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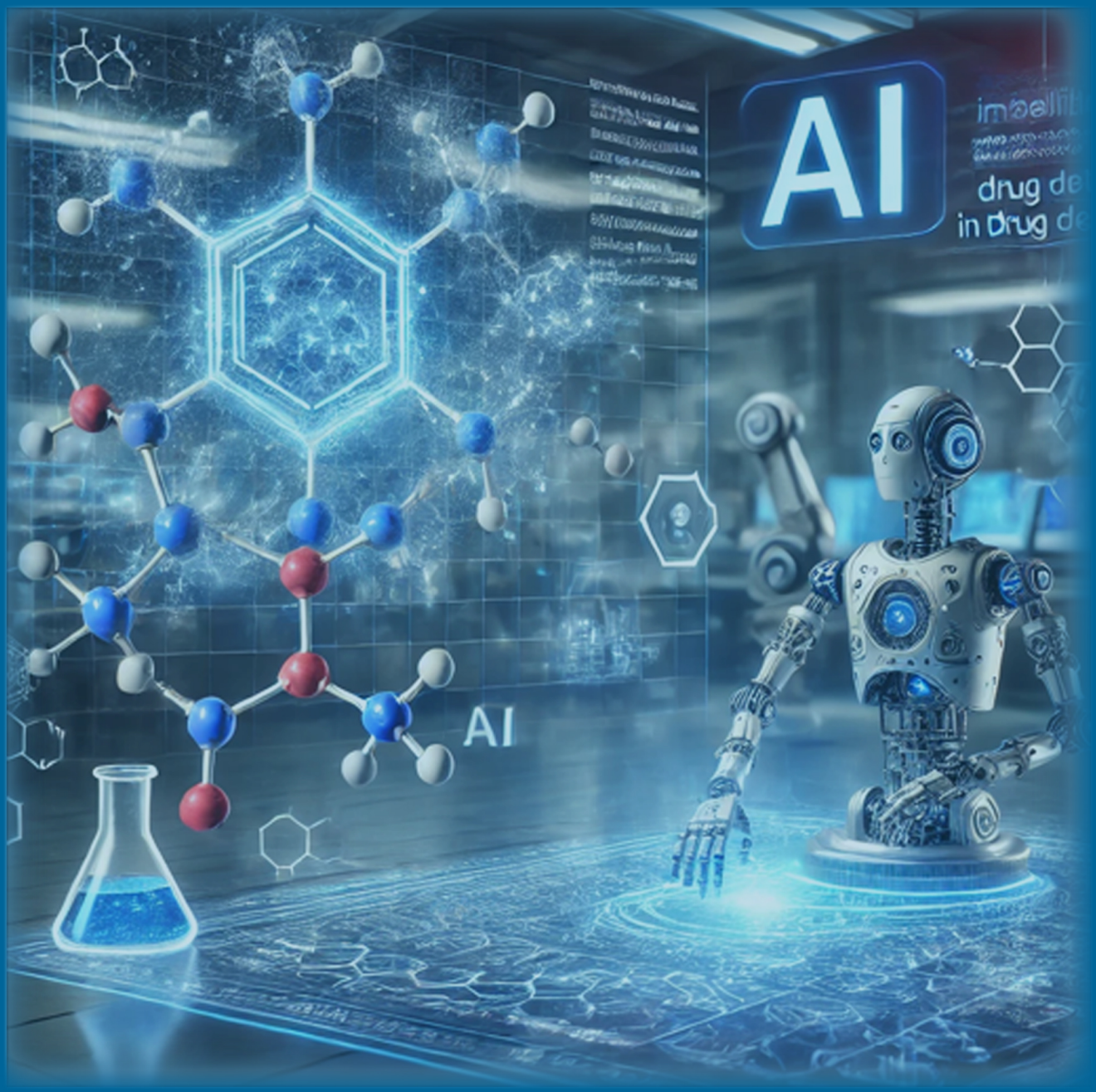

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Examination of Academic Publications of Ankara Hacı Bayram Veli University through Social Network Analysis

Gokcen Altun[1*]

Abstract: Nowadays, social network analysis, used in many different fields, is a highly effective method for visualizing and modeling inter-community relationships by determining a network structure. Ankara Hacı Bayram Veli University (AHBV) was established on May 18, 2018, with units transferred from Gazi University. This study evaluates the academic works of AHBV University from its inception to the present, particularly those expected to stand out in the fields of social sciences and arts, based on their bibliometric characteristics according to the SCI, SSCI, and AHCI indexes, using social network analysis methods. The aim of the research is to identify the areas where publications affiliated with AHBV University between 2018-2023 are concentrated, the prominent research trends in scientific studies, and the universities and institutions with which collaborations have been made. In the study, the evaluation of the publications produced by AHBV University was analyzed and visualized using social network analysis software via the R program, and subsequently interpreted. Such visualization studies will provide data sources for evaluating the publications produced by universities and for developing scientific publication policies. Additionally, by determining the institutions and research areas that hold strong positions within network structures according to calculated centrality, closeness, and other measures, this study aims to contribute to the development of AHBV University's scientific publication policy.

Keywords: Bibliometrics, Scientific publication, Social network analysis, Ankara Hacı Bayram Veli University

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1. INTRODUCTION

In Türkiye, the requirements for academics to have works indexed in citation indices are considered solely on a numerical basis. Although researchers believe that the number of publications alone is not significant, current practices such as the criteria for academic promotions compel researchers to be evaluated based on their publication counts. However, in recent times, the quality of works has also become increasingly important in the evaluation of researchers.

In the assessment of publications, besides the number and quality of publications, parameters such as the fields in which the studies are predominantly conducted, institutional collaborations, and citation counts of the publications have gained significance. Particularly in recent years, universities have taken these various parameters into consideration for rankings by different organizations or for their internal evaluations.

Researchers have turned to bibliometric studies under different headings in terms of the publications made. In the literature, there are studies employing bibliometric techniques for comparison purposes (countries, universities, departments, etc.) or for the examination of works under various parameters.

Bibliometrics is the application of mathematical and statistical methods to books and other communication media (Pritchard, 1969). In their study, Al and Tonta (2004) defined bibliometric analysis as the quantitative analysis of the characteristics of publications or documents, such as authors, subjects, publication information, and cited sources. Bibliometric analysis allows for the identification of the most productive researchers on any given topic, comparison

between countries and institutions, and understanding how scientific communication occurs in various disciplines (Al, 2008).

In recent times, there have been various bibliometric analysis studies conducted in different fields in our country. Yılmaz (2021) aimed to introduce systematic reviews, meta-evaluations, and bibliometric studies and provide information about their use in social sciences and educational sciences. In his study, Öçal (2023) conducted a bibliometric analysis of graduate theses prepared in the field of container transportation in Türkiye between 1999 and 2022. The researcher concluded that the theses were mostly master's theses, written in Turkish, and primarily conducted in the field of business administration. Furthermore, he noted that most studies were conducted in public universities in Izmir and Istanbul.

There are also bibliometric analysis studies related to social media, which has rapidly become a societal communication tool rather than just a personal communication tool in recent years. Akyıldız and Yılmaz (2020) conducted a bibliometric analysis using the science mapping method on studies titled "Social Media" in the WoS database between 2015 and 2020. Yeşiltaş and Şeker (2021) conducted a similar study by narrowing the field to examine educational studies related to social media. Using the WoS database, they found that Hacettepe University was the institution with the most studies on social media in the field of education. The study also revealed that the United States, the United Kingdom, and Australia were the top three countries with the most studies on this topic. In his study, Karakuş (2024) analyzed studies on the highly popular topic of digital violence.

Studies on the prominent topic of artificial intelligence have also been examined using bibliometric analysis by researchers (Akyılmaz, 2022; Ekinci, 2022; Turgut, 2023).

Bibliometric analysis of university journals and universities' own publications has also been a subject of research. Birinci (2008) examined 861 articles from the Turkish Journal of Chemistry using bibliometric analysis to identify the most productive authors and the institutions contributing to the journal. A similar study was conducted by Polat et al. (2013), who analyzed the works of the Journal of Economics and Administrative Sciences at Atatürk University using bibliometric analysis.

Scientific publications reporting the results of bibliometric analyses are highly important within science policy. Transforming descriptive studies into explanatory and guiding research will contribute to more efficient use of national resources.

The aim of this study is to offer a different perspective on academic publication performance by examining the publications indexed under the address of AHBV, which has a new identity and target, and by revealing the research fields, focused topics, and network structure with collaborating institutions.

2. MATERIAL AND METHOD

The concept of a network can be defined in its simplest form as the connection between entities (Christakis and Fowler, 2012). The three main elements that constitute a network are (1) actors, (2) the relationships between actors, and (3) the structure emerging from the different combinations of these relationships (Öztaş and Acar, 2004).

Social network analysis is becoming increasingly popular as a general research approach and method to understand complex interaction patterns. The network perspective examines nodes that are directly or indirectly connected by one or more different relationships. Theoretically, individuals, groups, organizations, communities, or countries can be considered nodes as any unit of analysis that is meaningful.

Some definitions related to social network analysis are as follows:

Node: Actors within social structures (individuals).

Edge: Relationships between actors (ties).

Adjacency Matrix: A matrix representing the ties between nodes in a network.

Degree Centrality: The number of direct connections an actor has, indicating the most active and influential entity within the network.

In-degree: The number of incoming connections, indicating the importance of an actor within the network.

Out-degree: The number of outgoing connections, indicating the actor that establishes the most relationships within the network.

Diameter: The maximum distance between connected nodes.

Closeness Centrality: The degree of proximity of a node to other nodes, either directly or indirectly.

Betweenness Centrality: The degree to which a node lies on the shortest path between other nodes.

Social network analysis has a wide range of applications in fields such as health, economics, and education. It is particularly beneficial as it provides visual representations of the results. Social network analysis facilitates the visibility of social relationships and information flow, the evaluation, comparison, and measurement of these relationships and flows. It can be used to identify individuals, teams, and units with significant roles within the network structure, uncover isolated units, identify opportunities to accelerate information flow, and determine areas where information sharing would have a higher impact (Demirgil, 2018).

This study aims to examine the bibliometric characteristics of the works indexed in the Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index under the address of AHBV

University and to evaluate the relationships of institutional collaborations through social network analysis. A search was conducted in the Web of Science database using the keyword 'Ankara Hacı Bayram Veli University' from the addresses, and 661 publications from the years 2018 to 2023, the founding year of the university, were identified.
The study utilized certain metrics, such as closeness and betweenness, to determine author and institutional collaborations. Closeness centrality is a measure of how quickly information can be disseminated. The formula for calculating closeness centrality, which measures the number of steps required to reach all other nodes from a specific node, is as follows:

$$C(x) = \frac{1}{\sum d(y,x)} \quad (1)$$

Betweenness centrality is a measure of the number of shortest paths that pass through a specific node;

$$\vartheta = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}} \quad (2)$$

is calculated as follows. In the equation;

$\sigma_{st}(v)$ = the total number of paths from s to t that pass through v
σ_{st} = represents the total number of shortest paths from s to t.
R programming language was utilized to obtain the network structure visualization of institutional collaborations at Ankara Hacı Bayram Veli University.

3. RESULTS

The total number of publications affiliated with AHBV University between 2018 and 2023 is 661. Of these publications, 92.6% are articles, 2.7% are book reviews, 1.7% are reviews, and 1.5% are full-text papers. The remaining 1.5% consists of editorials, biographies, corrections, and letters.

Table 1. Distribution of Publications by Type

Publication Type	Number	Percentage
Article	612	92.6%
Book Review	18	2.7%
Review	11	1.7%
Full-text Paper	10	1.5%
Editorial	7	1.1%
Biography	1	0.2%
Correction	1	0.2%
Letter	1	0.2%

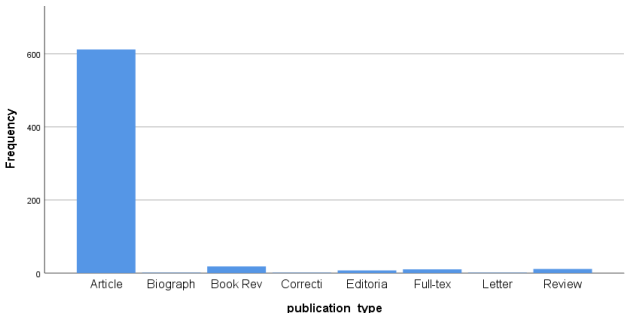

Figure 1. Distribution of Publication Types at AHBV University

In terms of publication language, it is evident that English is the predominant language. The languages following English are Turkish and Spanish, respectively. In this context, an increase in the number of articles in Turkish is anticipated, and encouraging efforts should be made in this direction.

Table 2. Distribution of Publications by Language

Publication Language	Number	Percentage
English	507	76.7%
Turkish	152	23.0%
Spanish	2	0.3%

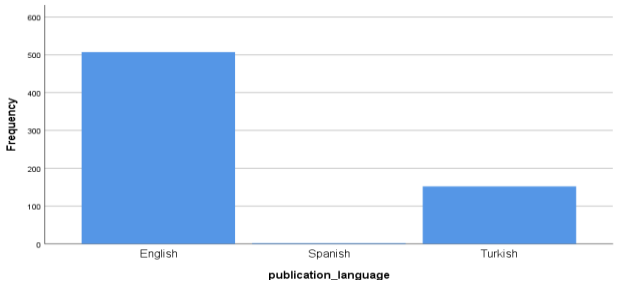

Figure 2. Distribution of Publication Languages at AHBV University

Examining the distribution of publication numbers by year, it is believed that the low number of publications in 2018 was due to some data being affiliated with Gazi University. It is observed that there was a significant increase in the number of publications over the subsequent three years, although there has been a slight decline in the number of publications over the last two years.

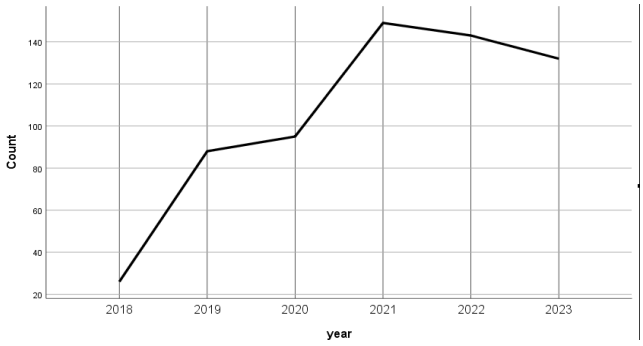

Figure 3. Distribution of AHBV University Publications by Year

The fields of study for publications affiliated with AHBV University have been evaluated based on the classifications defined by Web of Science. Between 2018 and 2023, authors at AHBV University have conducted research in 87 different fields

Table 3. Distribution of Publications by Field of Study

Field of Study	Number
Arts and Humanities	84
Business Economics	84
Physics	53
Chemistry	51
Materials Science	48
Mathematics	45
Engineering	37
Science and Technology	33
Fieldwork	24
Social Sciences	22

Table 3 displays the top 10 fields with the highest number of publications at AHBV University. As shown in the table, the highest number of publications, 84 each, are in the fields of Arts and Humanities and Business Economics. These fields are followed by Physics and Chemistry with 53 and 51 publications, respectively. It can be suggested that AHBV University, which aims to excel in Social Sciences and the Arts, should focus more on publishing in these areas. It is anticipated that the works in the Science field listed in the table were conducted by the Polatlı Faculty of Science at AHBV University.

Table 4. Distribution of Publications by Journal

Publication	Number	Index
Milli Folklor Dergisi	61	AHCI
Bilig	14	SSCI
Amme İdaresi Dergisi	10	SSCI
Journal of Gazi Academic View	9	ESCI
Journal of Art History	9	ESCI
Beytulhikme: An International Journal of Philosophy	8	ESCI
Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty	8	ESCI
Sosyoekonomi	7	ESCI
Sanat ve Tasarım Dergisi	6	ESCI
Mathematics	6	SCI
Physica B: Condensed Matter	6	SCI

Publications affiliated with AHBV University have been made in 200 different journals. The journals with the highest number of articles are summarized in Table 4. Among the 11 journals listed in the table, 6 are indexed in the Emerging Sources Citation Index, 2 in the Social Sciences Citation Index, 2 in the Science Citation Index Expanded, and 1 in the Arts & Humanities Citation Index.

Table 5. Distribution of Publications by Publisher

Publisher	Number
Elsevier	87
Taylor & Francis	60
Springer Nature	59
Geleneksel Yayıncılık Ltd	46
Wiley	28
Emerald Group Publishing	19
MDPI	16
Milli Folklor	15
Ahmet Yesevi University	14
Sage Publishing	14

The top 10 publishers with the highest number of publications are summarized in Table 5. Table 5 is useful for identifying the publishers of journals not listed in Table 4.
Table 26 provides information on the top 26 universities with which AHBV University faculty members have collaborated. According to the table, the most significant collaboration, with 96 publications, was with Gazi University. This result is expected, given that the two institutions were under the same umbrella before 2018, making it natural to have established collaborative groups in previous years. The second and third universities with the most collaboration are Hacettepe and Ankara Universities, which are among Turkey's most prestigious institutions. These are followed by Atılım and Bilkent Universities. The top five universities with which AHBV University faculty members have collaborated are all located in the same city.

Table 6. Institutions in Domestic Publication Collaboration

University/Institution	Number
Gazi University	97
Hacettepe University	49
Ankara University	41
Atılım University	18
Bilkent University	14
Ankara Yıldırım Beyazıt University	11
Selçuk University	11
Atatürk University	10
Erciyes University	10
METU	10
Ahi Evran University	9
Istanbul University	9
Nevşehir Hacı Bektaş Veli University	9
Akdeniz University	8
Karabük University	7
Istanbul Gelisim University	7
Kastamonu University	7
National Police Academy	7
Başkent University	6
Beykent University	6
Kırıkkale University	6
Marmara University	6
Ministry of Health	6
Muş Alparslan University	6
Necmettin Erbakan University	6
Osmaniye Korkut Ata University	6

The network structure of institutions affiliated with co-authors in publications with AHBV University has been examined using social network analysis. While the results of the analyses are visually summarized, degree, closeness, and betweenness centrality measures have been utilized to facilitate the identification of roles within the network structure.

Table 7. Centrality Values of Institutional Collaboration in Joint Publications

University/Institution	Degree Centrality	Closeness Centrality	Betweenness Centrality
AHBV University	363	0.03846154	2.927653976
Gazi University	6834	0.03571429	11.393194339
Hacettepe University	9398	0.03448276	5.804784998
Ankara University	7704	0.03333333	1.491661819
Atılım University	1090	0.03333333	0.016489048
Bilkent University	987	0.03125000	0.002745894
AYBÜ	2994	0.03846154	5.609026928
Selçuk University	4752	0.03571429	1.750340029
Atatürk University	2353	0.03703704	2.131516637
Erciyes University	4714	0.03571429	2.024166105
METU	4647	0.03225806	1.513122991
Ahi Evran University	1063	0.03571429	0.711175849
Istanbul University	7198	0.03846154	6.718799980
NHBV University	428	0.03571429	0.029877658
Akdeniz University	2882	0.03703704	1.427162919
Karabük University	862	0.03703704	0.208304998
Istanbul Gelisim University	283	0.03333333	0.018208007
Kastamonu University	643	0.03225806	0.039751025
National Police Academy	14	0.02127660	0.000000000
Başkent University	3040	0.03448276	0.113633465
Beykent University	1795	0.03030303	0.130556995
Kırıkkale University	1556	0.03846154	1.502077532
Marmara University	6430	0.03703704	3.319443765
Ministry of Health	1410	0.03225806	0.017116592
Muş Alparslan University	270	0.02857143	0.016748138
Necmettin Erbakan University	5271	0.03703704	1.081401847
Osmaniye Korkut Ata University	205	0.02857143	0.001038468

The study includes institutions with at least six joint collaborations with faculty members of AHBV University between 2018 and 2023. Additionally, the joint collaborations among 26 institutions, excluding AHBV University, were examined. According to Table 7, and as seen from the data, the institutions with the highest number of joint collaborations are Hacettepe, Ankara, Istanbul, Gazi, and Marmara Universities, in that order.

The Closeness Centrality value pertains to the collaboration of each institution with the other 26 institutions. Since these 26 institutions are those that AHBV University has collaborated with, it is expected that AHBV University has the highest value of Closeness Centrality (0.03846154). Like AHBV University, Ankara Yıldırım Beyazıt University, Istanbul University, and Kırıkkale University have also collaborated with the other 26 institutions. The structure of these institutions' connections provides them with the ability to reach other institutions in the network more quickly and directly. Following these institutions are Akdeniz, Karabük, Marmara, and Necmettin Erbakan Universities, with a Closeness Centrality value of 0.03703704. The institutions with the least collaboration are the National Police Academy, Muş Alparslan University, and Osmaniye Korkut Ata University.

Betweenness Centrality is used to measure the strategic importance and mediation capacity of a node within a social network. In other words, it acts as a bridge. This measurement calculates how frequently a node appears on the shortest paths between other nodes. In essence, the higher the Betweenness Centrality of a node, the more it controls or mediates the flow of information or resources between other nodes. A node with a high Betweenness Centrality value in the network indicates that it has the greatest influence on relationships within the cluster. According to Table 7, the highest Betweenness Centrality value of 11.393194339 belongs to Gazi University. Thus, Gazi University holds the most prominent position in the institutional collaboration network related to AHBV University publications.

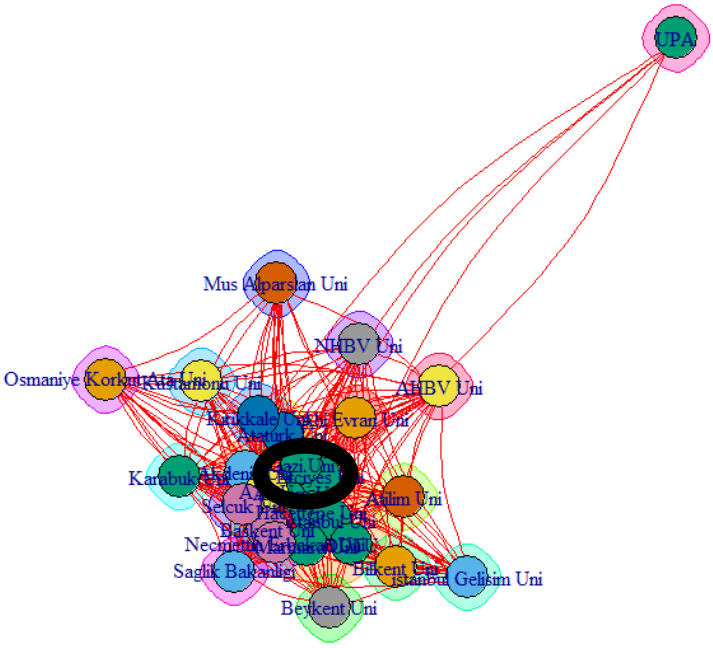

Figure 1. Institutional Collaboration Network Structure

Figure 1 illustrates the network structures among institutions collaborating with AHBV University. The figures are based on the number of publications and joint collaborations between the institutions. As indicated by the Betweenness Centrality value, Gazi University is positioned at the center of the network. Gazi University acts as a bridge between other institutions. Excluding the institutions at the outer edge of the figure, the remaining institutions are those with the highest number of publications and the most extensive joint collaborations. Institutions such as the National Police Academy, Muş Alparslan University, Osmaniye Korkut Ata University, Karabük University, the Ministry of Health, Beykent University, Istanbul Gelisim University, and Nevşehir Hacı Bektaş Veli University are the institutions with the lowest number of joint collaborations within this group.

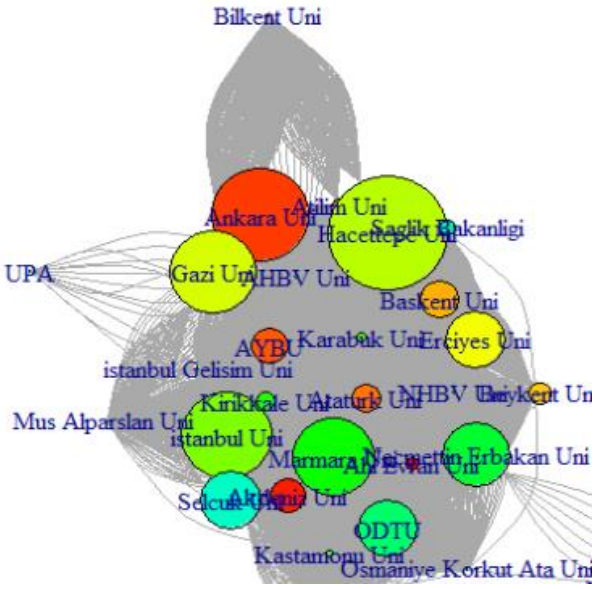

Figure 2. Institutional Network Structure by Centrality Measure

One of the primary goals of social network analysis is to visually present and interpret the obtained results. Figure 2 displays the network structures of institutions based on centrality measures. The size of the nodes is proportional to the centrality measures, which facilitates the interpretation of the figure. Upon examining Figure 2, it is evident that the institutions with the highest centrality measures, or in other words, those with the most extensive joint collaborations, are Hacettepe University, Ankara University, Gazi University, Istanbul University, and Marmara University. The institutions that follow are METU, Necmettin Erbakan University, Selçuk University, and Erciyes University.

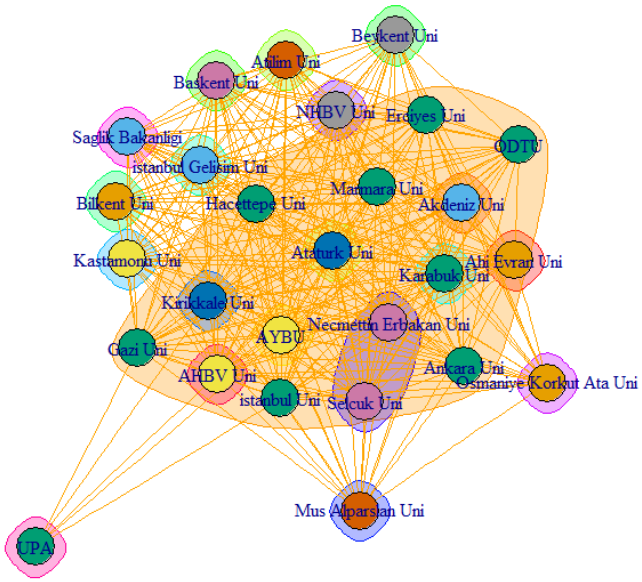

Figure 3. Network Structure Based on Institutional Communities

Figure 3 is designed to visualize groups of nodes that are densely interconnected. It can be observed that Necmettin Erbakan University and Selçuk University form a distinct group among themselves. Additionally, Figure 3 shows that Gazi University, Kırıkkale University, Hacettepe University, Nevşehir Hacı Bektaş Veli University, Ankara Hacı Bayram Veli University, Ankara Yıldırım Beyazıt University, Atatürk University, Marmara University, Erciyes University, Middle East Technical University, Akdeniz University, Istanbul University, Karabük University, Ankara University, Necmettin Erbakan University, and Selçuk University constitute another group. These universities are characterized by their dense interconnections and their role as bridging institutions among themselves.

4. DISCUSSION AND CONCLUSIONS

This study examines the institutions with which Ankara Hacı Bayram Veli University (AHBV) collaborates, based on the publications listed in citation indices. In this context, the institutions with which AHBV University has engaged in collaborative work, along with various aspects such as publication counts over the years, publication types, research areas, journals, and publishers, have been analyzed. The aim of this study is to contribute to the determination of AHBV University's scientific publication policy. According to the research findings, the majority of publications from the university are in English and are primarily articles. AHBV University has engaged in the most collaboration with some of Turkey's most prestigious and prolific universities, including Gazi, Hacettepe, and Ankara Universities.

The primary research areas of focus for the university are "arts and humanities" and "business economics." This aligns with AHBV University's objective to stand out, particularly in the fields of social sciences and arts.

The study, which evaluates various departments and research areas, uses bibliometric and social network analysis to highlight the areas where the university excels. This analysis will contribute to identifying not only the university's strengths but also areas where it needs to increase its research efforts, thus supporting the identification of priority areas in YÖK's strategic initiatives.

AHBV University has conducted its collaborative work with some of the largest and most research-intensive universities in Turkey. However, the university has fewer publications compared to these institutions. One of the primary reasons for this is the university's separation from Gazi University in 2018. The number of faculties, departments, and faculty members is significantly lower compared to the institutions with which it collaborates most. These highly collaborative institutions typically have faculties specializing in health sciences and engineering, which accounts for their high research output. AHBV University has demonstrated success in the areas it aims to excel in by engaging extensively in collaborative research with these institutions.

This study will assist in identifying the strengths and areas for improvement of the university based on parameters such as institutions, research areas, journals, and indices. It will also help in supporting the development of the departments that require enhancement.

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It should be written as short as possible and expressing the contribution made without giving the number.

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Peer-review
Externally peer-reviewed.

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Conceptualization: G.A.; Investigation: G.A.; Material and Methodology: G.A., Supervision: G.A.; Visualization: G.A.; Writing-Original Draft: G.A.; Writing-review & Editing: G.A., author has read and agreed to the published version of manuscript.

Conflict of Interest
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Settlement Suitability Analysis: The Case of Bursa City

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Abstract: Recently, the existing built-up area texture in cities has started to shift towards areas that are not suitable for settlement. In this sense, settlement suitability analyses play a critical role in the realisation of sustainable development goals. Detailed analyses are required to formulate an effective settlement strategy in regions with large and diverse natural features such as Bursa. In this study, in order to determine the areas suitable for settlement in the study area, which covers the borders of Osmangazi, Nilüfer and Yıldırım districts, which are the central districts of Bursa city, a settlement suitability analysis was carried out with the Analytical Hierarchy Process (AHP) method using 9 parameters consisting of slope, elevation, lithology, land use, precipitation, temperature, distance to stream, distance to fault and erosion. The main underlying data used in the study are 10m resolution Digital Elevation Model (DEM), lithology, land use, erosion, 30m resolution precipitation, and temperature (WorldClim) data of Bursa city. As a result of the analysis, it was determined that 9% of the city is very suitable, 44% is moderate suitable and 47% is unsuitable. The area where the city was established is in very suitable and moderate suitable class. It is observed that the settlements established in the study area, especially in the areas close to the fault line and the main river branch, are in the moderate suitable and unsuitable class. In addition, it has been determined that the erosion risk is in the low class, and the settlements far from the main river branch and fault line are in the very favourable class. While it is observed that Bursa city is located at appropriate values in terms of topography, it is seen that especially the southern part of the city is not sufficiently suitable in terms of distance to fault lines. The results obtained aim to contribute to sustainable settlement planning and to provide a guide for the methods and processes to be used in settlement suitability analysis.

Keywords: Analytical Hierarchy Process (AHP), Bursa City, Settlement Suitability Analysis.

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1. INTRODUCTION

Recent rapid population growth worldwide has led to the unplanned expansion of residential areas, resulting in numerous issues related to the natural environment. Over time, as residential areas in cities have become inadequate, areas unsuitable for settlement, such as steep slopes, valley floors, fault lines, agricultural lands, forest areas, and wetlands, have also been subjected to settlement pressures. This situation has caused a shift of settlements toward unsuitable areas (Degerliyurt et al., 2014; Tekeş and Cürebal, 2019).

Unplanned urbanization, misuse of natural resources, natural disasters, changing land use, and increasing population are leading to the expansion of existing settlement areas into disaster-prone regions. Unplanned growth, incompatible with the natural environment, has led to major environmental problems such as the destruction of nature and man-made hazards (Karaoglu, 2013; Tekin et al., 2018). These problems have caused loss of life and great economic losses. Especially, the destruction caused by hazards such as floods, landslides, and earthquakes has made the effects of poor settlement decisions even more apparent (Cui et al., 2021). Therefore, the expansion of urban areas towards disaster areas has increased the importance of appropriate site selection. This situation encourages urban planners and decision-makers to be more careful and meticulous in creating sustainable and livable cities, taking into account environmental, social, and economic factors for the efficient and sustainable use of natural resources.

