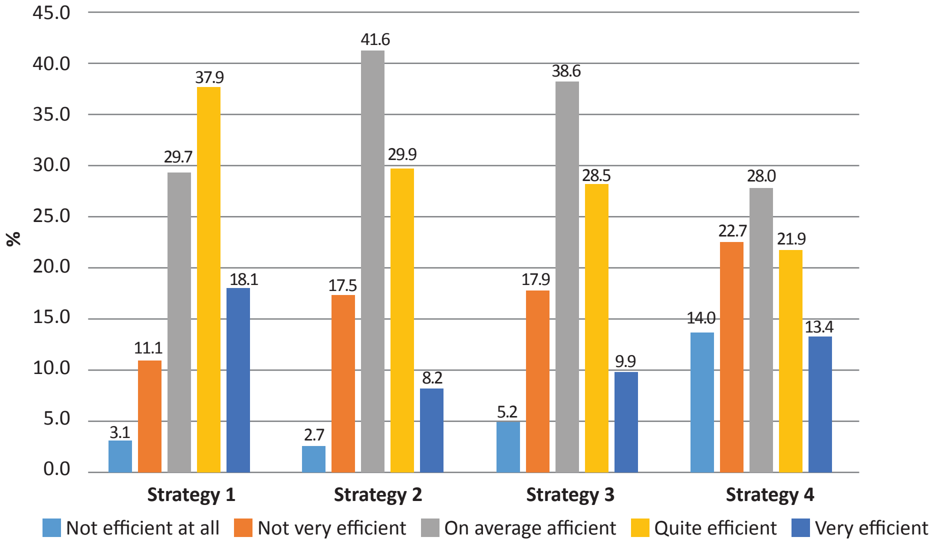

Figure 3. Frequency distribution (%) of preferences of undergraduate and graduate students for four deadwood management strategies.

Table 6. Students' preferences for deadwood management strategies considered in the survey (mean and standard deviation).

Characteristics	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Gender				
Male (n=172)	2.65±1.01	2.23±0.92	2.201.10	1.82±1.20
Female (n=313)	2.53±1.01	2.24±0.93	2.20±1.02	2.07±1.26
Age				
Less than 25 years old (n=220)	2.57±0.98	2.32±0.94	2.25±0.93	2.20±1.20
25-34 years old (n=224)	2.52±1.05	2.13±0.93	2.181.09	1.79±1.25
More than 34 years old (n=41)	2.85±0.91	2.32±0.79	2.07±1.03	1.80±1.25
Level of education				
Undergraduate students (n=237)	2.59±0.98	2.33±0.95	2.28±0.96	2.25±1.19
Graduate students (n=248)	2.75±0.95	2.35±0.95	2.160.97	2.10±1.24
Department				
Forest and Landscape-related departments (n=192)	2.75±0.95	2.350.95	2.16±0.97	2.101.24
Other departments (n=293)	2.45±1.03	2.16±0.90	2.23±1.04	1.90±1.24
Membership in environmental NGOs				
Yes (n=67)	2.61±1.11	2.16±0.90	2.10±1.03	1.69±1.28
No (n=418)	2.56±0.99	2.25±0.93	2.221.01	2.03±1.23

related departments, and Strategy 3 for students of other Departments. The non-parametric Mann-Whitney test showed statistically significant differences between students from different departments only for Strategy 1 (p=0.002).

Finally, the members of environmental NGOs assigned a preference to Strategy 1 compared to the non-members of environmental NGOs, while the latter assigned a greater preference to the other three strategies compared to members of environmental NGOs. However, the non-parametric Mann-Whitney test showed no statistically significant differences for all four strategies.

DISCUSSION

Our study provides valuable insights into the perceptions of Turkish undergraduate (Bachelor's) and graduate (Master's and PhD) students regarding deadwood in forests. Our study showed that Turkish undergraduate and graduate students have a good level of knowledge about the role of deadwood in forests (57.9% of total respondents had prior knowledge of deadwood in forests). Our sample of students highlighted the importance of deadwood as a key component of forests for three main positive aspects – soil fertilization after decomposition, provision of microhabitats and food sources for wildlife – while the importance of the negative aspects (increased risk of forest fire and harmful insects) have been less emphasized. The undergraduate and graduate students' opinion is in line with those of experts who pointed out the role of deadwood for biodiversity conservation providing microhabitats and food sources for wildlife (Johansson et al. 2006, Banaś et al. 2014). In the literature, the use of deadwood for bioenergy production is considered a suitable strategy for the economic valorisation of first decay classes of deadwood in degraded forests with a high amount of deadwood (Deuffic and Lyser 2012), but for our sample of students, the ecological aspects related to deadwood are more important than the economic ones. In addition, other studies emphasized citizens' positive perception of deadwood's ecological role. In fact, Bakhtiari et al. (2014) demonstrated that leaving deadwood in forests was generally accepted by Swedish citizens as a means of preserving ecosystem naturalness, while Kovács et al. (2020) showed that Japanese visitors associated photos of naturally occurring deadwood with aesthetic and spiritual values. Furthermore, some studies have shown that the ecological role of deadwood is closely related to a positive perception toward deadwood in advanced and high decomposition stages (Nielsen et al. 2012, Rathmann et al. 2020).