The widespread awareness of urban and environmental wastefulness is of great importance for local governments, especially in terms of sustainable urbanization. This situation has added a new one to the existing environmental debates on urban development and growth dynamics since the 1970s. In order to resolve the emerging controversies, it is necessary to carry out appropriate site selection studies that take into account the components of the natural environment in the settlement areas (Bayar, 2005). In this direction, the analysis of suitability for settlement enables the identification of areas that are compatible with the components of the natural environment.

Settlement suitability analysis is the process of evaluating and ranking certain settlement areas in terms of their suitability for defined uses (Jeong et al., 2013). It is also one of the basic steps for the planning and development of settlement areas (Mert and Acarer, 2018; Ozkan et al., 2019; Süel et al., 2021). The planning of a new settlement area often depends on various environmental, social, economic and political factors. Geographical Information Systems (GIS), which allows to bring together and evaluate many data, is an important tool used for this purpose (Chen et al., 2010; Özdemir, 2024). In the studies on the suitability of settlement areas, methods consisting of Analytical Hierarchy Process (AHP), Entropy Weight Method, Ecological Footprint, Fuzzy comprehensive evaluation were generally used and reliable results were obtained (Wang et al., 2017; Tang et al., 2017).

Many researches have been carried out on appropriate site selection and land planning in urban areas to find solutions to unplanned settlement problems (Erinc, 1980; Gupta, 2006; Nidumolu et al., 2006; Dai et al., 2001; Ekinci and Sonmez, 2007; Uy and Nakagoshi 2008; Özşahin and Kaymaz, 2015). The common aim of these studies is to assess how suitable a particular area is for settlement in line with various parameters. As a result of these analyses, sustainable and safe settlement areas are determined by taking into consideration factors such as natural disaster risks, environmental factors, infrastructure facilities, social and economic needs. In this way, it is aimed to prevent unplanned and irregular urbanization and to use resources effectively and efficiently.

The aim of this study is to conduct a suitability analysis for settlement in the districts of Osmangazi, Nilüfer, and Yıldırım within the city of Bursa using the AHP method, one of the Multi-Criteria Decision Making (MCDM) techniques. In the study, the question of where the research area is suitable for settlement was sought with the help of GIS techniques by using nine parameters: slope, elevation, lithology, land use, precipitation, temperature, distance to the stream, distance to the fault, and erosion. In this respect, the study is of great importance in terms of providing benefits to local administrators, researchers and planners to design the plans of settlement areas.

2. STUDY AREA

Bursa province is located between 39º 35' and 40º 40' east longitudes and 28º 10' and 30º 10' north latitudes in the south of the Marmara Sea in northwest Turkey. The province, which is largely within the borders of the Marmara Region, is surrounded by Kocaeli and Yalova to the north, Eskisehir and Kütahya to the south, Bilecik and Sakarya to the east, and Balıkesir to the west. Bursa, which has a total area of 10.886 km², has 17 districts including Büyükorhan, Gemlik, Gürsu, Harmancık, İnegöl, İznik, Karacabey, Keles, Kestel, Mudanya, Mustafakemalpasa, Orhaneli, Orhangazi, Nilüfer, Osmangazi, Yenisehir and Yıldırım. In this study, the central districts of Osmangazi, Nilüfer and Yıldırım within the borders of Bursa city constitute the study area (Figure 1).

Osmangazi, Nilüfer and Yıldırım districts are important regions of Bursa, reflecting its general structure and diversity. The study area is located in the south of Bursa Plain, on the northwestern foothills of Uludag. Uludag has a peak that rises to 2543 meters, starting from 100 meters above the Bursa Plain and creating flat areas at different elevation levels over a short distance. This city, which shows diversity from a geomorphological perspective, has besides main geomorphological units such as mountains, plateaus, and plains, landforms with very different characteristics, such as alluvial fans.

The geological structure of Bursa city generally consists of metamorphic, ophiolitic, volcanic, plutonic and sedimentary rock types representing the Paleozoic - Quaternary time interval. Bursa, Sogukpinar and Uluabat faults were effective in shaping the city structurally.

The study area has a transitional climate type between the Black Sea and Mediterranean climates. There are significant elevation differences between Bursa Plain and Uludag in a short distance, which leads to the diversification of the climate. The hottest months in the study area are July-September and the coldest months are February-March.

The most significant factor in the development of the current relief features of the city is the rivers. The alluvium brought by the rivers accumulates in areas where the slope decreases, forming intra-mountainous plains, piedmont plains, and alluvial fans. The city, which drains its waters into the Sea of Marmara via the Nilüfer Stream, has numerous seasonal or permanent rivers.

The study area is of great importance in terms of understanding the historical, cultural, economic and social dynamics of the city. However, it also offers important opportunities in terms of its location and ecological structure (Figure 2). Bursa is one of the most populous cities in Turkey in terms of population. The areas where the population (2.083.47) is concentrated in Bursa are Osmangazi, Yıldırım and Nilüfer districts (TÜİK, 2023).

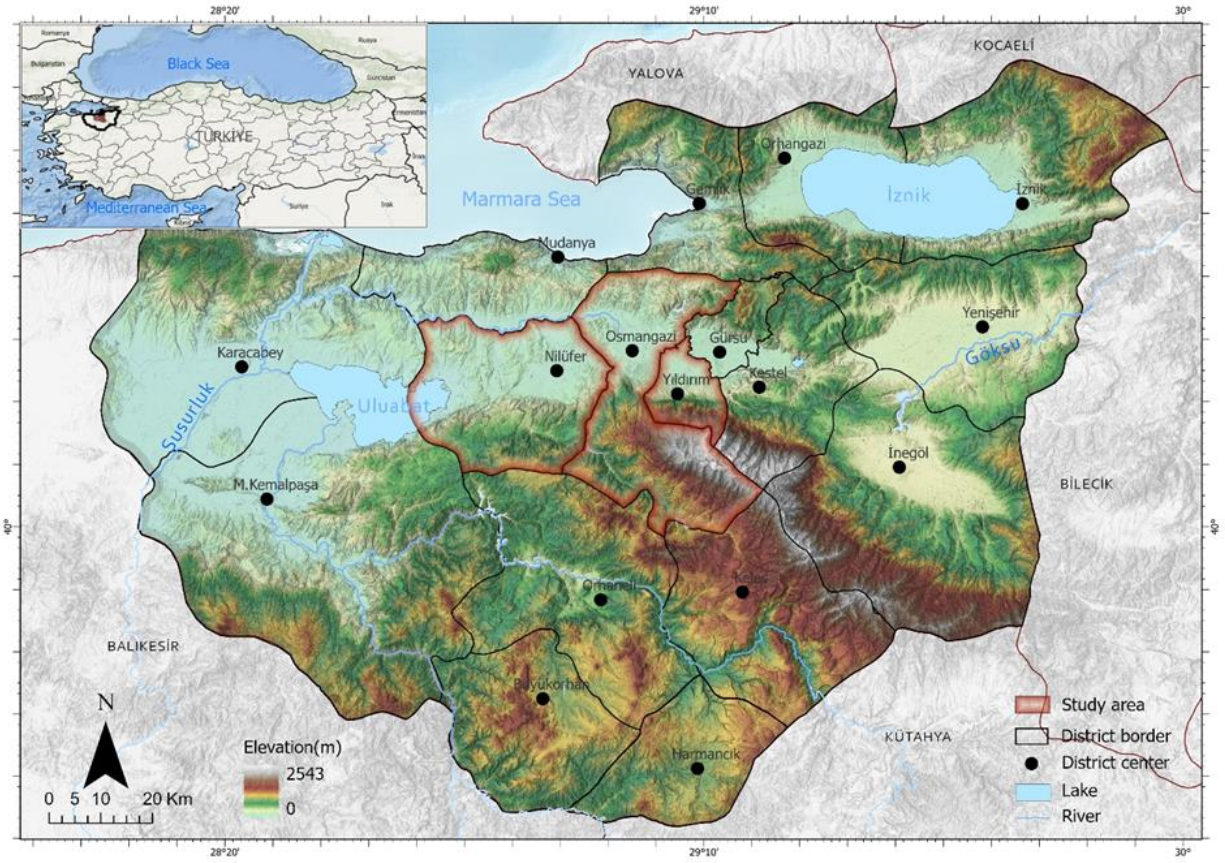

Figure 1. Location map of the study area.

Figure 2. Satellite image of settlement distribution in the study area.

3. MATERIAL AND METHOD

In the study, 10m resolution Digital Elevation Model (DEM), 1/100.000 scale lithology digital data and 30m resolution raster precipitation and temperature (WorldClim) data produced by Fick and Hijmans (2017), 1/25000 scale erosion data prepared by the General Directorate of Rural Services, and Corine land use data, whose applicability has been demonstrated in many national and international studies, constitute the basic base data. In settlement suitability analyses, the determination of suitable areas depends on many factors. In the study, using 9 parameters including slope, elevation, lithology, land use, precipitation, temperature, distance to rivers, distance to faults, and erosion, the suitability of the study area for settlement was investigated using GIS techniques to answer the question of where the most suitable areas for settlement are. In line with the purpose of the study, AHP, which is one of the MCDM methods widely used in the decision-making process of GIS-based applications, was utilized as a method. MCDM is a method that provides the opportunity to evaluate many measurable and unmeasurable parameters at the same time, and in addition, it can include a large number of parameters in the decision-making process (Dagdeviren et al., 2005).

AHP was first introduced by Saaty in 1977. In the AHP method, it is first necessary to determine the importance of each causative parameters suitability for settlement based on a binary evaluation. There are certain numerical values required for this. In this direction, pairwise comparisons and percentage importance distributions of the factors are made using the 1-9 comparison importance scale developed by Saaty, as shown in Table 1 (Yaralioglu, 2001).

Table 1. Analytic hierarchy process evaluation scale (Saaty, 1977).

İmportance value	Value definitions
1	Both factors are of equal importance
3	Factor 1 is more important than factor 2
5	Factor 1 is much more important than factor 2
7	Factor 1 is much stronger important than factor 2
9	Factor 1 is much superiority important than factor 2
2,4,6,8	Intermediate values

AHP helps users to determine the weights of parameters in solving a multi-criteria problem. It provides mathematical measures to determine the consistency of the decision matrix. The consistency index, which measures the consistency of binary comparisons, can be calculated using the following equation.

$$CI = \frac{\lambda max - n}{n-1} \qquad \textit{(Equality 1)}$$

In Equation 1, CI is the consistency index, n is the number of items compared in the matrix, λmax is the largest or principal eigenvalue of the matrix. In Equation 2, CR is the consistency ratio, CI is the consistency index and RI is the random index. A consistency ratio coefficient of less than 0.1 has a positive meaning. (Hanbali et al., 2021). Saaty (1977), suggested that if this ratio exceeds 0.1, the judgments might be too inconsistent to be reliable. A CR ratio of 0 indicates that the decision is completely consistent.

$$CR = \frac{CI}{RI} \qquad \textit{(Equality 2)}$$

Within the scope of the study, the class and percentage importance weights of the parameters whose scale coefficients were determined were obtained in a way to ensure consistency (Table 2). AHP weight values are determined according to the preferences of the decision makers and the weighting of the factors has an important effect on obtaining the result. In this context the validity of consistency was checked by calculating the consistency index and ratio. Subsequently, alternatives were determined considering these criteria, and a hierarchical structure was established.

Table 2. Parameters evaluated in the study and weights.

Parameters	Parameter classes	Suitability class	Weight
Slope	0-5	4	0.16
	5-10	3	
	10-15	2	
	15>	1	
Elevation (m)	0-300	4	0.12
	300-600	3	
	600-900	2	
	900>	1	
Lithology	Ophiolitic	1	0.07
	Plutonic	1	
	Volcanic	2	
	Metamorphic	3	
	Sedimentary	4	
Temperature (°C)	2.7-4.7	1	0.09
	4.7-6.7	2	
	6.7-8.7	3	
	8.7>	4	
Precipitation (mm)	531-617	4	0.09
	617-704	3	
	704-791	2	
	791>	1	
Distance to river	0-300 m	1	0.13
	300-1000	2	
	1000-2000	3	
	2000>	4	
Distance to fault	0-45	1	0.10
	45-90	2	
	90-135	3	
	135>	4	
Land use	Wetland	1	0.14
	Forest and natural area	2	
	Agricultural land	3	
	Settlement area	4	
Erosion	Low	4	0.10
	Moderate	3	
	High	2	
	Very high	1	

4.RESULTS and DISCUSSION

4.1. Parameters Used in Settlement Suitability Analysis

In the scope this study, to analyze the settlement suitability of Bursa city, 9 parameters consisting of slope, elevation, lithology, land use, precipitation, temperature, distance to streams, distance to faults, and erosion were applied to the study area (Figure 3). At this stage of the study, the values of parameters other than lithology, land use, and erosion were given as ranges and were not classified.

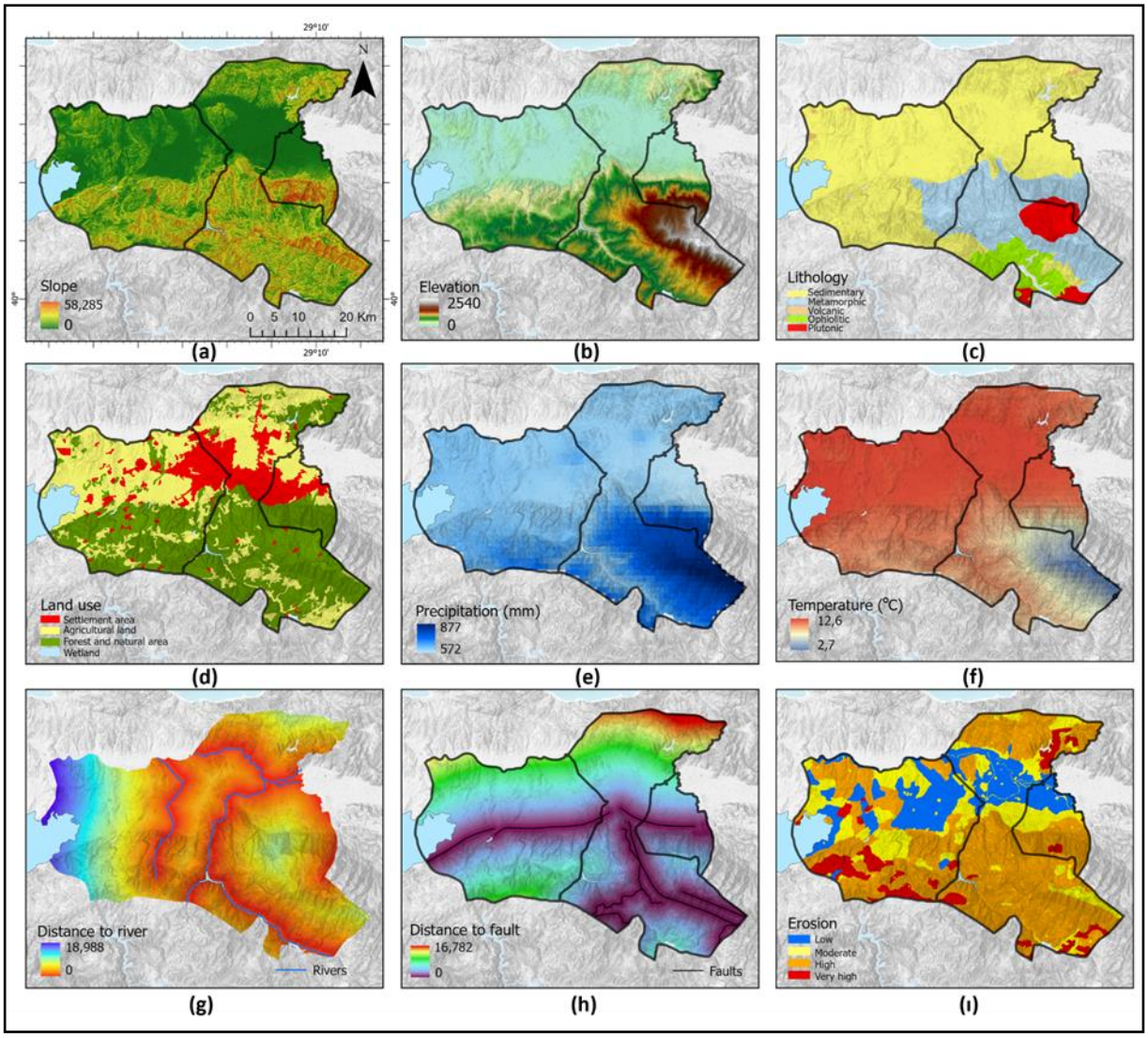

Figure 3. (a) slope, (b) elevation, (c) lithology, (d) land use, (e) precipitation, (f) temperature, (g) distance to river, (h) distance to fault, (ı) erosion (Value distributions of the parameters evaluated for the suitability for settlement analysis).

Slope: For settlement areas, slope refers to the degree of slope of the land. In the study area, slope values vary between 0 and 58 (Figure 3a). Steep slopes, generally with high gradients, reduce the suitability of land for settlement by introducing various challenges and additional costs, leading to infrastructure and transportation difficulties (Alam et al., 2023). For this reason, gently sloping areas were preferred for settlement in the study.

Elevation: It refers to the height of the settlement area above sea level. The elevation range of the study area varies between 0 and 2540 m (Figure 3b). Elevation is an important parameter in the selection and planning of settlements (Jeong et al., 2013). The reason directly affects climatic conditions, water resources, soil characteristics and infrastructure challenges. High areas are not suitable for settlement due to landslides, landslip and other geological risks. However, settlements established on the riversides or valley floors in low-lying areas are also exposed to flood risk. For this reason, this was prevented by considering the distance to the river parameter in the study.

Lithology: Lithological features help us to recognize the region in terms of topography. It is an important parameter as it greatly influences groundwater and surface water movement and accumulation (Miller, 1990). A distribution of sedimentary, metamorphic, volcanic, ophiolitic and plutonic rock groups is observed in the study area. Places where Plutonic and Ophiolitic rocks are observed are not suitable for settlement as the water will directly flow to the surface during sudden downpours (Figure 3c).

Land use: Land use are one of the important parameters in defining the earth. In settlement suitability analysis, land use should be considered as a basic parameter to prevent unplanned and uncontrolled development in urban areas. This is essential to ensure sustainable and orderly urbanization, conservation of natural resources and efficient delivery of infrastructure services. The study area consists of 4 classes: settlement area, agricultural area, forest and natural areas and finally wetlands (Figure 3d). Forest and natural areas and wetlands are considered as restricted areas for human settlement. Agricultural and settlement areas are

more important areas for settlement development as they are important for human livelihoods (Alam et al., 2023).

Precipitation: Precipitation is a highly influential parameter in the occurrence of disasters of hydrological origin (MGM, 2021). In areas of high rainfall, draining water and protecting infrastructure will be more difficult, making low rainfall areas more suitable for sustainable and safe settlements. When the precipitation data was applied to the study area, it was found that the values varied between 572 and 877 mm (Figure 3e).

Temperature: It directly affects the climate, agricultural productivity and quality of life of the region. Temperature is a determining factor especially for agricultural production. Appropriate temperature values are essential for the growth of plants and the sustainability of agriculture. When the temperature data was applied to the study area, it was found that the values varied between 2.7 and 12.6 (ºC) (Figure 3f). The part of the study area where the Bursa plain is located has high temperatures, while the part where the Uludag massif is located has the lowest temperature.

Distance to river: Although being close to rivers provides various services to people, settlements close to rivers are at high risk. It has also been observed that the vulnerability of settlements decreases as they move away from rivers (Ghosh and Kar, 2018). In this study, areas far from the river were considered suitable for settlement. The distance to the river in the study area varies between 0 and 18,988 (Figure 3g).

Distance to fault: Proximity to fault lines increases the risk of seismicity. Earthquakes cause damage to structures, loss of life and disruption of infrastructure. However, this varies depending on factors such as the intensity of the earthquake, its depth, proximity to the settlement and the durability of the structure. Therefore, areas away from fault lines are considered safer for settlements. In the study area, the distance to the fault varies between 0 and 16,782 (Figure 3h).

Erosion: The erosion parameter plays a critical role in assessing the risks of landslides and surface erosion. It reduces land productivity and threatens the safety of infrastructure. Soil susceptibility is low in erosion-prone areas, jeopardizing the safety of buildings and roads. In terms of suitability for settlement, areas with low erosion risk were given a score of 4, areas with moderate erosion risk were given a score of 3, areas with high erosion risk were given a score of 2 and areas with very high erosion risk were given a score of 1 (Figure 3ı).

4.2. Settlement Suitability Analysis

Most of the cities that are not built-in appropriate areas face various risks. Turkey has a susceptibility to various natural disasters such as earthquakes, floods and landslides due to its geographical location and geological structure (CRED, 2023). The city of Bursa has also been under the influence of these risks from past to present. In order to better understand the impact of these risks and the process of settlement suitability analysis, after analyzing the 9 parameters applied to the study area, the weight values of all parameters were calculated and overlay was performed with the AHP method. After this process, three suitability classes were defined on the settlement suitability map: Very suitable, moderate suitable, unsuitable. The distribution of the area covered by these classes is 9% very suitable, 44% moderate suitable, 47% unsuitable (Figure 4). The AHP consistency index (CI) of the 9 parameters used in this study is 0.05, the consistency ratio (CR) is 0.04. Similarly, Vilasan and Kapse (2022) found the AHP consistency ratio as 0.04 in their study. Hammami et al., (2019) found the CR value to be 0.013 and Kazakis et al., (2015) found it to be 0.08. According to AHP, the CR value should be <0.1 to validate the weight; otherwise, the weights of the comparison matrix need to be recalculated (Swain et al., 2020).

When the settlement suitability analysis result map of Bursa city is examined, it is seen that the areas close to the fault line and main river branch have moderate suitable and unsuitable, while the areas with high elevation, steep slope, high precipitation, low temperature and high and very high erosion risk are unsuitable for settlement. In addition, it was determined that slope, elevation and precipitation parameters showed low values, and settlements far from the main river branch and fault line were in a very suitable class.

Since settlements close to water sources in the study area may face flood hazards, various measures need to be taken. While it is observed that the city of Bursa is located in topographically appropriate values, it is seen that especially the southern part of the city is not built appropriately enough in terms of distance to fault lines. Settlements located close to rivers and fault lines therefore have moderate suitable and unsuitable.

The northern part of the study area is more suitable for settlement than the southern part. The reason for this is that the southern part of the district borders is located in a mountainous area that is unsuitable for settlement. The mountainous area is unsuitable for settlement due to its high elevation, gradually increasing slope, high and very high erosion risk, being located in forest and natural areas in terms of land use, and the lithological units do not show a distribution suitable for settlement.

In this study, a GIS based, medium resolution (10m) settlement suitability analysis was carried out for the city of Bursa. Using the AHP based on expert opinion, settlement suitability analyses and syntheses were carried out as a basis for planning, thus contributing to the identification of potential development directions.

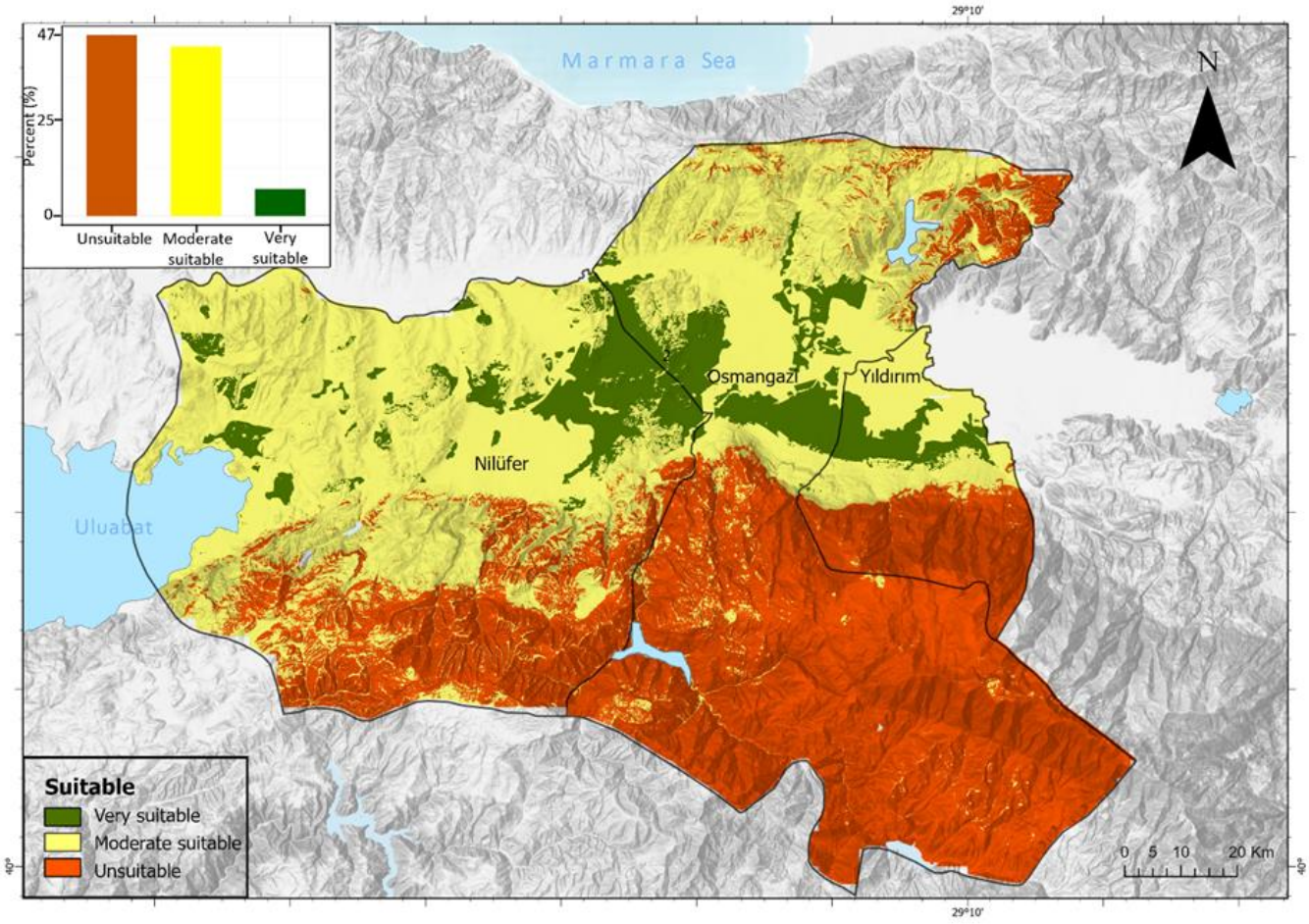

Figure 4. Settlement suitability analysis of Bursa city.

5. CONCLUSIONS

In order to determine the most suitable area for new development areas in the study area, which covers the borders of Osmangazi, Nilüfer and Yıldırım districts, which are the central districts of Bursa city, a settlement suitability analysis was carried out using GIS. In this respect, a comprehensive urban settlement suitability analysis has been carried out to identify potential and appropriate regional development directions for the city of Bursa and to form the basis for urban planning studies. For this purpose, after analyzing 9 parameters consisting of slope, elevation, lithology, land use, precipitation, temperature, distance to stream, distance to fault and erosion, the weight values of all parameters were calculated and overlay was performed with the AHP method. Determining the impact of the 9 parameters evaluated in the study for settlement suitability analysis, their priority order and weight for the study area is a comprehensive process based on expert opinion within the scope of the AHP method. As a result of the settlement suitability analysis for Bursa city, it was determined that 9% of the city is very suitable, 44% is moderately suitable, and 47% is unsuitable. The area where the city is located found the very suitable and moderate suitable classes. When the settlement suitability analysis result map of Bursa city is examined, it is seen that the areas close to the fault line and main river branch have moderate suitable and unsuitable, while the areas with high elevation, steep slope, high precipitation, low temperature and high and very high erosion risk are unsuitable for settlement. In addition, it was determined that slope, elevation and precipitation parameters showed low values and settlements far from the main river branch and fault line were in a very suitable class. Since settlements close to the river in the study area may face flood hazards, various measures should be taken. While it is observed that the city of Bursa is located in topographically appropriate values, it is seen that especially the southern part of the city is not sufficiently suitable in terms of distance to fault lines. In recent years, the city has been at the forefront with its identity as an industrial city. The increase in industry and urbanization together with the migration from rural to urban areas has led to the destruction of fertile agricultural lands in the city and increased out of purpose. This situation still continues today. Therefore, it is necessary to prepare land use plans and projects in order to reduce the misuse of land and its use in risky areas. For a solution, strategic planning should be made to support the development of regions suitable for settlement, and infrastructure and transport investments should be directed to these areas. In unsuitable areas, the natural structure should be preserved and conservation policies should be developed for these areas. The results will contribute to a sustainable and environmentally susceptibility settlement planning.

Ethics Committee Approval
N/A

Peer-review
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Conflict of Interest
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Impact of Thinning on Sexual Symmetry and Gene Diversity in *Pinus brutia* Ten. Plantation

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Abstract: Thinning is widely used in the context of sustainable forestry, but its impact on the gene diversity of the next generation remains unclear. In this study, we evaluated some commonly proposed genetic parameters for managing gene diversity in seed orchards. In this framework, we checked whether sexual symmetry, fecundity variation, and linked metrics (i.e., effective population size and gene diversity) can be used to optimize gene diversity through thinning in production forests. We divided trees in a Brutia pine plantation in southern Türkiye into three different canopy cover classes: the control group, the moderately thinned group, and the heavily thinned group, and monitored them. The results of our research revealed the impact of thinning on genetic parameters and showed that these metrics can be used to manage gene diversity in production forests. We believe that this study can function as a prototype for future studies using different thinning intensities in various regions and for different species to determine the most appropriate thinning intensities for sustainability.

Keywords: East Mediterranean, Forest tending, Parental balance, Reproduction, Silviculture

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1. INTRODUCTION

Thinning, an important component of sustainable forestry, has recently gained traction in the battle concerning climate change. Many studies have provided strong evidence that thinning to reduce competition among trees for essential resources provides benefits such as reduced drought-related mortality (Sohn and Saha, 2016; Cabon et al., 2018; Bello et al., 2019; Wang et al., 2019; Steckel et al., 2020; Zamora-Pereira et al., 2021), minimized wild-fire risk (Collins et al., 2014; Kalies and Kent, 2016; Palmero-Iniesta et al., 2017; Hevia et al., 2018; Tardós et al., 2019), and enhanced resistance to insect-pathogen outbreaks (Menkis et al., 2015; Bulman et al., 2016; Morris et al., 2021; Steel et al., 2021). Research has shown that the positive effects of thinning become stronger as the intensity of thinning increases and that heavy thinning, which involves lifting greater than 40% of the basal area, is particularly impactful (Collins et al., 2014; Kalies and Kent, 2016; Sohn and Saha, 2016; Cabon et al., 2018; Wang et al., 2019; Bello et al., 2019; Steckel et al., 2020; Zamora-Pereira et al., 2021). Although heavy thinning may offer greater short-term advantages, it may lead to a genetic bottleneck in future generations as it reduces the number of possible parents in the stand (Ellegren and Galtier, 2016).

In the literature, approaches to addressing gene diversity in the context of sustainable forestry have generally focused on seed orchards. Seed orchards are specifically engineered to grow genetically polymorphic (i.e., diverse) seeds for use in regeneration activities (Kang and Bilir, 2021). Burczyk and Chalupka (1997) and Kang and Lindgren (1999) have drawn attention to the delicate balance between male and female individuals in a population in the context of genetic diversity. Recent research has focused on measuring this balance via the maleness index (Cercioglu and Cetinkaya, 2021a; Jiao et al., 2021; Park et al., 2023; Kim et al., 2024). Defined as the proportion of male strobili that facilitate plant pollination, this index provides information on the sex distribution of a population (Burczyk and Chalupka, 1997; Kang and Lindgren, 1999). However, the impact of thinning on the gender balance (through maleness index) has not been investigated, yet.

Another research focus in the context of genetic diversity has been the monitoring of fertility or fecundity variation

and linked metrics (i.e., estimation of effective population size and gene diversity) (Özel and Bilir, 2016; Bilir et al., 2017; Park et al., 2017; Teodosiu et al., 2022; Xie et al., 2022; Wang et al., 2023). Fertility or fecundity variation is defined as a genetic parameter reflecting disparities in reproductive success among individual trees (Kang et al., 2003) Seed orchards target low fertility variations (Kang and Bilir, 2021). This implies that the trees in the gene pool are represented in a balanced way, i.e., that each tree contributes roughly the same number of offspring for the next generation (Kang, 2001). High variation indicates that some genotypes are disproportionately represented, thus potentially jeopardizing gene flow (Bilir and Kang, 2021). Effective number of parents refers to the minimum quantity of trees within a stand that can maintain genetic diversity (Bilir and Kang, 2021). By chance, allele frequencies in a population can fluctuate. This concept helps us understand the impact of this randomness, known as genetic drift (Kang et al., 2023). Previous research has not established a clear link between fecundity variation and commercial thinning, which is commonly used in production forests. By understanding the impacts of density reduction on gene diversity, we aim to contribute to the improvement of optimal management strategies for sensitive forestry operations.

The Mediterranean basin is a region suffering intensely from climate change (Pachauri et al., 2014; Cramer et al., 2020; Acarer, 2024). Brutia pine, which has a wide distribution area in Türkiye, stands out as one of the species at high risk in the region and as one of the species that may be most affected by climate change due to the latitudinal effect (OGM, 2020). Here, short-term approaches such as afforestation or thinning can be functional. However, in the long term, the intensity of thinning should be carefully calibrated so that the species' natural adaptation mechanisms (through gene diversity) are not disrupted.

Based on this background information, the present study addresses the changes in strobilus yields and gene diversity under different thinning practices in *P. brutia* plantations. Specifically, the following questions we focused on were: (1) How do different degrees of thinning interventions impact strobilus yields? (2) How do different degrees of thinning interventions impact sexual symmetry, fecundity variation, and the effective population size? (3) Can these genetic metrics developed for seed orchards be integrated into natural Brutia pine forests through thinning to improve conservation and management strategies? (4) What is the optimal thinning intensity for *P. brutia* in terms of gene diversity? Our findings are supposed to constitute a scientific foundation for the sustainable improvement of production forests.

2. MATERIAL AND METHOD

The investigation was implemented on an Brutia pine plantation (37° 07' 34"N, 36° 33' 04"E) in Hasanbeyli District of Osmaniye Province, Türkiye (Figure 1). The plantation is located on the Nurdagi pass, which serves as a connection between Çukurova and the eastern region. It is characterized by low hills, ranging from 750 to 800 meters in height, and has a subtropical dry summer Mediterranean climate (MGM, 2018).

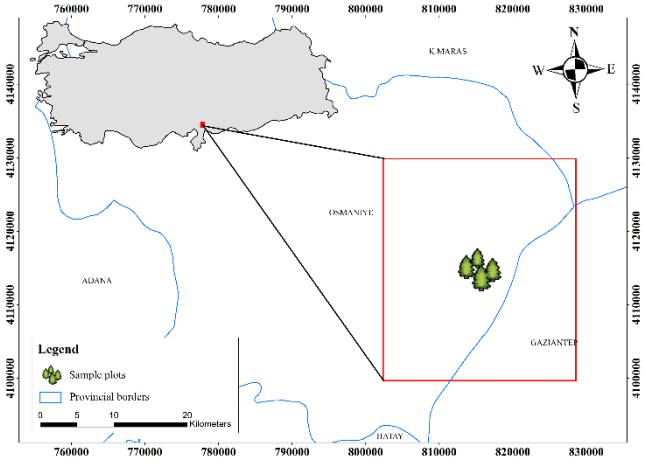

Figure 1. Location of the study area

Plantation was established in 1987, was planted at 3 m × 2 m spacing, and originated from a single provenance. The plantation was thinned two times in 2000 and 2010, and its density is irregular. In 2020, sample trees were stratified into three canopy cover classes (CCCs): S1, S2, and S3 stands. No thinning activity was organized in S1, which served as a control plot. The experimental activity was organized in S2 as a medium-thinning intensity plot and in S3 as a heavy-thinning intensity plot. Thinning treatments were conducted in S2 and S3, with an intensity of 30% and 60%, respectively. S2 and S3 were thinned from below by intervening in poorly formed crowns, twisted stems, and co-dominant and suppressed trees. While timber and cutting residues were removed after the thinning intervention, no vegetation below the main vegetation layer was removed, neither during nor after thinning. Measurements were performed 3 years after the last thinning. We chose strategically neighbouring positions for all three stands to minimize environmental impacts and ensure that only the effect of thinning is visible.

To determine the growth dynamics of the trees, measurements of height (abbreviated as H) and diameter at breast height (abbreviated as DBH) were carried out. Between March and May 2023, the count of female (abbreviated as Nf) and male (abbreviated as Nm) strobilus in each individual was recorded. Each Nf was counted individually using binoculars. The generation of Nm was examined using the conventional branch approach (Krouchi et al., 2004). For Nm, each individual tree was marked with four typical branches: one located to the east, one to the south, one to the west, and one to the north. The strobili on these branches were tallied and multiplied by total number of branches that have strobili (Bilir and Kang 2021; Park et al. 2023). The total strobilus number (abbreviated as TSN) was obtained by summing number of female and male strobili in every single individual.

Data underwent the Kolmogorov-Smirnov test originally. Given the non-normal pattern of the data set, Kruskal-Wallis test was run to assess differences among groups in the dependent variables. The Kruskal-Wallis test results were visualized as weighted boxplots that not only

summarized this information using quartiles, medians, and min/max values but also compared medians and distributed the data by group (MacFarland and Yates, 2016). Correlations among the growth and reproductive characteristics of the subject trees were examined using Spearman's correlation. All statistical tests were conducted using RStudio v. 2023.03.0-386 (RStudio Team, 2020).

The maleness index (M_i), which represents individual and/or collective contributions to the pollen gene pool during pollination in the forest, was calculated as (Burczyk and Chalupka, 1997; Kang and Lindgren, 1999):

$$M_i = \frac{pm_i}{pm_i + pf_i} \quad (1)$$

where pm_i and pf_i represent the male and female strobilus yield ratios for the i^{th} subject tree, respectively.

Fertility or fecundity variations reflecting inequalities in the number of trees involved in reproduction were calculated separately for female (Ψ_f) and male strobilus (Ψ_m) yield, respectively, as follows (Kang et al., 2003; Park et al., 2017):

$$\Psi_f = N\sum_{i=1}^{N} f_i^2 \qquad \Psi_m = N\sum_{i=1}^{N} m_i^2 \quad (2)$$

where N is the number of subjects, f_i is the fecundity for female strobilus yield of the i^{th} tree, m_i is the fecundity for male strobilus yield of the i^{th} tree.

To analyze the combined fecundity variation (Ψ), we initially examined the Spearman correlation coefficient (r) among female and male strobilus yields and then employed the following formulation (Bilir and Kang, 2021):

$$\Psi = 0.25(\Psi_f + \Psi_m) + 0.5\left[1 + r\sqrt{(\Psi_f - 1) + (\Psi_m - 1)}\right] \quad (3)$$

Effective number of parents (N_p), a concept that represents the count of adults contributing to the gene diversity of the next generation in a stand and is calculated by examining the relatedness of trees within the stand, was linked to fertility variations as follows (Kang et al., 2023):

$$N_p = \frac{N}{\Psi} \qquad N_p^{(f)} = \frac{N}{\Psi_f} \qquad N_p^{(m)} = \frac{N}{\Psi_m} \quad (4)$$

Gene diversity (GD) was computed according to fecundity variations and the number of subject trees as follows (Yazici and Bilir, 2023):

$$GD = 1 - \frac{0.5\Psi}{N} \quad (5)$$

Tree slenderness coefficient (TSC), which is often utilized as a common metric in the context of stability against windthrow on a tree or stand basis, was calculated as follows (Zhang et al., 2020):

$$TSC = \frac{Total\ tree\ height}{Diameter\ at\ breast\ height} \quad (6)$$

where the variables involved in the division must be of the same unit type (e.g., cm/cm or m/m).

3. RESULTS

3.1. Impact of Canopy Cover on Strobilus Yield of Trees

Strobilus yields (Nf and Nm) both differed significantly ($p < 0.05$) among canopy cover classes (Table 1 and Figure 2).

Table 1. Strobilus yields of *Pinus brutia* at different densities of canopy cover classes

CCCs *	RO **	Mean	Range
S1	Nf	20–800	257.26
	Nm	90–2610	1045.60
S2	Nf	291–1489	829.72
	Nm	300–8214	3329.18
S3	Nf	694–1915	1232.78
	Nm	750–9000	4712

* CCCs was canopy cover classes, S1 was control, S2 was medium thinning, S3 was heavy thinning; ** RO was reproductive output, Nf was female strobilus, Nm was male strobilus.

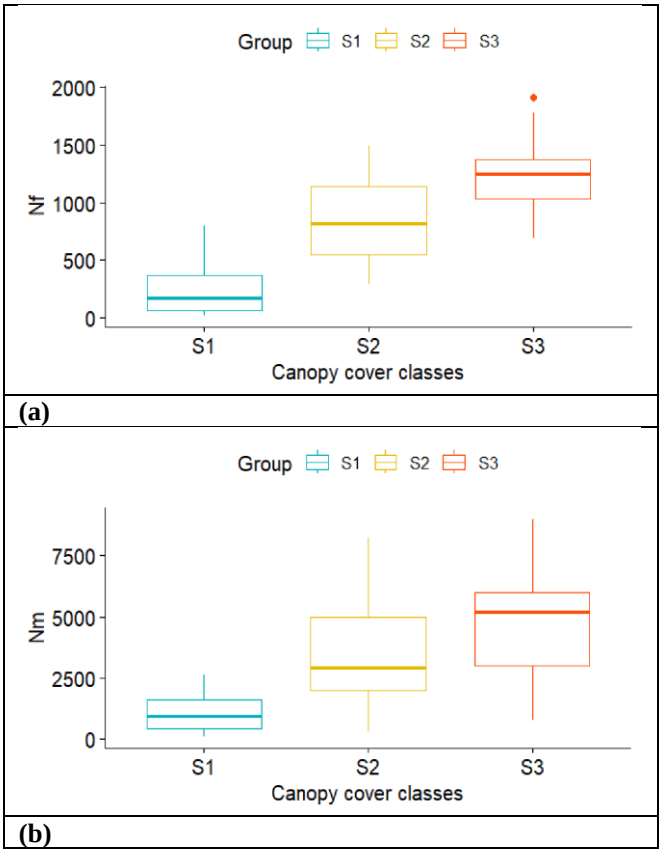

Figure 2. Female **(a)** and male **(b)** strobilus yields in canopy cover classes

The yearly Nf production of the two thinning densities was 222.52% and 379.20% ($p < 0.05$) greater than the control, respectively. The yearly Nm production of the two thinning

densities was 218.40% and 350.65% ($p < 0.05$) greater than the control, respectively. The yearly TSN of the two thinning densities was 219.21% and 356.29% ($p < 0.05$) higher than the control, respectively. In the control group, some trees were found to contribute asymmetrically to reproduction with extreme yields. For instance, in stand S1 (control), the five most fertile trees (10% of the subject trees) generated 22.83% of the TSN. In contrast, for S2 (medium thinning), this percentage was 20.12%, while for S3 (medium thinning), it was 16.08%.

3.2. Impact of Canopy Cover on Growth-Reproduction Correlations of Trees

As can be seen in Figure 3, there were overall significant ($p < 0.05$) positive correlations in terms of strobilus yields both within and among populations, as assessed by Spearman correlation analysis. There was no significant correlation between H and DBH and strobilus yields within groups, whereas there was a correlation between H and DBH and strobilus yields among groups, which was caused by the group effect. In this case, significant ($p < 0.05$) and positive correlations emerged among strobilus yields and diameter at breast height, while significant ($p < 0.05$) but negative correlations were observed among tree height and strobilus yields. In addition, the correlation analysis showed a moderate relationship with height and diameter for strobilus yields, while it showed an almost strong relationship (mean, $r = -0.68$) with the height-to-diameter ratio (i.e., slenderness).

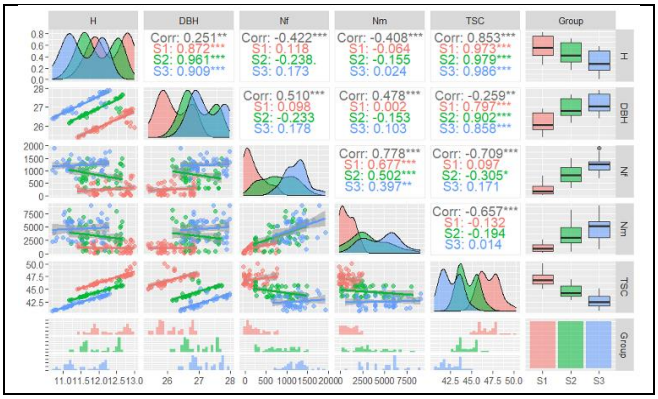

Figure 3. Scatter plot matrix for growth and reproductive outputs. Diagonal graphs show the distribution of outputs across canopy cover classes; graphs below the diagonal show the scatter and trend of measured outputs; and above the diagonal show the overall and within-group correlations between outputs.

3.3. Impact of Canopy Cover on Sexual Symmetry, Fertility Variation, and Linked Parameters

Maleness (M_i) and femaleness indices (F_i) fluctuated among canopy cover classes (Table 2). The M_i of the two thinning densities stabilized, decreasing by 5.26% and 3.90%, respectively, compared to the control. However, although sexual symmetry was approached in thinned stands compared to the control, a perfectly linear relationship was not detected in terms of maleness and femaleness indices in stands depending on the thinning intensity. Stand S2 was the one that approached sexual symmetry the most.

Table 2. Fecundity variation (Ψ), effective number of parents (N_p), maleness index (M_i), femaleness index (F_i), and genetic diversity (GD) in stands.

CCCs *	S1	S2	S3
Ψ	1.70	1.33	1.14
Np	29.41	37.59	43.86
Mi	0.80	0.76	0.77
Fi **	0.20	0.24	0.23
GD	0.983	0.9867	0.9886

* CCCs was canopy cover classes, S1 was control, S2 was medium thinning, S3 was heavy thinning; ** Fi = 1 - Mi.

The Ψ of the two thinning densities stabilized, decreasing by 27.82% and 49.12%, respectively, compared to the control. The N_p of the two thinning densities stabilized, increasing by 27.81% and 49.13%, respectively, compared to the control. The effective population size had a positive linear relationship with the degree of thinning in S2 (75% productive trees) and S3 (88% productive trees) and demonstrated linear growth in comparison to the control (59% productive trees). Gene diversity (GD), which is linked to effective population size and fertility variation, also increased from S1 to S3. Gene diversity loss was reduced by 0.0037 and 0.0056 in the two thinning densities, respectively, compared to the control.

4. DISCUSSION

4.1. Impact of Canopy Cover on Strobilus Yield of Trees

Adjusting the spatial arrangement of forests is a crucial component of the sustainable forestry approach. Thinning is a frequently employed technique for making this adjustment. We addressed the impact of thinning on fecundity so as to create a polymorphic seed bank for forest sustainability. The results showed that thinning significantly ($p < 0.05$) and exponentially increased strobilus yields in *P. brutia*. This finding is in line with the recognized notion that trees in more open canopy positions (with increased light availability due to thinning) produce significantly more reproductive structures compared to trees in the control group with denser canopies (Moreno-Fernández et al., 2013; Nguyen et al., 2018; Matsushita et al., 2020). This is consistent with and can be explained by the findings of Saatçioğlu (1971), who reported that a large nutrient expenditure in the mast year may result in poor seed formation the following year; that an increase in the carbon/nitrogen ratio in the tree is likely to increase flower formation; that hot summers reduce the uptake of nutrient salts due to soil drought and that sunny weather increases carbohydrate production; and that the tops of trees that receive light from all directions and are fully exposed produce the most flowers and fruit. Furthermore, the yield of male and female strobilus in thinned stands showed a linear increase. This suggests a consistent increase in reproductive effort following thinning.

Our study is in accordance with the research published by Ayari et al. (2012), who reported that trees with larger trunk diameters produce larger cones, that thinning practices can increase this production, and that this is perhaps one of the biggest advantages of thinning. Similarly, Ayari et al. (2011), looked at 79 Aleppo pine forests in Tunisia and detected a negative association between canopy cover intensity and seed and cone yield ($r_{seed} < -0.418$, $r_{cone} < -0.471$ $(p < 0.001)$). These findings are supported by other studies showing that thinning treatments have an ameliorative effect on trunk diameter, total height, and crown development (Prévosto et al., 2011; Adamopoulos et al., 2012; Ruano et al., 2013). The effects of thinning on the production of reproductive structures have been documented in Aleppo pines in various geographical locations, such as Tunisia (Ayari et al., 2012), Italy (Mencuccini et al., 1995), and Spain (Arista and Talavera, 1997), and in various forest tree species, such as *Pinus ponderosa* (Krannitz and Duralia, 2004), *Pinus pinea* (Moreno-Fernández et al., 2013), and *Pinus koraiensis* (Nguyen et al., 2018). In conclusion, with our results (i.e., the observed increase in fecundity and more even distribution of reproductive effort), we would like to emphasize once again that thinning is a valuable tool to promote successful reproduction in Brutia pine stands.

4.2. Impact of Canopy Cover on Growth-Reproduction Correlations of Trees

In terms of correlations, the most remarkable outcome we found was the almost strong (mean, $r = -0.68$) correlation between TSC and strobilus yields. Typically, research in the literature has focused on examining correlations between growth patterns and reproductive yields (i.e., strobilus and cones) and has found evidence of positive, negative, or neutral relationships. For example, Bilir et al. (2006) conducted a study in three clonal *Pinus sylvestris* seed orchards and found that although flower yield was not very high in general, it was positively affected by growth characteristics, and this was especially related to the diameter at the base. Gonçalves and Pommerening (2012) reported a significant positive relationship between cone yield and crown diameter in *Pinus pinea* and Çerçioğlu and Çetinkaya (2021b) in *Pinus brutia*. Çerçioğlu and Bilir (2018) reported that height had no effect on female flower yield in 2015 but had a positive and significant effect on male flower yield and 2016 overall flower yield in *Pinus nigra* Arn. subsp. *pallasina* (Lamb.) Holmboe. In the same study, crown diameter was found to have a positive effect on flower yield in 2015 and a negative effect on flower yield in 2016. In addition, it was emphasized that height and diameter at breast height were more effective on the number of seeds and cones, while the growth traits that were effective on reproductive traits were listed as height, crown diameter, and diameter at breast height. Chen and Willis (2023) reported that diameter was neutrally correlated with cone production. Similarly, Yücedağ et al. (2019) reported that there was no correlation between flower yield and growth traits in *Tilia tomentosa*.

In this study, unlike other studies, we employed TSC as the dependent variable and obtained a stronger correlation coefficient with TSC than with H and DBH. This finding suggests that TSC could be measured metrically and used as a criterion for plus tree selection, or that slenderness-reducing interventions such as crown pruning could be used to increase seed yield in seed orchards (Han et al., 2008). Indeed, TSC provided a realistic representation of both the diameter and height of a tree and showed that trees with larger diameters and proportional heights (i.e., not thin trees) generally had the largest reproductive outputs. Put simply, the most evenly growing non-thin trees appear to be the best reproducers. Based on our results, we believe that TSC is highly correlated with reproductive output production. Slenderness may explain why some trees produce a good reproductive output at very old ages. For example, Genç (2004) stated that *Cedrus libani*, which is predominantly distributed in Türkiye, produces both the desired quality and amount of timber and sufficient seed yield for regeneration studies only after reaching 100 years of age, so the rotation period should not be less than 100 years. Indeed, the Turkish General Directorate of Forestry uses rotations of 120–140 years for rich areas and 160–180 years for poor areas. For Taurus cedar, this period marks a period of weakened height development: good seed production and slenderness seem to go hand in hand.

4.3. Impact of Canopy Cover on Sexual Symmetry, Fertility Variation, and Linked Parameters

As mentioned above, although the beneficial effects of thinning on reproductive structures have been demonstrated in many studies, the existing literature lacks sufficient information regarding the impact of thinning on fertility distribution. In this study, we investigated how thinning practices may affect some genetic parameters that are widely recommended for managing gene diversity in seed orchards. In this framework, we first addressed the impacts of thinning on sexual symmetry, whose importance on gene diversity has been reported in many studies (Cercioglu and Cetinkaya, 2021a; Jiao et al., 2021; Kang et al., 2023; Park et al., 2023; Kim et al., 2024). In monoecious species such as pine, sexual asymmetry (i.e., numerical variations of male and female strobili) is common (Burczyk and Chalupka, 1997; Cercioglu and Cetinkaya, 2021a; Kim et al., 2024). Maleness and femaleness indices can help us get better insight into reproduction, and they reveal paternal and maternal contributions, respectively. If M_i is 0.5, female and male fertility are equal (Kang et al., 2023). The femaleness index can be calculated as $1 - m_i$, and describes the breeding success of female parents (Kang and Lindgren, 1999). Our results showed that thinning generally tends to produce gender balance. We found that maleness and femaleness indices fluctuated among canopy cover classes and showed a dynamic response to thinning intensity. The decrease in the maleness index after thinning treatments reflected a trend towards sexual symmetry, while no direct linear relationship was found between thinning intensity and indices. This suggests that source, plant interactions, or genotypic factors may influence sexual distribution.

Secondly, we discussed the effects of thinning on fertility variation (Ψ), whose importance for gene diversity has been recognized in many studies (Özel and Bilir, 2016; Bilir et al., 2017; Park et al., 2017; Teodosiu et al., 2022; Xie et al.,

2022; Wang et al., 2023). Fecundity variation is the residual variance in the fertility levels due to the among-individual variances (Kang, 2001). Fertility is related to individuals' reproductive capability and success, often measured as the number or ratio of offspring produced (Bilir et al., 2017; Park et al., 2017; Cercioglu and Cetinkaya, 2021a). If all trees in the stand produce an equal number of offspring, the fertility variation value is 1 ($\Psi = 1$) (Kang et al., 2003). Kang (2001) reported that a fertility variation value of 2 is normal for seed orchards and up to 3 for natural populations. In this framework, we found that thinning treatments led to a significant reduction in fecundity variation compared to the control, indicating more balanced reproductive success. This finding suggests that thinned stands show a greater balancing effect and relatively low fecundity variation. Low fecundity variation indicates more equal reproductive success among trees, while high variation causes heterogeneity between genetic and phenotypic success processes (Yazici and Bilir, 2023). Consistent with Kang's (2001) study, low values of fecundity variation suggest that genetic diversity can be increased in thinned stands.

Our third focus was the effective number of parents (N_p). Low (i.e., balanced) values of fertility variation indicate that the trees in the population are represented in the gene pool in close proportions and that the population size involved in reproduction is increasing (Cercioglu and Cetinkaya, 2021a; Bilir and Kang, 2021). We found that the thinning treatments provided a significant increase in this parameter. The increase in the number of effective parents indicates a potential increase in genetic diversity within the thinned populations (Table 2). The thinning treatments provided a stronger balancing effect compared to the control, indicating a more balanced representation of trees in the population in the gene pool. However, the difference in balancing between S2 (75% productive trees) and S3 (88% productive trees) was small, suggesting that thinning intensity has a limited effect on this parameter above a certain level.

Overall, this study has demonstrated the potential of thinning practices to increase and control genetic diversity in production forests. Fertility is critical for forest management and plays a key role in achieving maximum potential genetic gain. Uneven fecundity among parental trees is likely to affect gene diversity in the next generation (Park et al., 2023; Wang et al., 2023). The more equal the offspring of the parents are, the more likely it is that the next generation will have a wider range of genes (Kang et al., 2023). Species with too little gene diversity may find it increasingly difficult to reproduce properly, and offspring may have to deal with the same health problems observed in inbreeding (Ellegren and Galtier, 2016). Reduced genetic diversity can increase a population's vulnerability to certain types of diseases and epidemics (Kang and Lindgren, 1999). Especially in times of climate change, the importance of gene diversity increases even more. We emphasize that thinning has a significant impact on fecundity variation and that gene diversity can be tracked with the parameters used in our study when determining the degree of thinning in production forests.

4.4. Balancing Effect, Thinning Intensity, and Future Prospect

GD increases from S1 to S3, indicating that genetic diversity increases with decreasing closure. N_p also increases from S1 to S3, which means higher genetic representation with less closure. Ψ decreases from S1 to S3, indicating more balanced reproductive success with less closure. In S1, GD and N_p are the lowest, while Ψ is the highest. This indicates that the stand should be thinned to increase genetic diversity and the number of effective parents. In S2, GD and N_p are at intermediate levels, and fertility variation is lower than in S1. This suggests that some positive effects are seen, but further thinning could be beneficial. In S3, GD and N_p are at their highest levels, and Ψ is at its lowest. This maximizes the positive effects of thinning. The results obtained in S3, together with sexual symmetry, show the most successful results in increasing genetic diversity and increasing the number of effective parents. However, when it comes to management practices, it is often crucial to determine the optimal level rather than completely reducing them. Therefore, keeping the degree of thinning at 50% may be the most effective approach to increasing genetic diversity and ensuring more balanced reproductive success. This rate would result in substantial enhancements in genetic variety and the number of successful parents, while also minimizing the disparities between S2 and S3. This recommendation is modeled from the statistical mean, trends, and patterns observed in the data that is currently accessible. Nevertheless, further research and meta-analysis are required to reach a meaningful and conclusive outcome in the context of integration into global forestry.

CONCLUSIONS

Effective forest management requires a comprehensive approach that considers the impact of silvicultural practices such as sustainable forestry and thinning on both yield and ecosystem health. The results of this study show that stand density is critical not only for the amount of fertility but also for genetic diversity. The genetic parameters analyzed in this study can be valuable tools to assess the impact of thinning on gene diversity. Thinning has the potential to increase reproductive success by controlling tree density and optimizing pollination. This could lead to the conservation of valuable gene diversity and the creation of a healthy seed bank for future generations. Our results show that a thinning intensity that includes keeping it in the 50% band offers a balance and is acceptable. This emphasizes the importance of considering genetic diversity when determining thinning intensity in forest management plans. By supporting these findings with studies of different tree species in different age classes and incorporating them into regional forest management strategies, we can move towards a more sustainable future for forests. This approach ensures that the ecological well-being of forests and their ability to provide valuable gene resources for future generations are maintained. This study can be considered a prototype and can be supported by future studies with different thinning intensities and species in different regions. These studies will contribute to a holistic

understanding and help determine the most appropriate thinning densities, especially in response to climate change. In summary, we believe that this study can significantly contribute to the development of future forestry policies centered on natural regeneration by demonstrating the essential role of maintaining genetic diversity and manageability to ensure sustainable forest management amid global challenges such as climate change and habitat loss.

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Bibliometric Analysis of Durum Wheat Studies Addressed in Türkiye

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Abstract: Bibliometric analysis is a common and rigorous method for examining and analyzing large volumes of scientific data which can reveal the evolving nuances of a particular field while highlighting new areas within that field. There have been many bibliometric studies focusing on durum wheat; however, to our knowledge, there has been no study on the bibliometric analysis of durum wheat studies in Türkiye. Therefore, we performed a comprehensive bibliometric analysis on durum wheat articles addressed in Türkiye. A literature search on durum wheat studies in Türkiye was conducted using only the Web of Science (WOS) database. Publication date interval was limited between 01/01/2000 and 31/12/2023. Web of Science Index, document type and language were limited as Science Citation Index Expanded (SCI-Expanded), Article, and English, respectively. The data shows that there are a total of 486 articles related to durum wheat addressed in Türkiye from 01/01/2000 to 31/12/2023, in 186 different sources. Totally 1354 authors contributed the number of publications and the number of single-authored articles was 65. On the other hand, the number of co-authors per article was 4.31 and international co-authorships was 24.69%. The most productive years were 2019, 2018, and 2017 with 41, 33, and 30 articles, respectively. The poorest years for article production were 2001, 2002, 2005, 2013, 2014, and 2000 with <10 articles. The top 10 keywords have been durum-wheat (86 times used), quality (51), cultivars (47), yield (47), winter-wheat (42), growth (41), grain-yield (39), plants (39), wheat (35) and genotypes (31), respectively. Collaboration network analysis illustrates that there are eight different strong author groups and especially Çukurova University, Sabancı University and Hacettepe University have collaborated many times with other organizations in Türkiye to conduct studies on durum wheat. Although there has been a slight fluctuation in recent years, it is understood that durum wheat research has increased from the past to the present in Türkiye; however, studies strengthened with statistical models are needed to provide more concrete data.

Keywords: Bibliometrics, durum wheat, *Triticum durum* L., research, Türkiye

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1. INTRODUCTION

Wheat (*Triticum* L.) is the most widely grown crop globally, and is produced on more than 210 million hectares annually across over 90 countries, each with an annual production of at least 10,000 tons. While the three major cereals, maize, rice, and wheat, account for 90% of the cereals produced worldwide, wheat alone represents 26% of this production (FAOSTAT, 2023).

Wheat is also an important staple crop for Türkiye, and is one of the largest producers and consumers of wheat worldwide. Wheat consumption in Türkiye is about 170 kg per capita/year, which is one of the highest in the world (FAOSTAT, 2023). At the same time, Turkey is the world's

largest flour exporter and the second largest macaroni exporter (FAOSTAT, 2023). Wheat (*Triticum* spp.) is grown on more than 6.8 million hectares annually in Turkey, and wheat production is approximately 21 million metric tons (TUIK, 2023). 4.3 million tons of this production belongs to durum wheat (*Triticum durum* L.) and Central Anatolia and Southeastern are the regions with the highest durum wheat production.

Türkiye is known as one of the gene centers for wheat and its wild relatives; therefore, there is also a wide genetic variation for durum wheat varieties, landraces and their wild relatives. Many research studies have been conducted on durum wheat in Türkiye; however, there has been no detailed information for quantifying the published documents addressed in Türkiye.

In the literature, there have been publications with use of classical bibliometric methods to reveal the annual production globally for durum wheat research. The recent literature related to durum wheat and its end-use products includes many reports concentrating on agronomic practices, production systems, effects of stress factors on yield and quality, and genetic diversity etc. (Li et al., 2018; Arriagada et al., 2020; Beres et al., 2020; Santis et al., 2021; Taranto et al., 2023).

Bibliometric analysis is a common and rigorous method for examining and analyzing large volumes of scientific data which can reveal the evolving nuances of a particular field while highlighting new areas within that field. Currently, various bibliometric approaches combining statistics and visualization have been developing. One such approach is bibliometric mapping which provides information about knowledge fields that contain large and complex amounts of information in bibliographic databases. Using this approach, many studies have been conducted in different fields in Türkiye (Korkmaz et al., 2019; Ercan, 2020; Altay and Kaplan, 2023; Ergin et al., 2023; Beram, 2024), but there are no studies on durum wheat research in the literature. The aim of this study is to provide historical overview (from 2000 to 2023) of the structure and evolution of durum wheat research in Türkiye.

2. MATERIAL AND METHOD

2.1. Data collection

In the current study, the literature search on durum wheat studies in Türkiye was conducted using Web of Science (WOS) database. Bibliographic data were retrieved on July 10, 2024, by using the query (TS=(durum wheat) OR TS=(*Triticum durum*) OR TS=(*Triticum turgidum* var. *durum*) OR TS=(*Triticum turgidum* subsp. *durum*) OR TS=(*Triticum turgidum* ssp. *durum*)) AND (AD=(Turkey) OR AD=(Türkiye)), i.e., by using the searching parameters “durum wheat” or different scientific names of this species. The publication date interval was limited between 01/01/2000 and 31/12/2023. Web of Science Index, document type and language were limited as Science Citation Index Expanded (SCI-Expanded), Article, and English, respectively.

2.2. Bibliometric analysis and clustering

A package “bibliometrix” (Aria and Cuccurullo, 2017) in the RStudio software v.4.2. was used to perform all analyses. In this package, firstly, raw data were retrieved by the query explained in data collection section, and then were filtered for removing duplicated data by using the function “convert2df”. Afterwards, the processed data were used to generate and visualize the bibliometric maps by using the function “biblioshiny”.

3. RESULTS

The data shows that there are totally 486 articles related to durum wheat addressed in Türkiye from 01/01/2000 to 31/12/2023 in 186 sources. The line graph showing the annual article production about durum wheat in Türkiye is given in Figure 1. Annual growth rate (%), average citations per article, and average citations per year per article are 0%, 19.8 and 1.982, respectively. Totally 1354 authors contributed this number of publications and number of single-authored articles was 65. On the other hand, number of co-authors per article was 4.31 and international co-authorships was 24.69%.