From an aesthetic point of view, our results showed that a high percentage of students positively view deadwood in forest landscapes with special regard to large deadwood on the ground, while standing dead trees are less appreciated aesthetically. This result is partially confirmed by the pairwise comparison of different deadwood management situations in two forest types characterized by a different level of naturalness: a semi-natural Oriental beech and hornbeam forest and a Scots pine plantation. For both forest types, our sample of students prefers the situation without deadwood, followed by the situation with a moderate amount of deadwood. Many studies in literature have shown people's preference for managed forests where the deadwood is removed compared to those with a higher amount of deadwood (Tyrväinen et al. 2003, Golivets 2011, Jankovska et al. 2014, Pelyukh et al. 2019). In a pioneering study conducted in Finland, Tyrväinen et al. (2003) revealed an aversion of people toward standing dead trees. Similarly, a study in the urban forests of Riga, Latvia, indicated a preference for managed forests where dead branches and deadwood were systematically removed (Jankovska et al. 2014), while Paletto et al. (2017a) emphasized that visitors to the peri-urban forest of Florence, Italy, favoured active forest management practices. Therefore, the results of our study, as well as those of found in the literature, highlight that people perceive the positive role of deadwood in forests but, despite this, aesthetically prefer forests without deadwood. This can presumably lead to a difference in people's perception between recreational forests (without or with a moderate amount of deadwood) and biodiversity conservation forests (with a large amount of deadwood).

Observing the data by socio-demographic characteristics of the respondents, gender differences were observed, with some respondents, especially males, perceiving dead branches and deadwood in urban forests more favourably than others. In addition, only males over 34 years from Forest and Landscape-related departments assigned a higher preference to the situation with a moderate amount of deadwood than the situation without deadwood. In the literature, Pastorella et al. (2016) found that females have a more positive perception of forests with a high level of naturalness, while males prefer the more intensely managed ones. Likewise, Pelyukh et al. (2019) found that females are more aware of the role of deadwood for biodiversity conservation compared to males.

In summary, our results showed that undergraduate and graduate students are aware of the important ecological role of deadwood in forests. However, they still aesthetically prefer situations with an absence or a moderate amount of deadwood.

From a management perspective, our findings suggest that the preferred strategy among our student sample is to retain both standing dead trees and lying deadwood in the forest, focusing on mitigating forest fire and insect infestation risks (Strategy 1). This strategy, aimed at biodiversity conservation throughout the forest area, may not be optimal for recreational forests due to the widespread presence of deadwood. Strategy 4, which emphasizes biodiversity conservation in specific extended rotation stands characterized by a high amount of deadwood, may be more suitable for segregating recreational areas from biodiversity conservation zones. However, it garnered a lower level of preference from the students.

From a methodological point of view, the main limitation of this study is the investigation of the perceptions and preferences of only one target group of citizens (undergraduate and graduate students). In this sense, the study did not allow a comparison between young people and more mature people and between students with a lower education level. A second limitation is snowball sampling, which can create distortions and bias because the sample depends on the researchers' personal resources and contact.

Given our study's results and the international literature, several research questions and gaps emerge. Investigating cultural and geographical variations in deadwood perception is crucial, as perceptions differ significantly across regions and societies. Further research on deadwood's multifaceted roles in ecosystem services, such as soil fertility, habitat provision, and carbon sequestration, is warranted. Finally, bridging the gap between public perceptions and ecological realities can inform conservation strategies that align with public values. Addressing these research questions can enhance our understanding of deadwood perception and management, leading to more effective forestry and conservation policies.

CONCLUSIONS

In this study, we have conducted a comprehensive investigation into the perceptions and preferences of university students regarding the presence of deadwood in forest landscapes within the Turkish context. Our research sought to uncover a multifaceted understanding of how students from diverse educational backgrounds view deadwood, taking into account both its aesthetic and ecological dimensions. The main results obtained show that Turkish university students perceive the key role of deadwood for soil fertilization, provision of microhabitats and food for wildlife. In fact, the deadwood management strategy, which is considered more efficient for biodiversity conservation by students, is aimed at not removing both standing dead trees and lying deadwood from the forest. These students, although aware of the ecological role of deadwood, aesthetically prefer managed forests in which deadwood is moderate or absent.

Throughout the course of our study, several key themes and insights have emerged, shedding light on the nuanced relationship between students and deadwood. These findings not only illuminate the extent of ecological awareness among the student population but also highlight the significant impact of various socio-demographic factors on their attitudes and preferences.

Answer 1: Our research findings indicate that students across different educational levels (undergraduate and graduate) and academic departments generally do not hold negative perceptions of deadwood in forests.

Answer 2: Notably, this study highlights discernible differences in how university students perceive various components of deadwood. Lying deadwood is more positively and aesthetically received than standing dead trees.

Answer 3: Socio-demographic factors, such as gender and age, play a significant role in explaining the variations in individual preferences regarding deadwood.

Furthermore, students prioritize the ecological benefits of deadwood over economic considerations. Lying deadwood is more aesthetically pleasing, with preferences influenced by gender, age, and educational level. Conversely, aesthetic preferences for standing dead trees are influenced by age, educational level, and academic departments.

When selecting forest sites for recreational activities, the respondents generally favour sites without deadwood, aligning with international literature that associates deadwood with mismanagement and ecological harm. However, the present research reveals that students with ecological backgrounds hold a more positive view of a moderate amount of deadwood within recreation sites. Additionally, students' responses show a notable difference in support for a management strategy that promotes maintaining moderate amounts of deadwood across the forest landscape, particularly among those exposed to ecological education.

In the grand scheme of forest conservation, our research points toward a promising avenue where education, awareness, and informed choices can pave the path toward more sustainable and harmonious interactions between humans and forest ecosystems. As we move forward, fostering a deeper understanding of the ecological intricacies of our natural surroundings is becoming crucial for the well-being of both our forests and society at large.

Author Contributions

SB contributed to manuscript writing, collecting data and supervising the work. AP contributed to manuscript defining research framework and writing. CB contributed to manuscript developing survey and statistical analysis.

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Conflicts of Interest

The authors declare no conflict of interest.

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