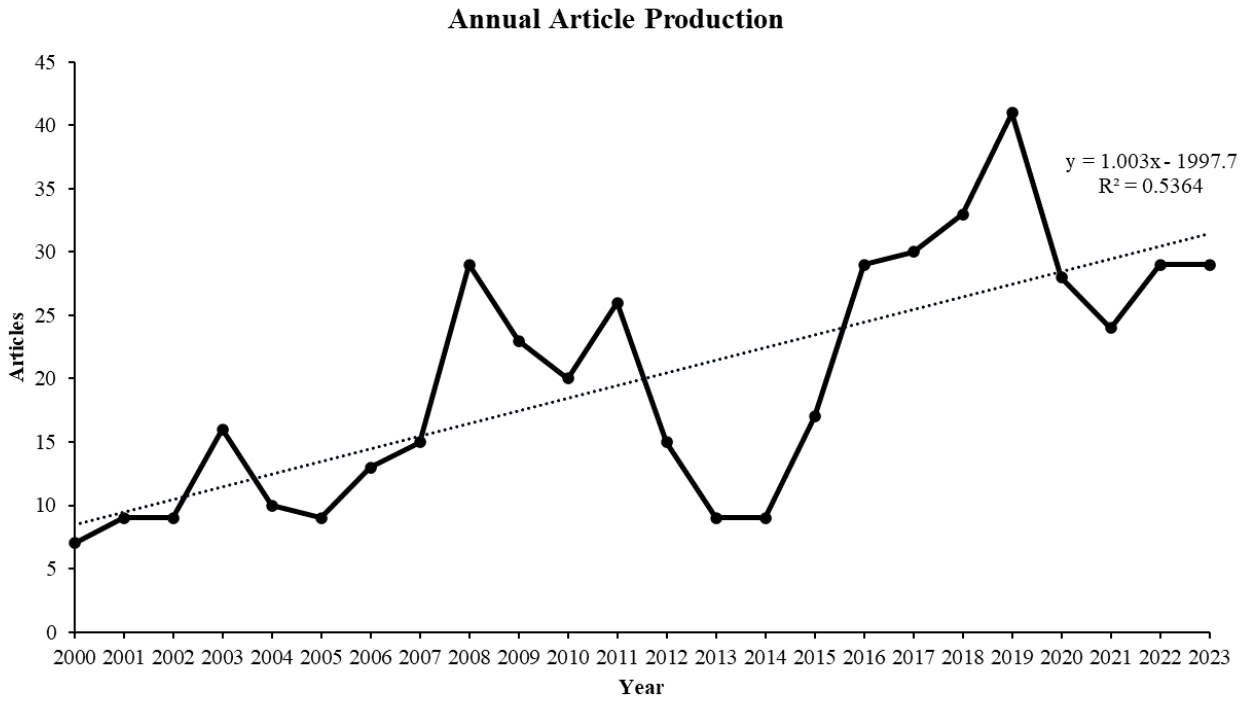

Figure 1. Trends in publications on durum wheat in Türkiye

The most productive years were 2019, 2018, and 2017 with 41, 33, and 30 articles, respectively. The poorest years for article production were 2001, 2002, 2005, 2013, 2014, and 2000 with <10 articles.

The most relevant sources are shown in Figure 2. This graph shows that Fresenius Environmental Bulletin (FEB), Turkish Journal of Agriculture and Forestry (TJOAF), Turkish Journal of Field Crops (TJOFC), Journal of Cereal Science (JOCS), Plant and Soil (PAS), Applied Ecology and Environmental Research (AEAER), Cereal Research Communications (CRC), Journal of the Science of Food and Agriculture (JSFA), Cereal Chemistry (CC), Genetic Resources and Crop Evolution (GRCE), Journal of Plant Nutrition (JOPN), and Notulae Botanicae Horti Agrobotanici Cluj – Napoca (NBHA) have been the top journals over 9 articles during the last 23 years. In particular, FEB and TJOAF are the most published journals with 32 and 20 articles, respectively. WOS categories of these journals are generally Agronomy, Plant Sciences, Environmental Sciences, Food Science & Technology, and Agriculture Multidisciplinary.

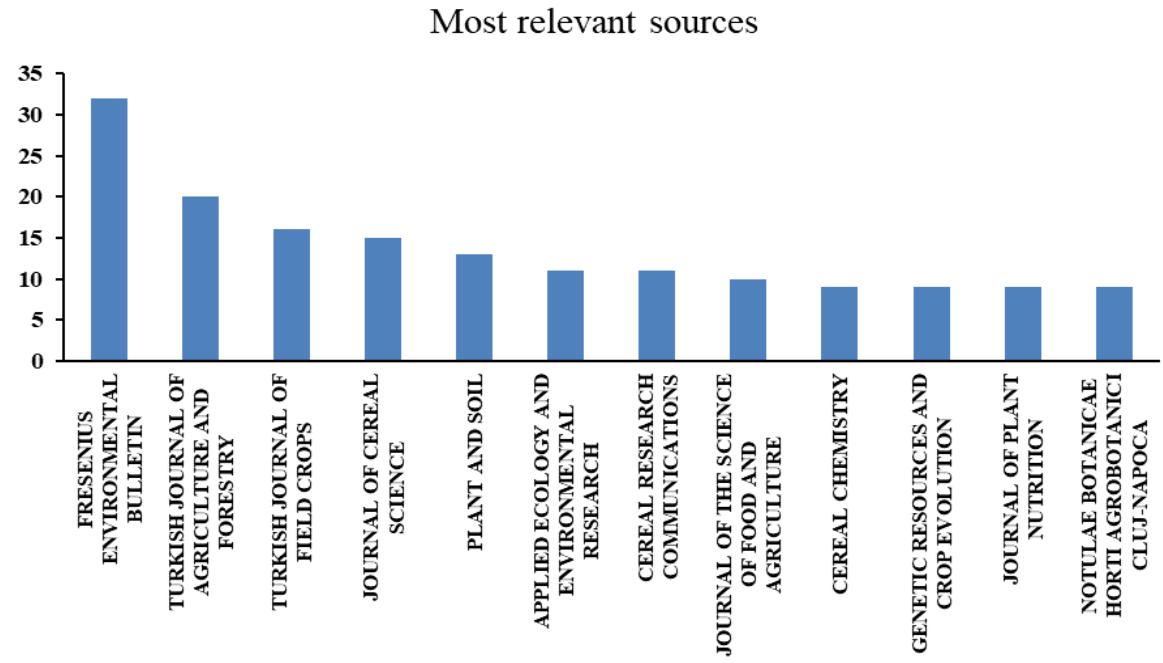

Figure 2. Top 12 journals with the most articles published

The most cited sources of published articles related to durum wheat in Türkiye are given in Figure 3. Top 10 cited sources over 200 citations were Crop Sciences (469 citations, 14%), Theoretical and Applied Genetics (459, 13%), Plant and Soil (422, 12%), Euphytica (407, 12%), Journal of Cereal Science (392, 11%), Cereal Chemistry (354, 10%), Field Crops Research (271, 8%), Plant Physiology (246, 7%), Journal of Experimental Botany (230, 7%), and Journal of Agricultural and Food Chemistry (218, 6%), respectively.

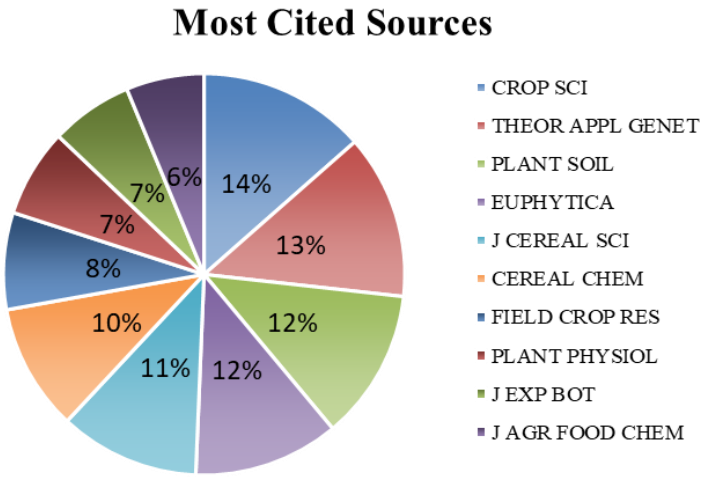

Figure 3. Top 10 most cited journals

The most productive authors for durum wheat studies in Türkiye during last 23 years are given in Figure 4. Top 10 authors are Cakmak I, Ozkan H, Ozturk L, Koksel H, Zencirci N, Budak H, Baloch FS, Morgounov A, Yıldırım M, and Alsaleh A, respectively. Although the rankings have changed, many of the most cited authors have also been among the most prolific. The most cited authors over 20 citations have been Cakmak I (54 citations), Alsaleh A (28), Baloch FS (28), Ozkan H (25), and Ozturk L (20), respectively.

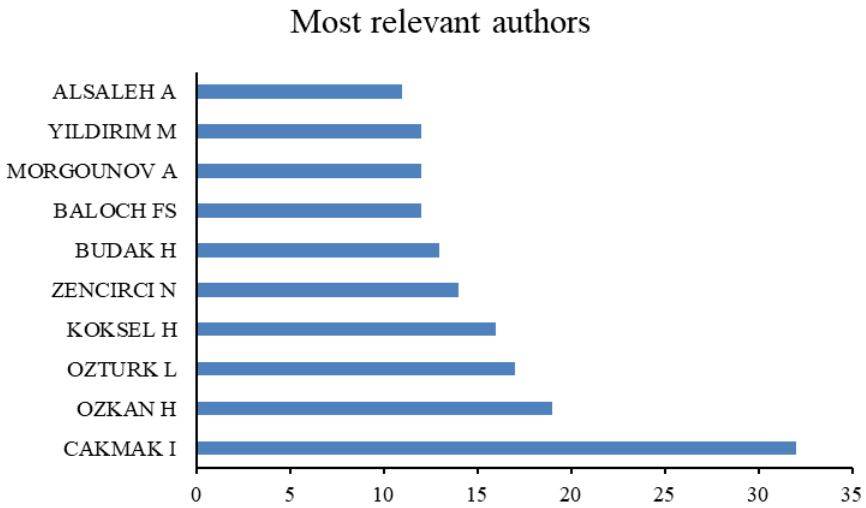

Figure 4. Top 10 prolific authors producing articles with durum wheat in Türkiye

Additionally, the parameters showing production efficiency, such as number of articles per year and total citations (TC) per year, of these prolific authors were visualized and are given in Figure 5.

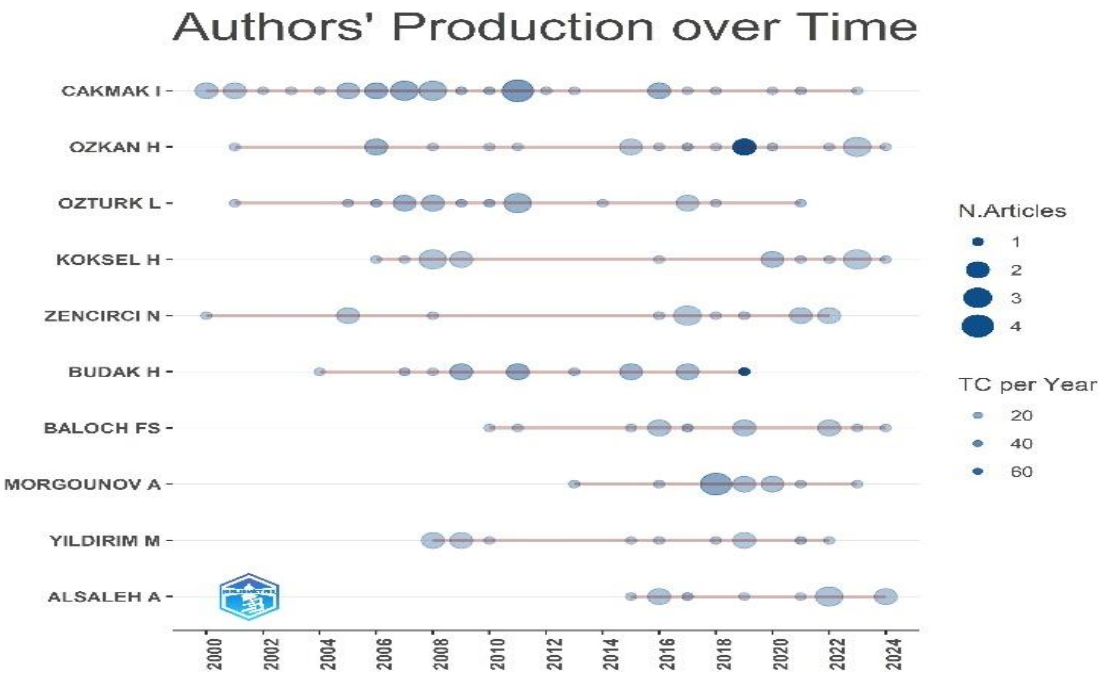

Figure 5. Number of articles and number of total citations per year of the most prolific authors

The top 10 organizations producing articles about durum wheat in Türkiye are illustrated in Figure 6. The most productive organizations are listed as Cukurova University, Sabancı University, Hacettepe University, Ankara University, Karamanoğlu Mehmetbey University, Dicle University, Abant İzzet Baysal University, Harran University, Ege University and Selcuk University, respectively. In particular, Cukurova and Sabancı Universities have been prominent with 94 and 83 articles.

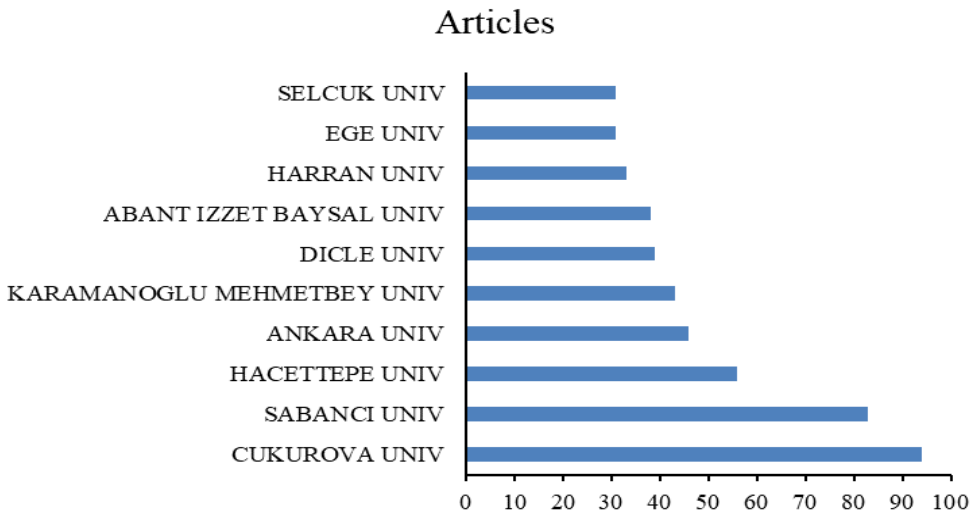

Figure 6. Most relevant organizations producing articles of durum wheat in Türkiye

The most frequent keywords were visualized as a WordCloud and this is given in Figure 7. The top 10 keywords have been durum-wheat (86 times used), quality (51), cultivars (47), yield (47), winter-wheat (42), growth (41), grain-yield (39), plants (39), wheat (35) and genotypes (31), respectively.

Figure 7. WordCloud showing the most frequent keywords used in durum wheat articles addressed in Türkiye

Collaboration network analyses were also performed to reveal relationships between authors and organizations. These analyses were visualized in Figure 8a and Figure 8b.

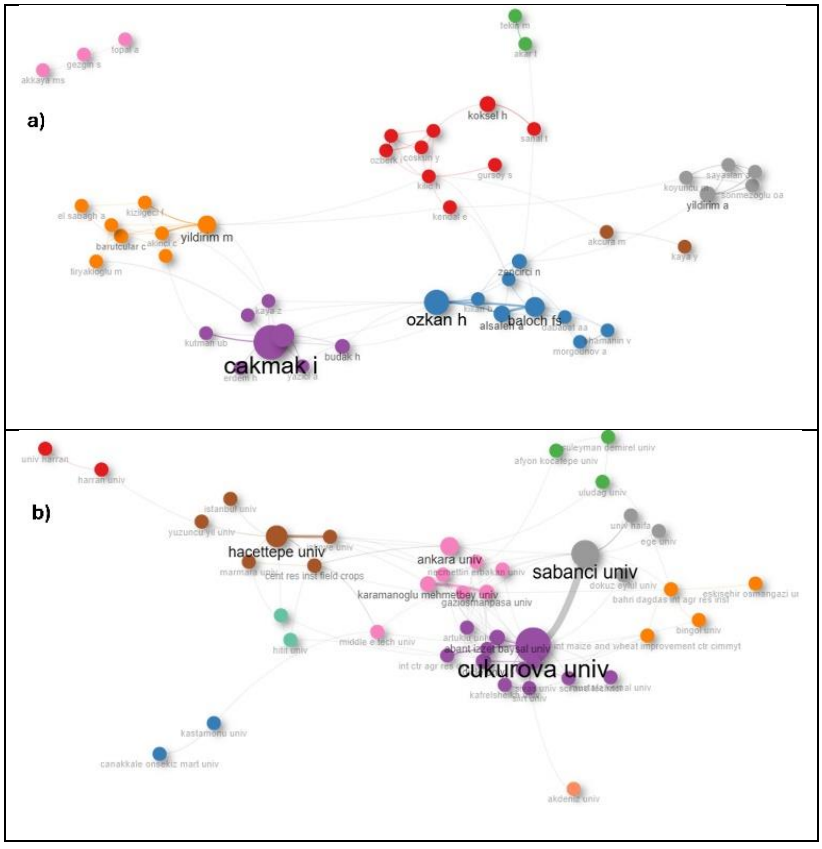

Figure 8. Collaboration network analysis showing the collaboration among authors (a) and organizations (b)

Figure 8a shows that there are eight different strong collaborative author groups producing articles about durum wheat in Türkiye. On the other hand, nine different strong collaboration groups were determined between organizations (Figure 8b). Especially, Çukurova University, Sabancı University and Hacettepe University have collaborated many times with other organizations in Türkiye to conduct studies about durum wheat.

4. DISCUSSION AND CONCLUSIONS

A bibliometric analysis about durum wheat studies was carried out with the objectives of quantifying the articles published by scientific journals indexed in Science Citation Index-Expanded in WOS and trends and their interactions from 2000 to 2023 in Türkiye. A total of 486 articles from the WOS database were analyzed by a package "bibliometrix" in R environment, and bibliometric maps were visualized.

This study has found that annual article production has fluctuated and the article production especially between 2016 and 2019 was higher than other years. Blanco (2024) generated a bibliometric map showing the global durum wheat research trend from 1961 to 2022 and determined that there has been an increased interest in worldwide durum wheat research during the last two years. He also reported that Journal of Cereal Science, Euphytica, Theoretical and Applied Genetics, Cereal Research Communications, and Cereal Chemistry are the top 5 journals for durum wheat research in the world. The present study shows that three of them are also among the most popular journals for durum wheat research in Türkiye (Fig. 2). Cecchini et al. (2020) analyzed the trend in research on durum wheat and pasta with a bibliometric approach and claimed that the general view of studies and their evolution during the years highlight a lower interest in genetic aspects in favor of topics related to health and nutritional quality.

Chandra et al. (2024) also reported a bibliometric analysis showing general wheat research trend in the world and determined that keywords such as "stress", "GWAS", and "gene" have been the most prominent words. The present study reports that the most prominent keywords are durum wheat, quality, cultivars, yield, winter wheat, growth, and grain yield in the durum wheat research in Türkiye (Fig. 7) and this shows that durum wheat studies in Türkiye are generally related to agronomy and quality. However, the research groups, especially in the developed countries, have concentrated on studies that correlate the data obtained as a result of molecular and agronomic studies rather than only agronomy and especially on solutions to the negative consequences of climate change. In this respect, in order to catch up with the trends in durum wheat research in the world, the studies carried out in our country should be directed in more detail and focused on today's solutions.

Overall, it is understood that durum wheat research has increased from the past to the present in Türkiye, however, studies strengthened with statistical models are needed to provide a more concrete data.

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Cognitive Ergonomics in Intelligent Systems: Screen Analysis and Design Proposal for Reducing Mental Load in the Design of User Interfaces of Autonomous Vehicles

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Abstract: This study aims to reduce the mental load of drivers and increase driving safety by designing user interfaces in autonomous vehicles according to cognitive ergonomics principles. Today, autonomous vehicles offer a usage scenario where the driver is only expected to intervene in critical situations and is in the role of observer or guest. In the design of user interfaces in these vehicles, cognitive ergonomics principles are of great importance and play a critical role to reduce the mental load of the driver and increase driving safety. In existing AR-based user interfaces, it is proposed to add new features to improve driving safety. In particular, detecting driver fatigue and displaying this information in the user interface will enable the driver to monitor the fatigue level and take necessary precautions. In this study, a design proposal for displaying driver fatigue level in an AR-based user interface is presented. In addition to improving driving safety, this proposal will contribute to a comfortable driving experience, personal health and well-being, analysis of driving habits and legal compliance.

Keywords: autonomous vehicles, cognitive ergonomics, intelligent systems, interface design

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1. INTRODUCTION

Autonomous vehicles can be defined as advanced automobile technology that has been given the ability to move without a driver driving the vehicle or with its own decisions by minimising human intervention. Technologies such as GPS, artificial intelligence models, sensors are used to provide mobility to these vehicles. The most important issue in the emergence of autonomous vehicles is to ensure safe driving by minimising driver errors. Autonomous vehicles are becoming increasingly widespread today and are preferred by users with many advantages. Many of the vehicles that are currently widespread around the world are vehicles equipped with mechanisms under direct user control. Although auto-controlled structures such as lane tracking system, collision avoidance systems, fatigue detection system, hill start support have been added to many of the vehicles in recent years, more user-active driving is still taking place. In autonomous vehicles, drivers are more in the role of in-vehicle guests or observers. In autonomous vehicles, drivers monitor variables such as whether the systems are working properly, speed and fuel status. In critical situations, the autonomous vehicle may ask the driver to take over driving control. Cognitive ergonomics is a concept that includes the processes of purposeful design of environmental factors in order to carry out the cognitive processes of the users on the system in the most efficient way. The combination of autonomous vehicles and cognitive ergonomics processes aims to reduce the mental load of users and increase driving safety. During driving, critical moments may occur when users need to take over driving control in emergency situations. In such situations, the driver's cognitive tasks come into play. Cognitive tasks require high concentration and instant decision-making skills of the driver. In such crisis management situations, the mental load of users may increase and stress levels may rise. The critical quality that autonomous vehicles should have is that the principles of cognitive ergonomics should be taken into account in the design of user interfaces, and a simple, practical and easy-to-use interface is expected to help users interact with these vehicles more effectively and safely. What is expected from cognitive ergonomics is to present

critical information in a clear and understandable way, to optimise the information density and to keep the stress level to a minimum so that the cognitive capacities of the users are not challenged when designing autonomous vehicles. The information density in the interface during a driving process under the control of the user may overwhelm the user, prolong the reaction time and even cause errors.

2. CURRENT STATUS OF USER INTERFACES IN AUTONOMOUS VEHICLES

In autonomous vehicles, touch screens are preferred to communicate and interact with the user. On the touch screens, technical status of the vehicle, speed, route information, battery and fuel status, and status information about safety measures are presented. Touch screens are supported by voice command and voice feedback technologies. This technology is a great cognitive ergonomics tool to control driving comfort and safety without taking the driver's attention off the road in driving that progresses to the user's control. Amazon Alexa integration developed for these situations allows drivers to manage functions such as making calls, playing music, navigation control with voice control. Some of the autonomous vehicles also maximise the level of cognitive ergonomics by activating haptic feedback and physical controls. Haptic feedback systems are preferred to provide feedback to drivers in critical situations. Users can be warned by vibrating equipment such as steering wheel or seat. These systems are generally activated in cases of uncontrolled lane following, exceeding the speed limit, and fatigue detection. Some autonomous vehicles use Augmented Reality (AR) displays to provide drivers with additional information on the road. AR-based displays project onto the windscreen and provide the driver with information such as navigation instructions, speed limits and obstacles on the road. Such interfaces play an active role in reducing mental load by providing access to important information without taking the driver's eyes off the road. Figure 1 shows an image taken from driving a Mercedes S-Class vehicle.

Figure 1. AR-based screenshot of a Mercedes S-Class vehicle driving (Youtube, 2024)

The three most important issues to be considered when creating user interfaces in autonomous vehicles are the difficulty of effective communication by overloading the user with information, difficulties in focusing users on important points due to complex designs, and mishaps that may occur due to incomplete feedback.

3. RESULTS

In AR-based user interfaces in existing autonomous vehicles, data such as navigation data, speed, fuel and battery status, lane alternatives are displayed to the user. One of the most important criteria of driving safety is the physical fatigue and attention status of the driver, which is critical in driving safety. Although fatigue detection is included in autonomous vehicles, it is not shown to the user in AR-based user interfaces and other interfaces. This is a situation left to the person's self-control and sensors. Continuous notification of this data to the driver allows both the driver to take precautions and other users in the vehicle to advise the driver.

Adding this feature to the AR-based user interface will contribute to safe driving by examining many topics such as comfortable driving experience, personal health and well-being, analysis of driving habits, legal compliance. When the fatigue detection system finds the driver's fatigue level high, it can automatically switch the vehicle to autonomous driving mode. This allows the vehicle to travel safely while allowing the driver to rest. Figure 2 shows a user interface design proposal that shows the fatigue detection level for the driver in an AR-based user interface to be designed.

Figure 2. Display of driver fatigue level in AR-based user interface

The motivation for proposing the introduction of this innovation can be listed as follows;

- Safety Protection Mechanism:

  The visual display of the driver's fatigue level on the AR-based interface allows the driver to monitor his/her physical condition in real time. In this way, as soon as the driver realises that the fatigue level has reached critical levels, he/she can consciously stop the vehicle for a rest break or switch the vehicle to automatic driving mode. This feature increases driving safety by preventing accidents that may occur when fatigue is not recognised or neglected. Considering that fatigue prolongs the driver's decision-making time and slows down the reaction speed, it is vital to provide instant access to this information.

- Differences with Existing Systems:

  Existing driver fatigue detection systems usually process data from sensors and provide passive warnings to the driver, which are usually just an audio or visual warning. However, these warnings do not present the degree of fatigue or how the fatigue level changes in

detail to the driver. The interface proposed in Figure 2 aims to overcome this lack of information. The continuous visualisation of the fatigue level gives the driver more control and allows him to consciously manage his fatigue state. Furthermore, this system allows the driver to recognise the situation not only to himself, but also to the other passengers in the vehicle, which creates a collective sense of safety.

- Proactive Safety Enhancement:

The system not only detects fatigue, but also has the ability to put the vehicle into automatic driving mode when the fatigue level reaches a critical threshold. This is a proactive safety measure that is often missing in existing systems. While other systems simply warn the driver, this design proposal aims to prevent fatigued driving by taking a step that directly affects driving safety.

- Enabling Driver Involvement:

The constant visibility of the fatigue level allows the driver to be more involved in the situation and reduces the possibility of unconsciously falling into a dangerous situation. In existing systems, the driver may not realise his/her fatigue status, but in this new interface, the driver can both see his/her own status instantly and if this situation worsens, the system can prevent possible accidents by automatically activating.

These advantages emphasise the importance of fatigue detection in an AR-based user interface and significantly improve both safety and the driving experience. A system that monitors driver fatigue and makes appropriate recommendations can make a big difference on long journeys or in challenging driving conditions.

4. LITERATURE REVIEW

A systematic review examined the role of AR technology in autonomous vehicles between 2012 and 2022 and found that vehicles equipped with this technology are more accepted and trusted by users (Kettle et.al., 2022). Fatigue while driving is recognised as an important cause of accidents, and this is also the case in autonomous vehicles. In particular, machine vision and deep learning are effective tools for detecting signs of fatigue in the driver's facial expressions. These technologies increase driving safety by detecting fatigue, warning the driver and switching the vehicle to autonomous mode when necessary (Fu et.al., 2024). Driver fatigue is one of the most important factors threatening driving safety. Therefore, detecting and managing driver fatigue in autonomous vehicles is of critical importance. In recent years, fatigue detection systems based on technologies such as machine learning and deep learning have developed significantly. These systems detect signs of fatigue by analysing drivers' facial expressions, eye movements and physiological signals and provide warnings to the driver based on this information. In particular, systems based on multimodal data fusion provide more comprehensive and accurate fatigue detection by integrating information from different data sources. These methods, when integrated with autonomous driving modes, offer an effective solution to increase the safety of drivers and prevent accidents that may occur due to fatigue (Peng et al., 2022; Guo et.al. 2019). Studies on the detection of driver fatigue and distraction to improve safety in autonomous vehicles show that the use of systems based on multimodal data fusion is becoming increasingly common. These systems make fatigue detection more accurate and reliable by combining different data sources. For example, Mandal et al. (2016) reported that high accuracy rates were achieved in the detection of driver fatigue by analysing eye movements. Li and Chung (2013) suggest that heart rate variability is an effective method for fatigue detection based on wavelet analysis. These findings emphasise the critical role of technology to ensure safe driving in autonomous vehicles. In recent years, research on autonomous vehicles and driving safety has particularly focused on driver fatigue and distraction. Advanced sensor technologies and artificial intelligence algorithms play a critical role in ensuring safe driving by detecting driver fatigue. For example, research by Xie and Chen (2018) shows that fatigue can be detected in the early stages by detecting the driver's yawning movements. Similarly, Shah et al. (2018) present important findings on simulating autonomous vehicles with high accuracy and analysing fatigue symptoms through these simulations. These studies on driver fatigue detection generally focus on multimodal data analysis and deep learning models. These technologies combine data from different sensors to provide more accurate fatigue detection and improve driver safety. For example, research by Vu et al. (2019) revealed that real-time fatigue detection can be performed using deep neural networks and that these systems make significant contributions to driver safety. Such advanced detection systems have been developed and implemented to improve the driving safety of autonomous vehicles.

Table 1. Comparative literature summary revealing the importance of the study

Author(s)	Year	Objective of the Study	Methods and Techniques	Contribution to Literature
Fu, S., Yang, Z., Ma, Y., Li, Z., Xu, L., & Zhou, H.	2024	Comprehensive review on advancements in driver fatigue and distraction detection.	Review of intelligent detection methods using machine vision, deep learning, and physiological signals.	Provides a detailed assessment of current detection technologies and proposes future research directions.
Kettle, L., & Lee, Y.-C.	2022	Systematic review of AR technologies in vehicle-driver communication.	Review of AR visualizations and their impact on situational awareness and driver performance.	Highlights the potential of AR to enhance driver trust and safety in automated driving systems.
Peng, K., Fei, J., & Yang, K.	2022	Development of a multi-attentional semantic segmentation approach for LiDAR data in autonomous vehicles.	LiDAR data analysis using a multi-attentional semantic segmentation model.	Introduces a new approach to LiDAR data segmentation, improving object detection in dense environments.
Guo, J. M., & Markoni, H.	2019	Detection of driver drowsiness using hybrid CNN and LSTM models.	Hybrid approach combining CNN and LSTM for analyzing driver facial features.	Demonstrates the effectiveness of hybrid models in enhancing drowsiness detection accuracy.
Mandal, B., Li, L., Wang, G. S., & Lin, J.	2016	Detection of bus driver fatigue using visual analysis of eye state.	Visual analysis focusing on eye state for detecting fatigue.	Shows the importance of eye state analysis in fatigue detection, particularly for bus drivers.
Li, G., & Chung, W.-Y.	2013	Detection of driver drowsiness using wavelet analysis of heart rate variability and SVM.	Wavelet analysis of HRV combined with SVM classifier.	Illustrates the efficacy of HRV analysis in combination with SVM for accurate drowsiness detection.
Xie, Y., Chen, K., & Murphey, Y. L.	2018	Real-time detection of driver yawning using deep neural networks.	Application of deep neural networks for yawning detection.	Proposes a robust method for real-time yawning detection, improving in-vehicle safety systems.
Shah, S., Dey, D., Lovett, C., & Kapoor, A.	2018	Development of a high-fidelity simulation environment for autonomous vehicles.	Simulation environment development combining physical and visual factors.	Offers a comprehensive simulation tool for testing and validating autonomous vehicle systems.
Vu, T. H., Dang, A., & Wang, J. C.	2019	Real-time detection of driver drowsiness using a deep neural network.	Application of a deep neural network for detecting drowsiness in real-time.	Validates the use of deep learning techniques for accurate and real-time drowsiness detection.

5. CONCLUSIONS

Cognitive ergonomics principles are fundamental in the design of user interfaces for autonomous vehicles, as they directly impact both driving safety and user experience. In autonomous vehicles, the driver's role shifts from being an active operator to a passive observer or supervisor, which introduces new challenges in maintaining safety and minimizing mental fatigue. AR-based user interfaces are particularly valuable in this context because they present critical driving information, such as navigation, speed limits, and hazard warnings, without diverting the driver's attention away from the road. This seamless integration of information minimizes cognitive overload, ensuring that the driver can stay focused on essential tasks without feeling overwhelmed. Moreover, the inclusion of advanced features such as fatigue detection within the AR-based interface goes beyond traditional alert systems by offering real-time monitoring of the driver's physical and mental state. Fatigue detection systems can analyze physiological signals, such as eye movements and facial expressions, to determine when the driver is becoming drowsy. This information, presented clearly on the AR display, allows the driver to take preventive actions, such as taking a rest or switching to autonomous mode, before fatigue leads to dangerous situations. The ability to proactively manage fatigue not only improves safety but also reduces stress, leading to a more comfortable and enjoyable driving experience. Incorporating these cognitive ergonomics-driven features into user interfaces can significantly enhance the overall well-being of drivers. By making critical information easily accessible and actionable, these systems empower drivers to make better decisions, fostering confidence in both the vehicle and their own driving capabilities. This confidence is particularly crucial as more drivers transition from conventional vehicles to autonomous models, where trust in the system is a key factor in adoption. The simplicity, practicality, and user-friendly nature of advanced AR-based interfaces also play a pivotal role in promoting the widespread adoption of autonomous vehicles. As these interfaces are designed to be intuitive and easy to use, they reduce the learning curve for drivers transitioning from traditional vehicles. This usability factor is crucial in encouraging a broader demographic of users to embrace autonomous vehicle technology. In turn, this can accelerate the integration of autonomous vehicles into everyday life, transforming transportation systems globally. In the future, the deep integration of cognitive ergonomics principles will not only optimize the user experience but also form the foundation of safer and more efficient transportation systems. These systems will leverage the power of human-centered design to ensure that both safety and comfort are prioritized, making autonomous driving a more reliable and accessible option for a diverse range of users. The result will be transport networks that are not only technologically advanced but also aligned with the cognitive and emotional needs of their users, contributing to the future of sustainable and intelligent mobility. This extended version further emphasizes the significance of cognitive ergonomics in enhancing both safety and user experience, while also underscoring the broader implications for the future of transportation systems.

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Investigation of the Effects of Waste Olive Pomace on Vermicompost

Alev Akpinar Borazan [1]*, Levent Degirmenci [1], Oznur Cumhur Degirmenci [2]

Abstract: The effects of olive pomace on the degradation of organic matter were investigated via vermicomposting. A biomass mixture of eggshells, cabbage, banana peel, napkins, nutshells, cattle manure, and soil was enriched with different quantities of olive pomace (0, 15, 30, 37.5%). These four mixtures, with a total of 2000g, were fed to 170 *Eisenia fetida* earthworms per mixture. Nitrogen adsorption-desorption, FT-IR, and elemental analyses analyzed samples collected from biomass at the end of 45 days. Results were evaluated to determine the effect of olive pomace on organic matter degradation and earthworm vitality. Nitrogen adsorption-desorption isotherms of feedstock revealed a decrease in void volumes, implying the formation of a compact structure with olive pomace addition. Vermicomposting of biomass enhanced biomass's compactness, further validated by decreases in BET surface areas, pore sizes, and pore volumes. The 31% increase of earthworm biomass in the presence of 37.5% olive pomace implied an affinity of *Eisenia fetida* towards olive pomace. This finding was further validated by FT-IR peaks obtained at 2850 and 2923 cm-1, showing increased biomass aromaticity due to the degradation of readily biodegradable aliphatic structure introduced by olive pomace. Ongoing organic matter degradation could be observed with the decrease of C/N ratios in the presence of olive pomace as high as 15%. However, a further increase in olive pomace increased the C/N ratio, which was explained by the increase in total nitrogen values during vermicomposting. Elemental analyses evaluated regarding C/N, O/C, and H/C ratios also indicated increased earthworm mobility with increasing olive pomace in the feedstock. The results obtained in the study were interpreted to introduce olive pomace as a preferable nutrition source for earthworms, which was the highlight of the present study.

Keywords: Vermicomposting, *Eisenia fetida*, olive pomace, C/N, biomass.

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1. INTRODUCTION

The daily production of solid wastes must be managed appropriately due to population growth. Composting has become a popular choice for disposing of solid waste because it produces an end product with high nutrient content. The biological breakdown of organic waste during composting produces a stable compound that resembles humic acid. The approach effectively reduces contaminants because of the ease with which organic residues decompose. Applying compost to the soil also lessens the negative consequences of soil salinization (Gutierrez-Micelli et al., 2007; Mohee and Soobhany, 2014; Lakhdar et al., 2009; Bello et al., 2022; Zhou et al., 2022). Despite the mentioned benefits, composting takes time and causes nutrient loss, such as nitrogen. Even though microorganisms are eliminated during the thermophilic composting stage, pathogens may still be present in the end product. Earthworms, used in vermicomposting, degrade organic residuals into smaller particles through digestion and aid in migrating microorganisms to the feedstock. Thus, it may be viewed as an expedited composting process. There are fewer human pathogens in the obtained vermicompost, another advantage (Gutierrez-Micelli et al., 2007; Mu et al., 2023).

Vermicomposting was one of the alternatives developed as a solution to the harm caused by chemical fertilizers. "Green Revolution" aimed to increase agricultural production and

accelerate the destruction of microbial flora, which decreased soil yield and nutrient quality (Göçmez et al., 2019). Recent investigations validated the effects of vermicompost on the chemical properties of soil and vegetables. In research conducted by Azarmi et al. (2008), the effect of vermicompost on soil characteristics was investigated for different vermicompost amounts. Results indicated that vermicompost-added plots (15 t ha-1) had significantly higher total organic carbon levels and N, P, K, Ca, Zn, and Mn levels than the control (Azami et al., 2008). Yang et al. (2015) studied the effect of vermicompost on tomato yield, quality, and soil fertility compared to chicken compost, horse compost, and chemical fertilizer. Results indicated increased tomato yield and vitamin C content with vermicompost utilization for a 60-70% soil-water regime. Manivannan et al. (2009) investigated the effect of vermicompost on clay loam and sandy loam soils and compared the results with inorganic fertilizers. It was reported that applying 5 tonnes of ha-1 vermicompost had significantly increased pore space, water holding, cation exchange capacity, total organic carbon, micro and macronutrients, and microbial activity for both soil types.

On the other hand, a decrease in porosity, organic carbon content, and microbial activity was observed for both soil types, and this result was associated with the use of inorganic fertilizer (Manivannan et al., 2009). Ansari and Sukhraj (2010) have investigated the effects of vermiwash, vermicompost, and their combination on soil parameters and the productivity of okra (Abelmoschus esculentus). Results showed a 64.27% increase in the average yield of okra compared with the control. The fats and protein content of its fruits were 23.86 and 19.86%. The combination of vermicompost and vermiwash enhanced the micronutrients in the soil (Ansari and Sukhraj, 2010). In addition, vermicomposting contributed to carbon mineralization, as demonstrated by Chen et al.'s research (2023).

Olive oil, an essential food in many Mediterranean countries, has become more significant economically in the region due to growing demand. Olive is also one of Turkey's most important agricultural products. 2018 TUIK data revealed the presence of 177,843,966 trees in Turkey, 126,874,171 of which were utilized for olive oil production (Bellitürk et al., 2020). Despite the considerable potential for sustainable production, olive pomace produced during olive oil production harms the environment. To eliminate or at least mitigate the harm done to the environment, the by-products obtained at the end of the process should be utilized as raw material for fertilizer, compost, or vermicompost production. The traditional press mill method was recently replaced with a two-phase extraction method to reduce water needs. However, process change had little effect on environmental damage reduction, as olive pomace, obtained as a side-product during the process, was the primary contaminant source.

Olive pomace includes organic matter, polyphenols, oil, and organic acids acting as pollutants in soil and water. Hence, its disposal is imperative to minimize environmental damage (Canet et al., 2008; Dajko and Vasilikiotis, 2015; El Joumri et al., 2023).

Higher germination rates and stem and root growth were reported when olive pomace was used as a vermicompost feedstock (Dajko and Vasilikiotis, 2015). Olive pomace used as compost and vermicompost feedstock was stated to be effective in accelerating the degradation of triazine herbicides (Delgado-Moreno and Pena, 2009). Considering the amount produced in Turkey, olive pomace had strong potential in vermicomposting, which would produce economically feasible organic fertilizer (Kaouachi et al., 2013). Based on the literature survey, olive pomace must be considered an acceptable candidate for use as a feedstock component. Further investigations must be conducted to clarify its role in organic fertilizer production. Consequently, an attempt was made to provide information to the literature about the effect of olive pomace on the degradation of organic matter during vermicomposting. The evaluation of the results also revealed the availability of olive pomace as a nutrition ingredient.

Based on the literature, olive pomace, when utilized in vermicomposting, should meet these conditions:

- Olive pomace should not harm *Eisenia fetida* during vermicomposting. An aerobic digesting period of 15 days was added to prevent this before vermicomposting.
- Olive pomace utilization in aerobic digestion depended on *Eisenia fetida's* preference. In other words, earthworms should choose and process olive pomace as a nutrition source during vermicomposting.
- Vermicomposting should result in the aerobic digestion of olive pomace. This hypothesis was tested with characterization studies and analyses detailed below

2. MATERIAL AND METHOD

2.1. Vermicomposting process

Chemical fertilizers, widely used to supply plants with the nutrients they need to grow, mainly contain nitrogen, phosphorus, and potassium. Unfortunately, agricultural soils are primarily deficient in these nutrients. Therefore, nitrogen, phosphorus, and potassium should be sufficient and balanced in the fertilization program. In a study on municipal solid waste composting, biodegradable components of mixed paper, garden, and food waste were used. Food waste and mixed paper waste were found to affect NH_3 and CO_2 parameters in compost formation in particular (Komilis and Ham, 2006). This study included some organic wastes following the literature. The reasons are presented below. High K content was determined in banana waste compost (Venecio et al., 2005). A fertilizer mixture containing eggshells reduced soil acidity and calcium deficiency, producing a marketable compost rich in calcium (Soares, et al., 2013). C and N minerals in compost made from cabbage waste and cow, pig, or chicken manure were suitable for garden use (Adediren et al., 2004). In the compost study with hazelnut shells, it was possible to increase drainage, provide air circulation and moisture retention during compost formation, regulate soil temperature, conserve moisture, and improve soil structure. Hazelnut shells were evaluated as a source of fertilizer and a supporting material in advanced composting technology (Rashid, 2011). Paper napkins can be classified as a biodegradable and compostable material

because their primary components are wood pulp and non-woven cotton (Kale et al., 2015).

The inoculums were prepared by mixing eggshells, cabbage, banana peel, napkin, nutshell, cattle manure, soil, and olive pomace (OP). Each ingredient was separately shredded in a food processor before mixing. Eggshells, cabbage, banana peel, napkins, and nutshells were frequent examples of domestic waste produced daily in houses. Their amounts were kept constant in the present study to focus on the effect of pomace on vermicomposting. The amount of household waste constituted 25% of the total organic load. Cattle manure, soil, and olive pomace were inoculated in varying amounts, constituting 75% of the final mixture. The amounts of ingredients used in composting and vermicomposting are given in Table 1. The mixtures were named Olive pomace (OP) 0, 15, 30, and 37.5% based on increasing olive pomace amounts.

Table 1. The amounts of inoculums used in vermicomposting.

Ingredient	Feedstock %			
	OP 0	OP 15	OP 30	OP 37.5
Eggshell	9.4	9.4	9.4	9.4
Cabbage	3.1	3.1	3.1	3.1
Banana peel	3.1	3.1	3.1	3.1
Napkin	3.1	3.1	3.1	3.1
Nutshell	6.25	6.25	6.25	6.25
Cattle manure	37.5	30	22.5	18.75
Soil	37.5	30	22.5	18.75
Olive pomace	0	15	30	37.5

Due to its facility, especially in laboratory conditions, the "Open-air composting" method was preferred for composting experiments. This method required constant monitoring, which is crucial for vermicompost systems prepared at identical conditions. Systems were monitored via temperature, pH, and moisture readings. Temperature readings were taken daily, while pH and moisture were determined at three-day intervals. The composting process differed from vermicomposting systems in aeration, which was conducted at 3-day intervals. Turning intervals and readings for monitoring were compliant with EPA (40 CFR Part 503) requirements. Composting was conducted mainly to compare organic matter degradation with vermicomposting. Hence, only total carbon and nitrogen amounts of compost samples were determined to emphasize the superiority of vermicomposting. All feedstocks were initially allowed to digest for 15 days before earthworm addition. This pretreatment ensured mesophilic temperature conditions during the process (Lleo et al., 2013). The digestion step was also essential to keep pH values at optimum levels due to pH values as low as 5.4 in the presence of olive pomace (Baddie et al., 2003). Low pH might create a hostile environment for earthworms; hence, pretreatment was conducted to prevent or decrease worm mortality and facilitate feedstock edibility. Both compost and vermicompost systems were monitored for 60 $(15+45)$ days to determine changes in pH, moisture, and temperature.

The vermicomposting process was conducted in plastic bottles. The bottles were cut from the top, and the lit area was covered with mosquito nets. The top portion of the bottle was then placed at the bottom, forming a space between the lid and the bottom. The remaining bottoms collected from other bottles were attached to layers. Air holes with identical distances were drilled throughout the bottom to maintain constant aeration. Finally, the attached bottles were covered with stockings to prevent earthworm migration. The temperature of the systems was measured from 5 points daily. The moisture and pH contents were measured via sampling. pH remained between 7-8 throughout the experiment, and the moisture content of the systems was consistently above 50%. Hence, systems remained still to avoid stressing earthworms. System preparation was illustrated sequentially with images given in Figure 1.

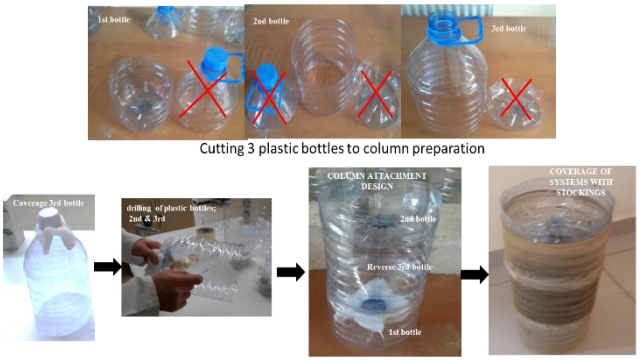


Figure 1. Composting column design

The total weight of each feedstock, placed in 5L bottles, was 2000g. This amount was adequate to feed 170 *Eisenia fetida* in each system for 45 days. The ratio of initial worm biomass per unit area of bedding (stocking density) was 5 for all systems. This ratio was previously stated as the optimum value of simultaneous vermicomposting and worm reproduction (Munroe, 2007). Bedding density and inoculum amount determined the duration of vermicomposting.

During the process, compost and vermicomposting systems' pH and moisture values varied between 6.5-8 and 70-75%. In the first week of digestion, the temperature increased from 21°C to 30°C, implying low thermophilic microbial activity. The temperature was then stabilized at 21°C until the end of the process.

2.2. Characterization studies

Elemental analysis of the feedstocks before digestion and the samples obtained after 45 days of composting and vermicomposting were conducted in LECO CHNS 628 device. Nitrogen adsorption-desorption isotherms were obtained via a Micromeritics Asap 2020 instrument. FT-IR analyses of the feedstocks before digestion and the vermicompost obtained afterward were conducted on a Perkin Elmer device in the 3800-4000 cm-1 range.

2.3. Statistical analysis

Elemental analyses and biomass determination were obtained as three replicated results expressed as mean values

± SD. The statistical evaluation was performed using SPSS 24.0 (SPSS Inc., USA). The evaluation of statistical significance was determined by ANOVA, followed by the Tukey Honestly Significant Difference test and t-test ($p < 0.05$).

3. RESULTS AND DISCUSSION

The Landfill Directive of the European Council mandated the reduction of organic wastes removed by landfilling, which gave rise to composting as an alternative method (Taşeli, 2007; EEA, 2009; EP, 2018). In all rapidly developing countries, the population is increasing; therefore, overall consumption increases, and there is a corresponding increase in the amount of solid waste produced. The By-law on Landfill of Waste (No:27533 2012/03) aimed to decrease the amount of biodegradable municipal waste landfilled in a scheduled period. According to the Turkish Ministry of Environment and Urbanization, a strategy to decrease the amount of biodegradable waste is ongoing (Gören and Özdemir, 2011). Organic content was mineralized during the process, and the product was re-evaluated in agriculture (Taşeli, 2007; EP, 2018). On the other hand, vermicomposting relied on the combined activity of microorganisms and earthworms, which would accelerate organic matter degradation. The first result presented in this study is a comparison of vermicomposting and composting activities to point out the superior performance of vermicomposting. Compost samples were obtained by keeping feedstocks for 45 days at identical conditions with vermicompost.

Results are given in Figure 2., regarding total C and N %. The increase in total C % values in compost and vermicompost systems depended on olive pomace addition (Figure 2a) except for the case of 37.5% olive pomace. The sudden decrease of total carbon in the presence of 37.5 olive pomace implied the occurrence of setbacks during sampling, which should have been emphasized considering the difficulty of working with an 8-ingredient feedstock. The increase in composts' total nitrogen % values could be explained by ammonia accumulation and evaluated as the presence of ongoing microbial activity. A comparison of three systems indicated higher degradation of organic matter in the presence of *Eisenia fetida*. The effect of earthworms on organic matter degradation could be seen with total nitrogen % values. The vice-versa trends of total nitrogen % for compost and vermicompost against feedstock indicated enhanced organic matter mineralization during vermicomposting (Fig 2b).

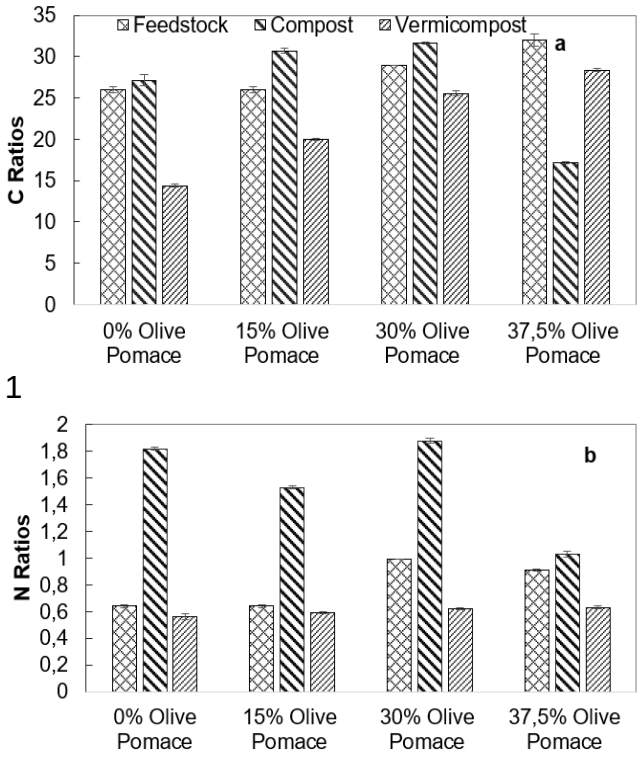


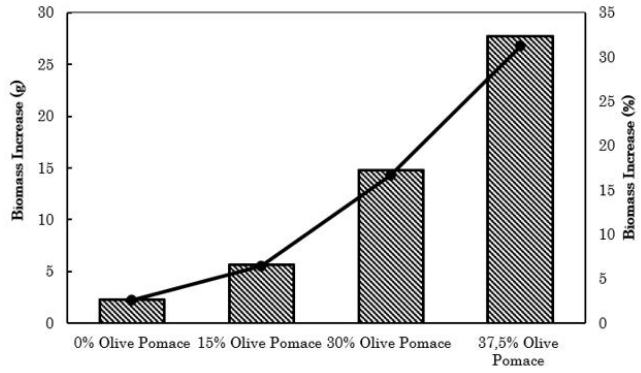
Figure 2. Comparison of a) Total C% and b) Total N% values of composting and vermicomposting processes according to different concentrations of olive pomace

Indicating the superior performance of vermicomposting against composting has only validated the results obtained in recent studies. On the other hand, olive pomace utilization as an ingredient of earthworm nutrition was a relatively new research object. Polyphenols and elevated salt concentration of olive pomace were two potential threats to increasing earthworm mortality during the trials despite the 15-day digestion period applied before the experiments. Hence, the initial task was to determine whether or not olive pomace was a suitable source of nutrition for earthworms. Hence, the most important goal during vermicomposting was to keep these earthworms alive, and 45 days was thought to be an adequate time to test this fact, considering a stock density of 5, which was high enough to create relatively harsh conditions for earthworms. Hence, earthworms were under no circumstances disturbed, and they were collected at the end of 45 days from systems to determine biomass change. Results indicated an increase of biomass with olive pomace supplement, reaching 31% for vermicompost prepared with 37.5% olive pomace. Preliminary results indicated an affinity of *Eisenia fetida* towards olive pomace (Figure 3).

Structural changes on feedstock during vermicomposting were shown by evaluating nitrogen adsorption-desorption isotherms and FT-IR results of feedstock and vermicomposts. Nitrogen adsorption-desorption isotherms supplied valuable insights on the effect of olive pomace and earthworms on organic matter structure.

Figure 4a-d indicated decreased adsorbed volume with increasing olive pomace in the feedstock. This decrease was thought to be due to the decrease in void volume. In other words, elevated olive pomace addition to biomass resulted in

the formation of a compact structure. On the other hand, observing a general decrease in adsorbed volume, surface area, pore size, and pore volume after vermicomposting, independent of the olive pomace amount in the mixture, was fascinating.



Feedstock	Biomass Increase (g)	Biomass Increase (%)
0% Olive Pomace	2.27±0.05 a	2.56±0.06 a
15% Olive Pomace	5.68±0.11 b	6.4±0.12 b
30% Olive Pomace	14.77±0.03 c	16.63±0.03 c
37.5% Olive Pomace	27.7±0.03 d	31.19±0.03 d

Different letters indicate significant differences ($p<0.05$) in biomass increase of different feedstock values in the same column

Figure 3. Effect of olive pomace in the feedstock on earthworm biomass yield

Despite a less pronounced volume decrease in the case of 37.5% olive pomace addition, results indicated the formation of a compact organic structure, which could come in handy by enhancing the water-holding capacity of soil during crop cultivation. In a study by Zhang et al. (2023) investigating the adsorption-desorption properties of soil and vermicompost prepared using different proportions of organic raw materials, the physicochemical properties of vermicompost were correlated with the ratio of raw materials used. The study showed that adsorption increased, but desorption decreased in vermicomposts, depending on the mixture composition.

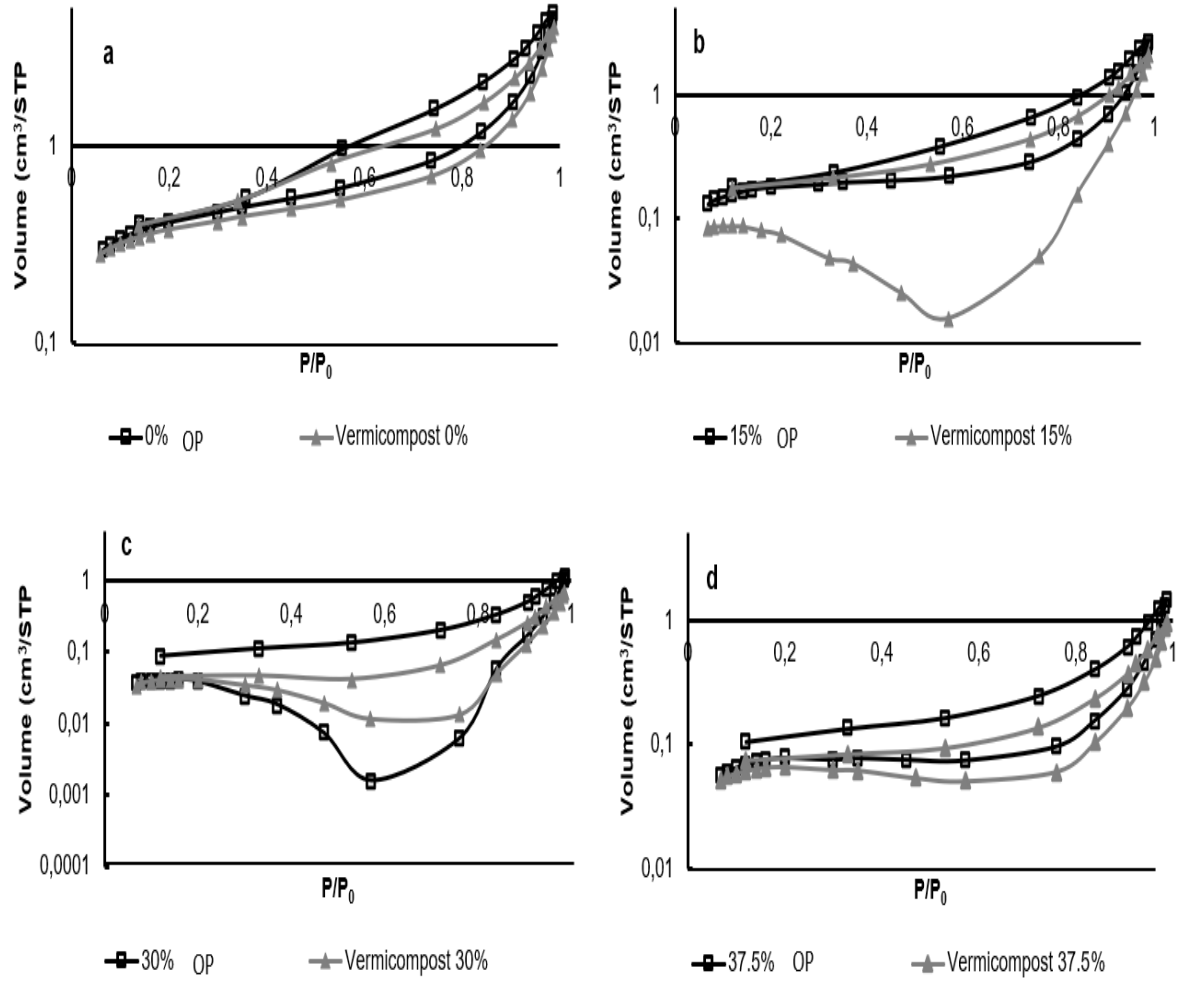


Figure 4. Nitrogen adsorption-desorption isotherms of feedstocks and vermicompost containing a) 0%, b) 15%, c) 30%, and d) 37.5% olive pomace

FT-IR analyses of feedstock and vermicompost were compared in Figure 5, and peak detail in Table 2. Figure 5a revealed a vice-versa earthworm behavior depending on olive pomace absence. In the case of an organic mixture without olive pomace, earthworms seemed to utilize all components and try to establish a balance between aromatic and aliphatic compounds, reflecting a decrease in intensities regardless of structure. On the other hand, introducing olive pomace altered earthworms' nutrition behavior. As seen from the figure, the intensities of peaks identifying aromatic structure increased while peak values obtained at 2850 and 2923 (Table 2) decreased (Baddi et al., 2003; Pospisilova and Fasurova, 2009; Helal et al., 2011). When the FT-IR graphs with different concentrations of olive pomace in Figure 5 are compared by the pre-decomposition and afterward of the feedstocks and the vermicompost, it is thought that aliphatic compounds are earthworms' feeding preference due to their easy degradability (Campitelli and Ceppi, 2008; Helal et al., 2011; Kumar et al., 2015).

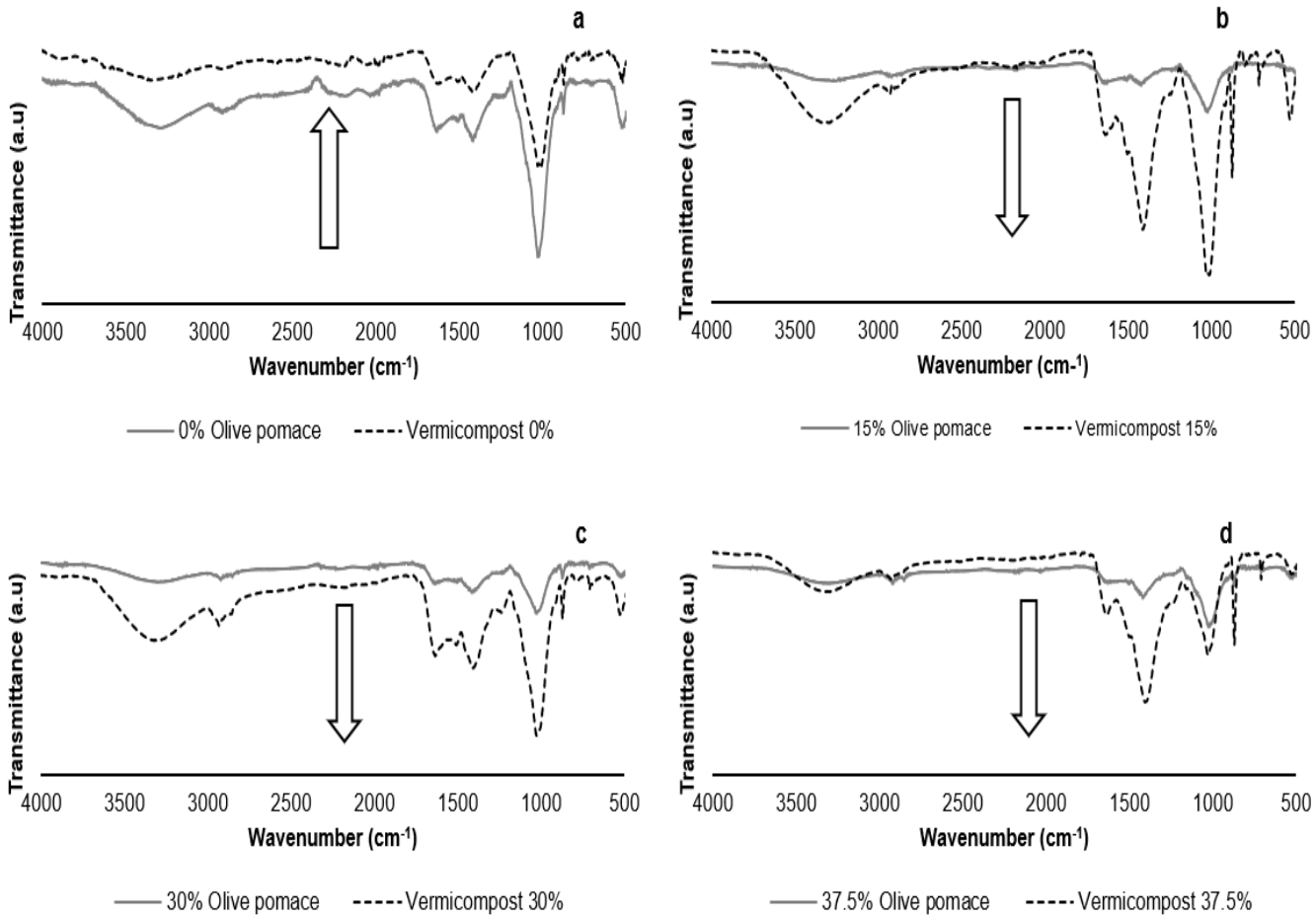


Figure 5. FT-IR analyses of feedstocks and vermicompost containing **a)** 0%, **b)** 15%, **c)** 30%, and **d)** 37.5% olive pomace

Table 2. Peak values were obtained with FT-IR analyses

Peak value, (cm^{-1})	Assignment	References
3280-3300	O-H stretch of alcohols and carboxylic groups	Sakellariadou 2006; Helal et al. 2011; Rajiv et al. 2013; Lim & Wu, 2015; Kumar et al. 2015;
2850; 2923	Aliphatic methylene	Campitelli and Ceppi 2008; Pospisilova & Fasurova 2009; Helal et al. 2011; Kumar et al. 2015; Das et al. 2015;
1632	Aromatic C=C double bonds	Baddi et al., 2003; Pospisilova and Fasurova, 2009; Helal et al., 2011;
1421	Phenol in humic content	Baddi et.al., 2003
874	C-H deformation of aromatic structure	Baddi et.al., 2003
1028	C-O stretching of polysaccharides, cellulose, and hemicelluloses	Baddi et al. 2003; Sakellariadou 2006; Campitelli & Ceppi 2008; Pospisilova &Fasurova 2009; Helal et al. 2011; El-Haddad et al. 2014; Kumar et al. 2015

The results of elemental analyses were also evaluated to validate findings obtained from characterization analyses, as illustrated in Figure 6, in terms of changes in C/N, O/C, and H/C ratios of feedstock and vermicompost. An increase in C/N ratios for vermicompost prepared with 0 to 37.5% olive pomace was observed. On the other hand, C/N ratios of the feedstock were decreased in the case of 0 and 37.5% olive pomace. This result was evaluated as an indicator of ongoing organic matter degradation, which seemed contradictory at first sight and could be justified by the observation of total nitrogen values in Figure 1. The change of vermicompost's total nitrogen values with increasing olive pomace was statistically significant ($p<0.05$) yet less pronounced than the total C% change. Consequently, increasing the C/N ratio by introducing olive pomace twofold higher than the previous loading amount was inevitable.

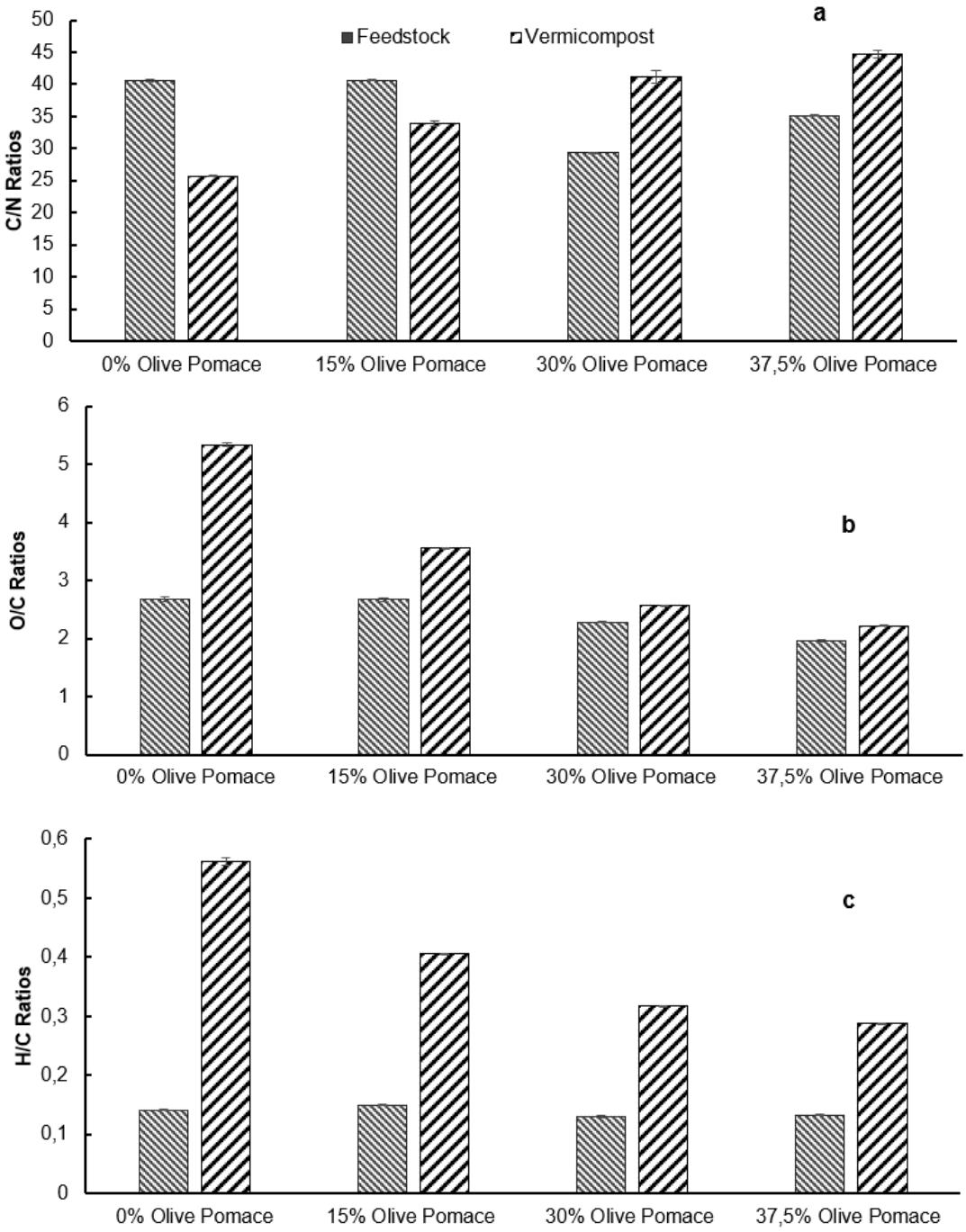


Figure 6. Elemental analyses results in terms of a) C/N, b) O/C, and c) H/C ratios of feedstock and vermicompost

H/C ratios of vermicompost were higher than its feedstock for all olive pomace % amounts. A statistically significant ($p< 0.05$) decrease of H/C with increasing olive pomace could be observed for all vermicompost, yet this decrease was evident only for 0 and 15% in the case of feedstock. The decrease of H/C ratios among vermicompost implied increased aromaticity. This result was consistent with previous findings obtained via characterization analyses. A

comparison of feedstock and its vermicompost indicated an entirely different behavior with increased H/C ratios after vermicomposting. This was an entirely different situation, implying the effect of vital earthworm activity resulting in the introduction of water to the systems (Baldock and Smernik, 2002; Hammes et al., 2006).

O/C ratios followed a pattern similar to H/C ratios. The decrease of O/C ratios with increasing olive pomace % was also evaluated as the indicator of aromatization during the vermicompost process. On the other hand, the O/C ratio of vermicompost obtained higher than its feedstock values also revealed earthworm activity leading to aeration of feedstock during vermicomposting (Baddi et al., 2003). The aeration of feedstock enhances microbial activity, which results in nitrogen utilization. This observation also explains the lower nitrogen values of vermicompost compared to compost, as shown in Figure 1.

Evaluation of results indicated increased aromaticity upon vermicomposting. Organic matter degradation progressed through aliphatic content. It was our understanding that easily degradable aliphatic content was the primary source of nutrition for earthworms, which determined the pathway of degradation. Similar observations were also obtained in recent studies with decreased aliphatic content in a mixture of cattle manure and two-phase olive pomace (Plaza et al., 2008).

Results validated olive pomace as a valuable food source for vermicomposting. However, economic viability is the primary factor, and our findings and the literature could only provide partial insight limited to the benefits of processed olive pomace as an organic fertilizer. Studies investigating olive pomace utilization in terms of economic viability mainly focused on the massive amount of waste produced, especially in Mediterranean countries. This waste would allow for the sustainability of the process above all. Olive pomace as a compost ingredient was recently proven to increase soil organic matter, microbial biomass, and nutrients beneficial to soil fertility. Amounts as high as 90% could be evaluated via aerobic digestion. In the case of vermicomposting, which accelerated aerobic digestion, the economic-environmental benefit of the process would prevent or at least decrease the utilization of expensive methods, as in the production of chemical fertilizers (Muscolo et al., 2019). Investigations were also being conducted by certain companies utilizing olive pomace to produce a valuable product. Bio humus prepared by mixing olive pomace with harvest residues was among the latest cost-effective examples introduced as an alternative to chemical fertilizers (Rautenstrauch et al., 2014).

4. CONCLUSIONS

Olive pomace obtained from olive mill wastes was digested for 15 days and utilized as one of the main components in vermicomposting. The earthworm population increased with increasing olive pomace in the feedstock, which was the highlight of the study, indicating fine adaptation of earthworms to olive pomace presence. BET analyses revealed the formation of a compact structure with the potential to improve water-holding capacity when added to the soil. FT-IR analyses also indicated the change of structure with olive pomace addition. However, a more pronounced result was shown with the intensity change trend upon olive pomace addition. Olive pomace addition increased peak intensities, identifying aromatic structure. It was thought that the easily degradable aliphatic compounds introduced by olive pomace had been consumed by earthworms, implying a shift in earthworms' affinity towards olive pomace.

The results obtained from elemental analyses validated the increase in aromaticity. However, the evaluation of results in terms of ratios also supplied valuable information on the behavior of earthworms during vermicomposting. A feedstock and its vermicompost comparison revealed an increase in the H/C ratio, which implied water's introduction to the system. Considering that the system was undisturbed throughout the process, water formation was evaluated as a consequence of vital earthworm activity. The change of O/C ratios also revealed a similar increasing trend between feedstock and its vermicompost. This increase was attributed to the aeration of the system throughout the process. Consequently, adding biomass with olive pomace increased organic matter degradation, vital activity signs, and mobility.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Author Contributions
Conceptualization: L.D.; Investigation: L.D., A.A.B.; Material and Methodology: L.D., A.A.B., Ö.C.D.; Supervision: L.D., A.A.B.; Visualization: L.D., A.A.B.; Writing-Original Draft: L.D.; Writing-review and Editing: L.D., A.A.B., Ö.C.D.; Other: All authors have read and agreed to the published version of the manuscript.

Conflict of Interest
The authors have no conflicts of interest to declare.

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Current Geography Studies in Türkiye

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Abstract: The main purpose of this study is to evaluate the master's and doctoral theses completed in the field of geography at the National Thesis Center of Turkey (YÖK) between 2018 and 2023 from a holistic perspective and to provide a new outlook for future studies. To this end, a database was created consisting of theses categorized by year, subject, type, method, university of the author, and the geographical region where the university is located. Within the scope of the study, a total of 1237 graduate theses were analyzed. Of these, 988 belong to master's programs and 249 to doctoral programs, indicating that master's theses outnumber doctoral theses. The most master's theses were produced in 2019 with 250 theses and doctoral theses were produced in 2023 with 66 theses. The least number of master's theses were produced in 2018 with 107 theses and doctoral theses were produced in 2020 with 26 theses. In both master's (519) and doctoral (142) programs, the majority of theses were produced in human and economic geography, followed by those in physical geography (master's (382), doctoral (84)). Within human and economic geography, tourism geography (111) was the most studied subject, whereas geomorphology (155) was the most examined in physical geography. Regarding the methods used in the theses, qualitative methods (488) are more frequently preferred in master's studies, while quantitative methods (121) are utilized in doctoral theses. Among the universities producing the most theses, Istanbul University ranks first in both master's (88) and doctoral (48) programmes. Evaluating the geographical regions of the universities where the authors are located, the Marmara Region ranks first in both master's and doctoral programs. These results will enhance the understanding of academic developments and trends in the field of geography, providing direction for future research. The findings of this study are significant for understanding current geography theses in Turkey. It is believed that increasing the number of postgraduate theses in geography and improving the quantity and quality of students pursuing postgraduate education in this field can provide a positive impetus to Turkey's development.

Keywords: Geography, Master, Doctoral, National Thesis Center.

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1. INTRODUCTION

Geography is one of the important branches of science that people apply to solve the problems they face through observation, research and interpretation because it is a field with a wide scope that integrates the subjects of social sciences and science (Yaşar et al., 2012; Tekeş and Cürebal; 2019). Geography, which is basically a science of the earth, has been defined in quite different ways from Eratosthenes to the present day and has experienced transformations in line with the needs of the time and society (Üçışık and Demirci, 2002). For example, Tümertekin (1978) defined geography as the study interaction all physical and human phenomena in separately places, and how this mutual influence between places creates patterns and organizes space. Hoşgören (2011) defines it as "describing the features, events and activities of the environment, their formation mechanisms, their relations with each other, their spatial distribution and the similarities and differences in this distribution together with their reasons". These definitions constitute only a few of the dozens of definitions of geography.

Geography provides a broad spectrum of information, ranging from the physical structure of the earth to the spatial distribution of human activities, thoroughly

examining both the natural environment and the interactions between human societies and their environment (Shattuck and Campbell, 2017). Understanding the interactions between natural events, environmental processes, and human activities is a main purpose of geography (Tuan, 1991; Mert and Acarer, 2018; Tekin et al., 2018; Süel et al., 2021).

Geography, as a broad discipline, provides extensive information through research conducted in various subfields. Geographical studies include 4 fields as physical, human, regional and education (Table 1.). Physical geography examines the physical characteristics of the place where people live, while human geography examines the society formed by human beings and their activities on earth. If the relations of physical and human geography features within themselves and with each other are analyzed in a piece of earth, this is a real geographical synthesis. The sub-branch of geography in which such studies representing geographical synthesis and integrity in the real sense are carried out is expressed by Regional Geography (Kayan, 2000). The Geography of Education defines the scope of this emerging interdisciplinary field. It highlights the intrinsic connection between geographical and educational studies by focusing on the geographical factors that impact formal education systems and various methods of knowledge transfer (Brock, 2016).

Table 1. Geography departments and field of science.

Department	Field of Science
Physical Geography	Geomorphology Climatology Hydrography Biogeography Natural disasters Mathematics geography Cartography…
Human and Economic Geography	Population Geography Settlement Geography Political Geography Historical Geography Health Geography Agriculture Geography Transportation Geography Industry Geography Tourism Geography...
Regional Geography	Continental Geography Regional Geography Countries Geography...
Education Geography	Geography teaching methods Subject area textbook review Introduction to the teaching profession Planning and assessment in teaching Teaching technologies ...

Research is usually carried out in the four main department and in a large number of specific scientific fields. These four main disciplines offer different perspectives and methods, reflecting the comprehensive nature of geography. Quantitative and qualitative methods used in geographical research play an important role in understanding the different types of data and approaches to analysis in the field (Clifford et al., 2010). Quantitative methods include measuring and analyzing data numerically. These methods are usually based on statistical analyses and are used to understand the quantitative (numerical) characteristics of the data. Qualitative methods provide a more in-depth and meaningful understanding of the data (Zadrozny et al., 2016). These methods focus on the qualitative characteristics of the data and usually include text or observation data (Merriam, 2015). These two methods are used complementarily to understand the broad nature of geography and to examine various geographical phenomena comprehensively.

There are many theses conducted in the field of geography in Turkey. Geography theses are academic research studies in various fields of geography. The database of theses is maintained by the National Thesis Center, conducted by the Council of Higher Education of the Republic of Turkey (NTC, 2024). Theses are added to the National Thesis Center database by the Council of Higher Education (YÖK) and made available for public use. In this sense, the National Thesis Center provides a central database of master's and doctoral theses, offering an opportunity to examine research trends and academic productivity.

In our country, there are many studies that handle theses as a database. However, these studies have generally been conducted for a specific department of geography. For example, Şardağ (2016) “A content analysis related to graduate theses made in Turkey in the field of geography about tourism”, Uzun (2018) "Assessment of graduate theses in the field of human geography: 2008-2017", Taş (2019) “Turkey’s Rural Settlements in Graduate Theses and Dissertations”, Çifçi (2017) ‟The Trends of Postgraduate Theses (2006-2017) on Geography Education in Turkey” and Yazıcı (2020) “Physical Geography Education: The Postgraduate Research Trends in Turkey” examined graduate theses on tourism geography, human geography, rural settlements, education geography and physical geography respectively.

The main purpose of this study is to conduct a comprehensive review of master’s and doctoral theses in the field of geography in the Turkish National Thesis Centre between 2018-2023. In this context, a database was created through the National Thesis Center, which includes information such as the year of the thesis, subject, type, method, the authors university of the author and the geographical region where the university is located. Results will allow a better understanding of academic developments and trends in the field of geography and will be a direction for future research. In this context, the results of this study provide important findings on current geography theses in Turkey.

2. MATERIAL AND METHOD

The data sources in the study consist of master's and doctoral theses published in the National Thesis Center in the geography department between 2018 and 2023, which are open to public use and can be accessed via the internet. The theses included in the study are the theses that were reached as a result of searches with the keyword 'geography' through the internet database called National Thesis Center of the Council of Higher Education (YOK). In this sense, with the detailed search option of the National Thesis Centre, studies whose discipline is geography and subject are geography were scanned by including the years 2018-2023 and thesis type (master and doctoral). The data obtained were evaluated and content analysis was performed. Then were interpreted with tables, graphs and maps.

Content analysis is one of the most important techniques frequently used especially in social sciences (Bardin, 1977). Content analysis is a systematic, quantitative and objective method used to describe and analyze the content of any symbolic behavior (Cartwright, 1953).

In this study, a total of 1237 master's and doctoral theses produced between 2018-2023 in the department of geography were evaluated. 988 of the theses are master's theses and 249 of them are doctoral theses. The theses evaluated were classified according to Table 2, and then the created database was examined separately.

Table 2. Example examination of theses made within the scope of geography departments.

Department	Author	Year	Type	Subject	Method	University	Geographical region of the university
Physical Geography	Mesut Demircan	2019	PhD	Sıcaklık verilerindeki kırılma tarihleriyle iklim indekslerinin ilişkisi	Quantitative	Ankara University	Central Anatolia Region
Human and Economic Geography	Oğuzhan Gürgen	2022	Master	Ardeşen ilçe merkezi'nin Kuruluşu gelişmesi ve kentsel fonksiyonları	Qualitative	Atatürk University	Eastern Anatolia Region
Regional Geography	Cumali Ögel	2023	PhD	Güneydoğu Anadolu Bölgesinin kalkındırılmasında sanayinin rolü ve sorunları	Qualitative	İstanbul University	Marmara Region
Education Geography	Özlem Yücel	2022	Master	Mekânsal kavramların coğrafya ders kitaplarında kullanımı	Qualitative	Marmara University	Marmara Region

Researches in the field of geography are generally conducted in four department of science and many fields of science. In this context, a total of 1237 theses were analyzed separately as master's and doctoral theses according to their branches of science and sub-branches (Table 3). Table 3 includes only the branches of science and sub-branches of the theses included in this study.

Table 3. Distribution of geography studies according to master's-doctoral theses.

Departments of Geography and their fields of science	**Master**	**PhD**	**Total**
Total	988	249	1237
Geomorphology	130	25	155
Climatology	71	21	92
Biogeography	8	3	11
Plant	32	1	33
Paleogeography	5	1	6
Hydrography	32	14	46
Natural disasters	58	13	71
Land use	43	5	48
Cartography	2	1	3
Mathematics	1	0	1
Physical Geography Total	**382**	**84**	**466**
Human and economic	230	67	297
Population	49	2	51
Settlement	13	11	24
Cultural	44	12	56
Political	9	6	15
Historical	5	2	7
Agriculture	22	4	26
Industry	12	9	21
Transportation	1	3	4
Energy	21	0	21
Trade	1	1	2
Offense	9	0	9
Tourism	95	16	111
Health	4	2	6
Environmental issues	3	7	10
Mining	1	0	1
Human and Economic Geography Total	**519**	**142**	**661**
Regions	5	8	13
Countries	15	0	15
Regional Geography	**20**	**8**	**28**
Education Geography	**67**	**15**	**82**
Total	**988**	**249**	1237
Percent	**80%**	**20%**	**100%**

When the master's and doctoral theses were evaluated together, a total of 466 theses were found in physical geography, 661 in human and economic geography, 28 in regional geography and 82 in educational geography. The order of these from the most to the least theses is human and economic geography, physical geography, educational geography and regional geography. Within the scope of physical geography, geomorphology, climatology, biogeography, plant, paleogeography, hydrography, natural disasters, land use, cartography, mathematical geography have been handled. In the field of Human and economic geography, population, settlement, cultural, political, historical geography, agriculture, industry, transportation, energy, trade, offense, tourism, health, environmental issues, mining have been handled. In regional geography, region and countries were studied. Finally, in educational geography, there is a wide range of topics such as geography teaching methods, textbook review, planning and evaluation in teaching.

In the study, Microsoft Excel was preferred for data editing and ArcGIS Pro from GIS software was preferred for mapping. 'R' software was used for creating and visualizing graphics.

3. RESULTS

In this study, postgraduate theses in geography studies registered in the National Thesis Centre were examined. The study covers postgraduate theses registered in the National Thesis Centre between 2018 and 2023. A total of 1237 theses have been evaluated within the scope of the study. Of the theses, 988 are master's theses and 249 are doctoral theses. In this context, a database containing information such as the university to which the authors are connected, the geographical region where the university is located, the subject of the theses, the type of theses, the method used and the year of publication was created through the National Thesis Centre. Thus, master's and doctoral theses in the field of geography were examined in various aspects.

3.1. Evaluation of Master Theses

A master's degree marks the starting point of an academic career; during this process, students aim to select their area of interest and establish connections with academics specialized in that field (Özçakmak, 2017). The master's program can be offered either with or without a thesis. In the thesis-based master's program, the objective is for students to effectively access, assess, and interpret information through scientific research. Conversely, the non-thesis master's program aims to equip students with comprehensive knowledge of their professional field and to illustrate how to apply existing knowledge in practical situations (Akın, 2016).

Within the framework of the study, when the distribution of 988 master's theses made in the department of geography between 2018-2023 according to years is examined, 107 master's theses were produced in 2018, 250 in 2019, 131 in 2020, 134 in 2021, 199 in 2022 and 167 in 2023 (Figure 1). The year with the highest number of theses (250) is 2019. The least number of theses was produced in 2018 (107).

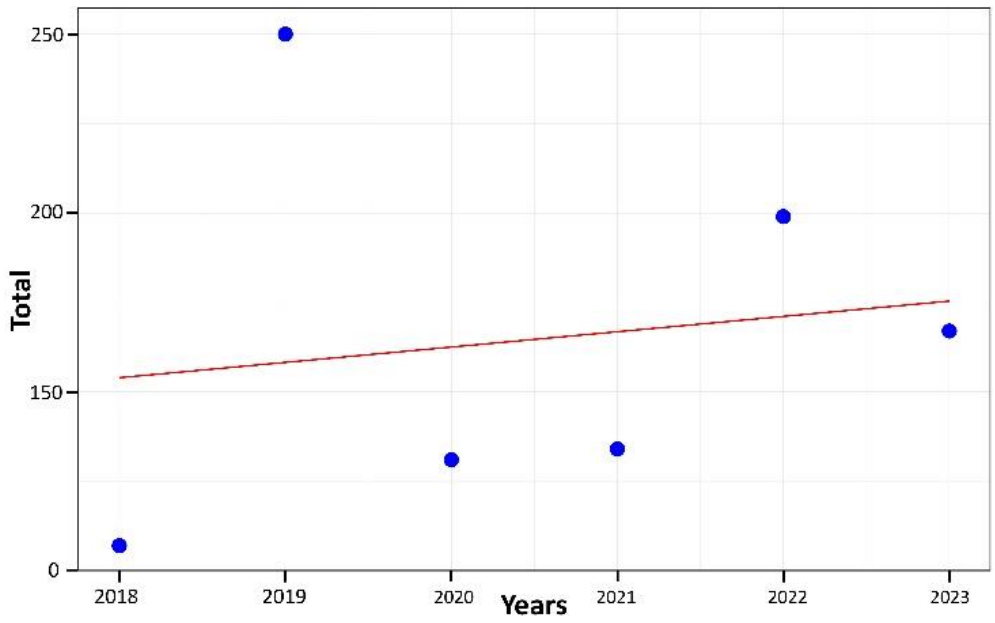

Figure 1. Temporal distribution of master's theses.

According to the evaluations, the first 10 universities that produced the most theses are İstanbul (88 theses), Atatürk (80 theses), Karabük (75 theses), Çanakkale (64 theses), Marmara (58 theses), Akdeniz (51 theses), Ondokuz Mayıs (47), Harran (43), Fırat (42) and Ankara (37) universities, respectively (Figure 2).

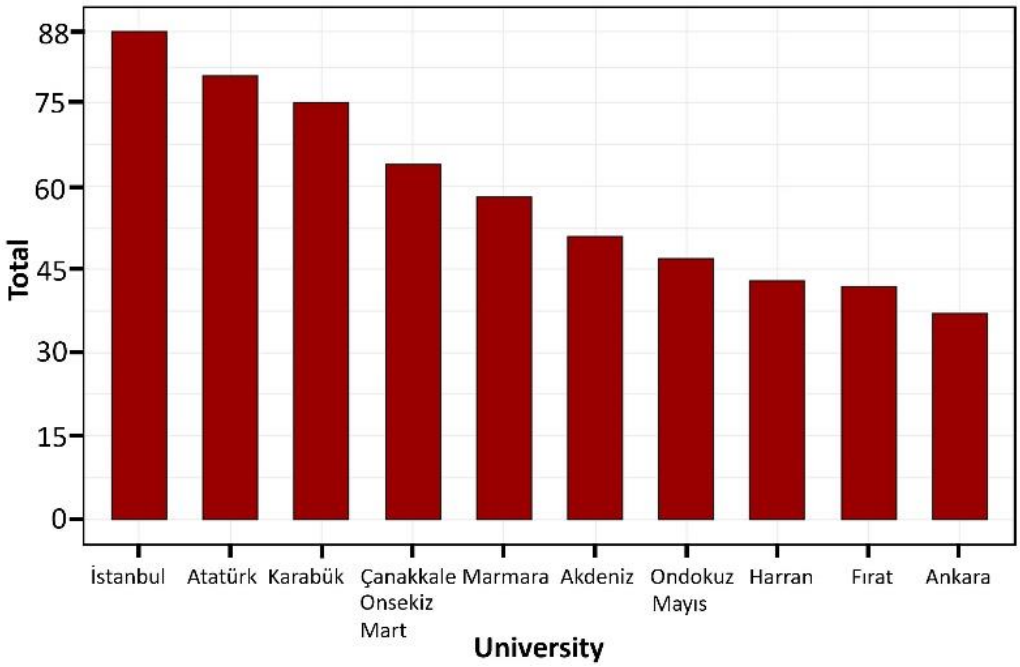

Figure 2. First 10 universities producing the most master's theses in the field of geography.

When the analyzed master's theses are examined based on the geographical region of the university to which the author is affiliated, the order is as follows: Marmara Region (299), Eastern Anatolia Region (184), Black Sea Region (133), Mediterranean Region (132), Central Anatolia Region (107), Aegean Region (67), Southeastern Anatolia Region (66), (Figure 3).

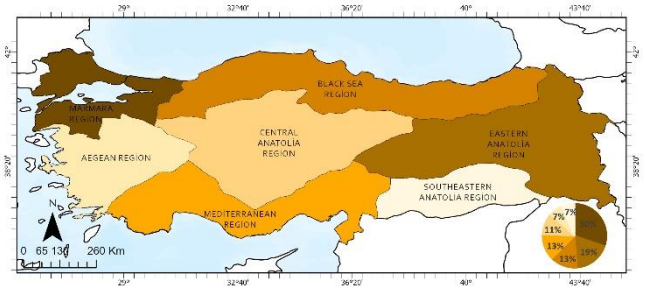

Figure 3. Distribution of master's theses on the basis of geographical regions.

The subjects of the master's theses evaluated in the study are divided into 4 classes as physical, human and economic, regional and educational geography. Accordingly, there are 382 theses in physical geography, 519 in human and economic geography, 20 in regional geography and 67 in educational geography (Figure 4). In master's theses, human and economic geography ranked first, while regional geography ranked last. Geomorphology, climatology, natural disasters, land use and plant geography are the top 5 most studied subjects in physical geography compared to other subjects. Human and economic geography, tourism, population, culture, agriculture and energy are the most studied subjects in human and economic compared to other subjects. In regional geography, country geography has been studied the most. There is a general distribution between subjects in educational geography.

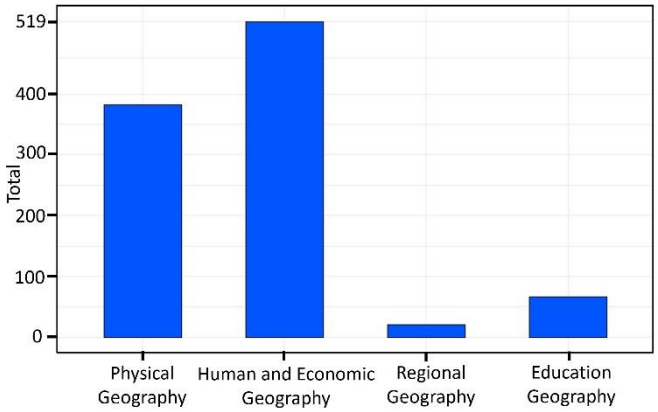

Figure 4. Distribution of master's theses according to branches of science.

Finally, 488 of the theses analyzed were qualitative, 378 were quantitative and 122 were mixed method. One of the most important sections of graduate theses is the methodology. When the method titles of the theses examined within the scope of the research are examined, some of the theses do not have a method title at all, while some of the theses have a method title, but there is no information about which method was applied in the study, how the data were analyzed, and which methods were followed in the study.

3.2. Evaluation of Doctoral Theses

The goal of the doctoral program is to create a new scientific methodology that introduces innovation to the field or to adapt an existing method for application in a different area, thereby equipping students with the skills necessary to design and conduct original research (Özdemir, 2018).

Within the scope of the study, when the temporal distribution of 249 doctoral theses made department geography between 2018 and 2023 is analyzed, 27 theses were produced in 2018, 34 theses 2019, 26 theses 2020, 47 in 2021, 49 in 2022 and 66 in 2023 (Figure 5). Although there is a decline in doctoral theses in 2020, there is a gradual increase between the other years in general. The year with the highest number of theses (66) is 2023. The least number of theses was produced in 2020 (26).

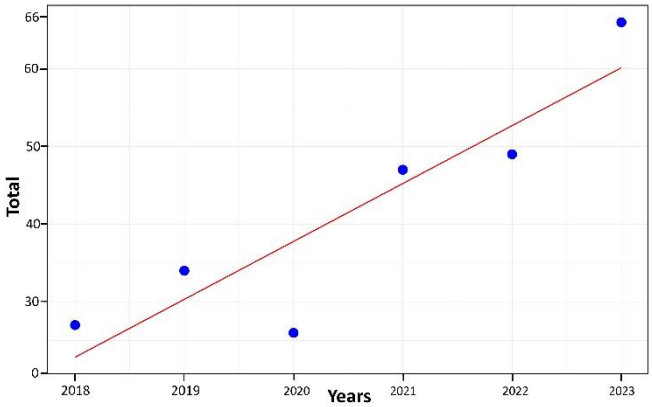

Figure 5. Temporal distribution of doctoral theses.

According to the evaluations, the first 10 universities that produced the most theses are İstanbul (48 theses), Ankara (24 theses), Marmara (22 theses), Atatürk (21 theses), Ondokuz Mayıs (16 theses), Karabük (15 theses), Çanakkale Onsekiz Mart (11 theses), Kahramanmaraş Sütçü İmam (11 theses), Fırat (10 theses) and Harran (8 theses) universities, respectively (Figure 6).

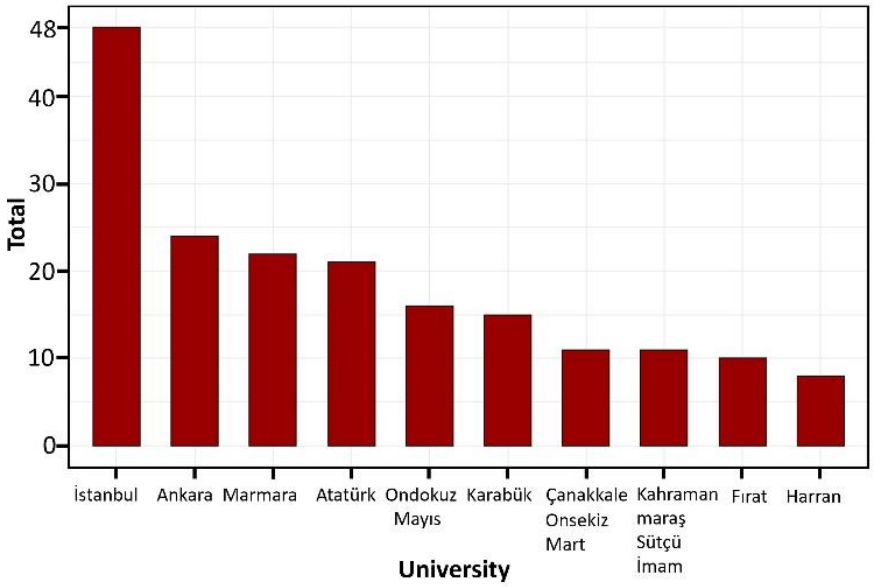

Figure 6. First 10 universities producing the most doctoral theses in the field of geography.

When the analyzed doctoral theses are examined based on the geographical region of the university to which the author is affiliated, the order is as follows: Marmara Region (100), Eastern Anatolia Region (39), Black Sea Region (33), Central Anatolia Region (32), Aegean Region (21), Mediterranean Region (16), Southeastern Anatolia Region (8), (Figure 7).

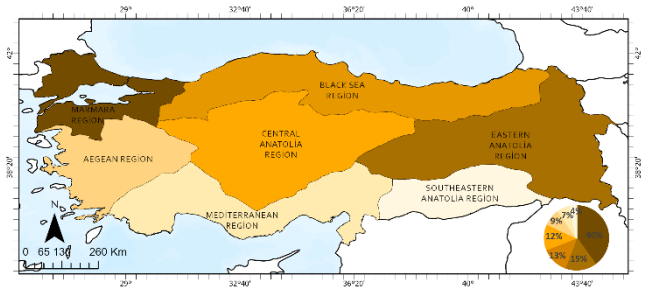

Figure 7. Distribution of doctoral theses on the basis of geographical regions.

The subjects of the doctoral theses analyzed in the study are divided into 4 classes as physical, human and economic, regional and educational geography. Accordingly, it has been determined that there are 84 theses in physical geography, 142 in human and economic geography, 8 in regional geography, and 15 in the field of educational geography (Figure 8). In doctoral theses, human and economic geography ranked first, while regional geography ranked last. The basic 5 most studied subjects in physical geography are geomorphology, climatology, hydrography, natural disasters and land use. Human and economic geography, tourism, culture, settlement, industry and environmental issues are the most studied subjects in human and economic compared to other subjects. In regional geography, regional geography has been studied the most. There is a general distribution between subjects in educational geography.

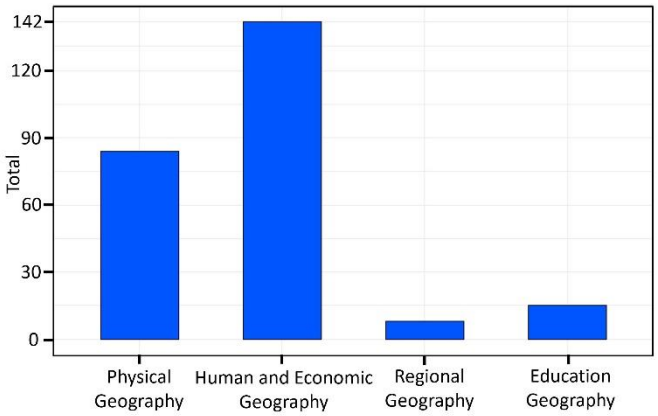

Figure 8. Distribution of doctoral theses according to branches of science.

Of the analyzed theses, 99 were qualitative, 121 were quantitative and 29 were mixed method theses. This shows that quantitative methods are becoming increasingly important, especially in terms of data analysis and objective measurement of outcomes. Nowadays, the basis of studies has shifted towards analysis and inquiries. In geography studies, engineering methods for analyzing, questioning and mapping data have gained importance.

4. DISCUSSION AND CONCLUSIONS

There are many things that need to be done in order to develop geography science and education in Turkey in a way that will respond to social and current needs. In order to advance the science and education of geography in a way that meets societal demands, various strategic approaches should be developed (Gerber and Williams, 2002). Comprehensive databases on geography studies should be created, these data should be made available for academic research, and in this process, deficiencies and new trends in current research topics should be identified (Miller and Goodchild, 2015). These databases will be a valuable

resource for future research that will both fill existing gaps and guide research trends. In this context, master's and doctoral theses at universities can provide an important resource for identifying existing gaps and areas for improvement. In particular, it can offer in-depth information on how to align with current issues and societal needs. In this study, master's and doctoral theses in the field of geography in the Turkish National Thesis Center between 2018 and 2023 were examined. A database consisting of information such as the year of production, type, topic, method, the university of the author, and the geographical region of the university of the theses examined has been evaluated. Thus, the general trends of the theses were tried to be revealed. According to the evaluations, there were more master's studies (988) than doctoral studies (249) in the field of geography. However, there is a increase in PhD studies year on year, indicating that the field continues to develop and research activities are increasing. Similarly, Kaya (2013) stated that there was an increase in doctoral theses in geography education after 2004, but this increase was lower than the increase in master's theses, and this situation was due to the low number of doctoral researchers. Among the universities producing the most theses, Istanbul University ranks first in both master's (88) and doctoral (48) programmes. In addition, when the geographical regions of the universities to which the authors of the theses evaluated are affiliated are examined, the Marmara Region ranked first as the region that produced the most thesis in both master's and doctoral programs. The subjects frequently addressed in the master's and doctoral theses examined within the scope of the research were also determined. In both master's (519) and doctoral (142) programs, most theses on human and economic geography were produced. This is followed by theses on physical geography (master's (382), doctoral (84)). In human and economic geography, tourism geography was studied the most (111), while in physical geography, geomorphology was studied the most (155). Likewise, Uzun (2018) determined tourism geography as the most studied human and economic geography subject in his study. This distribution may reflect the diversity of methods used in the research fields. In this context, the analysis revealed that qualitative methods (488) were more commonly used in master's studies, whereas quantitative methods (121) were more dominant in doctoral studies. This shows that quantitative methods are becoming increasingly important, especially in terms of data analysis and objective measurement of outcomes. These results will allow for a better understanding of academic developments and trends in the field of geography and will provide direction for future research. There is a limited number of studies on the orientations of geography studies in Turkey (Çifçi, 2017). In this context, the results of this study provide important findings on current geography theses in Turkey. According to the results of this study, it is thought that increasing the number of graduate theses in the field of geography and improving the quantity and quality of students who want to do graduate education in the field can give a positive impetus to Turkey's development. The relevant results were obtained from officially published and accepted theses. It is thought that the study will contribute in this respect.

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All studies were carried out by the corresponding author.

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The authors have no conflicts of interest to declare.

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Optimizing Soil Fertility through Machine Learning: Enhancing Agricultural Productivity and Sustainability

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Abstract: Nowadays, the sustainability of agriculture and food security have an increasing importance on soil fertility. Soil fertility is defined as the capacity of a land to grow crops and its potential crop productivity. However, factors such as increasing population, climate change, land use changes and environmental pollution threaten soil fertility. These threats can result in problems such as erosion, soil salinisation and organic matter depletion. Soil fertility is critical for the long-term health of agriculture and food security.

This study investigates the application of machine learning algorithms to optimize soil fertility, a critical factor in sustainable agricultural practices and food security. The research utilizes a dataset comprising 880 samples, each containing 12 different soil properties, including nutrient levels, pH, and organic carbon, to develop predictive models. Three machine learning algorithms Extra Trees, Random Forest and K-Nearest Neighbors (KNN) were employed to classify soil fertility and identify the key factors influencing it. Results indicate that the Extra Trees and Random Forest models exhibited superior performance, with the Extra Trees model achieving a high accuracy rate of 0.90 and a mean squared error of 0.09. The feature importance analysis identified Boron as the most influential variable, while Electrical Conductivity was deemed less significant. These findings demonstrate the potential of machine learning to enhance soil management strategies, offering a promising approach to improving agricultural productivity and sustainability. Future research should focus on expanding the dataset and applying these models across various agro-ecological zones to validate their adaptability.

Keywords: Soil Fertility, Machine Learning, Precision Agriculture, Artificial Intelligence, Sustainable Agriculture

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1. INTRODUCTION

Nowadays, the sustainability of agriculture and food security are gaining increasing importance with regard to soil fertility. Soil fertility is defined as the capacity of a land to grow crops and its potential crop productivity. This soil fertility is determined by the interaction of a number of factors, including physical, chemical and biological properties. However, in recent years, factors such as increasing population, climate change, land use changes and environmental pollution threaten soil fertility. Maintaining soil fertility is critical to the long-term health of agriculture and human nutrition. Fertile soils contribute to stable crops across cropping seasons and contribute to ensuring food security of societies. However, problems such as erosion, soil salinisation and organic matter depletion can reduce soil fertility and threaten the long-term sustainability of agriculture.

Soil fertility refers to the ability of soil to support optimum plant growth. It is influenced by various factors such as organic matter content, nutrient availability, pH and biological processes. Intensive agricultural practices have led to a decline in soil fertility due to erosion, loss of organic matter and deterioration of soil properties (Patzel et al., 2000). Cover crops have been used to improve soil fertility

by increasing organic matter content, nutrient availability and cation exchange capacity (Solomon, 2023). Soil fertility can be assessed by methods such as soil sampling, heating and titration to detect nutrient levels and organic matter content (Peng Chunjian, 2018). Furthermore, advances in technology have led to the development of electronic devices and systems that use image analysis to determine soil fertility based on colour values (Zhaorong et al., 2018). In general, soil fertility is a complex concept involving the interaction of environmental, physical and chemical factors and plays a crucial role in supporting plant growth (Henis, 1986).

Intensive agricultural practices have led to a decline in soil fertility, primarily due to soil erosion, loss of organic matter and degradation of soil physical, chemical and biological processes and properties. Cover crops have traditionally been used to improve soil fertility. Cover crops can serve as a valuable source of phosphorus (P) and reduce the need for inorganic P fertilisers for subsequent crops. Soil pH, an important indicator of nutrient availability and soil fertility, can be influenced by cover crops. Cover crops release nutrients through residue decomposition after termination, and factors such as cover crop residue quality, soil texture, biological activity and climatic conditions can influence the rate of nutrient release (Solomon, 2023).

Soil fertility is determined by the interaction and interweaving of physical, chemical and biological substances, and biological fertility is one of the least understood components. Soil microorganisms such as bacteria, actinobacteria, fungi, soil algae and soil protozoa play a crucial role in maintaining soil fertility and nutrient cycles. Understanding soil microbiology is essential for sustainable agriculture and meeting the needs of a growing world population (Nadarajah, 2022).

Soil fertility is a fundamental property of every soil type and is determined using various physiochemical methods for the purpose of applying soil fertilisers for plant nutrition. The soil fertility parameters tested include pH in potassium-chloride (KCl), CaCO3, humus, total nitrogen, P2O5 and K2O. The results of the research show that soil fertility is high in many places studied, but there are also areas that require remedial measures (Majstorović et al., 2022).

Soil fertility plays a very important role in agriculture and artificial intelligence (AI) techniques have been applied to improve soil fertility management. Various AI algorithms such as artificial neural networks (ANN), decision trees, random forests and k-nearest neighbours have been used to predict soil fertility and recommend the best crops to farmers (Sunori et al., 2022) (Swetha et al., 2023). These algorithms categorise soil into different categories by analysing soil data, including pH value, available potassium content and other factors, and provide accurate recommendations for crop selection (Swetha et al., 2023). Furthermore, machine learning algorithms such as logistic regression, support vector machines and ensemble techniques have been used to categorise soil into healthy and unhealthy categories based on chemical fertility and other characteristics (Patil, 2022). An approach combining deep learning, artificial intelligence (AI) and the Internet of Things (IoT) has been presented to provide fast and accurate results for soil fertility testing and crop recommendations and overcome the disadvantages of traditional soil testing practices (D N & Choudhary, 2021). The integration of AI with Internet of Things (IoT) technologies has also been investigated to optimise irrigation and fertilisation processes by assessing soil nutrients and moisture content in real time. These advances in AI have the potential to improve soil fertility management and increase agricultural productivity (Nyakuri et al., 2022).

Soil testing is an effective tool for evaluating soil nutrient levels and calculating the appropriate quantity of soil nutrients based on fertility and crop requirements (Raman & Chelliah, 2023). In order to classify village-wise soil nutrient levels and soil fertility indices, a group of 20 classifiers, including bagging, random forest (RF), AdaBoost, support vector machine (SVM), and neural network (NN), were employed, and the class label was evaluated on a scale of high, low, and medium according to their numerical value (Escorcia-Gutierrez et al., 2022). A soil classification method based on principal component analysis (PCA) based laser-induced breakdown spectroscopy (LIBS) and random forest (RF) algorithm was proposed, and the standard soil samples from six different mining areas were accurately identified and classified(Jin et al., 2023). Soil fertility capability classification (FCC) is a technical system to group the soils according to the kind of physical and chemical constraints they present under agronomic management (Hota et al., 2022). Remote sensing techniques based on machine learning algorithms can be used to predict and assess the physical and chemical parameters of the soil, which is extremely important for the fertilization process in precision agriculture(Radočaj et al., 2022).

Machine learning algorithms have materialized in soil fertility prediction as an encouraging method for enhancing production (Rajamanickam & Mani, 2021). Conditional inference tree (CIT) is a machine learning method able to untangle complex interactions while providing an interpretable model (Bastos et al., 2021). Soil parameters such as nitrogen, phosphorus, potassium (NPK), pH, organic carbon, moisture content, and few more things are considered for predicting the fertility of the soil and also to predict the right crops to be grown and nutrition required for it (Varshitha & Choudhary, 2022). Compared with other optimizer models, the adopted method is more suitable for the accurate classification of soil erosion, and can provide new solutions for natural soil supply capacity analysis, integrated erosion management, and environmental sustainability judgment(Chen et al., 2021). Since Machine Learning could play a key role in reducing the costs and time needed for a suitable site investigation program, the basic ability of Machine Learning models to classify soils from Cone Penetration Tests (CPT) is evaluated (Rauter et al., 2021). Features are independent variables such as climatic, edaphic or managerial data, indices or categories, soil tests, and tissue tests (Parent et al., 2021). proposed a model to estimate soil organic matter, total nitrogen, and total carbon where remote sensing data were used as inputs to a support vector machine and an artificial neural network to determine these three soil attributes (Sarkar et al., 2022).

Five machine-learning models – K-nearest neighbor (KNN), multilayer perceptron neural network (MLP), random forest

(RF), support vector machines (SVM), and extreme gradient boosting (XGB) – combined with the original data and three log-ratio transformation methods – additive log ratio (ALR), centered log ratio (CLR), and isometric log ratio (ILR) – were applied to evaluate soil texture and PSFs using both raw and log-ratio-transformed data from 640 soil samples in the Heihe River basin (HRB) in China (Zhang et al., 2020). It includes the identification of land arable, diversification of crops, restoration of organic matter, and rationalization of soil input (Kalyani & Prakash, 2020). In this paper, surface soil moisture was retrieved from Radarsat-2 and polarimetric target decomposition data by using semiempirical models and machine learning methods (Acar et al., 2020).

2. MATERIAL AND METHOD

This study presents a dataset analysis in which various chemical and physical parameters are analysed to determine soil fertility.

2.1. Dataset

The dataset used for this model is the Soil Fertility dataset (https://www.kaggle.com/datasets/rahuljaiswalonkaggle/soil-fertility-dataset). The dataset consists of 880 samples and 13 different properties are measured for each sample. These properties consist of Nitrogen (N), Phosphorus (P), Potassium (K), pH, Electrical Conductivity (EC), Organic Carbon (OC), Sulfur (S), Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Boron (B) and fertility as given in Table1 These data show that several chemical and physical parameters are important variables related to soil fertility. For example, nutrients such as Nitrogen and Potassium as well as pH and Organic Carbon levels directly affect productivity. The study results can provide an important basis for optimising soil management and fertilisation strategies.

The following table provides the descriptive statistics of the soil fertility data:

Table 1. Features of the data set

Variable	Mean	Standard Deviation	Min	Max	Units
N	246.74	77.39	6	383	mg/kg
P	14.56	21.97	2.9	125	mg/kg
K	499.98	124.22	11	887	mg/kg
pH	7.51	0.46	0.9	11.15	-
EC	0.54	0.14	0.1	0.95	dS/m
OC	0.62	0.84	0.1	24	%
S	7.55	4.42	0.64	31	mg/kg
Zn	0.47	1.89	0.07	42	mg/kg
Fe	4.14	3.11	0.21	44	mg/kg
Cu	0.95	0.47	0.09	3.02	mg/kg
Mn	8.67	4.30	0.11	31	mg/kg
B	0.59	0.57	0.06	2.82	mg/kg
Productivity Output	0.59	0.58	0	2	-

This table provides a general overview of the distribution of the soil fertility data and presents the basic statistical summary for each variable.

2.2. Machine-learning models and parameter optimization

Machine learning models Extra Trees, Feature Importance, K-Nearest Neighbors (KNN) and Random Forest (RF) used in this study.

2.2.1. Extra Trees

To classify soil fertility using Extra Trees machine learning methods, researchers can leverage the robustness and efficiency of this ensemble learning algorithm. Extra Trees, also known as extremely randomized trees, construct multiple decision trees randomly from the training dataset. This approach is particularly beneficial in soil fertility classification tasks due to its ability to handle high-dimensional data and reduce overfitting (Geurts et al., 2006).

By utilizing Extra Trees, researchers can improve the accuracy of soil fertility predictions by combining the outcomes of independent decision trees into a forest (Ekinci, 2022). This ensemble technique enhances the reliability of classifications by aggregating the outputs of multiple trees, thereby enhancing overall predictive performance (Ali et al., 2023). Additionally, Extra Trees can aid in feature selection, enabling the identification of the most significant soil properties influencing fertility levels (Baby et al., 2021). Figure 1 shows the structure of the Extra Trees method.

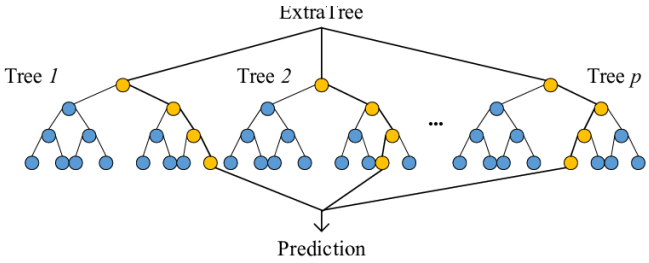


Figure 1. Extra Trees method (Chu et al., 2021)

2.2.2. Feature Importance

To classify soil fertility using Feature Importance machine learning methods, researchers can leverage the significance of relevant features in predicting soil fertility levels. By employing feature importance techniques, such as Mean Decrease in Impurity (MDI) measures, researchers can identify the most influential soil properties that contribute to soil fertility classification (Ahmadi et al., 2020). This approach aids in selecting the most relevant features while excluding irrelevant or redundant ones, thereby enhancing the accuracy and efficiency of the classification model (Talasila et al., 2020).

Furthermore, integrating Feature Importance methods with machine learning algorithms like Random Forest, Support Vector Machines, or Extreme Learning Machines can optimize the soil fertility classification process (Bondre & Santosh Mahagaonkar, 2019). By combining Feature Importance techniques with these algorithms, researchers can prioritize the most critical soil parameters for predicting soil fertility levels accurately (Trontelj Ml & Chambers, 2021). This integration ensures that the classification model

focuses on the key features that significantly impact soil fertility, leading to more precise predictions (Suruliandi et al., 2021).

2.2.3. K-Nearest Neighbors (KNN)

To classify soil fertility using the K-Nearest Neighbors (KNN) machine learning method, researchers can benefit from its simplicity and effectiveness in handling classification tasks. KNN is a non-parametric algorithm that categorizes data points based on the majority class of their nearest neighbors (Li et al., 2008). This method is particularly useful for soil fertility classification as it considers the similarity of soil samples based on their features, making it suitable for identifying patterns in soil properties that determine fertility levels (Koren et al., 2024).

By applying the KNN algorithm to soil fertility classification, researchers can leverage its ability to handle both classification and regression tasks (Shakeel et al., 2019). This flexibility allows for predicting soil fertility levels based on the characteristics of neighboring soil samples, enabling accurate classification of soil fertility into different categories (Li et al., 2008). Additionally, KNN can be used to identify hidden patterns in soil data, aiding in the discovery of relationships between soil properties and fertility levels (Raikwal & Saxena, 2012). The working system of the KNN model is given in Figure 2.

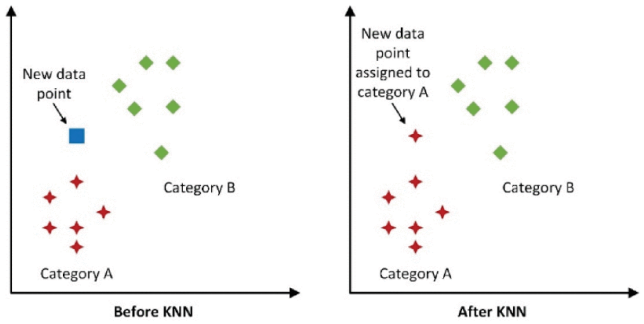


Figure 2. The working system of the KNN model (Aghaabbasi et al., 2023)

2.2.4. Random Forest (RF)

Random Forest is a robust machine learning algorithm that has demonstrated significant potential in soil fertility classification. Random forests are an ensemble learning technique that combines multiple decision trees, with each tree being built based on a random vector sampled independently (Breiman, 2001). This methodology has proven successful in various fields, including ecology, where it has shown effectiveness as a statistical classifier (Cutler et al., 2007).

In the realm of soil fertility classification, Random Forest has been employed to enhance predictions by taking into account the significance of different soil properties. Research has consistently shown that Random Forest outperforms other algorithms, such as linear regression, in predicting soil properties across various depths (Hengl et al., 2015). By utilizing the ensemble approach of Random Forest, researchers can achieve more precise predictions by aggregating the results of multiple decision trees. The working principle of the Random Forest model is given in Figure 3.

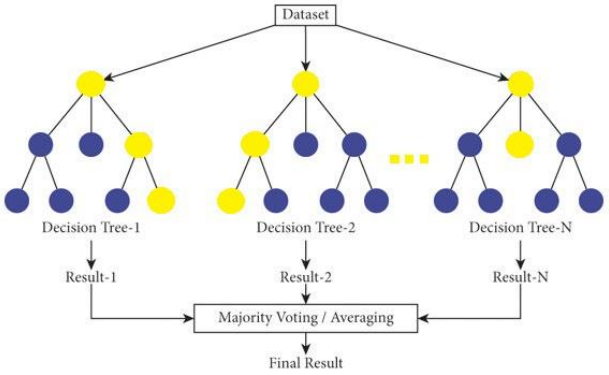


Figure 3. Working principle of the Random Forest model (Khan et al., 2021)

3. RESULTS

In this study, the classification algorithms Random Forest, K-nearest neighbour and extra trees were employed on the soil fertility dataset. GridSearchCV was utilised to optimise the performance of the classification algorithms. GridSearchCV is designed to identify the most effective combinations through cross-validation on a specified grid of hyperparameters. The final hyperparameters were selected by evaluating the model on metrics such as accuracy, F1 score and error rate.

The analysis of soil fertility data using machine learning algorithms yielded significant results. Specifically, the Extra Trees model demonstrated outstanding performance with a Mean Squared Error (MSE) of 0.09, Root Mean Squared Error (RMSE) of 0.30, and an R-Squared value of 0.74, indicating perfect prediction accuracy. Additionally, the accuracy of the Extra Trees model was found to be 0.90. The training results of the Extra Trees model shown in Figure 4.

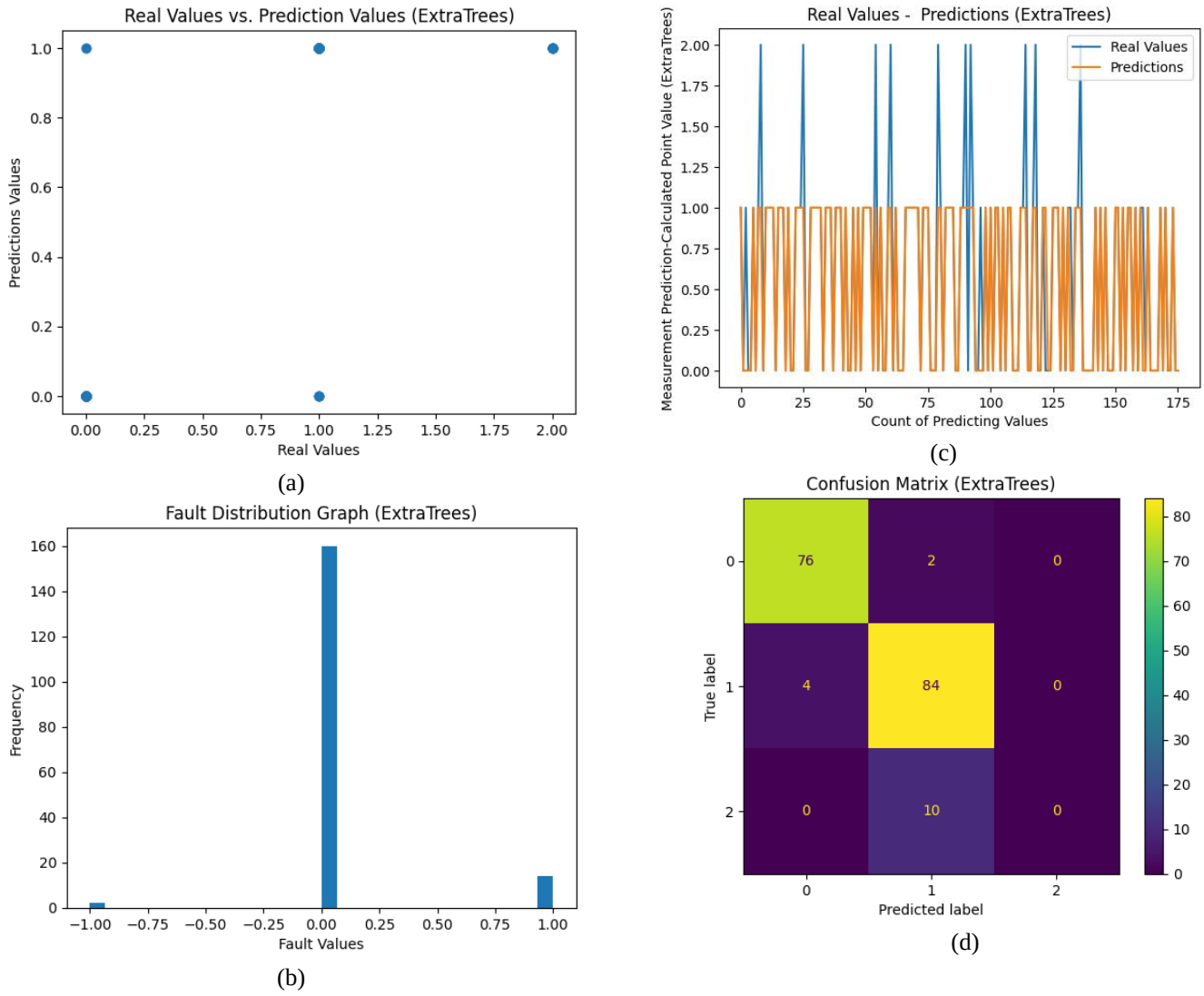
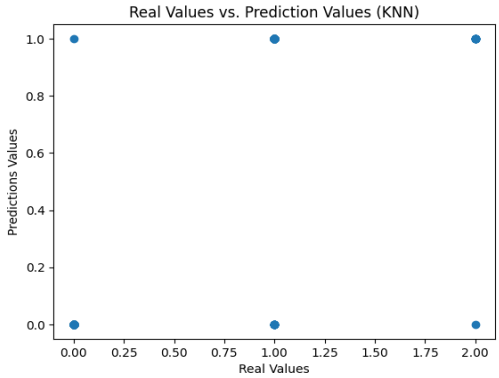


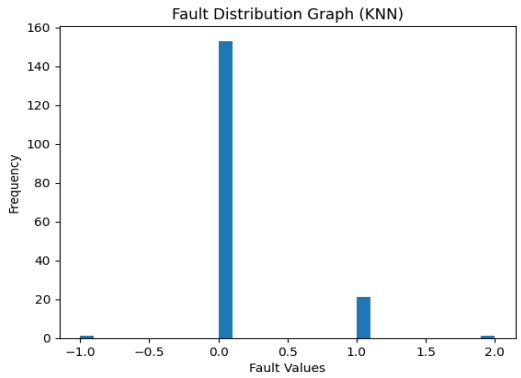
Figure 4. Extra Trees model training results (a. Prediction Graph, b. Error Distribution Graph, c. Prediction Accuracy Graph, d. Confusion Matrix Graph)

The confusion matrix in Figure 4(d) reveals a high-performance model that achieves an accuracy of 0.909. The matrix shows how well the model predicts the actual class labels (True labels) in three categories (0, 1 and 2). The rows represent the true labels, while the columns show the predicted labels. Each cell shows the number of instances classified accordingly. In general, the model performs well for classes 0 and 1, but struggles for class 2, where it fails to predict correctly. The unbalanced performance, especially for class 2, suggests that potential improvements are needed, such as addressing class imbalance or increasing the sensitivity of the model to this class.

Further comparative analysis between different machine learning models highlighted the efficiency of the Random Forest (RF) and K-Nearest Neighbors (KNN) models. The KNN model achieved an accuracy of 0.869, while the RF model achieved a perfect accuracy of 0.969. These results affirm the superior predictive capability of the RF model in classifying soil fertility based on the dataset used. Figure 5 shows the results of KNN and Rf models in comparison.



(a)



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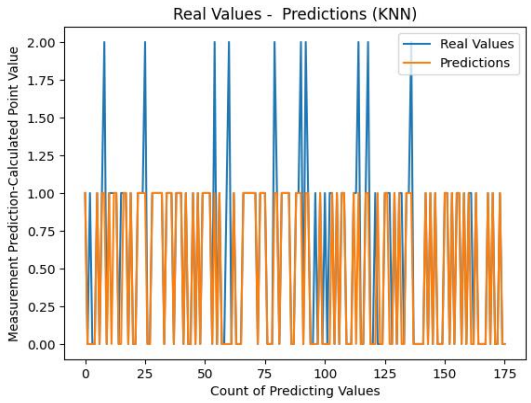

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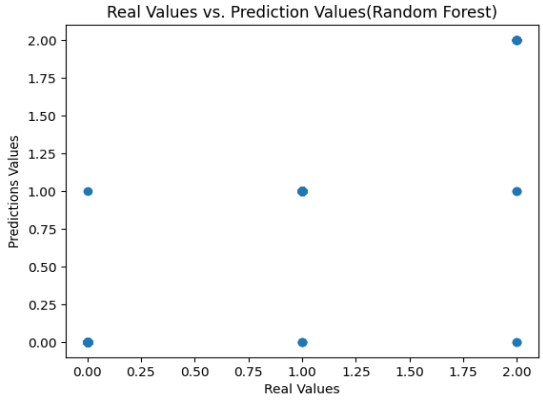
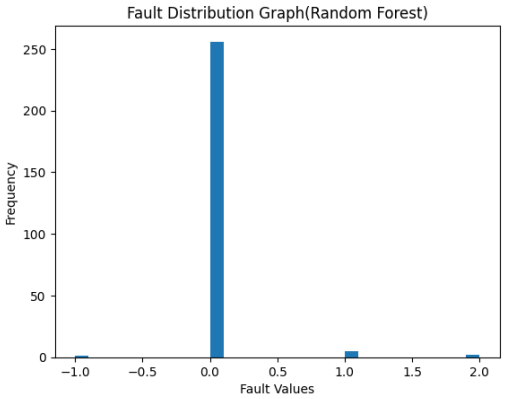
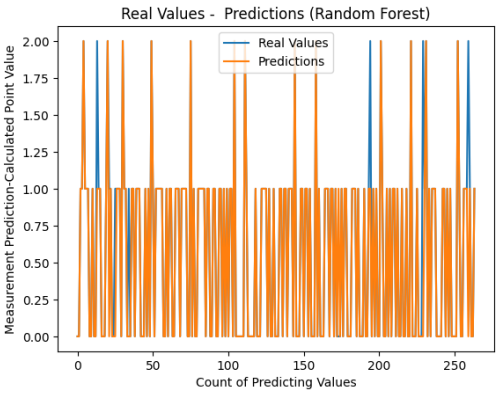


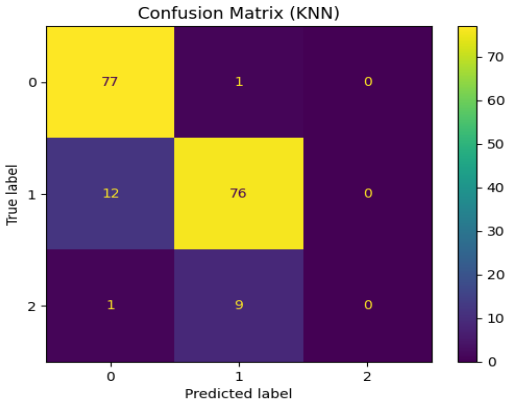
(d)



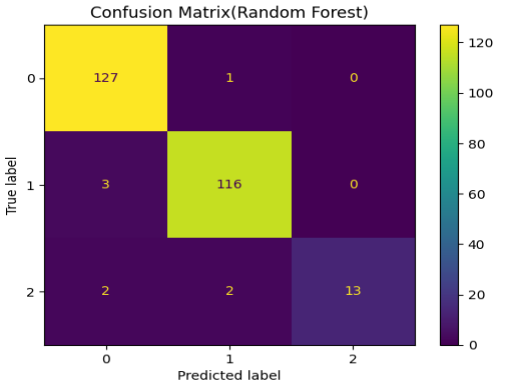
(e)



(f)



(g)



(h)

Figure 5. KNN and RF models training results (a. KNN Prediction Graph, b. KNN Error Distribution Graph, c. KNN Prediction Accuracy Graph, d. RF Prediction Graph, e. RF Error Distribution Graph, f. RF Prediction Accuracy Graph, g. KNN Confusion Matrix Graph, h. RF Confusion Matrix Graph)

The confusion matrix in Figure 5(g) indicates that the KNN model performs reasonably well but not perfectly. The matrix shows the number of true and predicted labels, where rows indicate true labels and columns indicate predicted labels. The KNN classifier showed strong performance in identifying instances in class 0, moderate performance for class 1, and failed to correctly classify any instance in class 2. This misclassification pattern highlights a difficulty with class 2, which may indicate that the model is unable to effectively discriminate this class.

The provided confusion matrix in Figure 5(h) shows the performance of the Random Forest classifier in three categories (0, 1 and 2). Each row corresponds to the actual class labels, while each column shows the predicted labels made by the model. The values in the matrix represent the number of instances classified under each predicted label. The Random Forest model performs robustly in discriminating between classes 0 and 1 with relatively few misclassifications. However, the classification accuracy for class 2 is slightly reduced, indicating that the model faces difficulties in distinguishing this class from the others.

The feature importance analysis revealed that certain soil properties significantly contributed to the fertility classification. The use of Mean Decrease in Impurity (MDI) measures allowed for the identification of key features, such as nutrient levels, pH, and organic matter content, which were crucial in predicting soil fertility. This underscores the importance of targeted soil management practices to enhance these critical parameters.

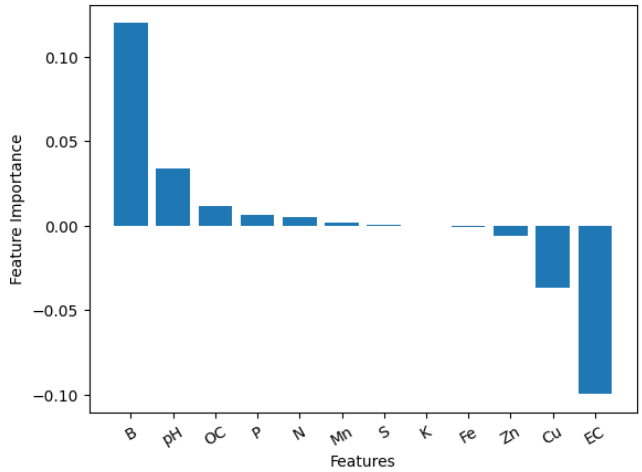


Figure 6. Feature Importance Graph

Figure 6 suggests that Boron (B) is the most influential feature in the model, significantly contributing to the predictions. In contrast, Electrical Conductivity (EC) has the least importance and may even negatively impact the model's performance. Features like pH and Organic Carbon (OC) also play crucial roles but to a lesser extent than Boron.

It is essential to consider these importance scores when making decisions about feature selection or further model tuning. Features with low or negative importance might be candidates for removal to simplify the model and potentially improve its performance. Conversely, ensuring the most important features are accurately measured and included in the model is critical for maintaining its predictive accuracy.

4. DISCUSSION AND CONCLUSIONS

The study demonstrates the potential of machine learning algorithms, in particular the Extra Trees and Random Forest models, to accurately predict soil fertility. The high accuracy achieved by these models underlines their robustness and reliability in performing soil fertility classification tasks. Furthermore, trait importance analysis provides valuable information for improving soil management practices by highlighting critical soil properties that influence fertility. The integration of advanced machine learning techniques with soil fertility assessment offers a promising approach for sustainable agriculture. By leveraging these technologies, farmers and agronomists can make informed decisions on crop selection and soil management, ultimately increasing agricultural productivity and sustainability. Future research should focus on expanding the dataset and exploring the application of these models in different agro-ecological zones to further validate their effectiveness and adaptability.

In conclusion, the application of machine learning models in soil fertility assessment offers a powerful tool for optimizing agricultural practices and ensuring long-term soil health. The findings from this study contribute to the growing body of knowledge on precision agriculture and highlight the importance of integrating technology with traditional agricultural practices to ensure sustainable food security.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Author Contributions
Conceptualisation: A.A., E.A.; Research: A.A., E.A.; Materials and Methodology: A.A., E.A.; Supervision: A.A., E.A.; Visualisation: A.A., E.A.; Writing-Original Draft: A.A., E.A.; Manuscript-review and editing: A.A., E.A.; Other: All authors have read and accepted the published version of the article.

Conflict of Interest
The authors have no conflicts of interest to declare.

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Comprehensive Examination of Diverse Assessment Methodologies Applicable to Sport Science Departments at Higher Education Institutions

Gerrit Breukelman[1], Lourens Millard[1*]

Abstract: Educators and educational leaders have engaged in ongoing discussions and debates concerning student assessment in higher education. Concerns have been raised by academics about the disconnect between assessment methods and actual student learning outcomes. The aim of this review was to conduct a comprehensive examination of diverse assessment methodologies applicable to higher education. Furthermore, a critical analysis was performed to evaluate the alignment of current assessment practices within the author's specific academic field with the various assessment methods under scrutiny, as well as to assess their efficacy. The literature review pertaining to the evaluation techniques employed in higher education underwent an electronic search across several databases: EBM Reviews, Current Contents, Science Direct, Google Scholar, CISTI Source (from 1995 to June 2021), Cochrane Database of Systematic Reviews and international e-catalogues. A total of (n=38) studies were found that met the necessary criteria to be included in the study. It is important to acknowledge that this examination should be regarded as a foundational framework, with ample room for future research to incorporate additional assessment approaches, given the multitude of options available. Assessment for learning, tasks of learning, and peer and self-assessment emerge as invaluable tools applicable across various disciplines within higher education.

Keywords: Assessment, Sport Science, Assessment Methods, Learning Outcomes, Assessment Practices.

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1. INTRODUCTION

Educators and educational leaders have engaged in ongoing debates concerning student assessment in higher education, as reflected in various studies (Boud and Falchikov, 2007; Gilles et al., 2011; Carless, 2015). Concerns have been raised by academics about the disconnect between assessment methods and actual student learning outcomes (Carless et al., 2006; Douglas et al., 2012; Webber, 2012). These discussions often revolve around critical questions, such as the relationship between students' performance in examinations and academic rigor, the most effective assessment tasks for promoting learning, the role of assessment practices in fostering lifelong learning, and the potential for feedback to enhance student progress (Carless, 2015).

Studies have identified that educators sometimes fail to connect assessment with the quality of teaching (Postareff et al., 2012), viewing assessment primarily as a tool for evaluation and grading (Sambell et al,. 2012; Torrance, 2012). Nevertheless, there is a growing body of literature suggesting that assessment can serve as a valuable instrument for active learning within the classroom (Bonwell, 1997; McGinnis et al., 2018). Despite the extensive discourse on assessment practices that promote learning, it seems that many academics continue to rely heavily on traditional pen-and-paper examinations as a means of gauging student knowledge (Carless et al., 2006; Duncan and Buskirk-Cohen, 2011; Gilles et al., 2011; Postareff et al., 2012). However, authors argue that testing in this conventional sense is often a passive process that can hinder the learning experience (Ertmer and Newby, 2013).

One potential root of this issue may lie in the lack of awareness regarding diverse assessment methods employed across various postsecondary institutions (Gilles et al., 2011; Postareff et al., 2012; Webber, 2012). Thus, in the context of this review article, the primary objective of the investigation was to conduct a comprehensive examination of diverse assessment methodologies applicable to higher education. Furthermore, a critical analysis was performed to evaluate the alignment of current assessment practices within the field of Sport Science with the various assessment methods under scrutiny, as well as to assess their efficacy.

Literature Review

The concept of assessment in education encompasses a range of activities aimed at gathering information about students' performance and achievements (Gronlund, 2005). Researchers emphasize two primary purposes for assessment: facilitating student learning and certifying student achievement (Norton et al., 2013; Carless, 2015). Formative and summative assessments are key tools that serve these purposes (Sambell et al., 2012; Carless, 2015), ideally overlapping seamlessly when effectively employed.

Formative assessment is an ongoing process that occurs throughout a course, engaging students with the subject matter and promoting familiarity with the material (Jacoby et al., 2014). Effective formative assessment requires active participation from both students and teachers, leading to deeper comprehension and long-term retention of concepts (McCoy, 2013). Valuable feedback from various assessment tasks plays a crucial role in enhancing students' performance (Sambell et al., 2012), making formative assessment synonymous with "assessment for learning" (Carless et al., 2006; McDowell et al., 2011; Hernández, 2012).

In contrast, summative assessment serves to evaluate student achievement and usually occurs at the end of a course or instructional phase (Gronlund, 2005). While common summative assessment methods include unit tests, exams, and final presentations, their timing limits the ability to modify student learning, primarily serving grading purposes (McDowell et al., 2011; Hernández, 2012). However, it is noteworthy that summative assessment can also serve formative purposes if it includes feedback to aid students in their learning process (Carless et al., 2006).

In higher education, many assessment strategies, such as course assignments, can fulfill both formative (assessment for learning) and summative (assessment of learning) functions (Taras, 2008; Hernández, 2012).

Assessment for Learning

Assessment for learning (AfL) is fundamentally rooted in the principle that all assessment methods should contribute to the process of student learning (Sambell et al., 2012). Key components of AfL encompass several crucial aspects, including the incorporation of authentic, real-world assessments (McDowell et al., 2011; Sambell et al., 2012). AfL places a strong emphasis on actively involving students in the learning journey, with a reduced focus on grades (Sambell et al., 2012). It provides learners with opportunities to apply previously acquired skills and knowledge in practical contexts (Sambell et al., 2012). Furthermore, AfL involves the provision of feedback, achieved through a combination of written comments and dialogues among students, peers, and instructors (McDowell et al., 2011; Sambell et al., 2012).

AfL also plays a pivotal role in nurturing independent learners (McDowell et al., 2011). These characteristics of AfL closely align with the cognitive constructivist theory, where educators actively engage students in the learning process (Paily, 2013). This engagement encompasses collaborative efforts, the integration of real-world scenarios, and self-reflection as integral components (Paily, 2013). The concept of social constructivism further expands on this approach, emphasizing the importance of involving others in the learning journey (Paily, 2013). It underscores the value of dialogue for sharing ideas, fostering collaboration, and promoting cooperation (Paily, 2013).

Through such active engagement and interaction, knowledge and understanding are cultivated through various forms of interaction, including teacher-student interactions, peer-to-peer interactions, and interactions with tasks or assignments (Torrance, 2012). This theoretical framework underscores the critical role of learners' experiences in the process of knowledge generation (Schreiber and Valle, 2013).

Learning-oriented Assessment

Learning-Oriented Assessment (LOA) serves as a pedagogical framework that closely aligns with the principles of assessment for learning, as delineated by Carless (2015). LOA represents a comprehensive approach that aims to enrich the learning experiences of students, both in the immediate and long-term contexts (Carless, 2015). This multifaceted framework comprises three interrelated components: the utilization of tasks as instruments for learning, the incorporation of self and peer assessment, and the facilitation of constructive feedback (Carless, 2015).

Each facet within the LOA framework actively engages students in the assessment process. This active participation empowers students to redirect their attention towards the generation of knowledge, with a pronounced emphasis on honing critical skills such as analytical thinking, problem-solving, and engaging in metacognitive activities. These skills are pivotal in nurturing their cognitive capabilities and fostering a deeper understanding of the subject matter (Demirci, 2017).

Tasks as Learning Tasks

In the pursuit of fostering effective learning experiences, a fundamental consideration lies in the authenticity of the tasks employed (Sambell et al., 2012; Carless, 2015). Authentic assessment, a specific subtype of extended performance assessment (Gronlund, 2005), embodies an

evaluative approach characterized by its heightened realism and complexity, integration of knowledge and skills, and its capacity to encourage deeper learning (Gronlund, 2005). While extended assessments require students to consolidate their acquired knowledge, it is the concept of authentic assessment that propels learners towards a more profound level of understanding. This approach compels students to apply their comprehension to real-world tasks or scenarios (Boud and Falchikov, 2007; Sambell et al., 2012).

Furthermore, authentic activities contribute to the acquisition of future-oriented knowledge and skills (Gronlund, 2005; Boud and Falchikov, 2007; Libman, 2010; Hui and Koplin, 2011; Trevelyan and Wilson, 2012; Sambell et al., 2012; Carless, 2015). These pedagogical approaches play a pivotal role in developing specific competencies and enhancing the critical thinking capabilities of learners (Oladele, 2011; Sambell et al., 2012). Scholars emphasize the importance of employing performance-based authentic methodologies in student assessment (Gibson and Shaw, 2011). Learners resonate with authentic approaches, making them invaluable tools for assessment (Gibson and Shaw, 2011).

To ascertain the authenticity of a task, educators can employ a set of questions outlined by Burton (2011). Beyond representing real-world contexts, these questions consider whether the final output is refined, whether higher-order thinking or metacognitive processes are engaged, and whether the assignment necessitates collaborative decision-making among students (Burton, 2011). Various activities fall under the umbrella of authentic assessments, including real-life tasks, exhibitions, interviews, journals, observations, oral presentations, performances, portfolios, patchwork texts, and simulations (Boud and Falchikov, 2007). Other methods include written and oral debriefing, peer and self-assessment, as well as small group collaborations (Gibson and Shaw, 2011). Problem-solving exercises, case studies, and role-playing also exemplify authentic activities (Carter and Hogan, 2013). Additionally, experiential undertakings embody authenticity (Hui and Koplin, 2011; Pierce et al., 2011).

Peer and self-assessment

The incorporation of authentic assessment modes serves as a catalyst for active student involvement in the learning process (Gibson and Shaw, 2011; Pantiwati and Husamah, 2017). Self-assessment and peer assessment, fundamental components of these modes, empower students to cultivate their ability to evaluate both their own work and that of their peers (Sambell et al., 2012; Yucel et al., 2014; Carless, 2015). Through this educational journey, students nurture lifelong learning tendencies (Boud and Falchikov, 2007; Sambell et al., 2012; Carless 2015), equipping them with the skills needed to make informed judgments and decisions in future scenarios they may encounter (Boud and Falchikov, 2007; Thomas et al., 2011; Sambell et al., 2012; Carless, 2015).

These methodologies, as asserted by Sambell et al. (2012), foster attributes such as independence, personal responsibility, and critical thinking. Moreover, peer assessment imparts valuable lessons to learners on how to handle constructive criticism and exercise responsibility when evaluating the work of others (Chetcuti and Cutajar, 2014). An additional advantage of peer assessment is that the competencies acquired serve as a solid foundation for engaging in self-assessment (Chetcuti and Cutajar, 2014). Central to the objective of self-assessment is the cultivation of metacognitive skills (Carless et al., 2006; Sambell et al., 2012; Nielsen, 2014). Metacognition involves learners gaining insight into their own learning process and is recognized as a significant determinant of effective learning outcomes (Stanton et al., 2021). Furthermore, self-assessment has the potential to empower students by fostering a culture of self-monitoring (Tan, 2009; Sambell et al., 2012). However, it is essential to emphasize that the autonomy granted to learners should be directed towards the sustained development of self-reflective abilities (Tan, 2009).

Methodology

Search strategy

The literature review pertaining to the evaluation techniques employed in higher education underwent an electronic search across several databases: EBM Reviews, Current Contents, Science Direct, Google Scholar, CISTI Source (from 1995 to June 2021), Cochrane Database of Systematic Reviews and international e-catalogues. A keyword-based inquiry led to the identification of MeSH headings such as "assessments," "higher education," "assessment methods," "educational assessments," "assessments in higher education," "assessment for learning," "peer assessment," "self-assessment," and "learning tasks," which were subsequently amalgamated. Only peer-reviewed articles in the English language were included in the search results. Original articles were categorized and singled out for further analysis.

Inclusion Criteria

The studies included in this review adhered to the following criteria: A keyword search was performed, generating MeSH headings, namely "assessments," "higher education," "assessment methods," "educational assessments," "assessments in higher education," "assessment for learning," "peer assessment," "self-assessment," and "learning tasks," which were subsequently combined and expanded. These headings collectively served as the basis for searching articles spanning the period from 2000 to 2023, as indicated in the data sources section. The rationale for conducting such an extensive search was to encompass a wide array of assessment methods potentially relevant to higher education. This comprehensive approach aimed to establish a foundational reference point for future research endeavours, facilitating the identification of further effective assessment methods for educators in higher education.

Exclusion Criteria

To uphold the integrity of this review and include only pertinent research, specific exclusion criteria were applied.

In the context of this investigation, exclusive consideration was granted to full-text articles composed in the English language. Additionally, articles were disqualified if their scope was exclusively directed toward educational phases other than higher education. Lastly, studies were omitted from consideration if they failed to furnish precise elucidation as to the rationales underpinning the superiority of certain assessment methods over others.

Data Extraction

Studies that did not meet the inclusion criteria were systematically excluded from the analysis. The initial phase involved the collection and thorough analysis of significant data, which encompassed an evaluation of assessment methods employed in higher education. The author also conducted an eligibility assessment for inclusion through a comprehensive analysis of full-text articles. The final selection of articles was subjected to scrutiny by a domain specialist, and any deficiencies were rectified until complete clarity was achieved.

All the selected papers were classified into two categories, namely "assessments" and "assessments in higher education," based on the journal or conference in which they were published, along with the corresponding keywords. Subsequently, data was extracted from the collected information. In order to scrutinize the contributions of each research study to assessment methods in higher education, data pertaining to analysis methodologies, window selection, and spatial aggregation features were meticulously extracted. Additionally, to gauge the interpretability of all the included research, information regarding the problem definition or study purpose and the inclusion of a theoretical framework or explanation was also systematically extracted. All these findings were then methodically categorized and consolidated under a unified framework, which will serve as the foundational structure for the subsequent discussion of the research findings.

RESULTS

An electronic search based on the above-mentioned criteria yielded a result of 38 electronic articles that was used for this article. Figure 1 illustrates the article selection criteria.

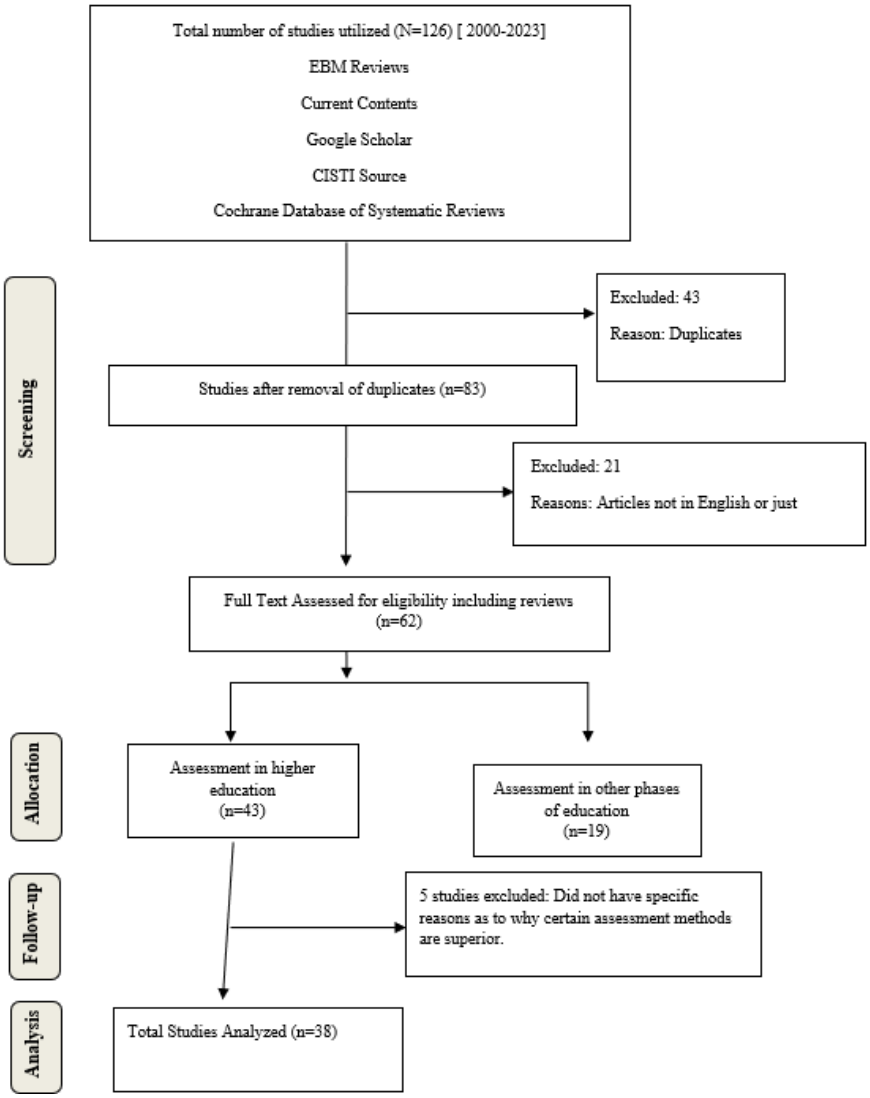

Figure 1: PRISMA Flow Chart of the study selection process

DISCUSSION

In the context of this review article, the primary objective of the investigation was to conduct a comprehensive examination of diverse assessment methodologies applicable to higher education. Furthermore, a critical analysis was performed to evaluate the alignment of current assessment practices within the author's specific academic field with the various assessment methods under scrutiny, as well as to assess their efficacy. The comprehensive examination of the assessment methods was performed in the literature review. This section will focus on evaluating the alignment of current assessment practices within the author's specific academic field.

In the domain of sports science, the acquisition of practical, experiential knowledge is of paramount importance. This necessity arises from the expectation that graduates must effectively collaborate with athletes or patients upon departing the educational institution. Consequently, the field of sports science predominantly employs work-integrated learning (WIL) as a fundamental component of its assessment methodologies. WIL affords students the opportunity to engage in supervised interactions with patients and evaluate their performance against predefined criteria outlined in a comprehensive handbook, with the aid of meticulously crafted rubrics. This assessment approach aligns with the principles of Assessment for Learning (AfL) as elucidated by McDowell et al. (2011) and Sambell et al. (2012). It bears the hallmark of genuine, real-world assessments, in contrast to purely theoretical evaluations. Furthermore, this pedagogical approach fosters active student involvement in the learning process, with a reduced emphasis on conventional grading systems, as advocated by Sambell et al. (2012). It not only facilitates the application of previously acquired skills and knowledge but also enables students to receive immediate feedback from their on-site supervisors (McDowell et al. 2011; Sambell et al. 2012).

Like many other academic disciplines, sport science actively engages in research endeavours, which are integrated into its curriculum through specialized modules. These modules impart theoretical knowledge through summative assessments, such as class tests. However, the most substantial evaluation components are practical in nature. These practical assessments encompass the formulation of research proposals, their subsequent presentation, the composition of scientific articles following specific journal guidelines, and the oral presentation of the articles' findings to the department. This assessment framework adheres to the principle of assessments as integral elements of the learning process. Integral to this pedagogical philosophy is the notion of task authenticity, as elucidated by Carless (2015). Authentic assessment, a subcategory of extended performance assessment as expounded by Gronlund (2005), embodies an evaluative approach characterized by heightened realism and complexity. It integrates both knowledge and skills and fosters deeper learning experiences (Gronlund, 2005). The assessment methods employed in the research module within the sport science discipline are meticulously designed to mirror the demands and expectations typically encountered in pursuing advanced degrees or academic careers, aligning with the discipline's overarching goals.

In striving to achieve the assessment objectives across all modules within the sport science discipline, a deliberate emphasis is placed on the promotion of peer and self-assessment, particularly in advanced, exit-level modules. The rationale for this pedagogical approach stems from the recognition that sport scientists often collaborate within teams in their professional careers. Consequently, it is imperative that they possess the skills necessary for evaluating the work of their peers, as this evaluation can significantly impact their own methodologies. Moreover, fostering the ability for self-reflection and adaptation is deemed essential. Given the sizable class sizes typically encountered in our programs, the utilization of peer and self-assessment methods is also operationally practical. Drawing from personal experience, one approach involves tasking students with creating presentations to demonstrate their grasp of specific topics. Subsequently, comprehensive rubrics are provided to both the presenting group and their peers, facilitating the peer and self-assessment processes. This approach aligns with the findings of Gibson and Shaw (2011) and Pantiwati and Husamah (2017), who assert that authentic assessment modes promote active student participation and enhance the learning experience. These methods are meticulously designed to encourage students to critically evaluate their own work and that of their peers (Sambell et al., 2012; Yucel et al., 2014; Carless, 2015). It has been observed that students in the sport science discipline gain valuable insights into their own capabilities and the relative depth of their knowledge in comparison to their peers. Consequently, they develop the capacity to make informed judgments and choices, a skillset that proves invaluable in preparing them for future assignments and assessments (Boud and Falchikov, 2007; Thomas et al., 2011; Sambell et al., 2012; Carless, 2015), a benefit that has been empirically validated through my instructional approach.

CONCLUSION

This review highlights the critical need for diverse and effective assessment methodologies within Sport Science departments in higher education. The findings suggest that while traditional assessment methods are still prevalent, there is a growing recognition of the benefits of incorporating formative, authentic, and peer assessment practices. These methods not only enhance student learning but also better prepare graduates for real-world challenges. Sport Science departments could consider adopting more work-integrated learning opportunities, such as practical placements and research-based assessments, to bridge the gap between academic learning and professional readiness. Additionally, fostering a culture of self-reflection and peer evaluation may empower students to develop critical thinking and adaptability skills. Future research could explore the long-term impacts of these alternative assessment strategies on student outcomes and employability, providing valuable insights for further curriculum development.

Epilogue

This article emphasizes the significance of employing diverse assessment methods in the field of Sport Science, acknowledging its inherently practical nature and the subsequent relevance in professional settings. Specifically, the adoption of assessment for learning, tasks of learning, and peer and self-assessment methods is highlighted. The integration of these assessment approaches is advocated not only for their theoretical underpinnings but, crucially, for their practical application within the Sport Science domain. The article underscores the importance of aligning assessment methodologies with the dynamic and hands-on nature of the field, ensuring graduates are well-prepared for the challenges they will encounter in the workplace.

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Conflict of Interest
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Yazar rehberi

Makale A4 sayfa boyutunda, Times New Roman yazı tipinde, 10 punto olarak ve düz metin şeklinde yazılmalıdır. Makaleye sayfa ve satır numarası eklenmelidir.

Kapak sayfası: Kapak sayfasında sırasıyla makale başlığı, yazar adı soyadı, yazar iletişim bilgileri bulunmalıdır.

Başlık ve özet (İngilizce): Özet 500 kelimeyi geçmeyecek şekilde yazılmalıdır. Araştırmanın gerekçesini, amaçlarını, uygulanan yöntemi, sonuç ve önerileri içermelidir. Özet sonuna 3-6 kelimeden oluşan anahtar kelimeler eklenmelidir.

Ana metin: Makale ana metni tek satır aralıklı olarak yazılmalı, çizelge ve şekillerle birlikte toplam 15 sayfayı geçmemelidir. Konu başlıkları 1., 1.1., 1.1.1., şeklinde numaralandırılmalıdır.

Dipnotlar: Metin içerisinde dipnotlardan olabildiğince kaçınılmalıdır. Çizelge ve şekillerde ise gerekli olması halinde ilgili objenin altında yer almalıdır.

Semboller ve kısaltmalar: Birim sembolleri Uluslararası Birimler Sistemine (The International System of Units; SI) göre olmalıdır.

Kaynaklar: Metin içinde geçen kaynaklar yazarların soyadları ve yayın yılı ile birlikte verilmelidir (Örnek: Özkan vd., 2008; Özdemir, 2015). Metin sonundaki kaynaklar önce alfabetik sonra kronolojik sıraya göre sıralanmalıdır. Bir yazarın aynı yılda birden fazla yayınına atıf yapılmışsa, bu kaynaklar yayın yılından sonra gelecek a, b, c… harfleriyle ayrılmalıdır (Örnek: Kandemir, 1999a; 2000b; 2001).

Çizelgeler ve şekiller: Bütün çizelge ve şekiller metin içerisinde atıf sıralarına göre ardışık olarak numaralandırılmalı ve ilgili yere eklenmelidir. Çizelgelerin üzerinde ve şekillerin altında başlıkları yer almalıdır. Çizelge ve şekiller hem elektronik ortamda hem de kağıt baskıda net olarak görünür ve anlaşılabilir olmalıdır. Şekiller en az 300 dpi çözünürlüğünde hazırlanmalıdır. Şekillerde kullanılan karakterler Times New Roman yazı tipinde olmalıdır.

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Kaynaklar

Kaynak kullanımları aşağıda örneklerde belirtilen şekillerde olmalıdır.

Instructions for authors

Manuscript should be written in A4 page size, with Times New Roman font and 10 pt font size, as plain text. Page and line numbers should be included into the manuscript.

Cover page: Cover page should include title of the manuscript, names and contact information of the authors.

Title and abstract (English): Abstract should not written exceed 500 words. Explains rationale, goals, methods, results and recommendations of the study. Keywords with 3-6 words should be included at the end of the abstract.

Main text: Main body of the manuscript should be written in single line spacing, and it should not exceed a total of 15 pages including tables and figures. Headings should be numbered as follows: 1., 1.1., 1.1.1.

Footnotes: Use of footnotes within the text should be avoided as much as possible. If necessary, it can be located below tables and figures.

Symbols and abbreviations: Unit symbols should comply with The International System of Units.

References: In the text, literature should be given with the last name of the author and year of the publication (For example: Özkan et al., 2008; Özdemir, 2015). At the end of the paper, references should be ordered first alphabetically and then chronologically. If there is more than one paper from the same author for a given year, these references should be identified by the letters a, b, c…, after the year of publication (For example: Kandemir, 1999a; 2000b; 2001).

Tables and figures: All tables and figures should be numbered in the order of their citation in the text, and they should be located in suitable places. Titles of the tables should be located above, and titles of the figures should be located below the related table or figure. Tables and figures should be easily visible and understandable both in print and electronic versions. Figures should be prepared in at least 300 dpi resolution. Characters within the figures should be in Times New Roman font type.

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Using of references should be in the form as follows.

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